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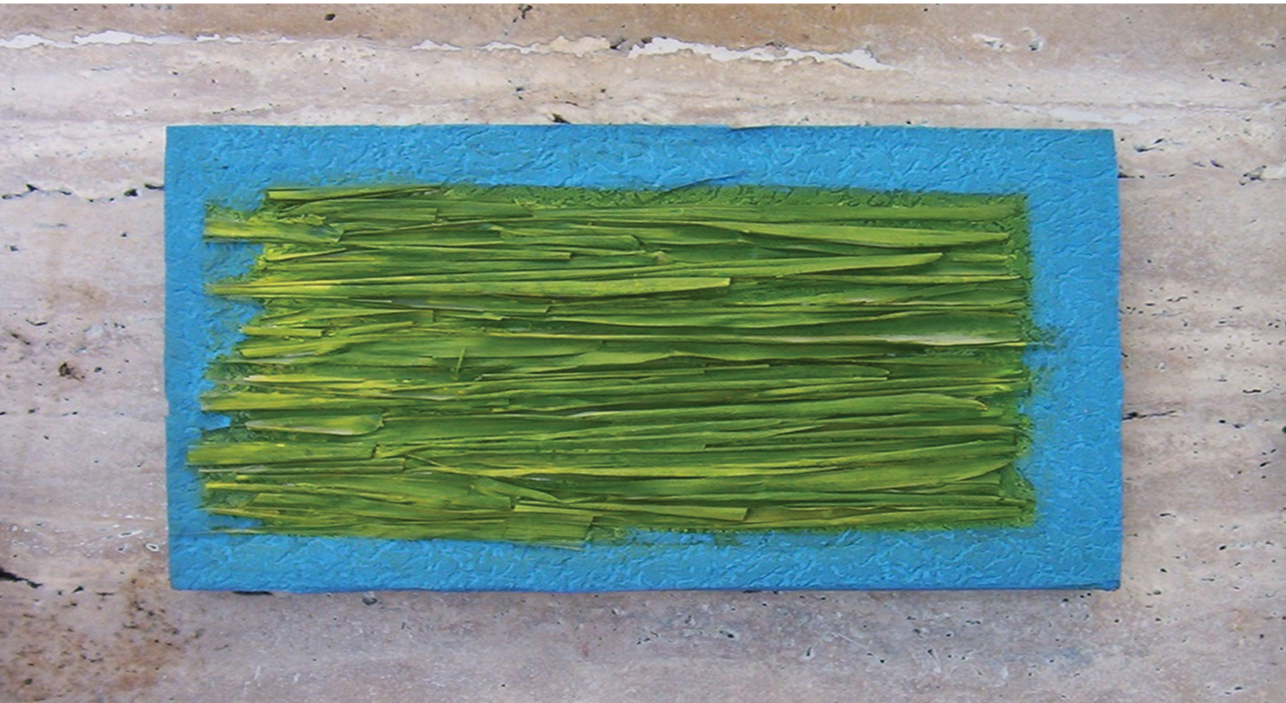

Biomass – a renewable energy source?

Sustainable complementary biomass (re)production through Landscape Quality Management

Vorgelegt von
Dipl.-Ing.
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geb. in Aachen

zur Erlangung des akademischen Grades
Doktor der Naturwissenschaften
- Dr. rer. nat. -
in der Fakultät Nachhaltigkeit
an der Leuphana Universität Lüneburg

genehmigte Dissertation

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Tag der Disputation: 10. Juni 2015

Lüneburg 2015

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Shaker Verlag
Aachen 2015

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Zugl.: Lüneburg, Univ., Diss., 2015

Title picture: Karin Koch-Lawniczak (2004): Composition with reed (adapted)

Printed in Germany.

ISBN 978-3-8440-3959-7
ISSN 2193-7575

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

Für Bennet

Executive Summary

In its original scientific sense ***bio*****mass** denotes *living* mass. Through *bio*mass not only is a biochemical energy potential being renewed, but also vital living and production conditions (e.g. climatic, water or soil conditions) as well as desirable components of quality of live (e.g. spaces for recreation and a sense on belonging). Not only the bioenergy sector itself, but in fact the sustainability of society and its economy depend on these regenerative ecosystem services. How to retain the capacity for such productive 'biological-ecological work' needs to be considered when using biomass as a source of energy for 'technical work' (i.e. for the technical generation of electricity, heat or mobility). Bioenergy techniques must therefore be seen in connection to the sustainable provisioning of the biomass in appropriate land use forms that need to be developed in the context of the landscape.

Starting from this argumentation, the present study takes up the societal question of how international standards for sustainable biomass production can be defined and established, which has been under controversial discussion, especially since the promotion of biofuels by the European Union. The current politically favored solution implemented for biofuels is the introduction of minimum standards in connection with product-related certification systems. However, the limits of such schemes are seen, among other factors, in the fact that they cannot cover indirect effects such as, for example, land use changes resulting from global economic interactions. Furthermore, sustainability standards are caught in the tension between the contradictory requirements of international validity and local specification. Thus, further measures from the area of national policy and land use planning as well as the embedding of the bioenergy sector in a global land monitoring and management system are expected. Experts assume that in the future, with globally increasing pressure on land, sustainability standards will be used not only for biomass in energy production but also for other agricultural products and land uses.

The thesis of this study is that the assessment and development of the sustainability of biomass production needs to be undertaken in relation to (1) a general and place-based consensus about basic and desirable landscape functions, services and qualities to be sustained in the landscape area, and (2) a common understanding of the general role of different biomass forms as well as the concrete contribution of human and organismic biomass producers to these conditions. This requires a governance process that can create landscape reference systems as integrated value and knowledge systems and that will be executed in relation to appropriate spatial units, organizational levels and temporal horizons.

The study develops a draft standardized adaptive process of Landscape Quality Management (LQM). It is the aim of this process to formulate, in an internationally recognized way, specific reference systems for a sustainable landscape development on the regional and local level, which make it possible to evaluate and pro-actively develop the sustainability of (biomass) production. Landscape Quality Management differs from existing sectoral and product specific certification systems by focusing on the landscape as shared living and production space of human and organismic societies. At the core lies a stakeholder process composed of three coherently interlinked scales: global, regional and local; of three phases: brainstorming, knowledge building and vision building; and of three polarities: incorporating general and context-specific aspects, integrating values and knowledge, and alternating projection and reflection. With a subsequent phase of action, monitoring and revision, the process forms an adaptive management cycle. The study proposes both elements of a standardized value and knowledge core in terms of general aspects as well as flexible process steps and building blocks for elaborating the context-specific aspects, but does not investigate institutional options and implications of LQM, which are, however, regarded as critical for a successful implementation.

The textual assessment framework of the LQM process links regenerative ecosystem services with landscape functions and qualities within a non-market supply and demand matrix. All three concepts mediate between value and knowledge systems in a suitable way. Regenerative ecosystem services and their ‘product qualities’, which are perceived and produced in the landscape area as temporal-spatial patterns on various scales, serve as criteria. It is intended that they be improved constantly through the management activities. Biodiversity – a category that considers the variety of life forms rather than their mass – is assigned a double role in the process: on the one hand as service provider through diverse functional traits on the supply side, and on the other hand as societal value in itself on the demand side. In addition, the knowledge core of LQM focusses on the (re)productive role of water and its management in the landscape, since the key renewal processes occur through the conversion of solar energy by the dynamic medium water. The question arises thereby whether the concept of ‘photosynthetic efficiency’ – based on the net product of biomass – might be too narrowly defined and thus calculated too low, if one also considers the ecosystem services associated with vapor production, such as temperature buffering, to be useful outputs in light of the inseparable physiological link between terrestrial photosynthesis and vapor production.

Based on the conscious construction of organismic activities as ‘productive biological-ecological work‘, the study goes on to develop the concept of ‘complementary biomass production’ as a regional Leitbild. This means using for bioenergy those plants and land

use practices which are not in direct competition with food production, but can rather provide regenerative ecosystem services and improve landscape qualities in a complementary manner; and integrating them so that the sustainability of the landscape in its entirety is increased. The process of landscape quality management supplies the reference system and the appropriate elements for the design of regional complementary biomass strategies. Furthermore, the study shows how different technologies associated with bioenergy and complementary biomass use can be sustainably designed from a perspective of the quality of landscapes.

The present study is located in the spatial planning sciences and pursues a social-ecological transdisciplinary research approach using various methods of knowledge integration. Concepts, approaches and knowledge stocks from several scientific fields and disciplines, such as social ecology and ecological economics, plant physiology and landscape ecology, sustainable land and resource management as well as quality-oriented process management, etc., have been extracted and synthesized out of the literature and documented studies. The principal feasibility of a complementary biomass strategy is explained and examined through case studies. The concept "(Re)Productivity" (Biesecker, Hofmeister 2006) serves as a theoretical framing and as a guiding theme throughout the study.

Beyond the bioenergy sector Landscape Quality Management could contribute to the certification of whole regions or river basins, as well as to the featuring of various quality products whose manufacturing contributes to the co-production of landscape quality. The process-based approach also allows specifically linking (standardized) environmental and quality management to LQM and its inherent sustainability requirements for production forms, land use and technology development. In this way, LQM could also be used, in principle, in the evaluation and design of the sustainability of other production activities at their energetic, metabolic and site interfaces to the landscape and its ecosystems. With the help of further research this could mean to embed technical (and other) innovations in the context of place-based long-term ecological and societal renewability.

Zusammenfassung

***Bio*masse ist im ursprünglichen wissenschaftlichen Sinn ein Begriff für die *Lebend*masse. Durch *Bio*masse werden nicht nur biochemische Energiepotenziale sondern auch essentielle Lebens- und Produktionsbedingungen (z.B. Boden-, Wasser-, Klimaverhältnisse) und wünschenswerte Lebensqualitäten (z.B. Erholungsräume, Identifikationsräume) erneuert. Von diesen regenerativen Ökosystemleistungen hängt nicht nur der Bioenergiesektor selbst, sondern auch die Erneuerungsfähigkeit der gesamten Gesellschaft und ihrer Wirtschaft ab. Der Erhalt der Kapazität für solch produktive ‚biologisch-ökologische Arbeit' ist bei der Nutzung von Biomasse als Energiequelle für ‚technische Arbeit' (d.h. zur technischen Erzeugung von Strom, Wärme oder Mobilität) mit zu bedenken. Bioenergie-Techniken sind daher im Zusammenhang mit der nachhaltigen Bereitstellung der Biomasse in geeigneten Landnutzungsformen zu sehen, die im Kontext der Landschaft entwickelt werden müssen.

Von dieser Argumentation ausgehend greift die vorliegende Studie die gesellschaftliche Fragestellung auf, wie internationale Standards für nachhaltige Biomasse-Produktion definiert und etabliert werden können, welche vor allem seit der Förderung von Biokraftstoffen durch die Europäische Union kontrovers diskutiert wird. Die derzeit politisch favorisierte und für Biokraftstoffe implementierte Lösung ist die Einführung von Mindeststandards im Zusammenhang mit produktbezogenen Zertifizierungssystemen. Grenzen solcher Produktzertifizierungen werden jedoch u.a. darin gesehen, dass sie indirekte Effekte, wie z.B. Landnutzungsänderungen resultierend aus globalen ökonomischen Zusammenhängen nicht abdecken können. Des Weiteren stehen Nachhaltigkeitsstandards im Spannungsfeld widersprüchlicher Anforderungen von internationaler Gültigkeit und lokaler Spezifizierung. Es werden daher weitere Maßnahmen aus dem Bereich nationaler Raumordnung und Landnutzungsplanung sowie die Einbettung des Bioenergiesektors in ein globales Land-Monitoring und -Management erwartet. Experten gehen zudem davon aus, dass Nachhaltigkeitsstandards mit global zunehmendem Druck auf die Landfläche zukünftig nicht nur für Biomasse zur Energiegewinnung, sondern auch auf andere Agrarprodukte und Landnutzungen anzuwenden sind.

Die These dieser Studie ist, dass eine Bewertung und Entwicklung der Nachhaltigkeit von Biomasse-Produktion ins Verhältnis gesetzt werden muss zu (1) einem generellen und ortsbezogenen Konsens über notwendige und wünschenswerte Landschaftsfunktionen, -leistungen und -qualitäten, die auf der Landfläche unterhalten werden sollen und (2) einem geteilten Verständnis über die Bedeutungen verschiedener

Biomasseformen für und Einflüsse menschlicher und organismischer Biomasseproduzenten auf diese Bedingungen. Dies erfordert einen Steuerungsprozess, der landschaftliche Referenzsysteme als integrierte Werte- und Wissenssysteme schaffen kann und in Bezug zu angemessenen räumlichen Einheiten, organisatorischen Ebenen und zeitlichen Horizonten durchgeführt wird.

Die Studie entwirft einen standardisierten, adaptiven Prozess eines landschaftlichen Qualitätsmanagement (LQM). Ziel des Prozesses ist, regional bis lokal spezifische Bezugssysteme einer nachhaltigen Landschaftsentwicklung in einer international anerkannten Art und Weise zu bilden, welche es ermöglichen, Nachhaltigkeit von (Biomasse-) Produktion zu bewerten und pro-aktiv zu entwickeln. Anders als bestehende, sektorale und produktspezifische Zertifizierungssysteme ist das landschaftliche Qualitätsmanagement auf die Landschaft als gemeinsamen Lebens- und Produktionsraum von menschlichen und organismischen Gesellschaften bezogen. Im Zentrum steht ein Stakeholder-Prozess bestehend aus drei Phasen: Brainstorming, Wissensbildung und Visionsbildung. Er verbindet drei Maßstabsebenen: global, regional und lokal, und beinhaltet drei Polaritäten: Beachtung genereller und kontextspezifischer Aspekte, Integration von Wissens- und Wertesystemen, sowie Wechsel von Projektion und Reflexion. Mit einer anschließenden Aktionsphase inklusive Monitoring und einer Revisionsphase bildet der Prozess einen adaptiven Management-Zyklus. Die Studie schlägt sowohl Elemente eines standardisierten Werte- und Wissenskerns im Sinne der generellen Aspekte als auch flexible Prozeßschritte und -bausteine zur Erarbeitung der kontextspezifischen Aspekte vor. Sie untersucht aber nicht institutionelle Möglichkeiten und Konsequenzen von LQM, wobei diese als Schlüssel für eine erfolgreiche Implementierung gesehen werden.

Der inhaltliche Bewertungsrahmen des LQM-Prozesses verbindet regenerative Ökosystemleistungen mit Landschaftsfunktionen und -qualitäten in einer nicht-marktbasierten Angebots- und Nachfragematrix. Alle drei Konzepte vermitteln in geeigneter Weise zwischen Werte- und Wissenssystemen. Regenerative Ökosystemleistungen und ihre ‚Produktqualitäten‘, die in der Landschaftsfläche auf verschiedenen Maßstabsebenen als räumlich-zeitliche Muster wahrgenommen und hergestellt werden, dienen als Kriterien. Sie sollen durch die Managementaktivitäten kontinuierlich verbessert werden. Biodiversität – eine Kategorie, die nicht auf die Masse, sondern die Vielfalt der Lebensformen setzt – erhält eine doppelte Rolle im Prozess: einerseits als Leistungserbringer durch vielfältige funktionale Merkmale auf der Angebotsseite und andererseits als eigenständiger gesellschaftlicher Wert auf der Nachfrageseite. Darüber hinaus fokussiert der Wissenskern des landschaftlichen Qualitätsmanagement auf die (re)produktive Rolle des Wassers und seiner Bewirtschaftung in der Landschaft, da entscheidende Erneuerungsprozesse über den

Umsatz der Sonnenenergie durch das dynamische Medium Wasser erfolgen. Dabei wird die Frage aufgeworfen, ob der am Nettoprodukt der Biomasse orientierte „photosynthetische Wirkungsgrad“ angesichts der untrennbaren physiologischen Kopplung zwischen terrestrischer Photosynthese und Wasserdampfproduktion nicht zu eng definiert und damit zu gering bemessen ist, wenn man auch die mit Wasserdampf assoziierten Ökosystemleistungen, wie z.B. Temperaturdämpfung, als nützlichen Output betrachtet.

Basierend auf der bewussten Konstruktion von organismischen Tätigkeiten als ‚produktive biologisch-ökologische Arbeit‘ wird im Weiteren das Konzept ‚komplementäre Biomasse-Produktion’ als regionales Leitbild entwickelt. Dies bedeutet, Pflanzen und Landnutzungspraktiken für die Bioenergie zu nutzen, welche nicht in direkter Konkurrenz zur Nahrungsmittelproduktion stehen, sondern in komplementärer Weise regenerative Ökosystemleistungen erbringen und Landschaftsqualitäten verbessern können; und sie so zu integrieren, dass die Nachhaltigkeit der Landschaft insgesamt erhöht wird. Der Prozess des landschaftlichen Qualitätsmanagement liefert hierbei das Bezugssystem und entsprechende Bausteine zur Erarbeitung regionaler komplementärer Biomasse-Strategien. Darüber hinaus zeigt die Studie auf, wie verschiedene mit Bioenergie und einer komplementären Biomassenutzung assoziierte Technologien aus einem Blickwinkel der landschaftlichen Qualität nachhaltig gestaltet werden können.

Die vorliegende Untersuchung ist in den Raumwissenschaften verortet und verfolgt einen sozial-ökologischen transdisziplinären Forschungsansatz unter Anwendung verschiedener Methoden der Wissensintegration. Konzepte, Ansätze und Wissensbestände aus mehreren Wissenschaftsbereichen und Fachdisziplinen, z.B. Sozial-Ökologie und ökologische Ökonomie, Pflanzenphysiologie und Landschaftsökologie, nachhaltiges Land- und Ressourcenmanagement, sowie qualitätsorientiertes Prozessmanagement etc., werden per Literatur- und Dokumentenstudien extrahiert und synthetisiert. Die prinzipielle Machbarkeit einer komplementären Biomasse-Strategie wird anhand von Fallstudien erläutert und überprüft. Das Konzept „(Re)Produktivität“ (Biesecker, Hofmeister 2006) dient in der gesamten Studie als theoretische Rahmung und als Leitkategorie.

Über den Bioenergie-Sektor hinaus könnte das landschaftliche Qualitätsmanagement einen Beitrag zur Zertifizierung von ganzen Regionen oder Flussgebieten leisten sowie zur Auszeichnung verschiedener Qualitätsprodukte, deren Herstellung gleichzeitig zur Co-Produktion von Landschaftsqualität beiträgt. Der prozessbasierte Ansatz ermöglicht es, (standardisiertes) Umwelt- und Qualitätsmanagement gezielt an LQM und darin erarbeitete Nachhaltigkeitsansprüche an Produktionsformen, Landnutzung und

Technologieentwicklung zu knüpfen. Damit könnte LQM im Prinzip auch auf die Bewertung und Gestaltung der Nachhaltigkeit von anderen Produktionsaktivitäten an deren energetischen, Stoffwechsel- und Standortschnittstelle zur Landschaft und ihren Ökosystemen angewendet werden. Mit Hilfe weiterer Forschung könnte dies bedeuten, technische (und andere) Innovationen in einen Kontext ortsbezogener und langfristiger, ökologischer und gesellschaftlicher Erneuerungsfähigkeit einzubetten.

Index

List of abbreviations

ATP	Adenosintriphosphate
BAP	Biomass Action Plan
BtL	Biomass to Liquid
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CHP	Combined heat and power plants
C&I	Criteria and indicator sets
CICES	Common International Classification of Ecosystem Services
DEU	Dissipative ecological unit
EFQM	European Foundation for Quality Management
ELC	European Landscape Convention
EMAS	European Eco-Management and Audit Scheme
EU-RED	European Renewable Energy Sources Directive
GAEC	Good acgricultural and environmental condition
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GHG	Greenhouse gas/ gases
GPP	Gross primary productivity
ILO	International Labor Organization
ILUC	Indirect land use change
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISCC	International Sustainability and Carbon Certification System
ISO	International Organization for Standardization
ISOE	Institut für sozial-ökologische Forschung (Institute for Social-Ecological Research)
LQM	Landscape Quality Management
LUC	Land use change
LUCC	Land use land cover change
MA	Millennium Ecosystem Assessment
NADPH	Nicotinamide adenine dinucleotide phosphate
NGO	Non governmental organization
NPP	Net primary productivity
OECD	Organization of Economic Cooperation and Development
PAH	Polycyclic aromatic hydrocarbons
PDCA	Plan Do Check Act/Adapt (management cycle)
RED	Renewable Energy Sources Directive

RES	Renewable energy sources
RSB	Roundtable on Sustainable Biofuels/ Biomaterials
SDS	Sustainable Development Strategy
SMR	Statutory management requirements
SOC	Soil organic carbon
SOM	Soil organic matter
SPU	Services providing unit
SRP	Short rotation plantation
TEEB	The Economics of Ecosystems and Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIFEM	United Nations Development Fund for Women (today UN Women)
WFD	Water Framework Directive
WTO	World Trade Organization

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Introduction

I. Societal background and problem definition

Renewable, non-exhaustible energy sources are a long-term prerequisite for all living, social and economic activities. Therefore, they are usually regarded as a key component of a sustainable development. Bioenergy, i.e. the generation of heat, electricity or mobility from biomass, presently holds the major share of the renewable energy supply. Due to its flexible use as well as its storage possibilities, biomass – as the resource of bioenergy – is further expected to take an important role in the future energy supply mix. In the light of political objectives such as energy supply security, climate protection and rural development, the bioenergy sector has received a great deal of governmental support in many countries in the past decade. An international market for biomass trade is being established. Demand for biomass resources will increase even more in the course of a change towards the anticipated "bioeconomy" (European Commission 2012b).

Despite these strong expectations, the energetic use of biomass is also the subject of widespread critique. A couple of years ago a significant change happened in the public debate about bioenergy. While initially bioenergy had been commonly understood and communicated as per-se sustainable in information campaigns, newspapers and the media, it then came under crossfire, especially during the promotion of biofuels through the European Union. In Germany, for example, headlines like "Teller oder Tank" (dinner plate or fuel tank) reflected this controversy, which assumed that bioenergy use would raise food prices.

The scientific discourse brings to the fore land use competition and various environmental and social issues associated with extended biomass production. In Germany, for example, 12.5 % of its arable land was used for the cultivation of energy crops in 2014.[1] Presently, the most common energy crops are high-yielding seeds like maize for the production of biogas, rapeseed for the production of biodiesel, and grain for the production of bioethanol. Furthermore, wood is used traditionally for heating as well as wood chips and pellets in combined heat and power plants (cf. Einig 2011; Wacker, Porsche 2011). It is assumed that the ambitious political targets for the increased use of bioenergy can only be met with biomass imports, shifting related issues abroad (Haberl et al. 2012, 114). Four fields of potentially competing and conflicting uses are identified in this regard (Wacker, Porsche 2011, 273):

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[1] https://mediathek.fnr.de/grafiken/daten-und-fakten/anbau/flachennutzung-in-deutschland.html (accessed 12/29/2014)

- Agricultural or non-agricultural use of land area (e.g. for tourism, nature protection or infrastructure etc.)
- Use of land area for the production of food or for non-food exploitation
- Energetic or material usage of biomass
- Use of biomass for either the generation of heat/ electricity or as transportation fuel

Furthermore, biomass production may compete with food production for other limited resources such as water and nutrients and will significantly increase heavy transport (Anton 2012, 39). Principally, the industrial monocultural cultivation of energy crops is viewed critically. If food crops are cultivated as energy crops, the same negative effects can be expected as with conventional agriculture (Gaasch et al. 2011, 344; Wiehe et al. 2010b). Typical environmental costs are, for example, biodiversity loss, soil degradation, or water eutrophication, which need to be accounted for in life-cycle assessments. Furthermore, the production of potent greenhouse gases (GHG) such as nitrous oxide by fertilization, as well as the release of carbon through direct and indirect land use changes (ILUC, see below), question the 'carbon-neutrality' of biomass and are to be included in full life-cycle GHG balances (Foth et al. 2007, 43–56; WBGU 2008, 4f; Anton 2012, 43f). With regard to bioenergy from forestry and the use of organic residues, erosion risks should be considered, along with the fact that European cropland soils lose about 3 % of their soil carbon per year, so that there is the need to recirculate more organic matter back to the land (ibid.). Additionally, non-governmental organizations (NGO) report land right conflicts and "land grabbing" for "agrofuel production" in developing countries (The GAIA Foundation et al. 2008, 7; Ernsting et al. 2007, 24). Clearly, such **negative effects** of common biomass production practices actually oppose sustainable development, as they affect the potentials of future generations to meet their needs (WCED 1987).

However, **positive and synergistic effects** of biomass-for-bioenergy production are also discussed. For example, representatives of the biofuel producers repeatedly emphasize that the production of biofuels from rapeseed oil, grain and sugar beets creates high-value, in part protein-rich animal feed as a by-product, and thus frees up feedstuff production areas to be used for other purposes (Rettenmaier et al. 2008). Environmental advantages in regard to water and soil quality, biodiversity and biological pest control are expected above all from short-rotation plantations at marginal locations or mixed cultures in cleared agricultural landscapes. Further synergies with conservation arise, for instance, when the grass cuttings from extensive grasslands is used, which can normally only be maintained through expensive landscape conservation measures (Foth et al. 2007, 61f; Petersen et al. 2007, 51). Usually the use of residues is favored, as long as an even carbon- and humus balance in the soil is assured through the re-circulation of organic material to the land (WBGU 2008, 6; Sims et al. 2008, 79). Large corporations are increasingly turning to the production of biofuels from microalgae, which have been researched since the 1960s and are attributed to have a high productivity potential due to the synergistic use of waste water and exhaust gases in pond systems (Sheehan et al. 1998).

Thus, dependent on local context and the type of land use system, bioenergy use can have both desirable and undesirable effects with regard to sustainable development. Therefore a controversial debate has evolved around the question of how biomass can be produced sustainably and through which criteria and measures this can be safeguarded. The favored political option is the introduction of product-bound certification schemes. In Europe, the Renewable Energy Sources Directive went into effect in April 2009, setting minimum sustainability standards for biofuels and bioliquids to account for ambitious political targets (European Parliament and Council 2009). However, the search process for an international agreement on rules and tools and a set of assessment criteria and indicators to safeguard sustainability is still on-going (Dam et al. 2010, 2468; Scarlat, Dallemand 2011, 1644; Zarilli, Burnett 2008, 41; Kerckow, Guerreiro 2011). Thus, bioenergy is not regarded as per-se sustainable anymore, but only if it is produced and used according to certain principles. However, these certification schemes are also disputed as e.g. discriminating bioenergy products against other agricultural products, delegating responsibilities to overwhelmed consumers, being too costly for smallholders, and requiring extensive enforcement and controlling capacities etc. (see Chapter 1.6.4).

Especially uncertain remains how the indirect effects of bioenergy use resulting from macro-economic interdependencies can be addressed. Indirect effects are distinguished from direct effects according to the decision-making options by the producer. Direct effects arise through the processes of biomass and bioenergy production. They can be addressed by influencing the behavior of farmers, traders and industrial suppliers, e.g. concerning crop choices or good practice, etc. Many research activities are therefore dedicated to the development of integrated cultivation techniques (e.g. mixed cultures) and different conversion technologies (e.g. second generation). Indirect effects result from interdependencies of global food, feedstuff and resource markets. They are mostly out of the direct scope of the bioenergy producers. Prominent examples are displacement effects, where due to cultivation of energy crops on arable land, new land may be taken into cultivation to serve the demand for food. Such dislocation of food production may lead to an undesirable conversion of areas with high carbon stock or high protection value, such as grassland or rainforests, referred to as indirect land use changes (ILUC) (Dam et al. 2010, 2460–2465; RSB 2013, 4).

So far such interdependencies of global market interactions and land use changes are not well understood. A high research need is seen in this field, especially in the development and adaptation of suitable environmental planning instruments. In order to capture, assess and mitigate such indirect effects and land use conflicts, an enhancement of governance options by spatial planning (Dam et al. 2010; Scarlat, Dallemand 2011, 1643; Wacker, Porsche 2011; Einig 2011) up to a "global land use management" is called for as "an essential requirement for a sustainable bioenergy policy" (WBGU 2008, 2).

However, in Germany for example, which has a long spatial planning tradition, the options to control bioenergy production by formal regional plans are rather limited, as this instrument is only binding to authorities and cannot directly influence the actions of farmers or foresters (Einig 2011). Nevertheless, some possibilities to stir biomass production activties exist, especially if information provided by landscape planning is well integrated in regional plans (Gaasch et al. 2011; Wiehe et al. 2010a). Much more hope is placed on informal instruments of a cooperative governance, especially on "Biomasseentwicklungskonzepte" (biomass development concepts) (Gaasch et al. 2011, 348) as a building block of "regionale Energiekonzepte" (regional energy concepts), including estimations of regional renewable energy and energy saving potentials, 'Leitbilder' and goals for the region, measures and incentive programs, as well as the development of networks around key energy actors of the region (Einig 2011, 385). Furthermore, Gaasch et al. (2001, 351) state that a consideration of ecosystem services, and a critical discourse about the present privileged agricultural production of commodity outputs, could contribute to mitigating future conflicts in the course of an expanded bioenergy use.

Kanning and Rode et al. (2010) specifically explored options for a "natur- und raumverträglichen Ausbau energetischer Biomassepfade" (environmentally friendly and spatially compatible expansion of energetic biomass pathways) in Lower Saxony in Germany. With regard to landscape functions they investigated the effects of biogas and biomass-to-liquid (BtL) production on soil fertility and erosion, groundwater and run-off, habitat and biodiversity as well as recreational landscape quality in three model regions, and developed recommendations for action on different levels. They find that formal planning can govern bioenergy supply directly only via controlling sites and installed capacity of biomass conversion plants. Indirectly, it can safeguard other spatial demands and landscape functions via designation of protection areas with restricted use such as drinking water protection areas, flooding areas, or nature and landscape protection areas (ibid. 149-155). Against this backdrop, Kanning and Rode et al. (ibid.) also stress the importance of informal strategic approaches and regional coordination with various actors groups. Besides regional development concepts, they point to the option to combine financial instruments with environmental/ sustainability standards. With regard to product related certification systems, as mentioned above, they state that landscape plans and frameworks including monitoring systems should deliver the basis of assessment. Landscape planning can furthermore develop Leitbilder of desirable landscape conditions and suggest measures of e.g. site-specific modes of land management, which could influence the actions of land users by means of consulting. However, such a pro-active developmental role of integrated landscape and regional planning or management is still weak (ibid. 241–251).

The present study ties in here. It places itself in a social-ecological research field of biomass production in the context of environmental/ spatial planning and sustainable territorial development. It attempts to contribute to the societal question: **How can the sustainability of biomass production be assessed and safeguarded?**

II. Thesis, aim and research questions

The **thesis** of this study is that a sensible assessment of biomass production sustainability needs to **consider the renewal of various functions, services and qualities in the landscape through biosynthetic living activities, and their solar energy turnover mediated by water**. Such an approach can lead to a complementary rather than competitive development of biomass production practices and its related technologies. Therefore, a process is required which can create and maintain regional (multi-scale) reference systems as integrated value and knowledge systems performed in accordance with meaningful landscape units. ‘Landscape’ is hereby understood as both the physical and visible expression of territory and environment. Such **landscape reference systems** should contain (A) a consensus about basic and desirable conditions to be sustained in the landscape, and (B) a common understanding or shared knowledge of the general role as well as the context-specific contribution of different biomass forms and biomass producers in relation to these conditions. Such a process will require a coordinating approach beyond codes of good practice, as most of the services and qualities are realized not on a single field or proprietary unit, but in a composition and discrete distribution of land-use (eco-) systems and their management practices in the landscape. Furthermore, it is assumed that knowledge about landscape processes determined by the flow and functions of water is a key, since critical processes of renewal at the landscape surface take place through the conversion of solar energy via the dynamic medium water.

Therefore, the **aim** of the study is to develop a **draft standardized adaptive mechanism of “Landscape Quality Management**” (LQM) – **embracing water as the**

key-element of life – which can serve to provide regional landscape reference systems and build capacity to *assess* the sustainability of biomass production in a specific context as well as to *develop* **complementary biomass** strategies, production practices and bioenergy technologies. The broader goal and personal ambition is to contribute to reversing trends of land degradation and to create regenerative landscapes with a 'blue thread' (Brüll, Bürgow 2014).

The following **research questions** are used to guide the process of exploration in this study and to dismantle the complexity of the initial societal question into workable and comprehensible sections in terms of the thesis and aim.

- What is the relation between renewability and sustainability from a social-ecological perspective on bioenergy? (Chapters 1.1-1.4)
- What are the chances and limitations of sustainability standards and certification systems with regard to assessing and developing sustainable biomass production systems? (Chapters 1.5-1.7)
- Which are suitable landscape and ecosystem related concepts to mediate between value- and knowledge systems; and how could they form a textual assessment framework of a potential LQM process? (Chapters 2.1-2.2)
- How can knowledge stocks with a focus on water inform LQM regarding the contribution of biosynthetic living activities to the maintenance of desirable conditions in the landscape area; and where are knowledge gaps? (Chapter 2.3)
- What could the envisioned LQM process actually look like and how could it support a sustainable biomass and bioenergy use? (Chapter 2.4-3)
- Which current biomass and bioenergy production practices and technologies show a complementary potential; and how should this be further developed? (Chapter 4)
- What could the envisioned LQM process generally mean for sustainable production and innovation? (Chapter 5)

III. Methodology and methods

The above-mentioned initial societal question places this study in the field of **transdisciplinary social-ecological research**. In the English speaking context, research about "social-ecological systems" is closely connected to "resilience theory" focussing on the adaptive governance of ecosystems (Becker 2012, 37; Folke 2006). The notion "social-ecological system" is used "to emphasize the integrated concept of humans-in-nature and to stress that the delineation between social and ecological systems is artificial and arbitrary" (ibid. 261f). "Social ecology" in Germany (developed by the Frankfurt Institute for Social-Ecological Research ISOE) defines itself as the science of "societal relations to nature" (Becker, Jahn 2006; Becker 2012).[2] The research object is the 'relations of crisis' between society and nature and the overcoming of their dichotomization. The various demarcation lines and hegemonial conditions between society and nature are examined critically, and both theoretical concepts and practical solutions for a sustainable development beyond the nature-culture divide are developed. Becker (2006, 23) states that "social-ecological systems" (e.g. land use systems) or phenomena under investigation (e.g. climate change) are best characterized as nature-culture hybrids, which consist of intertwined 'natural' (e.g. physical, chemical, biological, geological) and 'cultural' (e.g. values, institutions, knowledge, social networks) aspects.

Key categories of this study, i.e. 'landscape' 'biomass production' or 'ecosystem services', are understood here as natural-cultural hybrids and are explicitly analysed and discussed as such. The dividing line between 'society' and 'nature' is scrutinized especially with regard to the commonly presumed 'natural renewal' of biomass and 'renewability' of bioenergy (Chapter 1.2) as well as regarding the notion of 'biomass production' in its ecological and economic contexts (Chapter 1.3).

From the broad field of social ecology the "**(Re)Productivity**" **approach** developed by Biesecker and Hofmeister (Biesecker, Hofmeister 2006) is selected and used **as a guiding theme** throughout this study. With its central categories of "natural productivity", "productivity/ reproductivity", and "(re)productivity" it offers a basic model for 'sustainable production activities' (as further described in Chapter 1.1) as well as an access to a broader understanding of 'renewability' (as developed in Chapter 1.4). Furthermore, it complements the well recognized natural capital approach (Costanza, Daly 1992) by focussing on 'productivity' as a term also central to economics.

Social ecology is conceived as a transdisciplinary field of science. This means that its subjects are real world societal problems, which may arise from individual or political contexts and cannot be solved by one discipline alone. These problem areas require the combination of both natural and social scientific approaches as well as the inclusion of non-scientific types of knowledge in a meaningful and practical way. The challenge is to weave together categories, concepts and models etc. from heterogenous disciplines with very different professional languages, methods, and epistemic convictions. Thus the main ambition of transdisciplinary science is to produce **insight by knowledge**

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[2] The Vienna version of social ecology places the category of "social metabolism" in the center of research (Becker 2012, 44 with reference to Fischer-Kowalski, Weisz 1999).

integration, and to offer solutions for a sustainable development in a scientifically structured way. Therefore, transdisciplinary projects usually involve researchers from various disciplines, stakeholders and non-scientific experts as well as specific transdisciplinary integrative methods (Becker, Jahn 2006; Bergmann et al. 2010).

However, how can transdisciplinary research be a one person exercise, as executed in this study? According to the research group Inter-/Transdisciplinarity of the University of Bern, transdisciplinarity is understood in two ways: (1) a research mode as mentioned above, which involves a societal problem, and a collaboration of different disciplines and persons from outside the scientific community, and (2) a research mode which transcends the boundaries of the participating disciplines, by taking on a ‘meta-level’, relating and partially reframing and recombining concepts and categories to ‘make them fit’. Both positions, though, strive for synthesis. Therefore, ‘type-2-transdisciplinarity’ will essentially be part of ‘type-1-transdisciplinary’ if true synthesis is to be achieved (Defila et al. 2008).

This study attempts to take a pathway of ‘type-2’ transdisciplinary research, by drawing and relating information, approaches and knowledge stocks from document and literature studies, case studies and expert interviews, and by using integrative methods. The development of **transdisciplinary research methods** is a relatively novel field. Bergmann et al. (2010) describe various methods of knowledge integration derived from experiences in very different transdisciplinary research projects. The following methods, which do not presuppose personal interaction with researchers from other disciplines within a concrete project context, are applied:

- **Integrative theoretical framing**: A theoretical concept spanning over the relevant disciplines structures transdisciplinary research and providing a frame of reference which secures equal access of the different disciplines to the problem area (ibid. A.2.3, 67). As mentioned above, the (Re)Productivity approach is used as such a guiding theoretical orientation throughout this study.
- **Clarification of terms**: This method identifies key-terms and categories of the problem area, clarifies aspects of meaning of a term used in different disciplinary and everday contexts, and makes explicit different conceptions of the same term in different disciplines (ibid. A.1.1, 56f). Besides clarification of categories of renewable versus non-renewable energy (Chapter 1.2) or different understandings of landscape, landscape functions and landscape quality, etc. (Sections 2.2.1-2.2.3), this method is especially applied here to bring to the fore the opposing meanings of the term-combination ‘biomass production’ in the scientific ecological and economic-political contexts, which are constitutive for the debate about sustainable biomass production (Sections 1.3.1-1.3.2)

- **Double-sided criticism** of naturalistic and culturalistic research approaches: This method has been particularly developed for the analysis of societal relations to nature in social ecology. It can identify differences, shortcomings, potential conflicts or hegemonial relations between naturalistic and culturalistic approaches and enable access of both the natural and social sciences. Often, the resulting double descriptions of certain phenomena, issues or relations can be used for a conscious cognitive integration (of e.g. formerly divergent positions), which may open up new pathways for action. Double-sided criticism is especially used here for the development of a model of 'biomass production' as a historical construct and to reconcile economic and ecological points of view (Section 1.3.3).

- **Term construction**: This method is used to form new terms for issues or connections central to the problem area, but currently lacking description and recognition. These new terms should have a bridging character to show relations between and to link contributions of different disciplines (ibid. A.1.2, 57f). In this study this method is especially used by introducing the phrase of 'productive biological-ecological work', and by broadening the scope of renewability to 'renew-Ability' based on a combination of knowledge stocks from cellular biology, physiology, landscape ecology and ecological economics (Section 1.3.4, Chapter 1.4).

- **Categorial systems**: The use or invention of categorial clusters can offer access for different disciplines and practitioners to the problem area and its subjects. The categorial system should be clearly describable, well reasoned, and comprehensible from different perspectives (ibid. A.1.4, 61f). This method is used here by grouping ecosystem services into 'production services' and 'regenerative services', the latter further grouped into 'basic regenerative services' and 'recreational services', with regard to an analytical application of the (Re)Productivity category (Section 2.2.5). Based on this categorial system criteria for assessment are derived.

- **Conceptual model building**: The development of various types of models is a common method across many disciplines. In transdisciplinary research, conceptual models often function to link a theoretical level with empirical research. However, they can apply to all kinds of research situations and especially serve as a tool for abstracting and constructing settings and relations (ibid. E.1, 95–99). The model of the non-market demand and supply framework (Figure 10, developed in Chapter 2.2), the model of the (re)productive role of water (Figure 11, developed in Chapter 2.3) and the model of the standardized adaptive process of Landscape Quality Management (Annex 3, developed in

Chapter 3) are main applications of this method here. Further conceptual models of this study are also represented by graphical schemata.

- **Product as integration vehicle**: The development of specific products (like a useful analysis, prognosis, artifact or practical solution) often is the cause and aim of transdisciplinary research projects. In such cases the function of and requirements for the product form an interface for integration from the beginning. Typically, the envisioned product is compartmentalized into sub-products to select and define disciplinary contributions of the research partners. During the research process the results need to be synthesized in a couple of iterative steps (ibid. F.1, 106ff). In this study the proposed draft of an LQM mechanism (Annexes 3-6, developed in Chapter 3) can be considered such an integrative product. Beyond this study, the draft may be picked up as a “boundary object” (ibid.) by a transdisciplinary research project, involving various social and natural scientific disciplines and non-scientific experts, to be further elaborated into a more detailed, feasible, and practicable solution.
- **Integration through a Leitbild**: A ‘Leitbild’ is a vision or coherent overall picture often based on metaphors, which can guide the derivation or coordination of objectives (ibid. D.2, 91f). The Leitbild method is e.g. often used in landscape architecture and planning for initiation and coordination of various projects for landscape development involving many actors. In this study, the method is applied to the concept of ‘complementary biomass (re)production’. Based on the methods of term building and theoretical framing, this concept is further developed as a Leitbild, which – beyond this study – may serve as a guideline for regions and actor networks to develop sustainable energy landscapes, biomass strategies, production practices and technologies. The feasibility of this Leitbild is tested by analysis and interpretation of selected case studies (Chapter 4).

Transdisciplinarity is typical of research in the field of spatial and environmental planning or landscape architecture. Based on a comprehesion of “landscape as concretization of space[3]” (Sturm 2000, 200, translation[4]) and environment, this study locates itself in the spatial and environmental planning sciences, as explained in the first section, with a focus on landscape ecology and adaptive planning. Sturm (2000, 199) presents ‘space’ as an integration vehicle, pointing to the relations between physical-material, historic, cultural, and regulative aspects of space within time as the subject of investigation. She understands ‘methods’ as ‘being underway’ between a starting

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[3] ‘Space’ is meant in the sense of ‘territory’, not extraterrestrial space.

[4] All translations by the author unless otherwise indicated.

situation and a knowledge goal, driven by inquisitiveness (ibid. 22f). According to her analysis of scientific modes of logical reasoning, the methodic procedure of this study may be best described as ‘abductive heuristic’ (ibid. 44ff with reference to Peirce 1986). This means that, based on theoretical concepts and empirical material, a coherent structure is concluded in alternating deductive and inductive steps. Although no original empirical material is presented here, the present work draws on literature describing experiences from projects claiming to develop or practice sustainable biomass production via case studies.

Sturm (ibid. 27-33), furthermore, points to a critical analysis of subject-object relations as a context for methods, especially regarding thematic complexes dealing with environment/ nature/ ecology in spatial planning. While she recognizes ‘objective aspects’ as those attaching to the subject matter of research, she also acknowledges ‘subjective apects’ as those attaching to the researcher, such as his or her experiential background, previous knowledge and patterns of interpretation etc. Instead of claiming objectivity, the starting point of the researcher should be reflected for a “conscious subjectivity” (ibid. 31).

Writing in the personal form indicates this subjectivity in the following (this style, however, is not further followed through the work): Previous knowledge and experiences are an explicit component of this study, and should therefore be briefly mentioned here. My educational background is in biology, landscape ecology and planning as well as management and entrepreneurship. My professional experiences as an independent landscape designer and researcher are in landscape architecture and construction work, ecological engineering and technology development, as well as business and policy consulting, in the thematic fields of sustainable water, land and resources management and renewable energy. Clearly, this background to a large extent influenced the selection, interpretation and integration of sources and knowledge stocks in this study. Or put differently, with another background, the synthesis would likely have been different. However, I tried to reason the analytical and synthetic research steps by logical argumentation, so that the reader may decide whether the selection of concepts and knowledge stocks and their integration are comprehensible and useful, and where gaps or other views exist.

- **Selection of literature**: During the study, I experienced a main obstacle of inter- and transdisciplinary research. A scientific discourse with a history is behind almost every main category used, be it sustainability, biomass or biodiversity, ecosystem services, landscape functions or quality, various management systems, particular cropping systems, biochar or wilderness etc. For some categories I tried to unfold their meaning(s) (e.g. for ‘biomass’ in Chapter 1.3, for ‘landscape’ in Chapter 2.1, or for ‘eocsystem services’, ‘landscape functions’ and 'landscape quality' in Chapter 2.2). However, as it was not possible to deeply investigate each discourse, I partly relied on secondary sources providing overviews and reviews and partly tried to identify key literature in each field. Furthermore, specific selections, such as about water based models, were made based on previous knowledge. Regarding the analysis of European bioenergy policy, main policy documents were analysed in a chronological order.

- **Selection of case studies**: The case studies analysed in Chapter 4 were partly known to me from work preceding this study, and partly sought during this study via literature and internet research according to the categories defined in Sections 4.1.1-2. As Germany is ascribed a leading role in renewable energies, the applied research projects of the German "Fachagentur Nachwachsende Rohstoffe"[5] served as a starting point for the search of suitable and innovative case studies. Thus, many of the presented case studies are located in Germany. Since my cultural background is German, those case studies were also best accessible for me.
- **Expert interviews**: The expert interviews cited within the case studies all stem exclusively from my previous professional activity. These interviews were held within different research and planning contexts. They were non-standardized oral expert interviews (Kromrey 1990 cited in Sturm, 2000, 54) within the scope of field studies. Since I conducted them in the form of participatory observation (Mayring 1993, 56ff) the interviews were not structured. However, the concept of a complementary biomass production, which served as an observation guideline for my questions, was already circulating in my head. No additional interviews were done during this study.

For a single person, the application of a transdisciplinary social-ecological methodology of 'conscious-subjective' knowledge integration involves various steps of cross-disciplinary interpretation, e.g. of definitions, concepts or approaches drawn from the literature, without the possibility to clarify meaning in direct personal interaction. Furthermore, writing in English with a native German background, as well as integrating knowledge stocks from English and German literature, requires semantic interpretations, which may not exactly represent the original meaning. Being aware of these issues, I tried to meet quality criteria for inter-/ transdisciplinary research, such as "accessible writing, multidisciplinary accuracy, and interdisciplinary originality" (Schneider 2006a, 1) and "meaningful comprehensible synthesis" (Defila et al. 2008, translation). Last, but not least, it should be mentioned that the manuscript underwent professional American-English proof-reading.

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[5] http://international.fnr.de (accessed 7/7/2014)

IV. A note on scope and transferability

The scope of this study applies first to European territory and policy, particularly the bioenergy policy of the European Union, with respect to the implementation of the European Landscape Convention and the international relevance of sustainability standards. The results of the study may also be useful for institutionalized landscape and spatial planning, as well as regional management, river basin management and action programmms to combat land degradation and desertification. Furthermore, civil-society initiatives or private corporations seeking to develop or use sustainable biomass production systems and bioenergy technologies may be interested in this work.

A potential transferability of the approach to the assessment and development of other production processes and technologies at the interface to the landscape and its ecosystems is followed through the work and briefly discussed at the end.

1 Line of argumentation: Approaching sustainability through renewability

1.1 Relation of sustainability, (re)productivity and renewability

> "Ökonomie […] versteht sich […] als Teilnahme
> an den produktiven Kräften der Natur."
> Economy is participation in the productive forces of nature (free translation).
> *This is according to Ulrich Grober (2010, 123) Goethe's view on economy*

"Sustainability" is the ability to keep something in existence over a meaningful time span. Sustainability is always connected with temporality, especially longevity in relation to an expected lifespan (Costanza, Patten 1995). "Sustainable development" primarily relates to the continuation of human society based on a durable existence of the planetary life-support-system, respectively conditions and capacities able to satisfy diverse physical and mental needs with regard to pluri-generational social-ecological time scales. It is based on an understanding that the socio-economic system is dependent on and intertwined with the ecological system and cannot grow infinitely, according to the development model of industrial societies, within a world of finite resources and repositories. Sustainable development, integrating ecological, social and economic aspects, aims at the preservation and regeneration of living conditions and quality of life for peoples of the north and the south, for present and future generations as well as for non-human living beings (WCED 1987; Grober 2010; Kopfmüller et al. 2001).

Since social and ecological processes are *dynamic* and *evolving,* sustainable development cannot strive for a stationary or 'balanced' state, but rather for a long-term compatibility of the human population and its activities to the physical ecological system, able to endure in the long run. Sustainable development has to find its way through a field of tension between novelty and change on the one side and conservation and regeneration on the other side. This means that, besides all technical and cultural innovation, certain conditions and capacities vital for the survival and quality of life of future generations of humans and other living beings must be continuously sustained, or *renewed*.

In other words: within dynamic, co-evolving social-ecological systems 'renew-ability', the ability to restore structure or function, implicitly belongs to 'sustain-ability', the ability to hold up, to keep in existence. Thus, **renewability is a key property of envisioned sustainable societies**.

Evidently, society's current ability to continuously renew its life-support-system throughout its diverse activities is not in good condition. Otherwise we would not need to pursue and acquire qualifications for sustainable development. This societal failure is expressed in the "crisis of the reproductive" as Biesecker und Hofmeister (2006) put it, based on their analysis of the history of the category pair "productivity" and "reproductivity" within economical and ecological theory building. They include both the ecological crisis, expressed in well-known phenomena like climate change, biodiversity loss, desertification, water pollution etc., and the social crisis. The latter expresses itself in phenomena such as the ageing of societies, growing youth criminality, child poverty etc. and is also called a "crisis of reproduction work" (Rodenstein et al. 1996). Ecological and social crisis are seen as closely interwoven – as one social-ecological crisis[6] – having their common root cause in the separation of "the productive" from "the reproductive" by economic theory and practice (Biesecker, Hofmeister 2010, 1709; 2006, 17). "The reproductive" thereby is considered the life giving and life maintaining activities and processes in society and nature (Biesecker, Hofmeister 2006, 18), constituting the nourishing substrate of economic productivity.

This division, constructed by economic theory building, is led on the one side by a reduction of so-called 'productive labor' to mere manufacturing of commodities for the market. On the other side, other, potentially 'reproductive', activities are labeled 'non-productive' or 'unproductive' and are thus degraded in their value for economy and society. Since the economy, however, cannot function without such a 'reproductive sphere', the performance of social and ecological productivities is at the same time taken for granted, incorporated at no cost and thereby made invisible.[7] "In the act of

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[6] 'Social' usually refers to relations between humans, while 'ecological' refers to interrelations between organisms, environmental factors and humans as bio-physical beings. However these relations cannot be clearly set apart. Ecological relations are influenced by social behavior and vice versa.

[7] By defining production as those activities providing commodities for the market Adam Smith, originator of classical economic theory in the 18th century, made the first decisive step to set apart production from reproduction. Activities not taking place in the market are thus marked non-productive and excluded from economic valuation as a process of competitive pricing. In the course of assigning the 'reproductive role' to women due to their biological abilities, social caring activities are also mostly delegated to women as their 'natural role' and contained in private and unproductive, possibly consumptive space. Ecological services are presupposed as 'given' and taken for granted.

In Smith's theory the sustenance of family activities 'producing moral standards and ethical beings' – a prerequisite of regular functioning of the market embedded in stable national economies – is still included in the calculation of a "natural" wage; and the material source of commodities is expressed in "use values". This linkage to the reproductive sphere, however, is completely made invisible in the course of the development of utilitarianism and neoclassical economics: The so-called "homo oeconomicus", acting in the market purely driven by interests of maximizing utility, is an unrealistic model lacking any social and ecological connectedness. Production of commodities theoretically turns into mere production of utility, which is negotiated through subjective "exchange value" abstracted from any physical-material origin.

valuation, it [the economy, author's note] externalizes what it fully internalizes in the act of valorization, namely the so-called reproductive activities of animate nature and human beings" (Biesecker, Hofmeister 2010, 1709).

Furthermore Biesecker and Hofmeister point out that not only economics but also natural science has contributed to this process of segregation and blindfolding. The sciences of biology and ecology – especially with the development of the fields of production biology and ecosystem theory at the beginning of the 20th century – pick up the already economically reduced category of "production" and reframe its meaning from a fundamental science perspective by combining it with the invention of "biomass". The thus abstracted and naturalized category of "biomass productivity" also masks the diverse living activities of ecological systems, which actually are inseparably productive and regenerative at the same time (Biesecker, Hofmeister 2006, 99–122). Since "biomass production" is a central term in the discussion about bioenergy, biomass trade, and certification, its different meanings in the economic and ecological context, and their past development and present implications, are further investigated in Chapter 1.3.

The separation of productivity and reproductivity is deeply imprinted in societal structures. It affects and informs land management activities, and also underlies the debate about the sustainability of bioenergy use. It is a historical construct necessarily yielding an exploitative, non-regenerative, and unsustainable economic practice. To overcome this critical situation Biesecker and Hofmeister propose a "**(re)productivity**" **model** as a mode of a sustainable economy. In this 4-phase model "**natural productivity**" **embraces economic (labor) productivity as its origin (natura naturans) and result (natura naturata, a natural product that is at the same time productivity)**.

The latter is due to the fact that all economic production systems are open systems and physical-material in nature. They all without exception show an energetic and metabolic as well as site interface with the landscape and its ecosystems.[8] Besides producing goods and services for the market they systematically co-produce "**nature-culture hybrids**" (such as climate change, modified habitats, altered run-off patterns, chemical traces in organisms, mobilized nutrients, etc.) only accidentally if at all being able to continuously provide the necessary conditions for future lifeworld and economic processes (i.e. flood protected site, process water quality and quantity, relatively reliable temperature and precipitation patterns, biological resources, healthy and recreated human labor forces, etc.) (Biesecker, Hofmeister 2001, 162–165; 2009, 170ff; 2010,

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Ecological conditions, services and material ties are subsumed under the property of land and resources, thus appearing as productivity of capital instead of self-reliant ecological productivity (Biesecker, Hofmeister 2006; 2010, 1704f; Costanza et al. 2001; Jochimsen 2005).

[8] They also show multiple interfaces with the social system, which is not the subject of this study.

1706–1709). However, **only those productive systems can be considered sustainable or lasting, which through production reproduce their production prerequisites, namely relatively stable and favorable social-ecological conditions**. As a rule for “strong sustainability” (Daly 1999; Ott, Doering 2004) “**natural productivity**” – **simultaneously productive and reproductive** – **is thus to be sustained on the earth’s surface and consciously co-produced throughout all economic (re)production processes**. This means that especially ecological and social-female productivities, providing the productive foundations on which economic activities (both production and consumption) rest, are to be recognized as value creating capacities. Consequently they are to be consciously handled and shaped as valuable outputs of economic activities, instead of being degraded and exhausted by them (Biesecker, Hofmeister 2010, 1709f). Thereby “the category of (re)productivity may play a relevant role in ensuring that the vision of a sustainable mode of economic activity actually takes on shape, with what was marginalized in the capitalist economy as the “reproductive” coming to be recognized as the central productivity of sustainable societies — the productivity of nature and man, men and women alike” (ibid.).

With the categories of “natural productivity” and “(re)productivity” Biesecker and Hofmeister complement the internationally recognized approaches of “natural capital” and “ecosystem services” (Costanza, Daly 1992; Daily 1997b; MA 2003). The concepts are combined and used in this study to frame sustainability for biomass production with regard to human-ecosystem relation. Additionally the concept of ‘**biological-ecological work**’ is introduced in Section 1.3.3 to be **opposed to technical work, both eventually fuelled by bioenergy**.

“(Re)productivity” especially serves as a guiding theme in the line of argumentation further followed in this chapter, questioning and expanding ‘renewability’ of biomass not only with regard to the renewal of energy potentials, but also with regard to the renewal of living and production conditions and further components of quality of life.

1.2 Renewability of the energy potential

> May such Woods as do remain intire be carefully Preserved,
> and such as are destroy'd, sedulously Repair'd
> *John Evelyn, 1664*

All living and societal processes, including metabolic, economic and communicative activities, etc. are driven by energy. Without energy, they could not renew and would cease to exist. The continuous long-term availability of one or several energy sources is therefore a basic precondition for sustainable development. The terms "renewable energy" and "regenerative energy" show that the (apparently) self-regenerating character of these forms of energy is appreciated as a typical and essential property. The promotion of renewable energies is one of the main issues of sustainability strategies (European Council 2006; Bunderegierung Deutschland 2008). The use of biomass as a regenerative energy source is therefore regarded as deserving support as part of a sustainable development. Its renewability is the main criterion for the energy-political aim of supply security. Additionally important here, as it is for the other regenerative energy forms, are the criteria of CO_2 neutrality, or CO_2 emissions reduction within climate protection policy, and the potential of biomass for regional development. After the CO_2 neutrality and CO_2 reduction potential, however, had to be doubted strongly (see Section 1.5.1), the question arises whether biomass is really to be regarded as a renewable energy source per se. This question will be dealt with in the following chapter.

1.2.1 Biomass as resource of bioenergy and its capacity of re-growth

From the beginning of mankind biomass has been used as food, raw material and energy source. The energetic use of biomass by way of burning wood, besides the use of solar radiation (e.g. to dry fruit) is the oldest energy use known (traditional use of bioenergy). Due to its biochemically bound energy content, biomass, in the present energy system, counts as one of the primary energy sources (Figure 1).

By means of various conversion techniques biomass can yield useful energy (i.e. heat, electricity, transportation), called "bioenergy" for short (Kaltschmitt, Hartmann 2001, 3–8) (Figure 2). Bioenergy is regarded as renewable energy because of the capacity of re-growth of its resource biomass. "Renewable energies", as a category, differ from "fossil, limited, non-renewable energies", which are produced from resources that are irrevocably used up and do not renew within a human time scale. In contrast, the renewable energies are characterized as 'unlimited' and 'inexhaustible', which means that according to human time scales their energy potential will be either continually available or reproduced by continuous dynamic processes (Table 1).

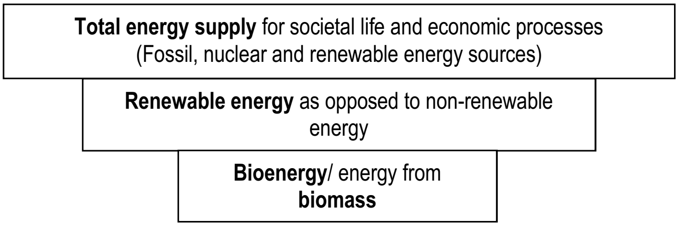

Figure 1: Hierarchy of categories - biomass within the societal energy system (author's portrayal)

“renewable energy. any energy resource that is naturally regenerated over a short time scale and either derived directly from solar energy (solar thermal, photochemical, and photoelectric), indirectly from the sun (wind, hydropower, and photosynthetic energy stored in biomass), or from other natural energy flows (geothermal, tidal, wave, and current energy). contrasted with nonrenewable energy forms such as oil, coal and uranium” (Cleveland, Morris 2006).

“Renewable energy sources are those that are naturally available and replenished. Renewable energy sources include solar, wind, hydro (water), geothermal, tidal power or ocean wave energy, and biomass. Non-renewable energy sources, such as the combustion of fossil fuels, rely on a limited supply that can be considered non-renewable since they are replenished slowly (or not at all)” (Walser, Lawrence 2010).

“Renewable energy is any source of energy which is continually replaced without depleting reserves. It is in general less polluting than its counterpart, non-renewable energy. Forms of renewable energy include: solar, wind, hydroelectricity, wave, biomass, and geothermal. Non-renewable energy sources such as coal, oil and gas exist in finite reserves and are continually being depleted. These energy sources also create considerable damage to the environment. Renewable energy is closely linked to alternative fuels.” (AVEL 2009).

“Fossil fuels are non-renewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. In contrast, renewable energy resources—such as wind and solar energy—are constantly replenished and will never run out.” (NREL 2009).

“renewable energy sources: All natural energy flows that are inexhaustible (i.e. renewable) from an anthropogenic point of view: solar radiation; hydropower; wind, geothermal, wave, and tidal energy; and biomass” (Cleveland 2004, Glossary)

Table 1: Sample definitions of renewable energy

<table>
<tr><th colspan="7">Sources of renewable energy</th></tr>
<tr><td rowspan="2">Potential/ Process</td><td rowspan="2">Radioactive decay, magma</td><td colspan="4">Solar fusion and rotation sun-earth</td><td rowspan="2">Rotation moon-earth, gravitation</td></tr>
<tr><td></td><td colspan="2">Temperature differences/ Water cycle</td><td>Photo-synthesis</td></tr>
<tr><td rowspan="2">Energy form</td><td rowspan="2">Geothermal energy</td><td rowspan="2">Solar energy</td><td>Wind energy</td><td>Hydropower</td><td rowspan="2">Bioenergy</td><td rowspan="2">Tidal power</td></tr>
<tr><td colspan="2">Ocean energy</td></tr>
<tr><td>Resource</td><td>Geothermal heat</td><td>Solar radiation</td><td>Wind</td><td>Water flux</td><td>Biomass</td><td>Tides</td></tr>
</table>

Table 2: Common classification of renewable energy sources (author's portrayal)
(For the connection of wind energy with the water cycle compare pages 130ff and 146f)

Renewable energies are generally classified by their sources, and accordingly distinguished from the non-regenerative ones: Sun, wind, water, geothermal heat, tides, and biomass as regenerative energy sources (Table 2), versus oil, coal, gas, uranium, deuterium, etc. as fossil and nuclear energy sources. By linking the terms "biomass" and "renewable energy" in a simplifying classification of resources a generally common concept of biomass as being as inexhaustible as solar or wind energy is created, which can be shown in the following simple deduction:

Renewable energies are inexhaustible + Biomass is a renewable energy source → Biomass is inexhaustible

This understanding of biomass is a social construct which has allowed the development of regulations and programs for the promotion of bioenergy (see Chapter 1.5). The categorical differentiation between renewable and non-renewable energies, however, is not primarily defined by the kind of resource, but by the temporal dynamic relation of use and reproduction of the energy potential in the respective society. Thus, the renewability of biomass cannot be simply presupposed as a 'natural and inherent property of re-growing', but has to be seen in a more differentiated relation to human land use activity and ecosystem behavior. This also applies to other forms of renewable energies which are influenced by ecosystem behavior. For example, the renewability of hydropower depends on the reproduction of precipitation and run-off patterns which have been used for the design of the technical facilities in the area concerned.

Besides its economic and political meaning as the resource of bioenergy, the term "biomass" is understood in a broader or more specific, general or scientific way, depending on context and topic of investigation. In its broadest sense biomass is defined as "total mass of living, dead and decomposed organisms of a habitat, also of the whole earth, including all organic matter produced by them" (Brockhaus

Enzyklopädie 2006, translation). This principally includes the energy sources coal, oil and natural gas which were produced in former ages by geological transformation from plants and micro-organisms. According to the relation of renewability of energy potentials and their societal use coal, oil and natural gas are excluded from the energy-political biomass category since they renew only in geological time scales, but can be exhausted by industrial use within a few centuries. For example, they are explicitly exempted from the scope of the German “Erneuerbare Energien Gesetz” (renewable energies act) for the electrical use of biomass by the “Biomasseverordnung”. This biomass ordinance defines “biomass“, eligible to be subsidized through the act, generally as energy sources stemming from phyto- and zoomass. Besides a list of accepted materials it contains a list of excluded materials, e.g. coal, oil, natural gas and peat (BiomasseV 2014, §2, 3).

The example of peat, however, shows that renewability and non-renewability can no longer be unambiguously defined. The boundary becomes fluid, depending on time scale and use. Peat is an organic substance, formed by peat mosses in moors, thus biomass, and was frequently used for heating in Europe in the past. In relation to the mining of peat in the past centuries, moors grow so slowly over thousands of years that peat is usually not regarded a regenerative energy source. In 1999 Finland, however, applied to the European Commission to recognize peat as renewable energy source within the directive for taxation of energy products (European Commission 1999). Finland uses peat for 7% of its total energy consumption. The vast moorlands of Finland in relation to its low population density suggest that peat could be a renewable energy source in this region. The Commission however, did not accept declaring peat an “intrinsically renewable resource”, but referred to a study of the evaluation of the peat industry in the new Member States and the regionally specific possibility to combine an adequate use of peat with recultivation techniques in moors, which could yield overall favorable ecological effects (ibid.).

Timber and biomass from energy crops generally count as renewable, since trees and energy crops grow within periods of one up to a couple hundred years, a time span relevant for human planning. Trees and energy crops, however, do not ‘automatically’ regrow out of themselves, but only if favorable environmental conditions of i.e. soil and climate, water and nutrient supply simultaneously renew under human management activity. The reproduction of those conditions – and therewith the presumed renewability of biomass – has to be critically scrutinized, not only for wood and energy crops, but also for residues stemming from food production, especially with a view to the world wide increasing population, land degradation, climate change, and water and nutrient scarcity (Section 1.2.3).

Biomass (in its broadest sense)	**Temporal scale of regeneration**	**Principally renewable in 'human time scales'?**	**Inexhaustibly usable?**
Oil, coal, gas	Billion years	No	No, therefore is separated from biomass as fossil energy source
Peat	> 1000 years	No	
Wood ('old-growth')	~ 200 – 1000 years	Depending on definition of 'human time scales'	Not really; only a few protected ones left; harvesting wood biomass contradicts ageing of trees
Wood (forestry)	~ 3 – 200 years	Yes	Depends e.g. on renewability of soil, stability of climatic conditions; space, water and nutrient availability; plant vitality, and harvesting cycles etc.
Energy plants and residues	1 – several years	Yes	
Algae	< 1 year	Yes	Depends e.g. on nutrient, water, and space availability

Table 3: Renewability of biomass sources relative to conditions and time scales of land use systems (author's portrayal)

Therefore an independent momentum of the renewing of growth processes does not exist. Since biological growth processes are driven by environmental factors, which nowadays, as mentioned previously, are natural-cultural hybrids, the renewal of (re)productive living and production conditions under human management is decisive. In the following this will be further elucidated by the historical example of the bioenergy crisis at the beginning of industrialization and by a potential scenario of nutrient scarcity.

1.2.2 History: Bioenergy crisis in Europe in the 17th century

At least one large scale bioenergy crisis has already happened in the course of history. Prior to and at the beginning of industrialization fossil energy sources were unknown. High energy consuming pre-industrial processes like glass and metal smelting or salt boiling were driven by combustion of charcoal, which was produced from coking wood in coal kilns. These processes used up so many forests that many European countries in the 17th century suffered from energy scarcity and land devastation. The remaining woods were in terrible condition, caused by the collection of firewood and harvesting timber for (ship) construction. In England, France and other European countries, scientists and authorities were assigned the task of conducting inventories in the (royal) forests and developing solutions for this resource problem. In the German "Erzgebirge" it was also feared that clear-cutting the forests would cause the florishing silver mining and melting industry to run out of (bio-) energy, thereby pushing the region into economic depression. To counteract this problem of national relevance, in 1713 Hans Carl von Carlowitz, the director of the royal Saxon upper mining authority "Königliches

Oberbergamt von Sachsen" introduced the idea of sustainable forest management with his "Silvicultura Oeconomica", one of the first handbooks of forestry, after he had travelled Europe and observed similar issues everywhere. This "Anweisung zur wilden Baumzucht" (instruction for cultivating wild trees) intended to manage the use of wood such "[...] daß es eine continuirliche beständige und nachhaltende Nutzung gebe" (that there will be a continual, steady and sustained usage) (Carlowitz 1713, 105 cited in Grober 2007, 19, translation). Carlowitz, most likely, made use inter alia of the book "Sylva" by John Evelyn (Evelyn 1664), who already in 1664 described the cultivation of various tree species in England, recommended outsourcing ironworks to the heavily wooded areas of New England in North America, and urged the consideration of the interests of future generations. In the following decades forest academies were established in Germany and France, where foresters from Russia to America came to study. The German wording "nachhaltende Nutzung", transferred to the French "production soutenu" and English "sustained yield" advanced to a paradigm for forestry within the next two centuries. Besides afforestation practices, Carlowitz also suggested measures for energy efficiency ("Holzsparkünste" in his words) such as the heat-insulation of buildings and the introduction of energy-saving stoves. Furthermore, he searched for substitutes for wood and recommended the use of peat. A short time later coal was used for salt boiling for the first time in Saxony and heralded the era of fossil energy (for the whole section see Grober 2007, 2010; Grober, Cunningham 2012).

Thus, the historical bioenergy and landscape crisis could only be stopped with the introduction of strict forest regulations along with the use of fossil energy sources. In this regard a current promotion of the use of biomass as substitute of fossil fuels on a large scale, e.g. co-firing in conventional coal burning power plants or processing in industrial biofuel plants, should be viewed with deep scepticism.

Remarkedly, the basic notion and semantics of sustainable development trace back inter alia to a bioenergy crisis. The classical concept of sutainable forest use, that is to harvest no more than can regrow within a certain time period, thereby reflects the principle of regenerability of natural systems.

However, while Carlowitz, with his idea of "nachhaltende Nutzung" (sustainable use), kept ecological aspects and caring activties (e.g. soil coverage) in mind, in the course of utilitarianism and the mathematical orientation of biology and ecology in the 19th century a purely quantitative view of "maximized sustained yield" prevailed. In Prussia, especially, forests soon mutated to purely economically efficient plantations through geometrically captured areas, thoroughly calculated tree stocks and systematically afforested monocultures. This was accompagnied by a drastic reduction of biodiversity (Grober 2007, 19–25). With the introduction of the category "biomass" production biology attempted to calculate 'natural' regrowth and renewal rates in forests as well as in fishery ecosystems so that a scientifically assumed, critical reproductive mass was not undermined (Biesecker, Hofmeister 2006, 113ff) (see Section 1.3.3).

Sustainability, however, cannot be determined merely by the renewal rate of a mass parameter. “What passes as *definitions* of sustainability are therefore often *predictions* of actions taken today that one hopes will lead to sustainability. For example keeping harvest rates of a resource system below rates of natural renewal should, one could argue, lead to a sustainable extraction system – but that is a prediction not a definition. […] Usually there is so much uncertainty in estimating natural rates of renewal, and regulating and observing harvest rates, that a simple prediction like this […], is always highly suspect, especially if it is erroneously thought of as a definition” (Costanza, Patten 1995, 194 with reference to Ludwig et al. 1993).

Prussian monocultural forestry is no longer regarded as sustainable. Today sustainable forest management in Germany not only comprises the renewal of a timber stock, but the maintenance of multiple welfare functions such as the regeneration and regulation of water, erosion protection and recreation (BWaldG 2010). In this sense not only quantitative but also qualitative temporal processes are to be considered for sustainable development (see temporal scales in Chapter 3.2). Species-specific rotation periods of 30-300 years, for example, do not allow trees to age, which reduces e.g. biodiversity, recreational, spiritual and educational value (Section 2.3.5) as can be experienced in old growth forests. Moreoever, pushing renewal rates through harvesting trees at an early age, on the one end, accelerates soil and landscape ageing processes on the other end (Section 2.3.2).

The quantitative view, however, is still deeply rooted. Nowadays it is expressed in the intense efforts to calculate greenhouse gas balances for biomass production. Another attempt is to calculate the bioenergy potential of residues by subtracting the amount of biomass to be returned to soils for maintaining carbon and nutrient balances from the total amount of available residue biomass as discussed below.

1.2.3 Scenario: Future nutrient scarcity?

As already mentioned, sustainable biomass production and food production is dependent on the persistence of suitable growing conditions, which includes nutrient availability from soils. Since natural soil fertility is quickly exhausted if biomass is continuously harvested but not returned, and to achieve high productivity, it is common practice in industrial agriculture to replace and add nutrients by inorganic fertilizers. However, in the future, such fertilizers may not be as abundantly available as they are today.

The industrial fixation of atmospheric nitrogen via the Haber-Bosch process, with 80% being used in fertilizer production, accounts for 80 million tons N per year releasing a massive flow of reactive nitrogen into the earth system (Rockström et al. 2009, 13; Galloway et al. 2008, 889). As a high-pressure and high-temperature process Haber-Bosch is very energy intense, using natural gas both as energy source and source of hydrogen for the synthesis of ammonia. With the decline of fossil energy sources and the expectation of rising energy costs, industrial N-fertilizers may become more costly and less available in the future. The introduction of efficiency measures in fertilizer production, transportation and application as well as the use of fertilizers from organic waste are proposed to address this problem (Gellings, Parmenter 2004). Furthermore, many pressing environmental problems like eutrophication of water bodies, dead zones and unoxic events in marine ecosystems, stratospheric ozone depletion as well as greenhouse gas formation and biodiversity loss are associated with the application and leakage of mineral fertilizers (Erisman et al. 2008). Rockström et al. (2009) therefore demand the limitation of reactive nitrogen flows to a quarter of its current value as a “planetary boundary” (Rockström et al. 2009).

About 20 million tons of phosphorus are mined from rock each year, of which 90% is used for food production, with about half of it lost to the ocean from croplands (Rockström et al. 2009, 13; Cordell et al. 2009, 293). While the use of P-fertilizer in Europe and North America is decreasing, worldwide its demand is expected to increase due to population growth, the growing popularity of meat and dairy-based diets, and the need to boost soil fertility in P-deficient regions, e.g. in Africa. In contrast to that, phosphorus, unlike nitrogen, is considered a finite resource, although it is a geochemically abundant element of the biological cycle as well. This is due to the fact that – according to different studies based on different assumptions and models – currently known high-concentration rock phosphate reserves, which can be exploited for P-fertilizer production, will become depleted within the next 60-400 years, while they are renewed only at geological rates of millions of years (Cordell, White 2011, 2029–2033). Moreover, Cordell & White (2011), transferring the peak oil model to phosphate rock exploitation, suggest that “peak phosphorus” will already be reached in about 20-30 years from now. Additionally, geopolitical and environmental impacts further constrain the accessibility and applicability of industrial P-fertilizers. Alone 85% of the global phosphate rock reserves are controlled by a single country, namely Morocco occupying Western Sahara. The second largest reserve (6%) is controlled by China, which recently imposed an export tariff on phosphate in order to secure the domestic supply. Other political and environmental concerns relate to uranium as a by-product of phosphate extraction. Since phosphate minerals are geologically accompanied by uranium and other heavy metals, the application of mineral P-fertilizer leads to an accumulation of uranium and cadmium etc. in the soils. This problem is likely to increase as the quality of exploitable phosphate rock reserves in terms of P-concentration and pollutants decreases, potentially requiring stricter legal regulations on P-fertilizer application as well as on P-reuse and recycling (ibid., Schröder et al. 2010). The whole situation is expected to worsen with the growing production of biofuels. Hein & Leeman (2012, 347) in their study on “the impact of first-generation biofuels on the depletion of the global phosphorus reserve” come to the conclusion that “current targets for biofuels […] will affect future food security and may have a net negative impact on future welfare”. As a solution to these emerging problems – similar to the case of nitrogen – efficiency measures along the whole value chain, demand management, and investing in “renewable phosphorus fertilizers”, including the recovery of P from crop residues, manure, food waste and human excreta, is proposed (Cordell, White 2011, 2043ff). However, very high efficiency gains and recovery rates would be required (Hein, Leemans 2012, 344ff). While peak phosphorus is still a much debated concept, consensus seems to be that a global to regional governance of sustainable phosphorus use is necessary.[9]

In summary it can be said that the present level of food supply is highly dependent on Haber-Bosch nitrogen, which can only be regarded as renewable if its production could be sustained with renewable energy and hydrogen sources in the long term. It is also highly dependent on mineral phosphorus, a non-renewable resource extracted from finite rock reserves. Despite all uncertainty one could easily imagine a nutrient scarcity scenario with fossil energy and rock reserves in decline. Such a scenario would mean at least two things: First, it would question the potential of biomass from high-input farming and second lead to a revival of the use of renewable nutrient sources.

Renewable nutrient sources are, besides nitrogen fixing legumes in the case of N and slow natural weathering processes in the case of P, basically **organic residues**. The latter, however, are also favored as suitable bioenergy sources. Their use is thought not to compete with food production and other land uses. The German Advisory Council on Global Change for example writes: “The use of biogenic wastes and residues has the advantage of causing very little competition with existing land uses. It involves no greenhouse gas emissions from land-use changes and cultivation […]. Overall WBGU attaches higher priority to the recycling of biogenic waste for energy (including cascade use) and to the use of residues than to the use of energy crops” (WBGU 2008, 6). Nevertheless it is acknowledged that a certain amount should remain to maintain soil carbon balances and fertility. “When using residues, care must be taken to meet soil protection standards - and hence ensure climate change mitigation” (ibid.). “A common concern relates to the removal of too many agricultural or forest residues from the soil

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[9] See the establishment of the European Sustainable Phosphorus Platform (ESPP): http://www.phosphorusplatform.eu (accessed 7/9/2014)

which might increase soil erosion or reduce the soil nutrient status over time. The appropriate amount that can be removed varies with soil type and site conditions" (Sims et al. 2008, 79).

While organically bound carbon typically decreases during bioenergy production (releasing CO_2), since it actually makes up the energy content, nutrients partially to fully remain in conversion residues (e.g. ashes, chars, sludges). Organic nitrogen for example is lost to the air during combustion and pyrolysis, but retained during anaerobic digestion. Phosphorus usually remains in ashes and chars as well as wastewaters and sludges. Thus conversion residues can be theoretically used to recirculate nutrients back to the land, compensating for what has been extracted by harvest. However, nutrients in conversion residues are not always well usable. Ashes and sludges, for example, often contain heavy metals and other pollutants, which limit their application to soil or require complex and energy-intense treatment. Phosphorus in biochar[10] for example is largely found in a form that is not available to plants (Libra et al. 2011, 82). Principally, biomass-to-bioenergy conversion processes could and should be designed in a way that promotes safe nutrient cycling and humus reproduction. This issue is further discussed in Section 4.2.2 (see also Figure 2). However, it could also be the case that traditional biomass-to-soil conversion processes like composting and fermentation (e.g. bokashi production) prove to be superior in this regard. A comparative study by the German Verband der Humus- und Erdenwirtschaft, for example, investigated the ecological performance of three biowaste converting processes: composting, anaerobic digestion including composting of the digestate, and co-firing, with regard to their potential contribution to soil fertility, soil biodiversity, and soil quality in terms of pollution prevention, as well as erosion protection and climate protection. The study revealed that composting shows the highest performance, closely followed by anaerobic digestion, while co-firing basically destroys any potential for positive ecological contributions (EPEA 2008).

Furthermore, the recirculation of organic material is also critical for water retention and the prevention of irreversible matter losses, especially of cationic plant nutrients like calcium and magnesium, which are also providing the buffering capacity of soils and therewith support the overall capability of plants to take up nutrients in exchange of protons. Irreversible matter losses from land to receiving waters, however, have increased in Germany, for example, since the introduction of non-renewable energy to agricultural systems, at rates of 50-100 times the natural background rate (Ripl 2003, 1928). This issue, threatening long-term soil productivity, is further elucidated in Section 2.2.2/ 2.3.4 and Chapter 4.3. Thus 'the appropriate amount' of biomass that can be removed is not solely a quantitative question of meeting certain carbon and nutrient

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[10] For an explanation and discussion of 'biochar' see Section 4.2.3.

budgets, but also needs to be related to landscape ageing processes (page 138) and the qualitative question of what is actually to be provided by the landscape and its soils over time.

Ultimately, all biomass including biogenic residue mass stems from land use (or aquatic) systems; and its sustainability of production must be viewed in their spatial-temporal development contexts. The historical example of a purely quantitatively interpreted "sustained yield concept" as well as a scenario of potential nutrient scarcity indicate that it is not only about the renewal of a bio-chemical energy potential and material stock, but also about the renewal of other landscape properties, functions, and services.

1.3 Renew-Ability of living & production conditions

> Energie ist die Fähigkeit, Arbeit zu verrichten.
> Energy is the capacity to do work (translation).
> *Max Planck*

1.3.1 'Biomass production' in the political-economical context

Within the international discourse about a sustainable use of biomass the wordings "sustainable biomass production" and "sustainable biofuels production" are used, especially in connection with the development of product certification schemes as a market instrument promoted by policy. Certification systems attempt to distinguish activties falling under these terms from non-sustainable ones (ISCC 2011, 4) (see Chapter 1.6). The International Sustainability & Carbon Certification system (ISCC), for example, claims that its logo "labels the provenance of the biomass, biofuels and bioliquids from sustainable production" (ibid, 14). "Biomass production" usually comprises agricultural, silvicultural, and aquacultural activities as well as activities making biogenic residues available for bioenergy production (Dam et al. 2008, 751). Main production pathways are given in Figure 2.

By means of various conversion technologies biomass resources are converted into biofuels whereby energy density is usually increased. Thus "biofuels production" further includes technical conversion processes, transport and storage, and eventually blending. The RSB standard of the Roundtable on Sustainable Biomaterials (formerly Roundtable on Sustainable Biofuels), for example, "identifies four types of operators subject to different sustainability requirements [...]. These include 'Feedstock

Producers', 'Feedstock Processors', 'Biofuel Producers' and 'Biofuel Blenders' " (RSB 2013, 5). The subsequent combustion of biofuels in different technical facilities, e.g. motors or combined heat and power plants (CHPs) are conversion processes as well, which finally yield the desired useful energy, i.e. transportation, heat for heating or process energy, and electricity driving further technical processes. The whole chain of custody from biomass provisioning over biomass conversion to delivering bioenergy to end users can be called "bioenergy production"[11] (UNEP 2011, 6) (Figure 2). The focus of this study is set on biomass production within a context of sustainable landscape development, not on logistics, conversion and trade. Consequences for conversion technologies, however, are touched upon in Chapter 4.2.

"The lion's share of global bioenergy use – almost 90% of the total, or around 47 EJ per year – is accounted for by traditional bioenergy: this represents around one tenth of current global energy use. This traditional usage involves burning wood, charcoal, biogenic residues or dung, mainly on inefficient three-stone hearths" (WBGU 2008, 3). The extraction of biomass from ecosystems, e.g. collecting fire wood, induces ecosystem change and may lead to land degradation in case of over-use. Together with health risks this is seen as a critical issue, especially in developing countries (ibid.). However, traditional bioenergy production for subsistence is usually not covered by sustainability standards[12], since there is no entry point into the market. Thus, 'production' in the context of certification only means activities manufacturing commodities (i.e. biomass resources, biofuels and bioenergy products) for the global and regional market in the classical economic sense (Chapter 1.1). Furthermore, although the above-mentioned production categories are not sharply defined, it becomes clear that biomass production basically refers to human economic activity regardless of the source or ecosystem from which the biomass stems. The actual biomass synthesizing activity – namely that of non-human living beings – is somehow contained within but not explicitly addressed by the term 'biomass production'. Additionally, the produced 'biomass' feedstock in this context denotes already harvested and collected, thus *dead* organic matter.

In contrast to that, scientifically, '*bio*mass' means *living* mass, and the category 'biomass production' in the ecological context exclusively refers to non-human, organismic activity, as is examined in the next chapters.

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[11] "The term 'bioenergy production' is used here to capture the various ways of producing biomass and converting it to solid, liquid and gaseous fuels, and to electricity. However, it is recognized that this term is not doing justice to the first law of thermodynamics (energy can be neither created nor destroyed, but only change form)" (UNEP 2011).

[12] In the sense of a sustainable landscape development the bioenergy use in the form of subsistence activities would have to be subjected to a sustainability check as well.

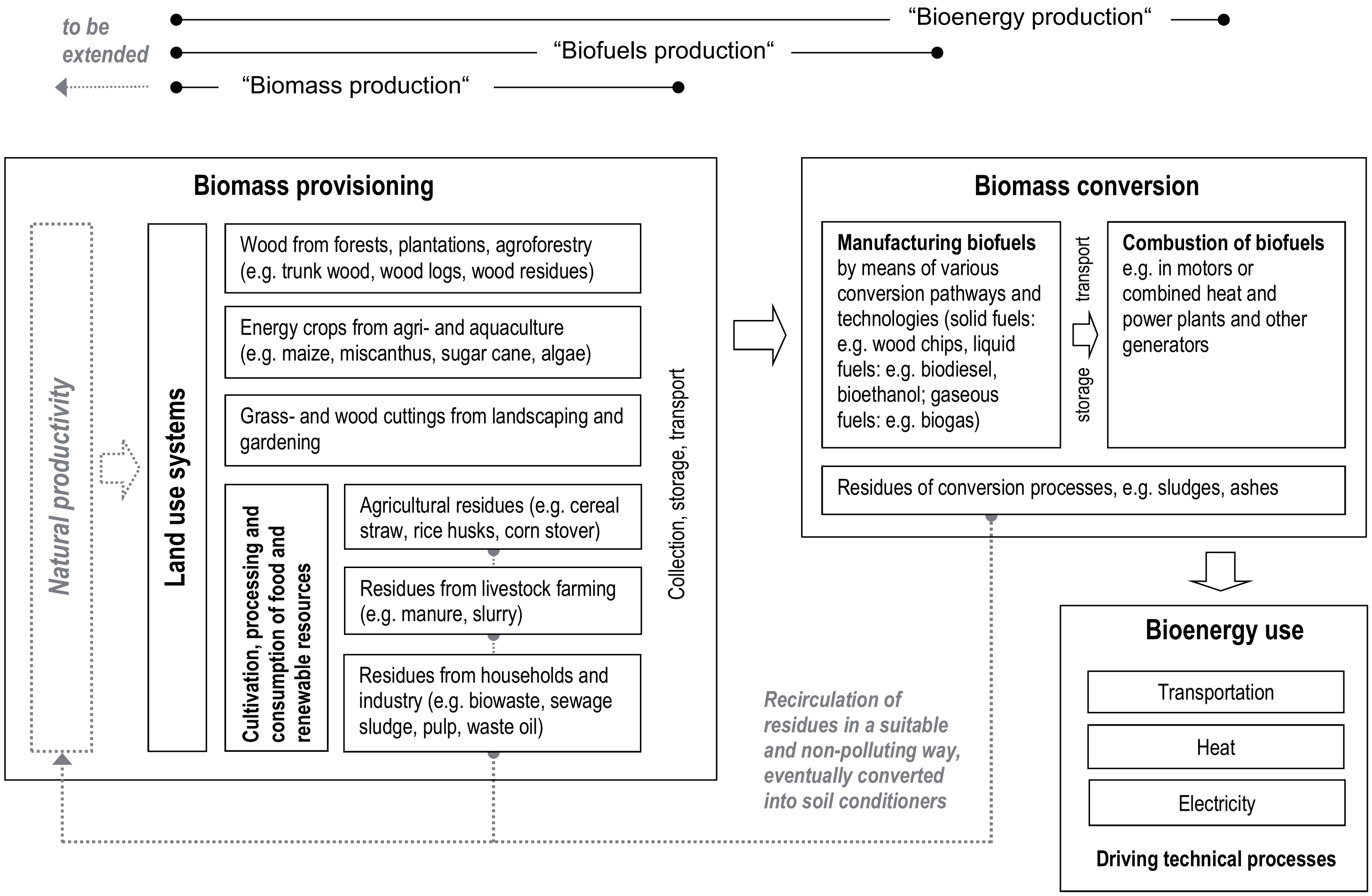

Figure 2: Bioenergy value chain and approximate fields of activity covered by common terminology. The dotted lines indicate that natural productivity is yet to be consciously included (author’s portrayal)

1.3.2 'Biomass production' in the scientific ecological context

In scientific ecology "**biomass**" is defined as "the total mass of all living organisms […] or of a particular set (e.g. species), present in an ecosystem or at a particular trophic level in a food-chain" (Allaby 2005, 56). The prefix *bio-*, derived from Greek *bíos* meaning '*life'*, thereby associates "the word to which it is attached [here: mass, author's note] with *living* organisms or processes" (ibid. 53). Thus, in a strict scientific sense biomass only encompasses the mass or tissue of living organisms, while dead organic matter in an ecosystem is called "detrital mass" or "necromass" (Greek *nekrós*: 'corpse, dead body'). Biomass is usually expressed as fresh or dry weight or as the carbon or calorific content per unit area. "**Production**" is understood as the biomass gain of an organism, a population or in an ecosystem between two points in time, while "productivity" refers to the (average) rate of production per spatial and temporal unit. Production occurs through "**biosynthesis**", i.e. anabolic cellular processes. Producing, biosynthetic organisms are principally all living beings[13]. "Phytomass" (biomass produced by plants) is commonly distinguished from "zoomass" (biomass produced by animals) and microbial mass (biomass produced by microorganisms incl. fungae), as well as "primary producers" from "secondary producers" (ibid. 56, 297, 353), (Townsend et al. 2008, 358; Schaefer 2003, 48, 76, 222, 274ff, 313; Lartigue, Cebrian 2009).

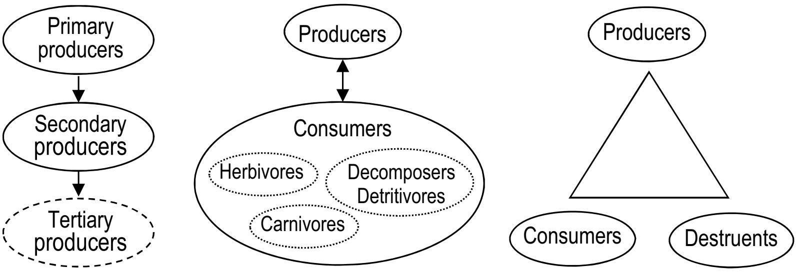

Figure 3: Common classifications of functional organismic groups in ecosystems with regard to trophic energy and carbon flows (author's portrayal)

Primary producers are "autotroph" organisms, which bio-chemically reduce carbon dioxide either by using solar radiation (photo-autotrophs) or anorganic chemical bonds (chemo-autotrophs) as the energy source, and build organic compounds (carbon-fixation). Photosynthesis is the basic process underlying photo-autotroph primary

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[13] In this sense, humans are also physiologically, not only economically, producers of biomass. However, one would not call their bodies 'biomass', except maybe from the perspective of robots in the movie "Matrix", which cultivate humans as a bioenergy source.

production performed by green plants, algae and photosynthetic bacteria. Chemosynthesis, practiced only by some specialized groups of bacteria (e.g. sulphur- or iron-oxidizing bacteria) can be neglected with regard to the magnitude of biomass production. **Secondary producers** are heterotroph organisms, which feed on primary producers and their debris using organic compounds as carbon and energy source (while those organisms feeding on secondary producers are called tertiary producers). According to their feeding behavior, i.e. consuming and decomposing living or dead organic matter, they are also classified as "**consumers**" (herbivore animals) and "**decomposers**" (detritivore animals and microbes) or "**destruents**" and thereby as functional groups opposed to primary producers, which are often simply labelled "**producers**" (Townsend et al. 2008, 359f; 2009, 429f; Lartigue, Cebrian 2009; Wittig, Streit 2004, 105; see also Section 1.3.3). The Oxford Dictionary of Ecology, for example, defines "producer" as "in an ecosystem, an organism that is able to manufacture food from simple inorganic substances (i.e. an autotroph, most typically a green plant)" (Allaby 2005, 354).
Primary producers use up some part of their photosynthetically fixed compounds in respiration to fuel their cellular processes. Primary productivity is therefore further distinguished into **gross primary productivity** (GPP) and **net primary productivity** (NPP) according to following equation:

NPP = GPP – autotroph respiration

Gross and net primary productivity can be looked at on various spatial-temporal scales (e.g. plant tissue, individual organisms, populations, and ecosystems up to the whole biosphere). In relation to a certain area (e.g. of a terrestrial ecosystem, biome or the entire land surface) or volume in case of aquatic ecosystems, NPP is the rate at which biomass is actually renewed per temporal unit. It is also an indicator of how much trophic energy is totally available for all other heterotroph living beings, including humans. NPP is estimated by means of different field tests, laboratory methods and satellite data and can be expressed as calorific content, mass of organic dry matter or carbon per area and year (Smith, Smith 2009, 568–571, 581; Haberl et al. 2007). It is used to characterize ecosystems in terms of their productivity[14] (Lartigue, Cebrian 2009).

To conclude, 'production', in scientific ecology, is mainly associated with the formation of biomass and provisioning of trophic energy by vegetation, which is commonly said to

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[14] Ecosystem productivity is not to be confused with **net ecosystem production** (NEP) as the actual accresence of biomass in an ecosystem over time which is not respirated (Smith, Smith 2009, 631).

form the ‘beginning of the food chain’.[15] ‘Productive’ ecosystems are usually considered those that build up a high net amount of phytomass per year consumable by heterotroph organisms.

Accordingly, in applied sciences, NPP and empirical biomass yields are used to compare different crops and land use systems regarding their productivity as provider of biomass and to calculate their potential for bioenergy use under different scenarios. To what extent biomass can actually contribute to a future energy mix is conversely discussed. Numerous potential studies are conducted in many areas and on many scales. However, their results vary greatly upon the assumptions made and are difficult to compare (Berndes et al. 2003; Foth et al. 2007, 29ff).

An often heard argument on the optimist side is that annual **global primary production** regularly regenerates an energy potential many times the world energy consumption. Global NPP is estimated to capture 4,500 EJ of solar energy each year (Sims 2004 cited in Ladanai, Vinterbäck 2009, 14). In investigating the “global potential of sustainable biomass for energy” in cooperation with the World Bioenergy Association, Ladanai and Vinterbäck (2009, 14) state that “about 5% of this energy, or 225 EJ, would have covered almost 50% of the world’s total primary energy demand in 2006”. Referring to studies by Hoogwijck et al. (2003)[16], Berndes et al. (2003) and Smeets et al. (2004), they suggest that by 2050 total bioenergy production from “surplus forest growth”, “agricultural and forestry residues”, and “dedicated woody bioenergy crops on surplus agricultural land” could meet world primary energy demand, while claiming that “the current stock of standing forest, with a total energy content corresponding to 2,001 EJ, is a large reservoir of bioenergy” (Ladanai, Vinterbäck 2009, 15,18).

In contrast to that, other voices point to the fact that a large portion of NPP is already consumed by humans to fulfill their needs for food, raw materials and living space, expressed in the **HANPP**-indicator (global **Human Appropriation of Net Primary Production**) (Haberl et al. 2007). HANPP is based on an estimation of the potential

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[15] Interestingly, it is suspected that not photosynthesis but fermentation evolved as the first living process. Earliest bacteria-like cells used organic molecules, created through geochemical factors, as their energy source. Only when these organic substances were almost used up did photosynthesis establish itself as a complementary process creating an oxygen atmosphere. This provided the basis for the development of respiration, which uses oxygen as an oxidizing agent and is more efficient than fermentation. Based on these fundamental cellular processes a highly interwoven food web developed further in the course of evolution (Alberts et al. 1989, 4, 381-387) within which the linear idea of a food chain represents a very rough abstraction. More appropriate is the concept of a linear energy flow through trophic levels (Smith, Smith 2009, 568).

[16] In the original study Hoogwijk et al. (2003, 119) point out, however, that it is “not ‘a given’ that biomass for energy can become available at a large-scale”, since the realization of potential depends on many factors like e.g. the future demand for food, the (increased) use of bio-materials, or competing land uses such as surplus agricultural land used for reforestation.

NPP of unmanaged biomes and indicates how much of this theoretical net primary production (NPP_0) is appropriated by the global human society through harvest, land use change, and human induced fires. Besides high-input farming, which (supported by fossil resources) can increase actual net primary production (NPP_{act}), in total, human land use decreases NPP compared to potential natural vegetation. Haberl et al. (2007) state that the global human appropriation of NPP lies at 23.8%, and warn against high hopes placed on the global bioenergy potential. Beyond that Foley et al. (2007) pose the general question of how much (more) biomass can be appropriated by the global human society before the functionality or renewability of ecosystems collapse: "[…] it is natural to ask how our use of terrestrial ecosystems can be sustained, let alone be expanded, as we consider the potential for future population growth, continued economic development (and associated changes in diet), and increasing interest in biologically based energy sources. Will the future growth of human land use come at the expense of continued ecological degradation […]? Ultimately, we need to question how much of the biosphere's productivity we can appropriate before planetary systems begin to break down. 30%? 40%? 50%? More? Or have we already crossed that threshold?" (ibid. 12586).

1.3.3 'Biomass production' as historical construct

The two previous sections show that 'biomass production' in the economical and ecological context has **opposing meanings**. 'Biomass' in a scientific ecological understanding means *living* mass in a given environment at a given time, while 'production' refers to the accresence of biomass in a given environment over a certain time span, especially associated with the *biosynthetic activity of vegetation*. In the economical-political context 'biomass' means *dead* harvested biogenic material, while 'biomass production' primarily refers to *human economic activities* of cultivating, collecting, storing and transporting biomass for the purpose of energy (and material) use. These contrary meanings underpin two **diametrically opposed extreme positions** forming a field of tension in the public biomass debate. The technical optimist perspective frames biomass as an inexhaustible resource and presumes a high potential of use. The conservationist perspective beholds the appropriation of biomass as a loss of habitat and nutritive energy in ecosystems and especially regards biofuels as the "greatest offence to biodiversity" (Weizsäcker 2007, translation). Both positions fall short, though, when reducing biomass to a biochemically bound energy content. Their dichotomous understandings and viewpoints are based on constructions with a historical development.

Biesecker and Hofmeister (2006, 109f), in their investigation of the development of the categories 'productivity' and 'production' in biological and ecological theory building, emphasize that the bipolar functional group labels ‘producers’ and ‘consumers’ were imported into the ecological context from neoclassical economics at the end of the 19th century, leading to an interacting dichotomization. With the emergence of **production biology** at the beginning of the 20th century, an already economically reduced production category, cut off from any social and ecological regenerative activities (Chapter 1.1), thus enters natural science and, combined with the invention of ‘biomass’, is naturalized there. Referring to Schramm (1984, 202f) Biesecker and Hofmeister (2006, 112–115) point to a scientific controversy from the 1930s in this regard. In an argument about the productivity concept of limnic ecosystems the position of zoologist Reinhard Demoll opposed the position of hydrobiologist August Thienemann. Demoll argued from a fisheries perspective, in which production is economically determined and clearly differentiated from biological reproduction of the fish population. He understood production as yield, as the highest amount which can be extracted without undermining the steady-state of the living fish biomass. In contrast to this applied science perspective Thienemann adopted a fundamental research position. He explicitly excluded managed ecosystems as special cases from his production concept. He understood biological production as the total mass of organisms and their excrements accumulating in a biotope during a certain time span, not to be confused with an economical yield concept. Thienemann’s concept finally prevailed in production biology. Therewith, “the distinction between a “reproductivity” (defined from a perspective of ecological systems) and productivity (defined along human utility demands), as suggested by Demoll, is given up. The “reproductivity” of natural systems [as a productivity that reproduces or sustains itself, author's note] thereby gets lost, and is subsumed under an abstract, desocialized, and unhistorical category of ecological production” (Biesecker, Hofmeister 2006, 115, translation). As in economics earlier, the ability of living communities to inseparably produce and regenerate also partially dwindles away in the ecological consciousness (ibid. 109–122).

First (re)productive organismic activities were cut off from the economic concept of ‘production’, then – transferring the economical production category into an ‘objective’ natural scientific category – human management activities were exempted from the ecological concept of ‘production’. This may have caused the described ambiguity of biomass production in the separated economical and ecological contexts (Figure 4).

From the beginning of production biology, the biomass concept was also applied to considerations of bioenergy use. In 1926 [about 200 years after Carlowitz was confronted with a European-wide bioenergy crisis, author's note] Edgar N. Transeau calculated a biomass balance of a hypothetical corn field in the form of an energy balance with the intention to show the potential of biomass as a future energy source (Schramm 1984, 213ff cited in (Biesecker, Hofmeister 2006, 116). On the fundamental science pathway this act of abstraction was taken further by emerging systems ecology into concepts of trophic energy flows and ecological efficiencies in ecosystems (see also Chapter 2.3.4), with the works of Arthur Tansley, Raymond L. Lindeman and Eugene P. Odum standing out in this regard. Besides all their (and others') achievements, systems ecology further reduced the biomass parameter from the magnitude of living beings and processes present in an area to mere numbers of energy and carbon content. In defining 'productivity' solely as biomass gain, as shown in the previous chapter, other multifaceted activties of living beings were automatically marked 'non-productive'. Ecological theory building (unintentionally) therewith supported the utilitarian economic view on land and living beings as 'natural resources' (Biesecker, Hofmeister 2006, 116–120). The quantification of living processes and its reduction to material and energetic factors actually made living tissue calculable and available on a large scale as a biomass resource and commodity for the market.

'Biomass production' is a vivid example of how the production category, as it is defined by economics and supported by the mathematical orientation of biology and ecology, masks the living (re)producing activity of non-human beings, while simultaneously completely incorporating it. In this sense it is also to be feared that a one-sided consideration of carbon flows, carbon balances and trading schemes as market instruments will not lead to the desired sustainability effects.

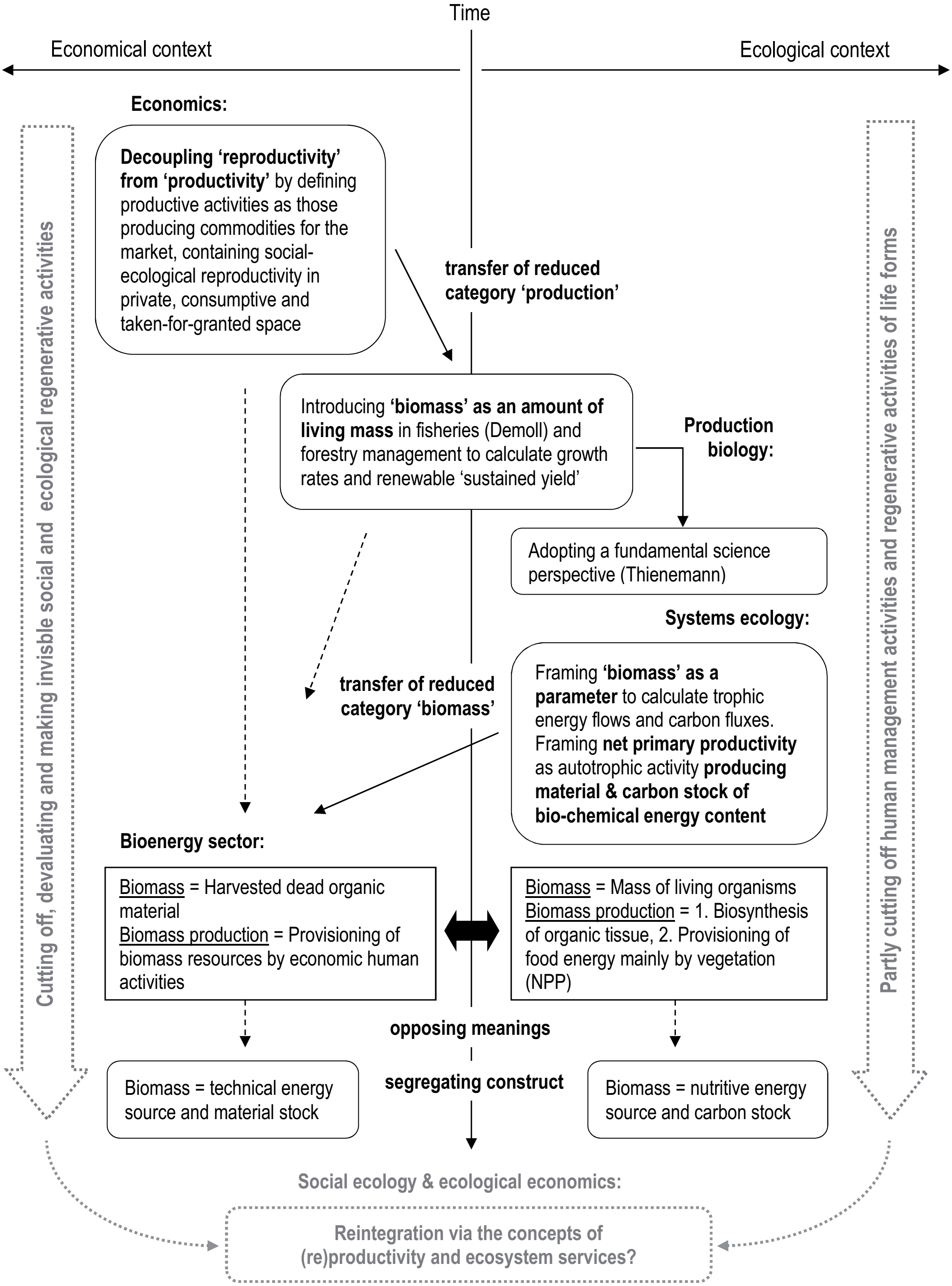

Figure 4: Model of the development of the category 'biomass production' as a historical construct (author's portrayal, simplified after Biesecker and Hofmeister, 2006, 75-130)

1.3.4 Living biosynthetic activity performing productive biological-ecological work

The different perspectives on the term 'biomass production', which mirror each other in their ambiguity, demonstrate not only points of contention in the debate on bioenergy but also the chances of a re-integration of economic and ecologic points of view. When both meanings are conciously combined again, for example through the category of (re)productivity, a thought and action space is opened in which human economic activity as well as that of the ‘living mass’, the living organisms, can be examined at the same time and on the same level. Therefore it might be helpful to conceive of biosynthetic organismic activities as productive ‘biological-ecological work’. This further construction will be explained by taking a closer look at the processes of photosynthesis and respiration on a cellular scale.

Light reactions and dark reactions, or more properly, carbon reactions, are commonly distinguished in photosynthesis. During the light reactions, which take place in the chloroplasts, water serving as an electron donator is oxidized by means of absorbed sunlight, and reductants (mainly in the form of NADPH) as well as ‘energy-rich’ molecules (mainly in the form of ATP) are generated. These are used in carbon (fixing) reactions to reduce atmospheric CO_2 (or CO_2 solved in water) and to synthesize sugar molecules. The sugars can either serve as ‘building blocks’ for the synthesis of more complex organic molecules or as ‘fuel’ in respiratory processes (Taiz, Zeiger 2007, 125–195; Alberts et al. 1989, 60; Campbell et al. 2009, 97ff; 2009, 256–270).

During respiration sugars (in the case of heterotrophs obtained from food) are catabolized whereby again ‘energy-rich’ bonds (mainly in the form of ATP) are created. These mobile fuel molecules together with enzymes drive all other cellular metabolic processes, i.e. the synthesis of organic molecules, the active transport of ions and molecules across membranes, and the generation of force and movement (Alberts et al. 1989, 60–69). “These three types of processes play a vital part in establishing biological order” and doing “useful work”[17] (ibid. 62f). More precisely, the close enzymatic coupling of exergon (energetically favorable) hydrolysis of ATP to endergon (energetically unfavorable) reactions enables the cell to perform **chemical work**, **transport work**, and **mechanical work**. ATP used up in such work processes is constantly regenerated by the respiratory chain – a set of reactions located in the mitochondria transferring electrons to water now serving as an electron acceptor – coupled with a chemiosmotic process via an electrochemical proton gradient (together known as oxidative

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[17] The exclusive biological order, i.e. of how enzymes are folded and integrated into membranes forming and separating reactive compartments, is thereby decisive for the regular performance of cellular energy conversion and work processes.

phosphorylation). In this way ATP acts as a renewable energy carrier of the cell (Campbell et al. 2009, 203ff, 234–239; Alberts et al. 1989, 349ff).

This look at the cellular level makes it clear that in analogy to energy-technical terminology, the complementary processes of photosynthesis and respiration could also be seen as biomass production and conversion processes, which provide biochemical energy for metabolic work processes. Or in other words: Using solar energy, **the process combination of photosynthesis** (plus chemosynthesis using unorganic chemical energy) **and respiration** (plus fermentation) **supplies the necessary bioenergy, by which all living beings perform cellular work**.

Collective cellular reactions “at work” (Hill et al. 2008) maintain an incredible variety of life forms, their morphological structures, physiological processes and behavioral patterns. This is due to the fact that cells are able to differentiate and assemble into distinct spatial patterns, and to respond to signals and changes of their respective surroundings (Alberts et al. 1989, 879–1000). Thus, on an **organismic scale,** biosynthetic processes form highly organized cell complexes, tissues and organs, which carry out **specialized functions and activities** well described by the plant and animal physiological sciences (see e.g. Campbell et al. 2009; Hill et al. 2008).

A prominent example from the plant domain is the specialized stomata cells in the epidermis of leaf tissue, which regulate CO_2 intake and water loss in response to changing conditions of light and atmospheric humidity. Another example is specialized root hair cells, which increase the surface area and take up water and nutrients by passive and active transport through selective membranes. Dead tissue can also have essential functions as is the case in the xylem, through which water is transported from the roots up to the leaves. A prominent example from the animal domain is muscle cell tissue, which enables animals to move by exercising contraction mechanisms.
Through such **physiological traits** organisms obtain **specific capabilities** which allow them to inhabit ecological niches and survive under very different environmental conditions (see e.g. Schoener 2009; Ackerly, Stuart 2009; Wikelski 2009). Often in the biological sciences it is emphasized how well form and function correspond in the biosphere, how well species have adapted to their environment in the course of evolution, and how well individuals can adapt to actual changes of environmental conditions.

However, living beings do not only adapt to their surroundings, they also actively shape it (Odum 1971, 23ff). With their metabolic processes and living activities **all organisms modulate their environment and manage their sites and territories**. Trees pump water and moderate temperature. Beavers build dams and moles dig tunnels. Insects translocate seeds and pollen. Earthworms form soil particles, and so on. Organisms also act on a global scale. A prominent example already mentioned is that green plants in former times created the oxygen atmosphere, which also triggered large scale geological processes such as precipitation of certain minerals (e.g. iron), building characteristic geological formations of today (Odum et al. 1980, 440ff). Not so well known may be activities of microorganisms like microscopic algae, bacteria and fungae. A theory by Hamilton & Lenton (1998) describes how microbes for the benefit of co-dispersal act as 'weather-makers'. Plankton patches of marine algae tend to cause thermals to form above them. They intercept sunlight and warm up surface water layers and the air above. This causes turbulences and bubble bursting processes, lifting the algae and other microbes up into the air. As a product of their sulphur metabolism some algae emit Dimethylsulfid (DMS), which is oxidized to sulphate functioning as cloud condensation nuclei. Latent heat released through condensation draws more air from below, enforcing winds and microbial take-off.[18] Clouds initiated by the algae serve them as vehicles for long distance transport and provide UV shelter. Some specialized bacteria and fungi commonly found in the atmosphere 'care for landing'. With their property of ice-nucleation they trigger precipitation, which enables the microbes travelling with the clouds to descend to the ocean or the land and to establish new colonies. This example illustrates that organisms are not only capable of influencing weather phenomena, but of actively creating them. Furthermore, "it is already established that biogenic cloud formation occurs on a scale fully capable of affecting world climate" (Hamilton, Lenton 1998, 1; see also Section 2.3.1 Water and climate services). The example also shows that living beings of different kind do not act independently, but often in close 'teamwork' (ibid. 9f).

Via their metabolic processes and physiological activities organisms are inextricably linked to each other and form living communities on an **ecosystem** or **landscape scale**. "By their concerted action in ecosystems they also adapt the geochemical environment to their biological needs" (Odum 1971, 23). By recirculating water and matter within their communities, dampening temperature fluctuations and reducing irreversible losses of vital minerals from the land to the sea, they keep their resources continuously available and 'sustain themselves' over space and time (Ripl 2003; Ripl, Wolter 2002). Such closely coupled life processes, especially of vegetation in cooperation with soil organisms, which are described in more detail in Section 2.3.1, can be understood as **integrated land, water and resources management activities**, by which organismic communities **create and maintain favorable living conditions**.

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[18] Another, eventually more feasible, explanation would be a condensation-induced rather temperature-induced pressure gradient making the air above the plankton patches rise quickly (see "biotic pump" hypothesis decribed in Section 2.3.1 Water and climate services)

Since these activities are performed by energy consuming biological cellular work processes, and create and maintain ecological relations and beneficial environmental conditions – also for humans – they are framed here as **‘biological-ecological work’** (opposed to human labor and technical work processes[19]).

Cooperative organismic land, water and resources management, alias biological-ecological work, provides multiple benefits to human societies and their economies, which is more and more recognized through the concept of **ecosystem services** (Daily 1997b; MA 2005; Sukhdev 2010). Ecosystems regulate the climate, produce fertile soils, purify water and provide opportunities for recreation and identification etc. In doing so, they continuously regenerate the preconditions for economic production. As this is a key argument in this study, the concept of ecosystem services and its implications for an economic mode of (re)productivity is further investigated in Section 2.2.1.

With regard to the concept of natural productivity, in total, biosynthetic living activity can be conceived as **productive biological-ecological work** in a twofold sense:

1. Independently of human utility, it brings about and maintains a rich diversity of life forms on earth, while it creates and regenerates living conditions. It is thus inseparably productive and reproductive.

2. Considering utility for humans, it is a value-creating activity, which (re)generates not only resources, but also the (pre)conditions for economic production. It thus largely contributes to the making of every product traded at the market.

Thus, living communities show ‘renew-ability’ not only as the ability to reproduce (sexually), but also as the ability to regenerate – through their production activities – favorable living and production conditions for themselves (and for human societies). It should be pointed out, however, that the notion of ‘biological-ecological work’ providing ecosystem services does not mean that it is work performed *for* humans. Rather the work and its services arise from auto-poietic dynamics, despite the fact that these today are largely influenced by humans. (For a reflection of the construction of ‘biological-ecologial work’ see Section 3.3.3.)

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[19] A line separating organismic work from human labor and technical work cannot always be sharply drawn, e.g. in the case of bacteria working inside the human intestine or in biogas plants, or in the case of genetically modified organisms. In biology definite separations are often difficult even if it comes to powerful categories such as ‘life’ and ‘death’, which cannot always be clearly distinguished, e.g. in the case of viruses. Nevertheless, such distinctions still make sense, despite not being applicable in a perfectly strict sense in every case. It should be noted though that organismic, human and technical processes are in close interaction and interdependence in the landscape, i.e. *not* working apart from each other.

1.4 Broadening the scope of renewability for sustainability

Human societies appropriate the living space created by ecosystems and change it according to their needs. They thereby create new living communities (e.g. agro-ecosystems) and conditions, which, in turn, constitute life possibilities and impossibilities for other organisms, and influence their behavior. Land use systems are thus hybrids of societal activity and natural productivity, in which human and organismic behavior is mutually intertwined. Biomass for energy use therein is a joint product of human and organismic land management activity. This is relevant insofar as the systemic category 'biomass' conceals the fact that living tissue of photosynthetic vegetation does not just renew a stock of bio-chemically bound energy or carbon, but also in cooperation with other organisms performs multiple other activities in the landscape on a daily basis, which provide the living and production conditions for society and economy and further components of quality of life. These capabilities, activities and services – which may be called 'natural productivity' as a whole – need to be explicitly recognized in the value chain of bioenergy production (Figure 3) and in any assessment of its sustainability.
If, for example, a landscape area is cleared of vegetation, e.g. if trees are cut, hedges removed and wetlands drained, for the purpose of rationalizing industrial agriculture, such as to increase the productivity of agrofuel feedstocks, then those services which had been provided by the trees, hedges and wetlands need to be technically replaced, e.g. by installations for flood protection or water purification etc. This entails technical energy requirements, which theoretically should be included in life cycle energy balances. On the other side, however, it is also possible to reestablish vegetation in already cleared agricultural sites and degraded landscapes areas by introducing certain energy crops (e.g. perennials), which then, even if harvested, can provide certain services again.

Taking human and organismic land management activities to be on an equal footing, **food energy can be understood as bioenergy for biological work processes and, vice versa, bioenergy as nutritive energy for technical work processes**. Technical work gained while fuelled by bioenergy then principally needs to be weighed against biological-ecological work that is eventually lost through land-use change or land degradation and would need to be replaced at another place or time by energy consuming technical capacity, if this is at all possible. Special attention needs to be given to irreversible losses of biological-ecological capacity in this regard (Section 2.3.5). The author takes the view of strong sustainability here, which means that technical capital is regarded as complementary to natural capital, but natural capital to a large extent cannot be replaced by technical capital (Daly 1999, 110ff; Ott, Doering 2004). However, the substitutability debate cannot be dealt with further here.

It is probably beyond dispute that not only renewable energy sources, but also the renewal of basic & desirable conditions and qualities of life such as high quality water and nutrient sources, a moderate climate and fertile soil as well as opportunities for recreation and inspiration, etc. are all equally indispensible for a sustainable development. Thus, *bio*mass can virtually only be regarded a 'renew-able' and 'sustain-able' energy source if its joint production by human and organismic land management activities regenerates not only the energy potential, but also other life-support functions. Therefore it is proposed here that the understanding of 'renewability' be expanded from a purely materialistic concept of 'self-renewal' of natural resources to a processoral natural-cultural unity of life giving and sustaining capabilities and activities.

The question is: What are the distinct properties of the respective land use ecosystems or nature-culture hybrids created by human will and intervention locally as well as in a regional distribution and in its 'sum' on a global scale? Which concrete services and qualities are required and desired or provided and degraded? And how can they be improved? Essentially, how can the 'natura-naturata-product' of economic production actually qualify as natura naturans - as productivity and long-term source for vital and desirable conditions and qualities of life in a specific landscape context?
Before returning to these questions in Chapter 2, the next sections investigate which objectives govern European bioenergy policy, based on which assumptions and which pathways for safeguarding the sustainability of biomass production are chosen.

1.5 European bioenergy policy

1.5.1 Objectives and assumptions

European bioenergy policy evolved over the last three decades. At least since 1986, when the Council announced the promotion of renewable energy sources (RES) as one of its energy objectives, investments have been taken especially in the field of technology development and demonstration projects through various research programs (European Commission 1997, 6). In the second decade a broad promotion of renewable energies took off with the adoption of the White Paper “Energy for the Future: Renewable Sources of Energy” in 1997 (European Commission 1997) and therewith also the promotion of bioenergy, especially of biofuels.

In the previous decade of 2000-2010 two main strategies determined operational policy objectives relevant for the bioenergy sector: the Lisbon Strategy and the European Strategy for Sustainable Development (EU-SDS): The Lisbon strategy focused policy measures on boosting economic growth and job creation with the underlying concept of a ‘knowledge economy’[20], while the first European strategy for sustainable development[21] adopted at the Gothenburg council meeting in 2001 “added an environmental dimension to the Lisbon process” (European Council 2001, 1). The two strategies were intended to be complementary. Decoupling economic growth from environmental degradation through resource efficiency and the development of environmentally friendly technologies were taken as the main pathways to make the objectives of growth and jobs compatible with sustainable development (Europäische Kommission 2002, 9; European Council 2006, 3). The growth paradigm itself has not been questioned, and is reinforced in the current Europe 2020 strategy aligning policy action towards “smart, sustainable and inclusive growth” (European Commission 2010b). The concept of resource efficiency is further deepened in the flagship initiative “A resource-efficient Europe” (European Commission 2011d), launched by Europe 2020.

A hierarchy of policy objectives underlies bioenergy policy within this strategic policy framework, managed by the Directorate-General for Energy. A chronological list of relevant policy documents analysed upon their policy objectives and targets is given in Table 4.

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[20] The overall strategic goal for European and Member State policy was set as “to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion” (European Council 2000, 2).

[21] The goal of sustainable development was included in the Treaty of Amsterdam in 1997.

Year	Policy document	Policy	Policy objectives outlined in the document	Targets concerning RES and Biomass (indicative, *mandatory*)			Reference
1995	White Paper on Energy Policy COM(95) 682	Energy	Sets 3 main energy policy objectives: (1) overall competitiveness (of the European economy on the world market), (2) security of energy supply, (3) environmental protection (by internalizing external costs and benefits).	—	—	—	46.
1997	White Paper on Renewable Energy Policy COM(97) 599	Renewable Energy	To promote market penetration of renewable energy sources (RES) in the European Union contributing to: - reducing dependency on imports, increasing security of supply, - reducing CO_2 emissions, - developing European industries and export opportunities, creating jobs, improving cohesion through regional development. Main contribution of RES growth expected to come from biomass.	2010	12%	share of RES in primary energy consumption (doubling from 6% in 1996)	1.1, 1.3.1
				2010	10.000 MW_{th}	established biomass installations (combined heat and power)	3.2.3, Annex II, 39
				2010	90 Mtoe (15 Mtoe 30 Mtoe 45 Mtoe)	projected contribution from biomass (from biogas from agricultural and forest residues from energy crops)	
2001	Renewable Energy Sources Directive 2001/77/EC	Renewable energy (electricity)	Implementation of directive proposal of the White Paper: To promote an increase in the contribution of RES to the internal electricity market for reasons of security and diversification of energy supply, of environmental protection, social and economic cohesion and compliance with the Kyoto Protocol of UNFCCC.	2010	22%	share of electricity produced from RES	(2), (3), Art.1; Art.3
						national indicative targets to be set by Member States	
2003	Biofuels Directive 2003/30/EC	Biofuels	To promote the use of biofuels and other renewable fuels to replace diesel or petrol for transport contributing to climate change commitments (Kyoto Protocol), environmentally friendly energy supply security and promotion of RES.	2005	2%	share of biofuels and other renewable fuels for transport related to energy content	Art.1, Art.3
				2010	5,75%		
2005	Biomass Action Plan COM(2005) 628	Bioenergy	To foster biomass use in the heating, transport (and electricity) sector to reach policy targets and objectives (reducing greenhouse gas emissions and dependency on fossil fuels. To stimulating economic activity in rural areas). To pave the way for further bio-energy growth by 2020 adding new technologies (2nd generation) to the mix.	2010	149 Mtoe	bio-energy use	6, 22, Annex III
2006	Biofuels Strategy COM(2006) 34	Biofuels	To carry forward the biofuels component of the BAP to boost development and use of biofuels in the transport sector meeting overall policy objectives (GHG reduction, diversify fuel supply, develop long-term replacements for fossil oil, diversify income and employment in rural areas) and meeting 3 specific aims: (1) To further promote biofuels ensuring that their production is "positive for the environment" and contribute to the Lisbon strategy, (2) to prepare for large-scale use of biofuels, (3) to explore opportunities for developing countries and EU's role to support sustainable biofuels production.	—	—	refers to the targets of the Biofuels Directive	3ff

2006	Green Paper on Energy Policy COM(2006) 105	Energy	To develop a common European energy policy to lead global energy debate To develop a common European energy policy to lead global energy debate. Proposes 3 main energy policy objectives: (1) sustainability (namely RES promotion, energy efficiency, climate protection), (2) competitiveness, (3) security of supply.	—	—	—	17ff
2007	Renewable Energy Road Map COM(2006) 848	Renewable energy	To further promote production and consumption of RES to enable the EU to meet the dual objectives of increasing security of energy supply and reducing greenhouse gas emissions, since review showed that the targets and projections set out in the White Paper 1997 would not be met by 2010. To provide a long-term vision and security for investments.	2020	20%	proposed share of RES in primary energy consumption	3, 9f
				2020	10%	proposed share of biofuels in overall consumption of petrol and diesel in transport	
2009	Renewable Energy Sources Directive 2009/28/EC	Renewable energy	To establish a common framework for the promotion of energy from RES. To lay down rules for joint projects, transfers between Member States and third countries, guaranties of origin, administrative procedures etc. To establish sustainability criteria for biofuels and bioliquids	2020	*20%*	*share of RES in gross final consumption of energy*	Art.1, Art.3, part B of Annex I
				2020	*10%*	*share of RES of final consumption of energy in all forms of transport*	
2010	Treaty on the Functioning of the Eropean Union	Energy	(a) ensure the functioning of the energy market; (b) ensure security of energy supply in the Union; (c) promote energy efficiency and energy saving and the development of new and renewable forms of energy; and (d) promote the interconnection of energy networks.				Art.194
2010	Energy 2020 Strategy COM(2010) 639	Energy	Reiterates the 3 goals of the 2006 Green Paper and refers to the targets set in the renewable energy sources directive.				2
2011	Energy 2050 Roadmap COM(2011) 885	Energy	Long-term vision to achieve (1) de-carbonization of the energy sector, (2) competitiveness (3), security of supply	2050	55%	Anticipated minimum share of RES in gross final consumption of energy	7
2012	Proposal for amendmend of the Renewable Energy Sources Directive COM(2012) 595	Renewable energy/ Bioenergy	To protect the environment and the functioning of the internal market (reacting on risks posed by indirect land use changes)	2020	*5%*	*Cap on the share of biofuels from food crops in the transport sector (relating to the 10% target of 2009)*	5, 14

Table 4: Objectives and targets in European energy/ renewable energy/ bioenergy policy

(Sources in chronological order: European Commission 1997; Eurpean Parliament and Council 2001, 2003; European Commission 2005, 2006a, 2006b, 2007a; European Parliament and Council 2009; TFEU 2010; European Commission 2010c, 2011e, 2012c*)*

Three main **objectives** govern **energy policy**: (1) **sustainability**, (2) **security of supply**, and (3) **competitiveness**. At this sectoral policy level the sustainability objective is basically understood as promoting renewable energy sources, energy efficiency, and climate protection. The security of supply objective aims to reduce EU's rising dependence on imported energy, especially imported oil, by demand management, developing domestic sources especially renewables and diversifying energy sources and routes. Competitiveness mainly relates to the competitive advantages of European citizens, industry and economy coping with challenges of the global market and rising energy prices (TFEU 2010, Art. 194; European Commission 1997; 2006b, 2010c).

Accordingly three main objectives as anticipated benefits of bioenergy policy correspond therewith: (1) climate protection, (2) energy supply security, and (3) rural development (European Commission 2005, 4ff), (European Commission 2006a, 3f) and will be looked at in more detail.

Climate protection

With its climate and energy package the European Union adopted the target to reduce 20% of greenhouse gas (GHG) emissions by 2020 compared to 1990 (European Council 2007, 10, 12), again reinforced by the Europe 2020 strategy. The GHG target is to be achieved inter alia with growth in the RES sector and corresponding mandatory targets of a 20% share of RES in gross final consumption of energy and a 10% share of RES in final consumption of energy in all forms of transport enacted by the Renewable Energy Sources Directive 2009. Biomass is expected to contribute the main share of growth of RES, respectively biofuels in the transport sector. With a view to 2050, "decarbonisation" of the economy "will require a large quantity of biomass for heat, electricity and transport" (European Commission 2011e, 11).

► Anticipated benefits/ sustainability aspects: Halting global warming and thereby mitigating effects of i.e. glacier melting and sea level rise, increased climate variability and more severe flood and drought events, which are projected to otherwise drastically aggravate the living conditions for peoples, ecosystems and species, and to cause high costs and a high potential for conflicts.

► Basic assumptions: GHG emissions especially CO2 are the main driving force of climate change respectively its projected effects. Bioenergy is CO2-neutral or a net reduction of GHG can be achieved over the life cycle.

The idea that bioenergy is carbon-neutral – because as much CO_2 is bound by the plants during photosynthetic production as is released through combustion – was broadly spread to the public in information campaigns. However, this “misconception” (House of Commons 2008, 6) is not valid anymore. It is now widely accepted that the actual CO_2 or GHG balances are strongly dependent on locally specific land characteristics, land-use changes and land management practices, such as soil characteristics and soil erosion/ mineralization rates, tillage, fertilizer and other farming practices, changes of vegetation and land cover, energy used for production and transport as well as time scales looked at, etc. (Zarilli, Burnett 2008, 22). The Impact Assessment of the Biofuels Strategy acknowledges that biofuels are not carbon neutral, but claims that life cycle assessments consistently show a net GHG reduction potential (European Commission 2006a, 13). To insure these positive impacts, GHG balances have been introduced as legal instruments through the RES Directive (Section 1.6.1). A closer look at the default method for GHG calculations with its associated uncertainties, assumptions and constructions cannot be taken here.

Critics note that ecosystem restoration or conversion of cropland to forests building up above-ground and below-ground biomass may be, at least for a certain period of time, far more effective in GHG reduction than production of biofuels on croplands and additionally provide environmental services (Righelato, Spracklen 2007). GHG emissions – the main focus in climate change mitigation policy – may also not be the only driving force of effects associated with climate change. I.e. more severe flood and drought events are often seen in connection with land-use change and unsustainable land and water management practices (see Section 2.3.1 Water and climate services).
Political support for bioenergy especially biofuels is therefore not solely justifiable by the climate protection objective. It is thus promoted with the twin objective of energy supply security.

Energy supply security

Energy supply security has a high political priority, especially with regard to economic growth and competitiveness. Stimulating the production and consumption of biomass would help to develop domestic energy sources and diversify routes of fuel imports. Biofuels are regarded as “the only available large scale substitute for petrol and diesel in transport” (European Commission 2007b, 7). It is also believed that through promotion of biofuels long-term replacements for fossil oil could be developed (European Commission 2006a, 3f) and the dependence on imported oil significantly reduced (European Parliament and Council 2009, 1 (2)). Therefore the use of biomass for biofuels has so far been treated more favorably compared with other bioenergy applications in the heat and electricity sector, although it is repeatedly stated by consulting experts that biomass used in CHP is far more efficient (Foth et al. 2007, 101) and electric mobility should be preferred (WBGU 2008, 7f). Large scale applications are promoted by encouraging Member States to use blending obligations[22] (European Commission 2006a, 7). In the long-term biofuels will especially serve aviation and heavy road transport, since electrification in these sectors seems not feasible (European Commission 2011e, 11).

► Anticipated benefits/ sustainability aspects: Continual, secure supply of energy sources at competitive prices as a basic presupposition for societal living and economic activities; enhanced political stability through decreased dependency on – in a few countries centralized available – fossil fuels.

► Basic assumptions: Biomass is renewable and to a ‘large’ extent inexhaustibly appropriatable.

As already mentioned, numerous studies try to estimate the (sustainably) available biomass potential on different scales using different approaches and assumptions of e.g. land availability and productivity of crops, cultivation methods and prospected productivity increases, food supply, population growth and environmental protection rules etc. (Foth et al. 2007, 29ff), which have not been analysed here. However, as set forth in Chapter 1.2, it can be generally asserted that the renewability of biomass is not just an inherent property of ‘regrowing’, but depends on the renewal (or reproduction) of suitable growing and production conditions on local up to global scales. In the case of phosphorus scarcity, for example, or further pressure on land by a growing demand for agricultural products and increasing land degradation, those conditions could change drastically and may lead to ‘bioenergy supply insecurity’ in the future as it has already been the case under different circumstances in the past (Sections 1.2.2-3). Secondly, as elucidated in Chapter 1.3, energy security does not stand alone, but needs to go hand in hand with food and water security and the provision of other basic services delivered by biological-ecological work.

Thus achievement of the security-of-supply objective is also closely bound to developing sustainable land-use patterns and (re)production methods on local and regional levels involving global implications.

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[22] Blending obligation means a mandatory requirement to mix conventional fuels with a certain percentage of biofuels as it has been implemented i.e. in Germany through the controversial Biofuels Quota Act (2007).

Rural development

Stimulating economic activity and diversifying income and employment opportunities in rural areas as the third bioenergy policy objective relate to the broader goals of competitiveness and cohesion and are usually targeted with regional and rural development policies. Biomass production is expected to contribute to rural development, which is vice versa supposed to guarantee the necessary feedstock supply. Regional Biomass Action Plans will be supported also in developing countries, which could help them release their economic potentials, while giving emphasis to social and ecological sustainability criteria (European Parliament and Council 2009, 1 (1)-(4); European Commission 2005, 13; 2006a, 11–15).

► Anticipated benefits/ sustainability aspects: Improvement of living conditions; local prosperity and quality of life in rural regions

► Basic assumptions: The value created in the region ‘stays’ in the region, contributing to local prosperity. Increased income derived from biomass production means an improvement of quality of life for the inhabitants of the region.

Whether biomass production actually leads to increased local prosperity depends on many factors, e.g. the type of economic operators and scale of operation, the property regimes of land, infrastructure and equipment, the location in the retail chain where the main profit is generated, the flow and distribution mechanisms of the profit, the fluctuations of global commodity prices etc. as well as how funding schemes are constructed. Gilbertson et al. (2008) point out that biofuel projects supported under the Clean Development Mechanism, due to its funding structure, will more likely lead to large-scale agrofuel plantations while neglecting local smallholders’, civil societies’ and indigenous communities’ creative initiatives and movements (Gilbertson et al. 2008, 45f based on Ernsting et al. 2007). Zarrilli and Burnett (2008, 28) state that due to their high costs, certification schemes (see Chapter 1.6) “may fail to promote the economic interests and development of the local area and counter a country’s rural development aim”.

In case economic benefits are realized in the region, this does not necessarily mean an increase in quality of life. Beyond basic needs and consumption there are many more factors contributing to quality of life.[23] Whether biomass production actually leads to an increased quality of life for the local population firstly depends on how quality of life is perceived by them. It further depends on the values that are assigned to and activities

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[23] Quality of life and its diverse components is becoming an increasingly studied subject i.e. by the so-called ‘science of happiness’ underpinning efforts to replace pure economic welfare measures such as the gross national product by more adequate indicators.

realized on the respective piece of land before or during biomass production as well as labor conditions, land-use rights, environmental effects, etc.

It can be concluded that none of **the benefits or sustainability aspects** anticipated in the policy objectives are given. All of them **are relative**. Whether biomass for energy uses actually deliver on their promise strongly **depends on crops and cultivation practices in relation to the regional and local context** such as value assignments and property regimes, soil conditions and land cover, water and nutrient availability, land use patterns, scale and time of landscape processes, perception of landscape etc. Therefore pure promotional targets and programs to increase the share of bioenergy use cannot be sufficient or may even be dangerous. The OECD Roundtable on Sustainable Development comments on biofuels: “Their potential is limited and their environmental benefits rely on critical assumptions that must be met in order for biofuels to be sustainable. [...] A key question is how to ensure that production will indeed be sustainable” (Doornbusch, Steenblik 2007, 39). Accompanying policy measures are therefore requested to safeguard sustainability of biomass production. To realize the anticipated benefits, especially place-based context-driven tools would be needed within a broader sustainability picture.

While this is partly acknowledged in European bioenergy policy documents from the beginning, measures for promoting market accession, development and growth in the bioenergy sector, especially the biofuels-for-transport sector, clearly dominate over measures for safeguarding the sustainability of biomass production, at least until 2008 as described in the following section.

1.5.2 Pathways of sustainability measures

An analysis of sustainability concerns and measures addressed in the most relevant policy documents shown in Table 4 is given in Annex 1 (including references to the section below).

The first European Sustainable Development Strategy (EU-SDS 2002) gave no guidance on measures to safeguard sustainability of biomass production under either of the relevant priority areas of sustainable consumption and production or natural resources management (Europäische Kommission 2002, 36–40). Concerning the latter the renewed SDS of 2006 just refers to the Biomass Action Plan (see below). Under the key area climate and energy only promotional measures to increase the share of biofuels and to support second generation technologies are given (European Council 2006, 7–14). NGOs criticize this weakness of the SDS (Buitenkamp, Hontelez 2006, 9f).

The 2009 SDS revision refers to the introduction of sustainability standards for biofuels (as discussed in Chapter 1.6) (European Commission 2009a, 6).

1997: From the beginning the White Paper on Renewable Energy Policy acknowledges that environmental effects of biomass production can be adverse. However no environmental measures are provided for in the energy sector. It is mentioned that respective measures should be covered in agricultural and regional policy programs.

2001: The first Renewable Energy Sources Directive addressing the electricity sector does not differentiate between different renewable energy or biomass sources in terms of adverse effects to sustainable development. It is generally assumed that RES contribute to environmental protection and sustainable development.

2003: The Biofuels Directive implements reporting requirements for the Commission on i.e. the sustainability of biofuels crops, environmental impacts and live-cycle perspective of biofuels and other renewable fuels with the intention to distinguish between different crops and fuels according to their climate and environmental balance. Measures should be taken on the Member State level in terms of giving priority to those fuels showing the best balance.

2005: The Biomass Action Plan BAP identifies the production of biomass with both negative and positive impacts as one of three main impact areas and points to the need to observe site-specific environmental requirements when producing biomass. However, this impact area is not addressed in the accompanying Impact Assessment. The BAP envisages mandatory national targets for a strong promotion of large scale application of biofuels and simultaneously proposes introducing a certification system covering minimum sustainability standards for biofuels production bound to the targets. Also, it mentions the promotion of second generation technology research.

2006: The Biofuels Strategy then identifies capturing environmental benefits of biofuels as one of seven key policy axes to develop biofuels. One measure is to develop a forestry action plan to encourage the use of forestry material for second generation technologies. It is mentioned that environmental standards should apply to feedstock production not only in the EU, but also in third countries, and that sustainability criteria should not only apply to energy crops, but all agricultural land. The accompanying Impact Assessment even suggests that complementary to a life cycle approach a farming system approach is needed on the overall ability of the farm to provide environmental services. [It is argued in this study that furthermore a whole landscape area approach is needed to assess and develop the performance of different land-uses and their spatial-temporal patterns upon delivery of ecosystem services sustaining landscape functions and qualities]. Concerning EU territory the strategy refers to agricultural policy and cross compliance rules. Concerning third countries it acknowledges that desirable effects are much more difficult to control and favors a "balanced approach" in trade negotiations, balancing development of domestic supplies with imports.

2007: The Renewable Energy Road Map identifies environmental and social aspects as one of seven key principles in future RES policy development. However the accompanying Impact Assessment only considers positive effects as potential impacts. It is assumed that tackling climate change with RES policy will generally lead to positive effects on biodiversity, since climate change is regarded as the main driver of biodiversity loss. Possible negative effects on biodiversity are mentioned, but regarded as local, minor and avoidable through the introduction of incentive and support schemes that discourage the conversion of land with high biodiversity value.

2009: Resulting from extensive criticism and discussion in 2008, i.e. about a requested moratorium on biofuel targets (House of Commons 2008), the revised Renewable Energy Sources Directive finally leads to the introduction of concrete certification measures for eligible biofuels and bioliquids as the favored political option to safeguard sustainability of biomass feedstock production (Section 1.6.1). Contribution of biofuels produced from waste, residues, non-food cellulosic and ligno-cellulosic material count twice as much as that of other sources towards the target (Art. 21/2). The rules for calculating the GHG impact of biofuels and bioliquids grant a default GHG bonus if biomass is obtained from restored degraded land (Annex V). Several certification schemes have now been accepted under this directive.[24]

2011: The Energy Roadmap 2050 states that biofuels from non-food sources, such as waste, algae and forest residues should continue to be promoted, while also continuing work to ensure sustainability.

2012: Reacting on uncertainties and risks identified with regard to indirect land use changes the Commission proposed an amendment to the Renewable Energy Sources Directive. This includes a 5% cap for the use of food-based biofuels to meet the 10% renewable energy target in the transport sector.

Based on this document analysis three main political pathways to achieve sustainability in biomass production may be distinguished:

Pathway 1 - Regional action: Concrete sustainability measures should be taken on a regional level. Regional development funds and respective programs of Member States should include environmental criteria to give financial incentives to those bioenergy projects and investments which reduce environmental pressure or correspond to criteria of agri-environmental schemes such as low water consumption, low fertilizer and pesticides input, organic farming, and biodiversity protection. Regional Biomass Action Plans including environmental and social sustainability considerations should be

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[24] http://ec.europa.eu/energy/renewables/biofuels/sustainability_schemes_en.htm (accessed 9/8/2012)

supported both in the Community and in third producer countries. This pathway strongly depends on the regional interpretation of sustainable development and the measures under rural development programs. However, it could be especially interesting with regard to complementary biomass strategies as outlined in Chapter 4.1.

Pathway 2 - Source specific differentiation: Sustainability should be improved by sorting out 'bad systems' and encouraging those biofuels showing a good environmental and climate balance differentiated by the crops and other resources used as feed-stocks, including their cultivation and conversion methods. This pathway is especially expressed in the preferential treatment of biofuels made from waste, residues, non-food cellulosic material, and ligno-cellulosic material and biomass resources stemming from degraded land together with the promotion of 2nd generation biofuels. As discussed in Section 1.2.3 and Chapter 4.3 for the use of residues and in Section 4.1.2 (Jatropha case study) for the use of 'waste land', such a generalization is to be scrutinized and may be misleading. A case-specific appraisal is needed (House of Commons 2008, 12).

Pathway 3 - Product specific certification: Sustainability should be safeguarded by demanding that the production process of the biomass/ bioenergy product has to comply with certain sustainability standards over the whole supply chain. This pathway is discussed in the next chapter.

1.6 Sustainability standards for biomass product certification

> Sustainability standards are sets of criteria and indicators, which describe the requirements to be fulfilled by a sustainable product or process.
>
> *(Lewandowski, Faaij 2006, 90)*

1.6.1 Legal mandatory standards

The European Renewable Energy Sources Directive (RED) (European Parliament and Council 2009) sets legally binding minimum standards for domestic and imported biofuels and bioliquids to count towards the mandatory national targets and to prove eligibility for financial support (Art.17(1)). Compliance with the standards will be verified through certification commissioned by biofuel producers and controlled by Member States. The following criteria are set out in Article 17(2)-(6) of the directive:

1. **A minimum GHG saving level** of 35% (from 2017 on 50%) **is to be achieved** by providing GHG gas balances executed in a certain method.

2. **Land with high biodiversity value is excluded** from biofuels feedstock production determined by the status of this land in or after January 2008: primary forest and ‘undisturbed’ wooded land, protected areas, highly biodiverse ‘natural’ and ‘non-natural’ grassland, unless the harvesting of the biofuel feedstock serves to protect the grassland status.

3. **Land with high carbon stock value is excluded** from biofuels feedstock production determined by the status of this land in January 2008: wetlands, continuously forested area (> 1ha) with trees higher than five metres and canopy cover > 30%, land with trees (> 1ha) with trees higher than five metres and canopy cover between 10-30% or trees able to reach those thresholds in situ, unless the feedstock cultivation does not change the status of January 2008.

4. **Peatland is excluded** from biofuels feedstock production determined by the status of the land in January 2008, unless the cultivation and harvesting of the peatland does not involve drainage of previously undrained soil.

5. **Agricultural feedstock production on Community territory needs to meet cross compliance rules** laid down in Council Regulation 73/2009 Art. 6.1 and Annex II part A Environment and point 9. This means that biomass farmers within the European Community have to (1) fulfill statutory management requirements (SMR) in compliance with the ‘birds and habitats, groundwater, sewage sludge, nitrates and pesticides directives’ and (2) keep land in good agricultural and environmental condition (GAEC) with regard to soil erosion protection, soil organic matter and soil structure maintenance, retention of landscape features, protection of permanent pasture, buffer strips along water courses and respect of local permitting procedures for irrigation water. GAEC standards are specified by the Member States, taking regional conditions into account (European Council 2009). SMR and GAEC standards do not apply to third producer countries.

Further social and ecological sustainability criteria i.e. laid out in Article 17(7), 18(9), 19(6) and 23 (1)-(5) are not binding to the targets. They are only covered by monitoring and reporting requirements for the Commission concerning third producer countries representing a significant source of biofuels and their feedstock consumed in the Community:

- Impact on social sustainability, commodity prices, food security and land-use rights
- Country's state of ratification and implementation of ILO Conventions
- Country's state of ratification and implementation of the Protocol on Biosafety and Convention on International Trade in Endangered Species
- Feasibility to introduce mandatory requirements in relation to soil, water, and air protection
- Impact of indirect land-use changes on GHG emissions
- Biodiversity impacts, displacement[25] impacts and other indirect land use changes

WTO rules designed to provide for non-discriminatory market access pose one major barrier towards implementing more advanced legally binding sustainability standards. Investigations by Vis et al. (2008) based on work by Bronckers et al. (2007) suggest that bioenergy certification schemes are potentially conflicting with rules of the General Agreement on Tariffs and Trade (GATT 1994). Biofuels sustainability criteria, especially, fall under GATT 1994 Articles I and III requiring equal treatment of domestic and imported 'like products'[26] in any incentive, regulation or taxation scheme enacted by WTO member countries. Since sustainability criteria do not directly relate to product properties but to qualities of the production process – understood as 'non-product-related' characteristics (Zarilli, Burnett 2008, 31) – such mandatory standards imposed on third countries will most likely be rejected under WTO's dispute settlement mechanism.

However, exemptions to these rules provided by GATT 1994 Art. XX make possible environmental measures with regard to issues affecting the environment of the importing country or agreed upon by other international treaties. Bronckers et al. (2007 cited in Vis et al. 2008) conclude that GHG and carbon sink related measures are probably acceptable. Soil, water and air quality are considered as local environmental criteria difficult to address under WTO rules with respect to national sovereignty, but do not conflict per-se. Biodiversity criteria may be acceptable as they are covered by international treaties. Social criteria seem not to be compliant at all (Vis et al. 2008, 63–70). Therefore, local environmental as well as social criteria are left out of the obligatory

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[25] 'Displacement effects' also referred to as 'leakage effects' or 'indirect land use changes' mean a dislocation of food production or other land-use activities due to the increased demand for bioenergy crops. When biomass for energy is cultivated on arable land of former food production, for example, it can 'displace' food production activity to other i.e. former uncultivated locations, thereby increasing GHG emissions or pressure on biodiversity (Zarilli, Burnett 2008, 23f; Lewandowski, Faaij 2006, 91).

[26] 'Like products' is a term not clearly defined in GATT1994. It refers to a product's physical properties and qualities as well as its place in the market (Zarilli, Burnett 2008, 33). Since biofuels produced from sustainable sources most likely do not differ from biofuels produced from unsustainable sources in terms of i.e. composition and end-use, they are probably regarded as 'like' (Vis et al. 2008, 112).

set of the Renewable Energy Sources Directive so far, but are somehow considered by the reporting requirements.

While it is absolutely justifiable and necessary to prevent WTO member countries from imposing ‘their’ standards on other countries due to very different cultures, habits and conditions, the concept of ‘like products’ is problematic when looking at it from a social-ecological angle of (Re)Productivity and ecosystem related approaches. ‘Like products’ should not be distinguished on the basis of the manner in which they were produced. With the split categories of ‘productivity’ and ‘reproductivity’ in mind one can say that the concept of ‘like products’ reinforces this separation by artificially segregating the product from its production process, its social-ecological co-products and reproductive conditions. Soil, water and air quality for example are co-produced in every production process with a site, water and atmospheric interface and thereby are product-related processes and characteristics. Also, they cannot be regarded as local environmental issues anymore. In their sum (and being more than that) they have long become global issues with multiple ecological, social and economical interactions and feedbacks between countries and their territories. Therefore, sooner or later the international community will have to somehow agree on global sustainability standards, while giving enough room for individual country profiles and ways on how to best meet them (Section 1.6.3). Accordingly, the acceptance of environmental and social standards in the WTO regime should be improved (WBGU 2008, 12, 16f).

Presently, however, the Renewable Energy Sources Directive does not allow European Member States to set additional mandatory standards. But they can use international or develop national voluntary schemes consistent with the mandatory criteria set upon acceptance of the Commission (Art.18 (4)-(8)). The mandatory criteria are thus to be understood as minimum requirements and as a first step. It is pointed out that “voluntary certification and other measures will have to play an important role to cover the issues that obligatory sustainability criteria cannot address effectively” (Vis et al. 2008, x, xii).[27]

1.6.2 Components and criteria of voluntary schemes

Numerous initiatives developing sustainability certification schemes as voluntary market instruments for biomass, biofuels or bioenergy production have been and still are conducted on a national and international level by intergovernmental and non-

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[27] The Community can also negotiate bilateral or multilateral agreements with third producer countries corresponding with the directive. This opens up a legal space for the possibility of regional or area-wise schemes as investigated in this study, which could serve to accompany or partly replace product specific certification systems (e.g. for small enterprises and regional chains-of-custody) in the future.

governmental organizations, companies and sectoral roundtables.[28] Such initiatives and schemes are, for example, the Netherlands Technical Agreement NTA 8080:2009 based on works of the Dutch Cramer Committee for Sustainable Production of Biomass, the Roundtable on Sustainable Biomaterials (RSB), and the ISO/TC 248 project committee working on sustainability criteria for bioenergy (ISO/CD 13065[29]). Van Dam et al. (2008, 2010) and Scarlat & Dallemand (2011) give good overviews of up to 67 initiatives.

“Certification is the process whereby an independent third party (called a certifier or certification body) assesses the quality of management in relation to a set of predetermined requirements (the standards)” (Lewandowski, Faaij 2006, 84). Sustainability standards for biomass should ensure that the production of the particular bioenergy product including its feed-stocks does not counteract sustainable development. Voluntary standards do not conflict with WTO rules but are only effective within eco- or socially sensitive markets. Certification systems apply to the whole supply chain and can be understood as a form of communication between suppliers and buyers along the chain (Zarilli, Burnett 2008, 1).

The development of sustainability standards is a multiple step procedure which leads to the formulation of a set of sustainability principles, criteria, indicators and verifiers (ibid.; Lewandowski, Faaij 2006, 90–98; Vis et al. 2008, 99). The first step should be the development of a mission, including a sustainability definition. Sustainability principles that describe the objective of certification are derived. They are broken down into more concrete sustainability criteria and indicators to measure the performance of these criteria. Before being fixed, criteria and indicators sets (C&I) should be tested in the field. Verifier tools are the means of checking and controlling the performance of indicators by auditors i.e. through visits of facilities, measurements in the field, checking of book keeping etc. Where it is not possible to derive meaningful indicators, reporting on the particular subject of the criterion is usually required. Many indicators are described as good practice or management rules (Lewandowski, Faaij 2006, 90–95; Zarilli, Burnett 2008, 1). Such hierarchical structure is used “to translate the broad concept of sustainable biomass production into measurable units” (Vis et al. 2008, 99).

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[28] Multiple standards covering certain sustainability aspects already operate in various fields. They can apply to different product categories, i.e. food products, such as bananas, coffee and citrus products etc.; to production sectors, i.e. forestry, agriculture and fisheries etc.; to whole projects, i.e. projects funded by the World Bank; or to different assessment categories, i.e. environmental effects, fair trade conditions or responsible business behavior. These systems, however, are very heterogeneous. None of them are directly applicable to biofuels. To fill this gap, multiple organizations have taken the initiative to develop their own certification systems for sustainable biomass production (Lewandowski, Faaij 2006, 85–89; Fritsche et al. 2006; Scarlat, Dallemand 2011).

[29] http://www.iso.org/iso/catalogue_detail.htm?csnumber=52528 (accessed 12/29/2014)

Criteria found in certification schemes address the following main areas of concern (Lewandowski, Faaij 2006; Dam et al. 2010; Cramer et al. 2007; RSB 2013):

- Greenhouse gas balances/ carbon stock
- Biodiversity/ habitat/ ecosystem services
- Water conditions
- Soil conditions
- Air quality and other environmental topics
- Local food security and competition with other biomass uses (raw material, construction material, medicine)
- Labor conditions/ fair remuneration
- Land rights/ land ownership
- Prosperity of local communities/ rural and social development
- Economic viability/ Long-term business perspective

The different schemes, though, vary in many ways, e.g. in number and content of criteria, individual environmental and social aspects, methodologies and default values to calculate GHG balances and carbon sinks, interpretation of biodiversity-rich-areas and mapping approaches, explicitness of indicators and their system boundaries, monitoring and verification procedures, and requirements to consult external stakeholders, etc. This shows a proliferation of standards, which bears the risk of decreasing confidence and acceptance among stakeholders and consumers, increasing confusion at the market, and potential abuse (Dam et al. 2008, 774f; Dam et al. 2010; Scarlat, Dallemand 2011). Therefore many experts recommend to internationally harmonize schemes and meta-standards or rather to develop one global generic standard (Dam et al. 2010, 2468; Scarlat, Dallemand 2011, 1644; Zarilli, Burnett 2008, 41; Doornbusch, Steenblik 2007, 43, 144; Foth et al. 2007, 73, 92). An international search process on whether and how to come to such an international standard is still on-going. Besides international harmonization, however, there is also the need to better reflect regional and local conditions and values.

1.6.3 The standardization paradox

(Unified) sustainability criteria, indicators and verifiers need to be clearly comprehensible and formulated as concretely and quantifiably as possible to avoid ambiguity and too much space for interpretation, and to be ‘objectively’ assessable by auditors (Lewandowski, Faaij 2006, 101f; Dam et al. 2008, 768; 2010, 2457, 2465; Vis et al. 2008, 77). However, if this is done as a ‘one-size-fits-all’ approach on an international level, the certification system may become stiff and bureaucratic and will very likely lead to meaningless requirements at the unique local level.

With regard to the reiterated need for precise and quantifiable criteria Zarrilli and Burnett (2008, 21f) state that “social sustainability criteria are particularly difficult to quantify because the formulation of indicators requires normative decisions. Criteria that call for “equitable land ownership”, “fair and equal remuneration” and for farmers to be “content with their social situation” cannot be described or evaluated in a scientific manner. These types of evaluations are inherently subjective and require detailed knowledge of the local context.” Zarrilli and Burnett (ibid.) as well as Lewandowski and Faaij (2006, 100) further state that also ecological criteria often lack quantifiable parameters for assessment, but do not indicate the issue of normative decisions involvement here. Van Dam et al. (2010, 2457) point out that cumulative effects of single production activities and system boundaries extending production sites need to be taken into account.

Setting and assessing ecological indicators and cumulative effects, however, also involves normative decisions. For example, identifying threshold values that prevent ecosystems from flipping from desirable to undesirable states requires a normative decision about what is a desirable and undesirable ecological state. It was found in a study about the resilience of the Everglades National Park in the U.S., for instance, that sawgrass ecosystems changed to cattail dominated ecosystems due to phosphorus released from upstream agricultural production. Certain soil phosphorus levels in the wetlands were found to be the threshold value (Walker, Salt 2006, 15–27). If biomass production practices were present among the upstream agricultural activities, their phosphorus leakage would have to be assessed against cumulative effects of these activities towards these values. But the initial decision that sawgrass ecosystems are preferred over cattail ecosystems for multiple reasons of resilience considerations, biodiversity values, recreational atmosphere, etc. is a normative decision. Furthermore identifying such threshold values requires profound knowledge of local ecosystem behavior over time (eventually even over generational time spans). It also requires knowledge about drivers of change that may act on higher scales, e.g. changing wild fire, drought and freeze regimes in the case of the Everglades. Another example is to decide on an ‘acceptable degree’ of e.g. soil erosion, when trade-offs have to be made between different criteria or on an ‘acceptable improvement’ represented by a slight or great degree of parameter change, when process indicators are chosen.

Such normative decisions as well as knowledge building and (long-term) data tracking over time (e.g. land-use change or soil-ageing analysis) lay beyond the scope of single biomass producers and single experts of accredited certifying bodies. Operators and auditors need to refer to situative social and ecological knowledge and frameworks existent in a region, with regard to the state and trend of biodiversity, ecological corridors, ecosystem services, thresholds, (informal) land rights, food security, and poverty, for example. One could argue that there usually are legal frameworks existent in a region, which could be identified and used as references. However compliance with legal requirements should be self-evident, though they are usually included in certification systems as first principle. But voluntary certification systems need to go beyond legal minimum requirements in the respective producer countries; otherwise they may not make sense. Furthermore, legal frameworks might be weak or lacking and/ or are still characterized by purely sectoral viewpoints. Additionally, information and data are often scattered over many local authorities and other organizations and it requires immense efforts to gather and synchronize them.

It seems that sustainability standards inherently encounter a **paradox of conflicting requirements**. On the one hand there is the need of an internationally valid and acceptable standard including the concrete and clear formulation of explicit criteria & indicator sets and verifier methods. On the other hand the formulation of meaningful criteria and indicators with normative implications needs to be undertaken in accordance with regional peculiarities, local experiences, stakeholder and community consulting as well as to allow for learning and adaptation in changing circumstances.

In this regard Lewandowski and Faaij (2006, 90) refer to an approach and manual developed by the Center for International Forestry Research (Ritchie et al. 2000) to assess sustainability in community managed forest landscapes, where an expert round identifying C&I sets is followed with a round of local consultation to concretize the sets around shared knowledge. Van Dam et al. (2008, 768, 773f) and Schlegel and Kaphengst (2007) mention the need for regional specification, but do not give further advice. Foth et al. (2007, 73), demanding a multilateral agreement on sustainable biomass, declare that such agreement on a global level could only include very abstract criteria. Mechanisms are to be foreseen which can guarantee an adequate concretization of the criteria according to local conditions. Therefore, some schemes work on national interpretations of their principles and criteria to ensure implementation according to specific conditions. Others provide for national or regional initiatives to adapt the standards to local conditions (Scarlat, Dallemand 2011, 1639). However, there is the “risk that the sustainability criteria will not be interpreted in an equivalent way at national level, and will not be applied with the same rigour” (ibid. 1645). Furthermore, only working one way in terms of defining global criteria and refining them on regional to local level may also not be adequate. Local conditions may actually require critical context-specific criteria, which would have been overlooked at the global level.

Fraser et al. (2006, 115) point to the paradox requirements of sustainability standards in a similar field of identifying sustainability indicators as key elements of Logical Framework Analysis often required by major national and international development funding agencies. In their analysis of three different case studies they conclude three points: (1) for a successful integration of top-down and bottom-up approaches, mechanisms need to be developed to bring together experts and community members; (2) to avoid frustration and maintain interest, the selection of indicators by stakeholders needs to be actually coupled to political decision-making processes (e.g. landscape governance through land management programs and land-use plans); and (3) choosing the ‘right’ scale of local-regional assessment as well as matching political with environmental boundaries remains a challenge (ibid. 126).

1.6.4 Critique of bioenergy related certification

Besides the contradicting needs for international harmonization and regional specification, certification systems for biomass product sustainability face many more problems and are also heavily criticized. Their limitations are recognized for example through the following issues:

- Experiences from sustainable forestry certification suggest that through the use of voluntary standards responsibility is transferred from governments to consumers (Dam et al. 2008, 768).
- Certification on a selective basis may lead to a segmentation of the market rather than a reduction of unsustainable practices (Doornbusch, Steenblik 2007, 41). It furthermore does not cover subsistence activities.
- Certification systems are usually too costly for smallholders. Developing countries experience that audits of their domestic assessment bodies are often not accepted by importing countries, so that expensive foreign certification services need to be used (Zarilli, Burnett 2008, 27). Group certification and “light versions” of certification systems developed with fewer requirements for smallholders are attempts to solve this issue (Dam et al. 2008, 769; Vis et al. 2008, x).
- Traceability through the chain-of-custody is difficult and costly. Certification procedures along complex global trading routes usually commissioned by the economic operators may be an easy subject of conflicts of interests and corruption (Dam et al. 2008, 769; Doornbusch, Steenblik 2007, 41; Gilbertson et al. 2008, 19).
- Certification systems require effective controlling mechanisms and extensive controlling capacities to make a real difference. Often criteria have just declarational character and only need to be confirmed by signed self-commitments. The challenge to verification and monitoring is very high. (Foth et al. 2007, 72; Dam et al. 2008, 768, 769; Gilbertson et al. 2008, 19). Otherwise,

there is the danger of “green-washing”, when strong criteria are demanded, but enforcement is weak (RSB 2009).

- Many standard setting initiatives lack the involvement of stakeholders, especially from the local level and the global south (Schlegel, Kaphengst 2007, 9; Dam et al. 2008, 769; Gilbertson et al. 2008, 20).

The main criticism, however, arises from the discussion about indirect impacts (see Introduction, Section i). Certification schemes are not deemed to be effective regarding indirect land use changes (ILUC), impacts on food prices, and other indirect effects lying outside the scope of action of the economic operators. Such “off-farm” or “spill-over” effects of land-use changes and macro-economic interdependencies of food-feed-fiber-fuel markets must be observed and dealt with differently on regional, national, and international levels (Dam et al. 2010, 2460–2465; Scarlat, Dallemand 2011, 1643; RSB 2013, 4; Dam et al. 2008, 776; Foth et al. 2007, 72; Zarilli, Burnett 2008, 23ff; Schlegel, Kaphengst 2007, 10; Vis et al. 2008, 79; Doornbusch, Steenblik 2007, 42; Gilbertson et al. 2008, 17).

Generally, one can ask whether global trade and transportation of huge amounts of biomass makes sustainable sense at all and whether bioenergy promotion inducing such intensive matter flows should be dropped completely. However, international biomass trade is likely to become an increasing reality that needs to be dealt with even without promoting political targets. Also, on a regional market level or in decentralized renewable energy-mix applications it will be important to identify whether certain biomass production pathways are sustainable or not.

1.6.5 Extension of standards and call for landscape governance

So far legal minimum standards and most voluntary schemes mainly address biofuels, since they have caused the most controversy. It is often criticized, though, that sustainability standards should equally apply to other bioenergy uses such as the generation of electricity and heat from biomass sources (WBGU 2008, 11, 16). However, due to the difficulties of developing a harmonized scheme for a wide variety of biomass feedstocks, the Commission in their report on the need for a sustainability scheme for energy uses of biomass other than biofuels and bioliquids[30] proposes no binding criteria at EU level, but gives recommendations for national schemes (European Commission 2010a). Neverthless, “there is no justification why, for example, different or even higher sustainability requirements should be applied to the production of corn used

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[30] The report was requested by Article 17(9) of the Renewable Energy Sources Directive.

for bioethanol than corn used for biogas production or food and fodder. Sustainability standards should therefore be extended to all types of bioenergy feedstocks or even biomass production” (Schlegel, Kaphengst 2007, 9). This issue has also been raised by biofuel producers who feel that their products are discriminated against other agricultural products (RSB 2009). “Global land-use standards” are called for “to regulate the production of all types of biomass for a wider range of uses (food and feed, use for energy and use as an industrial feedstock, etc.) across sectors and national borders” (WBGU 2008, 12). Extension of standards is a main point in the search for solutions to limit indirect land use changes. “Applying a double-standard policy between biofuel and food/feed/fiber production is very likely to lead to indirect displacement effects. Only a certification scheme addressing biomass feedstock production (cultivation) regardless of the final use might be able to avoid different impacts, either direct or indirect” (Scarlat, Dallemand 2011, 1643). “In order to prevent the various indirect effects, sustainability standards should ideally be applied globally to all agricultural commodities” (ibid. 1645). Similarly, van Dam et al. (2010, 2464) recommend “extending measures to mitigate impacts from ILUC to all lands and commodities”. Thus, there is the hope that “an interesting environmental benefit that might come from a sustainable biofuels market could be the better regulation of all internationally traded agricultural commodities” (House of Commons 2008, 10/ 24.).

Moreover, the need for a pro-actively performed sustainable land use management or landscape governance from regional to international levels is spelled out, which has the capacity to control undesired land use change in different parts of the world and to context-specifically match promotional bioenergy activities with other relevant resource and ecosystem management strategies as well as spatial planning concerns. The German Advisory Council on Global Change WBGU indicates, for example, that an integrated analysis of regional soil and water availability should be conducted when cultivating energy crops and their production aligned with regional strategies for sustainable soil and water management (WBGU 2008, 14). The British House of Commons’ Environmental Audit Committee even points to the urgent need to align biofuels policy to an ecosystem approach accounting for the true value of a wider set of ecosystem services. While it welcomes a British ministerial policy initiative to incorporate an ecosystem approach into policy making, it concludes that bioenergy policy has failed so far in this regard (House of Commons 2008, 19f). In order to successfully address macro-level impacts and facilitate producers’ engagement in sustainable production “incentives and support schemes for bioenergy should be linked to an effective land use policy” (Schlegel, Kaphengst 2007, 12) as well as capacity building in the producer countries (Zarilli, Burnett 2008, 29, 43). Bringezu et al. (2007, 44) argue that “due to substitution and competition effects, any biomass strategy needs to consider the interrelations of material, energy and land use and should be embedded into a cross sector strategy for sustainable use and management of resources”. To cope with negative indirect effects of land use change and land use competition, but also to create synergies with conservation efforts, use of land-use policies in a country or region, especially of landscape and spatial planning instruments, should be made (Fritsche et al. 2006, 43; Foth et al. 2007, 65f). Scarlat and Dallemand (2011, 1643) ultimately state that, “preventing undesired land use changes requires a verifiable land use and sustainable land management policy and adequate tools that identify and prevent them. A monitoring system for land use […] and land use planning could be a useful tool to address land use changes. […] However, to be effective, a system monitoring land use should apply to all agricultural crops regardless to the final use of the crop […], otherwise this could not be able to prevent indirect effects”. Finally, van Dam et al. (2010, 2468) in their review titled “From the global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning”, conclude: “Addressing unwanted LUC requires first of all sustainable land use production and good governance, regardless of the end-use of the product. To a large extent, the decisions on where and how to produce bioenergy crops should therefore be a land use management decision”.

Such land use management or landscape governance issues are named as an important subject of further research activities. “Scientific assessment of land use change issues is urgently needed in order to design policies that prevent unintended consequences from biofuel production. Following this approach, more technical and scientific work should be carried out” (Zarilli, Burnett 2008, 42). WBGU further conceives a global land use management as a key task for international governance to deal with prospected land-related conflicts emerging from land use competition being accelerated by but reaching far beyond bioenergy use. Developing “the components of a global land-use management system” is recommended as a critical field of research connected with sustainable bioenergy use (WBGU 2008, 2, 10, 17f).

This study locates itself within such an international research context of sustainable resource and land use management and attempts to contribute to solutions in this field.

1.7 Standardized process for landscape reference systems – a possible solution?

Emanating from standards for biofuel products there is a clear necessity and tendency to expand sustainability standards stepwise from single products and producing sectors to all types of biomass production and connected land uses as well as from single initiatives to multilateral and global agreements. The next question would be why only biomass resource related land uses should undergo a sustainability assessment and not other land based activities such as industrial production, tourism, mining, and urban development etc. generally consuming resources and interfering with social-ecological processes and ecosystem capacities. If certification was done individually for all those fields on a product or sector basis, one could easily imagine unbearable cost, administrative burden, proliferation and confusion arising. Therefore it is argued here to take on a **'landscape-area-wise' regional approach**.

A possible solution to resolving the above-mentioned 'standardization paradox' could be to introduce a standardized process which could create and maintain regional reference systems within a broadly accepted sustainability picture. Such an envisioned continual, cooperative and coordinating management process involving multiple scales, land uses and stakeholders will be called here a '**standardized adaptive mechanism of Landscape Quality Management**'.

The '**standardized' part** of the process is **to avoid arbitrariness and interest-led interpretation of sustainability** and will contain generic principles and criteria which can be considered and agreed as generally valid. It will be guided by a global vision and integrated, consistent theoretical approaches of sustainability or more precisely of what is to be sustained on the land surface respectively by land management/ land-use activities.
The '**adaptive' part** of the process is **to allow for regional concretization of criteria & indicator sets, flexibility, creativity and learning**. It will not only work top-down, but also bottom-up thereby linking multiple scales (Chapter 3.2).

Foth et al. (2007, 45) state that a clearly defined (site-specific) reference system is necessary to compare results of environmental impact assessments of different biomass cultivation practices in different regions and thereby refer to discrete climate and soil conditions. However, as argued in Section 1.6.3, such reference systems also need to consciously and transparently include valuation processes, since they are to be considered normative frameworks for local action. Therefore the reference systems are to be designed as integrated value and knowledge systems with the possibility to evolve in time with agreed changes in values and knowledge. Global and local levels should be equally involved in the regional process since values differ with scales and some effects can only be assessed on a global and some only on a local level. Such regionally concrete reference systems elaborated in a standardized manner could then be used to assess single production activities against a reference framework of sustainable landscape development.[31]

However, assessment alone may not guarantee actually arriving at sustainability in biomass production. But if *assessment* is used to *develop* complementary biomass production systems (Chapter 4) in a mutual relationship of producers and regions, a truly sustainable development of the biomass sector or even the agricultural sector could be achieved. Therefore it is suggested here that the reference building process be embedded in and executed by a pro-active coordinating management activity – namely 'Landscape Quality Management' – which could particularly deal with direct and indirect land use changes, crosslink sectoral strategies and action plans, facilitate problem solving and support creative, tailor-made solutions and co-operations.

Linking the standardized process and management activity to clear and meaningful spatial boundaries (Chapter 3.1) would allow for **certification of landscape regions and production units participating with their products in such a scheme**, especially relevant for regional biomass value chains and smallholders (Chapter 3.6). In the case of trans-regional to global chains-of-custody an LQM process could ideally complement product specific international schemes[32], or potentially replace them in a **long-term vision of an area-wide, world-wide LQM implementation** (e.g. in the form of an international agreement). Such an approach seems more costly in the beginning, but may prove more effective and efficient in the long run, when taking increasing pressure on land and resources, risk of proliferation and confusion by multiple incongruent schemes and the extension of sustainability standards to all commodities and land uses into account.

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[31] Wherein 'landscape' is not only understood as a pictoresque scenery, but rather as the concrete 4-dimensional (spatial-temporal), sensual and functional, living and production space of human societies and its economies, shared with other living communities (see Chapter 2.1).

[32] Richert et al. (2006, 6f, cited in Van Dam 2008, 770) investigated the option of "product land combinations" as one of three possible policy tools, meaning that only biomass from regions complying with sustainability principles are allowed for government support. However, they do not conclude on any objective preference for one of the tools.

1.8 Summary and conclusions

Within dynamic, co-evolving natural/cultural systems the ability to continuously renew basic and desirable living conditions is key to sustainable development. According to Biesecker & Hofmeister (2006) this ability of ecosystem and social processes is being exploited and has declined because ‘reproductivity’ – understood as life giving and supporting activities and capacities – was separated and devaluated from ‘productivity’ through economical *and* ecological theory building, while simultaneously it has been completely incorporated by practicing market economy and thereby made invisible. This historical construct affects and informs land management activities and also underlies the debate about the sustainability of bioenergy. A mental and physical reintegration of both productive and reproductive processes expressed in the category “(Re)Productivity” is needed.

The separation of productivity and reproductivity is reflected in the phrase ‘biomass production’ and its opposing meanings in different contexts. In an economical perspective the term ‘production’ primarily refers to human activities of cultivating energy crops, mobilizing biogenic residues, transport and storage of biomass etc., while the term ‘biomass’ is understood as harvested *dead* matter, resource and commodity for the regional or global market. In scientific ecology ‘*bio*mass’ originally means *living* mass in a defined living space while ‘production’ – imported from economy as an already reduced category – refers to the accrescence of biomass between two points in time, especially by photosynthetic activity of vegetation (Net Primary Production). In systems ecology ‘biomass’ further developed into a countable parameter of material, carbon and energy stock and thereby supported the appropriation of biomass as a resource by the market (more recently the calculation as a carbon sink in carbon trade). Consequently the classification of ‘biomass’ as a renewable energy source refers to its property of containing a bio-chemically bound energy potential principally re-growing in generational cycles relevant to humans, while other regenerative functions and activities of *living* tissue and organic material within ecosystems and landscapes are cut-off and made invisible in the debate. Furthermore not only the use of the categories ‘biomass’ and ‘production’, but also ‘renewability’ is to be critically examined in this context.

The line distinguishing renewable from non-renewable energy sources passes along a temporal-dynamic balance between societal use and ‘natural’ renewal of the energy potential. Renewable energy sources are therefore by definition characterized as ‘inexhaustable’. Accordingly, the renewability of biomass is presumedly taken for granted in renewable energy policy aiming inter alia at diversifying and securing energy supply.

However, biomass for human energy use including residues is produced in land-use-ecosystems by combined activities of vegetation, humans and other organisms. Whether it is inexhaustibly usable depends on the renewal of suitable growing/living conditions such as the renewability of soil, stable climatic conditions, nutrient and water availability, absence of diseases etc. which are also, more or less favorably, co-produced by human (land-use) activity. A scenario of nutrient scarcity – representing other possibly drastic changes to be expected with global change – questions the continuation of an abundant nutrient supply and suggests the possible revival of organic residues as a renewable nutrient source which could considerably change their potential use for bioenergy. The history of the European bio-energy crisis through the use of charcoal from woods for metallurgy in the 17th century, which led to the introduction of the principle of 'sustained use' in forestry (later developing into the concept of 'sustained yield') is another expressive example showing that the renewability of biomass is not an inherent 'natural' property of re-growing, but needs to be looked at in the context of hybrid, social-ecological land-use systems and their changes.

Biomass productivity is, however, not just dependent on the renewal of adequate living and production conditions. *Bio*mass synthesis as (re)productive *life* process of vegetation and other organisms vice versa creates and regenerates distinct living and production conditions on a daily and seasonal basis.
On a cellular scale photosynthesis and respiration can be understood as biomass production and conversion processes providing bioenergy for metabolic *cellular work*.
On an organismic scale biosynthetic processes are coupled to a myriad of other physiological processes by which the organisms perform *living activities*, such as forming soil, managing water and temperature, multiplying surface area, and creating scent and color.
On a landscape scale these physiological activities of living communities, especially those of vegetation and soil organisms covering the land surface, can be viewed as *land management activities* (re)creating valuable services and qualities, which constitute the living and operating space for human societies and their economies. Those activities can thus be understood as *productive biological-ecological work.*

With such a social-ecological perspective and (re)productivity in mind, a space opens up where land management activities of humans and other living communities can be examined 'on an equal footing'. Food energy can be understood as bioenergy for biological work processes whereas bioenergy can be understood as food energy for technical work processes, both valuable for sustainable development. Technical labor gained while fuelled by bioenergy then principally needs to be weighed against biological-ecological work that is eventually lost through land-use change or land degradation and would need to be replaced at another place or time by energy

consuming technical capacity, if this is at all possible. Special attention needs to be given to irreversible losses of biological-ecological capacity in this regard.
Moreover these (re)generative capabilities, functions and land management activities of diverse biomass forms and producers need to be taken into account when promoting bioenergy and assessing and designing bioenergy land-use systems. Although renewable energy is a long-term prerequisite for all life and economic processes, the long-term renewal of other basic conditions such as the provisioning of water and nutrients etc. is equally important for sustainable development. Therefore it is proposed here that with regard to sustainability, the term ‘renewability’ should not solely apply to the renewal of energy potentials, but to the renewal of life support systems.

In contrast to this, European bioenergy policy is more narrowly geared towards (1) climate protection, (2) energy supply security and (3) rural development. These policy objectives represent anticipated benefits and sustainability aspects linked to bioenergy promotion which are based on critical assumptions. Biomass production and bioenergy applications are thought to show a net GHG reduction potential, to be inexhaustibly available to a ‘large extent’ and to contribute to rural employment and regional prosperity. All of these potential benefits as well as negative effects, however, are highly dependent on local to regional circumstances as well as macro-economic dynamics. Thus context-driven integrated policy measures that are not purely promotional are needed to realize the beneficial effects and to safeguard sustainability of biomass production.

One attempt to sort out ‘good’ from ‘bad’ systems is to prioritize certain biomass production pathways according to certain types of resources, cultivation systems, technologies and land expected to show a better environmental balance. Mostly the use of residues and perennial crops, short rotation plantations, 2nd generation technologies, and cultivation on marginal land or ‘wasteland’ is advised. However, in a local context such generalization is problematic and may be misleading. A case by case appraisal is needed.
Besides supporting Regional Biomass Action Plans, the presently favored political option to safeguard sustainability of biomass production is the introduction of sustainability standards and certification schemes. Legal standards implemented through the Renewable Energy Sources Directive require minimum GHG savings calculated on a life cycle approach, the exclusion of land with high biodiversity and carbon stock value from production as well as the application of cross compliance rules on European territory. A wider set of sustainability standards including social and local environmental criteria potentially conflict with WTO rules and are therefore only covered by reporting requirements for the Commission.

To cover some of the aspects obligatory standards cannot meet and striving for global coherence and international acceptance, voluntary standards are being developed by various initiatives. However these are also disputed as being too costly for smallholders, segregating the market, transferring responsibility from governments to overwhelmed consumers, requiring extensive controlling capacities, and lacking stakeholder involvement, etc.

It appears that sustainability standards inherently encounter a paradox of on the one hand demanding precise globally applicable criteria, indicator and verifier sets to avoid too much space for interpretation, and on the other hand allowing for regional specification and derivation of criteria & indicator sets according to the context-specific cultural and environmental peculiarities. Mechanisms are needed which provide for the translation of a broader sustainability picture, including abstract criteria on a global scale, into concrete adequate criteria and indicators on a local/ regional scale as well as the mutual consulting of experts and community members also working the other way around.

Most importantly, another barrier to effectively safeguarding sustainability in biomass production is that product bound certification cannot address indirect land use changes resulting from macro-economic interdependencies, which lay outside the scope of producers and other economic operators. Furthermore, sustainability standards should be coherent and agreed upon internationally. They should not only apply to bioenergy, but to all agricultural production or even land uses, since biomass for energy use cannot be separated from its food, material and other end uses. Therefore some sort of landscape governance and global land use management is called for to deal with the wider implications of bioenergy regarding land use competition or land related conflicts.

A possible solution to resolving the ‘standardization paradox’ and to mitigating unsustainable land use changes is to develop a ‘standardized adaptive mechanism of Landscape Quality Management’ - a standardized, but flexible process which could create and maintain regional landscape reference systems for sustainable production. This option, explored and drafted in this study, could not only serve to assess, but also to encourage and design bioenergy systems, which complement rather than compete for other land uses. Taking on a landscape area-wise and areawide perspective it may allow for regional certification applying to all products and services produced within meaningful boundaries and thereby avoid the proliferation of product and sector related standards.

Recalling ‘(Re)Productivity’ and the need to broaden the concept of ‘renewability’, bioenergy can only be regarded as renewable and sustainable if those land-use systems producing the energy stock simultaneously reproduce favorable living and production conditions as well as other qualities desirable for sustainable development.

The reference systems should therefore answer the question of what should be sustained in the referenced landscape area, and how the particular biomass land-use system – be it energy crop plantations, bio-residue collections or mobilized wood resources from private forests – performs with regard to this over time.

Consequently any assessment of biomass production sustainability needs to be undertaken in relation to
(A) a general and regional/local consensus about basic and desirable conditions to be sustained in the landscape area by land use and land management activities, and
(B) a common understanding of the general role of different biomass forms as well as the concrete contribution of human and non-human biomass producers to these conditions.

Thus, the landscape reference systems need to be designed as integrated value and knowledge systems containing both general and context-specific aspects. They need to be suited to assess the land management performance of a single plot of land in relation to the performance of a wider land-use pattern within meaningful boundaries. Accordingly, the main task of the management activity would be to coordinate land-use activities and bring the decision-making level of single farms and landowners into a cooperative relationship with the societal demand level realized on various landscape scales. The reference building mechanism should explicitly contain the value and performance of regenerative, social and ecological, activities. Only these can safeguard a long-term source of well-being for future generations, but are presently not perceived and honored by the economical system, which is a main driver of land use/ land management decisions.

‘Landscape Quality Management’ – as conceptualized in the next chapters – may itself be understood as a professional process of regenerative capacity building in society, which could balance purely production oriented market incentives and create an innovative enabling environment for reintegrating ‘reproductivity’ into ‘productivity’.

2 Concept building: Landscape Quality Management (LQM)

Sustainability needs to be achieved (1) within relations between humans and their societies (social dimension, e.g. fair distribution of wealth), and (2) within relations between humans, other living communities and dynamic environmental forces (ecological dimension, e.g. climate stability). These relations are intertwined and can be set apart neither from each other nor from the economic dimension, which comprises both relations between humans and relations to non-human species and environmental factors. On the contrary: all three dimensions - due to their interdependencies - are to be acknowledged and integrated for sustainable development (Kopfmüller et al. 2001).
The focus in this work is set, however, on (2) human-ecosystem interaction, the effects of which are realized in changes over time in the landscape as a social-ecological hybrid (Chapter 2.1). Conclusions and tasks are derived for a regenerative socio-economic behavior with regard to developing a sustainable human-ecosystem relationship. How to build a just, stable and renewable social fabric which also constitutes an economic production prerequisite is not the subject of this work. While the (Re)Productivity concept may also offer an interesting approach in this regard (Biesecker, Hofmeister 2010, 1707), this is not further followed here. Demands arising from such a social sustainability perspective towards land management and landscape quality, however, may be readily included in an LQM process via the concept of cultural services (see Sections 2.2.1 and 2.2.4). Furthermore, this work focuses on possible content, structure and sequence of a Landscape Quality Management process, not on how such a process should be politically and institutionally anchored. Implications for different national planning systems, for example, would need to be worked out with social and political science expertise.

According to the thesis derived in the first chapter, the actual performance of land and water management activities of both human and non-human actors[33] and their combinations in land use patterns with regard to a multi-stakeholder/ multi-level agreement of a desired and envisioned sustainable landscape development, which is to be continuously checked and adapted[34], is put in the focus of the LQM process. As

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[33] Human actors in terms of land & water management performance are understood here as humans and organizational institutions directly intervening with the land surface and water bodies, such as land owners, farmers, foresters, engineers, industries, municipalities etc. Non-human actors are all other organisms and their living communities operating on the terrestrial surface and in aquatic systems.

[34] As already argued in the beginning such an outcome in terms of developing a sustainable relation between humans and their life support systems cannot be a static reference state (as often targeted with conversation and planning approaches), but should rather be seen as an intentional, co-evolutionary pathway made passable by tools such as reference images and indicators which may be adjusted along the route.

argued in the first chapter special attention is given to the regenerative activities and capacities of living communities influenced by human behavior.

At least three useful concepts – recognized by different political agendas – can be identified as entry points, which mediate between value and knowledge systems by linking environmental, ecosystem or landscape states, structures and processes to societal needs, individual and social well being, quality of life and sustainable development:

1. Ecosystem and landscape services
2. Multifunctionality of agriculture and landscapes
3. Environmental and landscape quality

In the following chapters, how they relate to each other and how they could be used to form the subject-matter of Landscape Quality Management and its process of standardized adaptive reference building suited to assess sustainability of biomass production is investigated. First, however, the use of the landscape category itself in this work is clarified.

2.1 The landscape category

Landscape is about the relationship between people and place.
It provides the setting for our day-to-day lives.
(Swanwick, et al. 2002, 2)

In the English-speaking context "landscape" is commonly understood as "a view or vista of scenery on land" and "a picture depicting such a view" (The American Heritage Dictionary 1994, 469). In different scientific, political and planning contexts the understanding of the landscape category is usually broader than that, and encompasses not only the 'scenic image', but also the physical-material components and interactions that actually make up the image (see for example different landscape definitions in Barau, Ludin 2012, 10ff). "Landscape" is a relatively old word which underwent semantic changes in the course of time dependent on cultural contexts.The English word "landscape", like the German word "Landschaft" or the Dutch word "landschap", developed as a collectivum (a plurality seen as an entity) of the word "land" by adding the suffix "-ship" (landship), in Old English forming "landscipe".[35] While the word "land" at this time means 'open area', the suffix "-ship" denotes the state or condition of, the qualities or character associated with or the power implied by the respective substantive (Hoad 1986, 257f, 435; Kluge, Seebold 1995, 501). Originally a topographical-political category, "landscape" evolved to an aesthetic-symbolic and then physical-material category. For the German cultural and language context, for example, Kirchhoff and Trepl (2009, 19f) and Trepl (2012) characterize this change of meaning as follows:

- In Old High German 'landscaf' refers to a tract of land clearly demarcated by the jurisdiction of a certain right.
- In Middle High German 'lantschaft' also refers to the entire class of a region, that is a collective of persons.
- Since the Early Modern Age 'Landschaft' has been used as technical term in painting for the pictorial portrayal of an area.
- Later it was also used in literary and academic language, where 'Landschaft' no longer meant the painted but rather the contemplated, real area.
- The concept of the geographical landscape arose only in the nineteenth century out of the science of Geography, based on Alexander v. Humboldt's physiognomy.
- After the era of mis-use by National Socialism, a conscious distancing from the conservative ideal Landschaft took place through the (apparently) 'nonjudgemental' ecologisation of the term in science.

In Germany today, 'landscape' is broadly ambiguous both in the common usage and in the literature. Trepl (2009) distinguishes between subjectivist and objectivist conceptions of landscape, where the subjectivist conception sees landscape as a mental/ visual construct and the objectivist conception sees landscape as a material-functional whole. Similarly, Donadieu and Périgord (2007) point to culturalist (aesthetic-symbolic) and naturalist (functionalist) as well as mixed conceptions of landscape in different European countries. In current landscape science, policy and planning, there is a tendency and practical need to merge the two poles. Landscapes "[...] should be studied [...] managed and evaluated with a biperspectivable systems view [...] as products of material, [...] biogeophysical systems and as mental, cognitive noospheric systems" (Naveh 2001, 269). In a broad and converging sense the European Landscape Convention (ELC) defines: "'Landscape' means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or

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[35] The word is further known as "lantscaf" in Old High German, "landscipi" in Old Saxonian, "lantscap" in Middle Dutch, "land skapr" in Old Norse etc.

human factors" (Council of Europe 2000, Art.1a). The present study basically follows this definition. However, some important aspects associated with the category are highlighted in the following to describe in more detail how the notion of "landscape" is used in this work.[36]

The landscape category is closely associated with a more or less wide view, e.g. from an elevated standpoint opening up an image of a scenery, and thus with a human perspective as clearly stated by the ELC. It thereby **transparently entails a human projection component**, which is inescapable when talking about nature, environment or ecosystems.[37] A prominent example is the 'discovery of the landscape view' by the poet Petrarcas mounting Mont Ventoux in France in the year 1335 (Ritter 1989 cited in Trepl 2012, 53f). The example also shows that the landscape can be experienced only from a certain distance, a distance to the single features and to everyday activities, as a kind of 'purposeless' looking. To actually see the landscape one must pause a moment or longer. The landscape can therefore serve as a **matter of contemplation and reflection.**[38]

Literally, since there are always different points of view, '**landscape' is a multi-scale phenomenon**. In their investigations about landscape perception Grodzynskyi and Grodzynska (2009, 160), for example, found four scales at which landscapes are perceived: (a) landscape as a place at the local scale level, (b) landscape as a scene, as a composition of places at the chorological level, (c) landscape as a regional integrity at the regional level, and (d) landscape as a concept ('extrascale' or global scale level). They also stress that the whole process of landscape perception involves a few scales simultaneously (Grodzynskyi, Grodzynska 2009, 160). To the regional level one may add the bird's-eyed remote sensing and 'Google Earth' view, which becomes more and more important in landscape analysis (Barau, Ludin 2012).

The **landscape** cannot only be looked at from different scales, but also from various professional and everyday perspectives. Multiple disciplines can recognize themselves in it (Barau, Ludin 2012, 11). It thus **allows for different approaches of studying and collaborative management including broad stakeholder involvement in a transdisciplinary way** (e.g. by the natural and social sciences as well as arts, architecture and planning or consultation of practitioners and the public etc.) (Naveh 2001, 269f, 280; Termorshuizen, Opdam 2009, 1043). Furthermore, the landscape and

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[36] The author is convinced it is precisely the fuzziness and the possibilities of association that make this term suitable for an integrative management process.

[37] A human perspective thereby does not necessarily mean an anthropocentric standpoint, though. Other living beings and their needs can be equally considered and valued in landscape development (see below), but not apart from a human projection viewpoint (Brüll et al. 2011) (see also Chapter 3.2 Regional process and Section 3.3.3).

[38] For an in-depth discussion of the emergence of the landscape view and contemplative landscape experience see Trepl (2012, 37-63).

its features are both **accessible by rational analysis and general abstraction as well as emotional relation and individual appreciation**. “As a source of information, landscape requires interpretation. Man establishes his relationship with the landscape as a perceiver of information, which can either be analysed scientifically or experienced emotionally” (Otero et al. 2007, 19). Landscape images have been and still are used to express and evoke feelings (e.g. in advertisements) and to transport imaginations of desirable societal conditions and human-nature relations (Trepl 2012). Landscape regions often have names and allow for personal and social identification. They can be easily associated with places where people “live and work and for which they are responsible” (Termorshuizen, Opdam 2009, 1043).

Figure 5: Landscape painting and photography playing with perspective, light and atmosphere. Left: Meindert Hobbema (1689): The Avenue at Middelharnis. Right: Ansel Adams (1942): The Tetons and the Snake River. (Source: Wikimedia Commons, public domain)

The landscape category is in particular marked by landscape painting, especially since the discovery of the graphical perspective during the Renaissance, which made possible the representation of visual depths and realistic spatial impressions on a two-dimensional medium (Trepl 2012, 38f, 58f). Its projection rules (e.g. horizon corresponding with eye level, drawing lines meeting in vanishing points etc.) are based on the effective three-dimensionality of the landscape and the bio-physical process of visual-sensual perception of light rays. The landscape category may therefore be particularly associated with a characteristic spatial pattern and a sensual atmosphere mainly composed of color and light (but also sound and smell as often described in landscape lyrics), which changes in time, i.e. with the weather, during the day and the seasons, and within years and centuries.

Landscapes are shaped both by bio-physical processes (e.g. tectonic movements, water run-off, wind erosion, biological activity etc.) and socio-economic activities and

driving forces (e.g. global market, land use/ land management and industrial activities, personal motivations, cultural habits, zeitgeist, etc.), which are interwoven and cannot be clearly distinguished anymore. A flood, restructuring a riverine landscape for example, may be a result of combined factors, such as ‘natural’ precipitation, man-made land cover changes and climate change. **Landscape is** therefore to be considered **a nature-culture hybrid** (see page 17). From this standpoint the common distinction of ‘natural’ and ‘semi-natural’ versus ‘cultural landscapes’ is difficult to justify and may actually be counterproductive in efforts to sustainably develop landscapes (Hofmeister, Mölders 2007).
Landscapes have an individual shape and history. This means that every piece of land in a certain landscape area possesses spatial and temporal site characteristics given by the landscape (and earth system) context. Spatial properties are determined e.g. by latitude, bed-rock, minerals and soil type, topography and location in the watershed, etc. as well as by vicinity to agglomerations, transportation infrastructure, location within scenery, and genius loci etc. Temporally dependent properties of a site could be characterized e.g. by daily and seasonal changes, soil ageing and ecological tipping points, succession and land development phases, irreversibility, or the meaning of a site obtained through historical epochs and events etc. Temporal properties are important process and value determinants, but often do not receive as much attention in impact analysis as spatial properties (Kümmerer, Hofmeister 2008). Landscapes typically serve as a projection surface (e.g. via scenario and modelling tools) for desirable and undesirable futures. Single sites and processes can gain importance in such landscape visions. Hence, **landscapes – their past and (anticipated) future – provide the concrete spatial-temporal matrix for the context-specific management of land, land use, ecosystems and resources**.

In summary it can be said that “landscape” is a trans-disciplinary, multi-scale, spatial and temporal category, which combines nature and culture, general and individual aspects, as well as aspects of projection and reflection. These properties seem to make it suitable for a comprehensive assessment and management process as envisioned in this work.

A disadvantage of the term “landscape”, though, is that in general language usage it is often just associated with a picturesque image rather than with vital functionality, with managed rather than unmanaged terrain, and with the absence of built structures. However, “landscape” is not necessarily synonymous with rural countryside or beautiful scenery. **Landscapes** in a broader understanding as advocated by the European Landscape Convention also **encompass** urban and industrial areas, sometimes called “cityscapes”, as along with wilderness areas and “waterscapes” (lakes, estuaries, coast lines, etc.): **basically all areas within and along the terrestrial surface**. Outstanding landscapes as well as everyday or degraded landscapes should be equally considered (Council of Europe 2000, Art. 2).

The scope of the European Landscape Convention also includes marine areas (ibid.). Marine areas contain, for example, submerged land surfaces, such as coral reefs, continental shelves, and sea bottoms or suspended surfaces such as particulate matter and algae blooms, which form characteristic patterns and often yield fascinating pictures. Thus, they can be considered ‘landscapes under water’, or simply “seascapes”.[39] The formation of landscapes and seascapes is highly interdependent. Seascapes and their global oceanic currents determine climate and weather events on land, which has a decisive influence on the character of landscapes. Vice versa, seascapes are highly influenced by matter transported from land to the sea, recognized for example in eutrophication and acidification processes.

Since the landscape category is not only fuzzy in its meaning, but also in its geographical scale and extent, different spatial units may be ascribed to it, as discussed in Chapter 3.1. Vertically, land-/seascapes could reach from bedrock and sea bottoms, with their deep water and groundwater layers, to the (scenic) sky, with its atmospheric composition and cloud cover. Horizontally, in an areawide approach land-/seascapes basically accomodate *all* land uses, economic sectors, and other social activities. Further on in this study, only terrestrial landscapes are considered for reasons of simplicity. However, the assessment and management framework laid out in this study may also apply for seascapes.

Hence, a wide range of meanings, scales and units can be and are adopted here under the term “landscape”. Generally, the landscape can be conceptualized as a concrete, sensual, and evolving, social-ecological “Gestalt system” (Naveh 2001, 273) *realized* in space and time (in both meanings of the term: *perceived* and *brought about*). Over all (rather than ‘environment’, ‘ecosystem’, ‘land’ or ‘territory’) the landscape is the daily experienced living space (or extended “living room”, Polickova 2009) of humans, shared with other living beings.[40] The landscape with its physical features may also be considered the common ‘production space’ of metabolic industries and living communities.

This concept of landscape “differs from the one that may be found in certain documents […] by considering it as a part of physical space. This new concept expresses, on the

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[39] See e.g. (accessed 5/14/2012) http://www.stockholmresilience.org/research/landseascapelab.4.39aa239f11a8dd8de6b800020511.html

[40] Certainly, other living beings do not ‘perceive landscapes’. Landscapes can therefore not be ‘their’ living space. “Habitat” or “ecological niche” may be more apropriate terms to describe what we consider the living space of organisms. ‘Shared’ means here that other living beings inhabit and create those landscapes perceived by humans. However, the environment also selectively projects itself inside other organisms capable of sensual perception (Ditfurth 1986), maybe as ‘scentscapes’ or ‘soundscapes’ or different ‘lightscapes’, influenced by human activities.

contrary, the desire to confront, head-on and in a comprehensive way, the theme of the quality of the surroundings where people live; this is recognized as a precondition for individual and social well-being (understood in the physical, physiological, psychological and intellectual sense) and for sustainable development, as well as a resource conducive to economic activity" (Committee of Ministers 2008, I.2).

In this sense **landscapes and their dynamics build the (re)productive context of economic, social, and biological-ecological activities** from a human perspective and are co-products of those activities at the same time.[41] They are the physical and visible results of lived human-ecosystem relation (natural product/ natura naturata) as well as the starting point (capacities) for future relations (natural productivity/ natura naturans). The kind and attitude of the relation shows up in landscape qualities changing over time (see Chapter 2.2.6).

If "**landscape**" is understood or discussed in such a broad sense – **as a perceived area with a characteristic shape and individual history, constituting common living and production space of human societies, their economies and other living communities** – the landscape category may help to overcome hindering cleavages of land and water, city and countryside, nature and culture, and the worlds of science and people's day-to-day life.

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[41] Either directly, i.e. through agricultural or forestry activities and other land uses, or indirectly, through man-made environmental effects such as climate change or the distribution of chemical traces influencing organismic behavior and thus their landscape forming activities.

2.2 Regenerative landscape functions, services and qualities

> Flowers play in each and every colour, which excites and makes people joyful.
> The trees swing their leaves and whisper pleasantly in the wind,
> the birds join in with all kinds of wonderful songs,
> the whole regnum vegetabile emits a delicious fragrance.
> Insects swarm around in the air, and sit down here and there like embroideries.
> […] One must be made of stone, if one is not refreshed by all this.
>
> *Linné, 1758 (translated by Arler, 2000)*

2.2.1 The concepts of ecosystem and landscape services

In contrast to the term ‘landscape’, which is a polysemous everyday word established historically over a long period of time, and which was adopted by politics and science, ‘ecosystem’ and ‘ecosystem services’ are scientific concepts that are increasingly present in the worlds of politics and everyday life. Ecosystem services have been defined as the “benefits people obtain from ecosystems” (MA 2003, 3) or – with regard to multiple benefits people derive from one service – as “the direct and indirect contributions of ecosystems to human well-being” (Groot et al. 2010b, 25). They are also conceptualized as the yields of a productive natural capital stock, which is to be maintained as a minimum requirement for sustainable development (Costanza et al. 1997; Costanza, Daly 1992). They should be understood as gifts as opposed to something that is earned, as well as an accomplishment rather than a delivery (Costanza 2008 based on Barnes 2006).[42] Ecosystem services “sustain and fulfil human life” (Daily 1997a, 3) in many ways. Besides producing directly appropriatable goods such as biomass used for food, material and energy purposes, ecosystems maintain vital “life-support-functions”, e.g. through the following services extracted from Daily (ibid. 3f):

- Purification of air and water
- Mitigation of floods and droughts
- Detoxification and decomposition of waste
- Generation and renewal of soil and soil fertility

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[42] This is well expressed in the German category ‘Leistung’ (translating both into ‘service’ and ‘performance’). It is therefore recommended here to use the term ‘Ökosystemleistung’ in the German language context, better reflecting the intended use of the ecosystem services concept, rather than the term ‘Ökosystemdienstleistung’.

- Pollination of crops
- Moderation of temperature extremes
- Providing of aesthetic beauty and intellectual stimulation that lift the human spirit.

The most recognized collection and classification of ecosystem services is the one compiled by the Millennium Ecosystem Assessment – including provisioning, regulating and cultural services as well as supporting services (MA 2005) – slightly modified by the TEEB study (Sukhdev 2010).

To understand the concept of ‘ecosystem services’, it is important to recall the scientific concept of ‘ecosystem’. Ecosystems are generally understood as living communities (biocoenosis) within a physical living space (biotope). “Communities of organisms interacting with the abiotic environment comprise, and characterize ecosystems” (Elmquist et al. 2010, 45). Or expressed similarly: “An ecosystem is the set of organisms living in an area, their physical environment, and the interactions between them” (Daily 1997a, 2). The Convention on Biological Diversity (CBD) defines: “’Ecosystem’ means a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit” (United Nations 1992, 3), as is also adopted by the Millennium Ecosystem Assessment (MA 2003, 3). ‘Ecosystem’ is a functional category and as studied by (systems-) ecology primarily relates to the management of energy and matter flows.[43] Ecosystems comprise interactions between organisms and non-living (abiotic) factors (e.g. primary productivity, water cycling, and temperature management) as well as interactions among different organisms or species (e.g. pollination, predation, trophic energy flows) indirectly influencing energy and matter flows (US EPA 2009, 12). They may include humans and their actions as biophysical beings as well as their constructed physical structures and industrial metabolic flows.

Ecosystems in their early interpretation are composed of **functional groups of organisms** respective of their role within ecosystems assigned according to the transformation of energy and material, especially nutrients and biomass (Odum 1971, 8ff). As described in Chapter 1.3.2, ‘autotrophs’ are specifically distinguished in their time and space related activity from ‘heterotrophs’ as are ‘producers’ from ‘consumers’ and ‘decomposers’. These categories are still widely used, for example in large scale ecosystem services modelling (Boumans et al. 2002, 536). As already mentioned in Chapter 1.3.3, the naming of organismic groups as ‘producers’ versus ‘consumers’ may not be the most adequate and desirable notation since it reduces productivity solely to

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[43] Ecosystem studies are distinguished from ecological community studies, the latter focusing more on the structure and behavior of species and populations, both however considered valuable for ecosystem services assessment (Elmquist et al. 2010, 47).

biomass production and thereby reinforces the economic gap between ‘productivity’ and ‘reproductivity’. However, consumers are also called secondary producers and other roles and functional categories are added to the classical ecosystem model depending on the services and activities looked at, such as primary and secondary regulators, soil processors, pollinators, etc. (Elmquist et al. 2010, 48f).

Such (necessarily reductionist) functional understanding of living communities inherently involves the **concept of division of labor**. Each group, by undertaking specific activities and maintaining characteristic processes, seeks to fulfill certain functions or roles in relation to keeping ‘the whole system running’, thereby mutually sustaining their generational life cycles. These multiple interactions between specialized organisms in response to environmental driving forces and disturbances are called “ecosystem functions”, when relating to certain functional aspects (such as primary production, nutrient and water cycling etc.) (Costanza et al. 1997, 254; Groot et al. 2010b, 16ff), or “ecosystem functioning”, when relating to the ecosystem as a self-organizing or self-renewing whole. Ecosystem functions can be understood as subsets of biophysical structures and processes that provide services (Groot et al. 2010a, 264). They are the ultimate source of, but should not be confused with, ecosystem services (US EPA 2009, 12; Costanza et al. 1997, 253). “These relationships generate ecosystem services only if they contribute to human well-being, defined broadly to include both physical well-being and psychological gratification. Thus, ecosystem services cannot be defined independently of human values” (US EPA 2009, 12).

Hence, firstly, **the concept of ecosystem services allows the concrete description and acknowledgment of multiple physiological activities of living communities as productive biological-ecological work**, vital for human well-being and economic productivity. Secondly, ‘ecosystem services’ is a transdisciplinary scientific concept that **allows the conscious mediation between value and knowledge systems, and the highlighting of the process of value-creation by ecosystems and its agents.**

On the one side the concept is by definition linked to human valuation as stated above. It basically adopts a utilitarian approach to value (MA 2003, 128–132), which is often criticized. Ecosystems respectively the species and individuals that make them up can and should also be esteemed independently from the performance of their work or their utility, just for the beings they are.[44] Such concepts of “existence” or “intrinsic” versus “instrumental” value[45] are, however, considered important and are not excluded by the

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[44] In the same way that humans are appreciated both as beings and labor forces and should not solely be reduced to the latter evoking an exploitative attitude (for further explorations see Section 3.3.3).

[45] While existence value (like instrumental value) is based on a utilitarian approach, where valuing the pure existence of e.g. a species is connected with evoking human satisfaction, intrinsic value is derived

concept of ecosystem services (US EPA 2009, 13ff; Costanza et al. 1997, 255). “Of course the importance of ecosystems goes beyond their role for human well-being. Non-utilitarian sources of value must also be taken into consideration in order to make appropriate management decisions” (MA 2003, 147). However, in a consensus building process the concept may give occasion to become aware of value systems, underlying world views and related human-nature relationships (see Chapter 3.3.3).

Presently, there is not much acknowledgement of the daily productive work and value-creation of living communities at all. This is especially true of economic productivity theory, which takes the (re)production of essential living and production conditions for granted at zero cost (Biesecker, Hofmeister 2010, 1704f). Much research is therefore dedicated to developing and applying methods of ecosystem services valuation to help internalize the change of value of an altered mix of ecosystem services in land-use, economical and political decision making (MA 2003, 130–137; Goulder, Kennedy 1997; Costanza et al. 1997; US EPA 2009, 15) especially with regard to evaluating trade-offs (MA 2003, 2, 127).

On the other side ecosystem services assessment is bound to knowledge of ecosystem functioning. Estimating the change of a mix of ecosystem services – the losses of their degradation or the gains of their restoration – with regard to future generations, especially, requires at first estimating their biophysical changes connected with continuous human intervention or alternative management regimes (MA 2003, 137; US EPA 2009, 15). Therefore an understanding of how ecosystem services are produced by biophysical processes and interactions is essential. This is equally important for protecting ecosystems from land-use development as well as for the design of sustainable land management practices and technologies, i.e. for biomass production on already developed land. For the latter, human activities need to be intertwined and synchronized with timely activities of other living beings, so that, together, they yield a sustainable flow of ecosystem services.

Thus, a concept of ‘how the respective ecosystems work’ (including acknowledging associated uncertainties) is a prerequisite for any planned environmental design and management process if one does not solely want to rely on the trial and error method (Groot et al. 2010b, 18). Usually, conceptual and computational models of ecosystem functions/ functioning support ecosystem services assessment in attempting to understand how these are sustaining, respectively to develop measures on how to sustain them. It is recommended to use conceptual models and derived “ecological production functions” to predict ecological responses to human intervention in value-

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from various religious, spiritual and cultural world views (MA 2003, 140–143). This can involve intrinsic rights, where all living beings are regarded to have a right to exist and flourish independent from human satisfaction (Goulder, Kennedy 1997, 24–27) or at least a moral concept, in which humans do *not* have the right to massively extinguish other forms of life.

relevant terms (US EPA 2009, 28–31). Ecological production functions are the constructed mathematical expressions of perceived and parameterized biophysical and social-ecological relationships producing the respective services in question. Ecosystem services here serve as the link between ecological interrelations, molded into models predicting human-ecosystem behavior, and normative decisions based on valuation exercises insofar as they could and should be expressed in both physical units and units of value such as rankings and monetary terms.

Comprehensive work on ecosystem services and related fields was and is carried out and conducted in national and international research studies (Sukhdev 2010; MA 2005; US EPA 2009), networks (e.g. the Ecosystem Services Partnership[46]), and programs (e.g. the call of the German Federal Ministry of Education and Research on Sustainable Land Management[47]). An Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) proposed by international organizations following the example of the IPCC has been established.[48] The EU recently recognized ecosystem services in its Flagship Initiative for a Ressource Efficienct Europe (European Commission 2011d), its Biodiversity Strategy (European Commission 2011a) and Green Infrastructure Strategy (European Commission 2013). Promoting ecosystem services is now one of several investment priorities of regional/ cohesion policy (European Commission 2011c, Art. 5).
Although the ecosystem services concept is already internationally recognized, many practical issues remain to operationalize it for decision making. Many ecological models, for example, lack transparent and understandable linkages to value relevant terms. Modelling exercises are mostly very complex and require a great amount of costly and often unavailable data (US EPA 2009, 22, 32f). Most importantly, ecosystem services can seldom clearly be mapped to single ecosystems. Finding the appropriate scales and boundaries are critical issues (MA 2003, 107–126) (see also Chapters 3.1-3.2).

Ecosystems and their services are realized on multiple scales. Since ecosystem is a functional category it can be applied to entities as small as biofilms on pebble stones or as large as the entire earth system. However, associated with ecosystems are usually concrete physical *structures* visible in the landscape/ seascape dominated by a certain type of vegetation and water regime, e.g. forests, grasslands or wetlands, deserts, lakes and coral reefs[49] etc., which in large scale assessments are aggregated into biomes along with land-use/ land-cover categories (Costanza et al. 1997, 256; MA 2005). Ecosystem boundaries should be drawn where the internal interactions outweigh the

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[46] http://www.es-partnership.org (accessed 3/29/2010)

[47] http://www.bmbf.de/en/furtherance/13138.php (accessed 3/2010)

[48] http://www.ipbes.net (accessed 11/2/2012)

[49] In the case of coral reefs the ecosystem is characterized by animals rather than plants creating land surface within waters.

external interactions. For pragmatic reasons this is assumed to be the case when discontinuities such as the spatial distribution of organisms or environmental features appear and at best coincide (MA 2003, 51). The designation of spatial-structural units as ecosystems is, however, “more conceptual than based on any distinct spatial configuration of interactions” (Elmquist et al. 2010, 45), but it is convenient. It matches an image of living communities in a living space.

Such a simplified association of ecosystems is also kept here, when using the term ecosystem further on (unless otherwise stated), with a view to the necessity of consistently using a not too abstract terminology in stakeholder dialogues and public consultations when elaborating landscape reference systems.

Ecosystems in this phenomenological sense, however, are strongly interconnected through dynamic elements, such as water, air and migrating animals. Some ecosystem services can be linked with groups of animals moving across ecosystems (e.g. pollination, pest control) or with the management of water from upstream to downstream ecosystems (e.g. flood prevention, erosion control). Cultural services, such as aesthetical and spiritual benefits, could be a result of a monotone landscape structure, e.g. wide open grassland forming a section of a larger ecosystem, or a mosaic structure of several ecosystem patches, as it is usually the case in fragmented cultural landscapes.[50] Thus, many ecosystem services are realized not by single ecosystems, but a discrete spatial-temporal distribution of living communities and processes in the landscape (Termorshuizen, Opdam 2009, 1042f; Vandewalle et al. 2009, 29ff). As has already been claimed for certification exercises, it might also be useful for the assessment of ecosystem services to take on a ‘landscape-area-wise’ and areawide perspective. Therefore ecosystem services are also referred to as **landscape services** (ibid; Mander et al. 2007), especially when they are realized on a ‘landscape scale’.

One approach departing from the land surface as a whole is the concept of “multifunctional landscapes”, the subject of the next section along with “multifunctionality of agriculture”.

2.2.2 The concepts of multifunctionality of agriculture and landscapes

Aspects of multifunctionality are crucial concepts in European and international policy design for agriculture, environmental protection, and international trade, affecting biomass production. They are also discussed in the context of sustainable land

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[50] In Central Europe ecosystems can usually be considered part of landscapes due to partitioned structures of dominating cultural landscapes. In other regions ecosystems such as rainforests or savannas stretch over areas larger than what would be visualized as a landscape. However, many substructures exist there as well and ecosystems can be nested within each other (Elmquist et al. 2010).

development, especially of rural areas. Multifunctionality served as a paradigm for the European CAP reform in 2003, decoupling payments from quantitative commodity production levels and shifting them to rural development and production of environmental and health benefits. At the same time it has been criticized as an excuse to continue subsidizing (Wiggering et al. 2003; Casini et al. 2004, 4–10). The literature on the concept is very controversial. Van Huylenbroeck et al. (2007), Hagedorn (2007) and Vejre et al. (2007) give good reviews of how multifunctionality is understood from different perspectives. Only a few points relevant for this work will be highlighted here. Two pathways dealing with the concept of multifunctionality in land use systems have been identified: the *agricultural path* and the *landscape path* (Vejre et al. 2007).

Multifunctional agriculture

Multifunctionality of agriculture is an activity-oriented concept. The farm is the primary management and study unit (Vejre et al. 2007, 94f). The OECD provides an analytical framework for multifunctionality in agriculture and states in an often cited report: “Multifunctionality refers to the fact that an economic activity may have multiple outputs and, by virtue of this, may contribute to several societal objectives at once” (Maier, Shobayashi 2001, 11). Agriculture is considered multifunctional because “beyond its primary function of supplying food and fiber, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation, the sustainable management of renewable natural resources and the preservation of biodiversity, and contribute to the socio-economic viability of many rural areas” (Maier, Shobayashi 2001, 9). “It should be noted that multifunctionality is not regarded a specific character of agriculture, but pertains to any economic activity” (Vejre et al. 2007, 95). Multifunctionality (respectively the underlying concept of jointness, see below) can apply to e.g. fisheries, household production, and banking etc. (Maier, Shobayashi 2001, 133–138). Traditionally it is well known in forestry, providing for multiple production, protection and welfare functions as described in many European state policies on forest management. Multifunctionality in this sense is not only used as an activity- but also sector-oriented concept.

The multiple functions of agriculture for society can be grouped in different ways, for example into primary and secondary functions (Vejre et al. 2007, 98) or social, ecological and economic functions (Huylenbroeck et al. 2007, 16–21) or be ascribed to different classifications of landscape functions (see multifunctional landscapes below).

To avoid arbitrariness in the use of the concept, the OECD further points to the following key elements of multifunctionality as a working definition: “i) the existence of multiple commodity and non-commodity outputs that are jointly produced by agriculture; ii) the fact that some of the non-commodity outputs exhibit the characteristics of externalities or public goods, with the result that markets for these goods do not exist or function poorly" (Maier, Shobayashi 2001, 13). In this understanding two basic concepts underlie multifunctionality: (1) *jointness of production* and (2) *externalities of agriculture*.

"**Jointness of production**" refers to the fact that several goods and services[51] (i.e. ecosystem goods and services) are jointly produced by the same agricultural activity due to some inter-connectedness in the production process. A prominent example is the production of 'open landscapes' by e.g. cereal or meat producing farms creating a 'steppe-like' agro-ecosystem. Joint production may stem from bio-physical interrelations and/ or institutional arrangements (technical and institutional jointness, see below). "**Externalities of agriculture**" refers to those non-commodity outputs or by-products produced by agricultural activities that affect third parties not involved in the economic transaction, often causing market failures concerning the provisioning of public goods. Both positive externalities (such as increasing the beauty of a scenery) and negative externalities (such as air pollution) are included in the approach as an object of study or potential policy intervention.[52]

An *empirical* and *normative* use of multifunctionality is distinguished and attributed to its **supply and demand side** (Huylenbroeck et al. 2007, 8–11), as well as related to **technical and institutional jointness** (Hagedorn 2007, 110f).

On the **supply side** the multifunctionality approach is used to analyse which non-commodity outputs are co-produced by the agricultural activity, and whether these examine properties of positive or negative externalities. This empirical aspect of multifunctional agriculture – respectively the analysis of the underlying character of jointness – also serves as an analytical framework to determine whether a national policy intervention to internalize externalities and thereby correct market failure according to a nation's domestic needs is necessary or justified with regard to international trade liberalization (Maier, Shobayashi 2001, 22f). Thus, the empirical side of multifunctionality analysis is closely linked to (and actually does not make sense without) the normative side of multifunctionality.

On the **demand side** the multifunctionality approach can be used to identify which functions are expected by society to be fulfilled by agricultural activities and the rural countryside which directly links multifunctional agriculture to landscape functions (see below) (Huylenbroeck et al. 2007, 10). "By placing multifunctionality in a 'normative' context, the focus of the discussion would shift towards the societal objectives associated with agriculture in the various countries, including equity and stability

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[51] Also often named tangible and non-tangible outputs or (intended) products and (unintended) by-products or side-effects, etc.

[52] For extensive explanations of "joint production", "externalities" and "public goods" with regard to multifunctionality of agriculture see Maier and Shobayashi (2001).

objectives” (Maier, Shobayashi 2001, 14).[53] The normative aspect of multifunctional agriculture thus implies the valuation of desired versus undesired commodity and non-commodity output bundles as well as measures to achieve jointness yielding more ‘goods’ than ‘bads’. Technical and institutional jointness can be distinguished in this regard (Hagedorn 2007, 110f).

Technical jointness of commodity and non-commodity production arises from technically or bio-physically coupled processes (e.g. erosion induced by water runoff from bare soils) within a particular production activity (Hagedorn 2007, 110). Technical jointness can be influenced to a certain extent by the design of technologies (e.g. machinery and equipment), choice of management practices (e.g. cropping, tillage, fertilizer or mowing systems), as well as spatial ‘farm design’ (e.g. size and arrangement of fields, hedges and trees, contour and terrace farming, etc.), and thereby lead to different outcomes of positive or negative externalities (e.g. increased or reduced run-off, water quality or biodiversity). It is a matter of land-use decision by the land manager, which is to a certain extent driven by institutional arrangements such as corporate farm structures, the global market and regional markets, European Common Agricultural Policy (CAP), etc.

Institutional jointness of commodity and non-commodity production arises from organizationally coupled processes (e.g. payments for biodiversity measures or allocation of resources) affecting farming systems. It points to the way different activities related to agriculture and its multiple outputs are “jointly institutionalized either within the farm firm, or even beyond the limits of individual farms, in individual and collective arrangements of farms and by rights and rules” (Hagedorn 2007, 109f). It is a matter of coordinative mechanisms at different scales which are not restricted to the market-state-dichotomy, but could also include civil society initiatives and community organization etc. (Hagedorn 2007).[54]

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[53] From the normative point of view an agricultural activity is considered multifunctional when its output bundle contributes to several societal goals at once. In case the activity undermines important functions (e.g. carbon storage in the soil) one would then speak rather of the activity being ‘dysfunctional’ in this regard. The activity could still be functioning perfectly from the standpoint of the farm owner generating income and profit. It should be noted that the term ‘functional’ usually is a positively (as opposed to negatively) connoted and not a value-free term. Speaking of ‘functional’ means that something works according to an expectation [lat. *fungere*: perform]. It thus lends itself to the normative side, which does not exclude its being used as an analytical concept. However, to speak of “multifunctionality” as a neutral characteristic of an activity (Maier, Shobayashi 2001, 14) in the case of generating both functional positive and dysfunctional negative externalities is somewhat confusing for people not deeply involved in the scientific and political debate. The term is thus further used here in its normative meaning of being regarded a useful analytical tool in a normative context (i.e. policy programs for sustainable production).

[54] The proposed reference building mechanism of landscape quality management is to be seen in the range of institutional jointness based on considerations of technical jointness associated with biomass production and appropriation (see Section 2.3.2). As already mentioned, however, the focus in this work lies on how such a process could be working, with only a few thoughts on how it could be institutionalized.

Technical and institutional jointness are interrelated and can be both studied (empirical side) as well as partially ‘designed’ towards desirable multifunctional output bundles (normative side) i.e. for sustainable landscape development.

Depending on the character and design of jointness the outputs could be complementary or competitive. In terms of mere technical jointness outputs are complementary when the increase in production of one output also leads to an increase of another desired output. They are competitive when the increase of one output reduces the other output (Huylenbroeck et al. 2007, 8). For example, the production of biodiesel from rape seed and protein-rich fodder from its press cake are complementary outputs. In contrast, the production of biogas from corn competes with the production of corn for food. Complementary and competing relationships are not necessarily fixed. Complementary relationships can turn for example into competing relationships beyond certain productivity levels, as shown for beef production and species diversity of grassland (Havlik et al. 2005, 493f).

Based on knowledge of jointness (Section 2.3.2) complementary relationships can be achieved through designing production processes and technologies and ‘arranging’ different production activities in farming systems and land use patterns. A concept of **complementary biomass (re)production** with regard to yielding multiple ecosystem goods and services is derived here at this point and further elaborated in Chapter 4. By shaping jointness (designing, coupling and arranging technical and organizational processes) as far as possible towards complementary output bundles, **synergies between different functions** can be obtained, **resulting in true multifunctional** rather than dysfunctional **activities** in a normative sense.

However, that an activity is multifunctional does not necessarily mean that it is sustainable. This depends on which functions are regarded necessary and desirable for sustainable development. A biomass production system that actually contributes to the three main European bioenergy policy goals of climate protection, energy supply security and rural development (page 45f) is multifunctional. But if it thereby depletes water resources, for example, it is not sustainable. Therefore the agricultural or sectoral path of multifunctionality alone cannot serve to assess and develop sustainable (biomass) production. It does not account for the extent and distribution of different land-uses. Thus, when speaking about a multifunctional activity in the context of sustainability, again systems identifying the necessary and desirable functions and underlying interactions are needed as references. In this way the landscape path of multifunctionality may serve to determine important functions and roles for sustainable production with a cross-sectoral view on the whole landscape area.

Multifunctional landscapes

Multifunctionality of landscapes is a spatially oriented concept. The land respectively the complex land system area at different spatial levels is the primary unit of investigation (Huylenbroeck et al. 2007, 10; Vejre et al. 2007, 94). With reference to Forman and Godron (1985) Vejre et al. (2007, 94) point out that from a landscape science point of view: “the landscape is regarded a physical spatial unit that may fulfill several purposes (possess several functions) for the society, and landscapes house per definition several spatial units that may fulfill different purposes (different functions)”. In this sense landscapes are regarded as per se multifunctional. Concern, however, arises from how different functions are distributed on the land area and whether different functions are ‘balanced’ within a landscape.

The term “multifunctional” is understood in a normative sense as opposed to “monofunctional”. “Multifunctional landscape” is a synonym for a desirable condition of a landscape where many functions such as production, regulation and habitat functions (see below) are realized simultaneously or in close vicinity within the land area. Contrary to the integrated functions many European cultural landscapes displayed during times of self-sufficient regional markets, there has been a trend of “segregation of functions and eradication of other functions than production from the land areas” through industrialized land-use in modernity accelerated by the development of the global market (ibid. 97). “During the era of the industrialization of agricultural and silvicultural production, monofunctional land use was in general considered the most economically efficient land use development strategy. This strategy has resulted in monofunctional landscapes archetyped in areas of industrialized agriculture (Figure 6). Similar trends can be seen in forests and suburban dwellings and industrial and commercial zones” (ibid.).

These trends may be due to the dominance of “segregating institutions like markets and competition, and their interplay with technological innovation […] only capable of attributing economic value to commodities” (Hagedorn 2007, 115). They could also be seen as a consequence of the separation of ‘the productive’ from ‘the reproductive’ (see also Section 2.2.5).

The segregation of functions into different spatial areas is seen as a cause of environmental problems. Especially in densely populated areas and times of emerging land scarcity, trends of monofunctional land use require more land area and put more pressure on yet undeveloped land. This is also feared with regard to pure market-oriented biomass production. “Monofunctional use of landscapes often implies operations large land unit that hampers positive synergies between different potential functions within a landscape. Furthermore, monofunctional land use does not reflect the multifaceted character of the human demands” (Vejre et al. 2007, 97f). Vice versa multifunctional land use devoted to multiple landscape functions is desirable, because the landscape is not only a place of individual economic activities, but the common living space of humans and other creatures with diverse needs (page 82).

Figure 6: Image of a monofunctional agricultural bioenergy landscape for the production of sugarcane ethanol (Source: Sweeter Alternative, Creative Commons License CC BY-ND 2.0 https://www.flickr.com/photos/sweeteralternative/457946196)

Landscape functions can be classified in many ways, e.g. similar to agricultural functions into economic, ecological and social functions (Huylenbroeck et al. 2007, 10), or into production, regulation and habitat functions (Bastian, Schreiber 1999 cited in Hermann et al. 2011, 11f), or similar to ecosystem services into provisioning, regulation, habitat and cultural/ information functions (Groot, Lars 2007, 18; Groot et al. 2002). Another attempt at taxonomy of landscape functions can be found in Brandt and Vejre (2004) distinguishing ecosystem functions from land use functions and transcending functions. The following landscape functions are typically assessed through the German legalized system of landscape planning (Haaren et al. 2008, 19):

- Biodiversity function
- Landscape experience function
- Natural yield function
- Water resources function
- Retention function
- Archive function of the geotopes
- Climate function

However, it seems that no widely accepted definition of landscape functions or multifunctionality of landscapes is readily available (Vejre et al. 2007, 98). On the one hand "landscape functions are often described as being synonymous with landscape processes" (ibid.). This is especially true for functions derived from an ecological or ecosystem perspective such as regulation functions, seen as "capacities" (Groot et al. 2002, 394) and "the actual ('functional') processes and components in ecosystems and landscapes that provide the goods and services that have, direct or indirect, benefit to human welfare" (Groot, Lars 2007, 17). Similar to ecosystem functions, landscape functions then represent a sub-set of environmental agents, driving forces and interactions constituting a 'functional department' – like different processes of weathering, root-uptake, excretion and mineralization perform nutrient cycles or different processes of solar radiation, carbon fixation and transpiration etc. regulate the climate – without which the whole landscape (respectively its inhabiting communities) would not 'function', or in other words without which the landscape area could not serve as a living space for most human and non-human living communities. (The same meaning of function can be found in medicine when talking about physiological body functions such as the blood circulation system comprising the heart, arteries and veins, the blood media and its constituents etc.) Such **understanding of ecosystem and landscape functions as** 'departments' or **'sets of specialized processes'** leans more towards the **supply side of multifunctionality**.

Analogous to functional departments in companies (e.g. production, research & development or marketing & sales) performing specific tasks necessary for the functioning and survival of the whole company in the market and its delivery of products (goods and services), this perspective is called here the 'company perspective'.[55]

On the other hand landscape functions are understood as "societal functions of a landscape" (Bastian et al. 2006, 362 with reference to Haase 1990) representing societal requirements on the land surface arising from different needs of a 'functioning' society, such as needs of nutrition and housing or recreation and identification, etc. Such **understanding of landscape functions as 'demand sets'** evidently leans towards the **demand side of multifunctionality**. In this sense, the concept of multifunctional landscapes in the context of sustainable land development is also called

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[55] To distinguish functions from services, there is the claim that landscape functions (as process sets) like ecosystems functions exist in the absence of humans (Termorshuizen, Opdam 2009, 1041). While ecosystem functions empirically could be studied apart from human valuation (but always involving human constructions and projections, which are almost inseparable from values held) this seems to be implausible for landscape functions, since the term "landscape" itself as described in Chapter 2.1 is closely tied to the 'human view'. Additionally, it is difficult to imagine how for example production functions (e.g. on the supply side understood as ecological process sets delivering certain food products) or information functions (e.g. those processes bringing about flowering meadows used and appreciated for relaxation and contemplation) could be seen independently of human preferences and intervention.

a “demand-oriented approach” (Wiggering et al. 2003, 7). With reference to Barkman et al. (2004) Wiggering et al. (2006, 240) further write: “Multifunctionality denotes the phenomenon that the landscape actually or potentially provides multiple material and immaterial “goods” that satisfy societal needs or meet societal demands by the states, structures or processes of the landscape [...]. A landscape that displays this phenomenon can be called a multifunctional landscape.” A human demand and value perspective principally also underlies the ‘habitat function’ of landscapes. Habitats should be protected or restored because they fulfill certain ecological roles or house certain species. However, humans select which target species and habitats are to be protected according to e.g. criteria of rarity (red list), symbolic meaning or ‘naturalness’ and/ or intrinsic value ascribed to them.

Accordingly, from the normative point of view, at least two elements characterize landscape functions. Landscape functions (i) arise from societal needs and values (including a broad range from physiological and psychological needs to ethical values), and (ii) are imposed on the land surface as a whole or should be maintained in a particular landscape. Thus, in a demand-oriented understanding landscape functions are the ‘roles and tasks’ ascribed to a landscape or to be fulfilled and maintained within a landscape. Such a perspective is called here the ‘client perspective’.

However, the **supply and demand sides of ‘function’ appear to be two sides of the same coin** and neither side makes sense without the other. Company and client perspective are mutually dependent on each other. “[...] the important issue with the invention of landscape functions is not the classification system of the landscape functions, nor the function terminology at all, but the identification of needs and demands and the landscape states, structures and processes on which they depend” (Casini et al. 2004, 19). Thus, the concept of **‘landscape functions’ is also a category bridging between value and knowledge systems**. In the German system of spatial “landscape planning” the concept is actually advocated and consciously used as such (Haaren 2004; Haaren et al. 2008, 2011; Bastian et al. 2006; Syrbe et al. 2007) on a level similar to ecosystem services. “Land evaluation with the help of landscape functions [...] is an important step to transform scientific knowledge to social categories, and to bridge the gap between nature and human society” (Bastian 2000, 147).[56]

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[56] The German Federal Nature Conservation Act, providing the legal basis for the system of landscape planning, defines as one overarching objective to safeguard the “Leistungs- und Funktionsfähigkeit des Naturhaushalts” (BNatSchG 2009, §1), which is officially translated as the “productivity and functionality of ecosystems” (German Federal Ministry for the Environment 2010, 8). However, the dictionary also offers “capacity for work” or “ability to perform” as translations for “Leistungsfähigkeit” as well as “work”, “performance” and “service” as translations for “Leistung” (Schöffler 1979, 588f). Thus, since there is no direct expression in English, “Leistungsfähigkeit des Naturhaushalts” could also be interpreted as the ‘capacity of ecosystems to perform biological-ecological work and to provide ecosystem services’.

Despite its long tradition, challenges also remain in applying the concept of multifunctional landscapes/ landscape functions. Making the multifunctionality concept operational in a landscape assessment and management framework "presupposes, that (i) all demands on land use and landscape functions are identified and considered simultaneously and (ii) their spatio-temporal interrelations are analysed in the land use context […]. The problem is to properly characterize and delineate landscapes and to derive information of all groups expressing demands on the use of landscapes" (Wiggering et al. 2006, 240). This requires a participatory process involving expert knowledge, and should not be a process of pure interest led negotiation (ibid; Casini et al. 2004, 31). However, as equally holds for ecosystem services, a critical issue is to find the right units and scales or resolutions to assess and address landscape functions together with parameters indicating quantitative and qualitative performance (Groot, Lars 2007, 28–32; Casini et al. 2004, 32; Burkhard et al. 2012).

2.2.3 The concepts of environmental and landscape quality

Environmental quality

Preserving, protecting and improving the quality of the environment[57] are important policy objectives of the European Union (TFEU 2010, Art. 191.1). In respect thereof "environmental quality" means the "properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms" and is understood as "a general term which can refer to: varied characteristics such as air and water purity or pollution, noise, access to open space, and the visual effects of buildings, and the potential effects which such characteristics may have on physical and mental health (caused by human activities)".[58] Normally, environmental quality is closely associated with ecological characteristics, such as water, air and soil quality. However, the European definition also comprises aesthetic qualities, related to visual effects and further land use characteristics, e.g. accessibility.

In order to achieve the above-mentioned goal, the introduction of environmental quality standards has a long political tradition. In environmental legislation environmental quality standards are mainly used to restrict emissions and imissions in order to reduce pollution and degradation of the environmental media (or 'protective goods') water, air, soil, flora and fauna. The European Commission's Joint Research Center defines:

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[57] The environment is defined as "the combination of elements whose complex interrelationships make up the settings, the surroundings and the conditions of life of the individual and of society, as they are or as they are felt" (http://glossary.eea.europa.eu/terminology/concept_html?term=environment (accessed 1/22/2013)

[58] http://glossary.eea.europa.eu/terminology/concept_html?term=environmental%20quality (accessed 1/22/2013)

“Environmental quality standard” (EQS) means the concentration of a particular pollutant or group of pollutants in water, sediment (any material transported by water and settled to the bottom) or biota (all living organisms of an area) which should not be exceeded in order to protect human health and the environment”.[59]
More recently, standards are also applied to the actual quality of the medium itself, such as through the Water Framework Directive. A “good status” of water in surface and groundwater bodies is to be achieved to serve both the healthy use by humans and as an aquatic habitat (European Parliament and Council of the European Union 2000, Art. 4). The good status is not only determined by the absence of pollutants, but also by a multitude of other “quality elements”, such as oxygenation conditions, quantity and dynamics of water flow or biotic composition (ibid. Annex III-1).

A slightly different understanding of environmental quality as “quality of place” can be found within the context of urban planning and quality of life research (Marans 2003; Kamp et al. 2003). It combines not only multiple quality elements of different environmental fields but also objective and subjective attributes of environmental conditions and perceived responses, a method which is promoted as well for landscape quality assessments.

Landscape quality

Specifying “landscape quality objectives” is a central component of landscape policy promoted by the Council of Europe’s Landscape Convention (Council of Europe 2000, Art. 6D). The European Landscape Convention (ELC) therewith aims to improve the quality of people’s life and thus to contribute to individual and social well-being (Luginbühl 2006). It defines landscape quality objectives as “the formulation by the competent public authorities of the aspirations of the public with regard to the landscape features of their surroundings” (ibid. Art. 1c). Which features are concerned is left completely open. A definition of “landscape quality” by itself is also not given. However, the guidance document accompanying the ELC suggests a broad range of potential landscape quality objectives e.g. relating to historical meaning, environmental potential, and visual obstacles of, or public access to, landscape features and places (Committee of Ministers 2008, II.2.2).

Within the scientific community there is no consensus on the concept of landscape quality (Otero et al. 2007, 19). Similar to the landscape category itself (Chapter 2.1), different narrower or wider meanings of ‘landscape quality’ exist. Otero et al. (2007), for example, found the concept of landscape quality in different works referring to visual

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[59] http://ihcp.jrc.ec.europa.eu/our_activities/public-health/eqs/eqs/ (accessed 2/22/2013)

characteristics, diversity, coherence and continuity, ecological value, and the concept of ‘naturalness’.

Visual aesthetic quality is probably the most common understanding of landscape quality. It has been predominant in landscape quality assessment over the last half-century (Daniel 2001, 267–270; Vizzari 2011, 108), consistent with the narrower meaning of landscape as scenery or vista. In this sense – parallel to a long-standing debate in the philosophy of aesthetics – “landscape quality assessment has featured a contest between expert and perception-based approaches” (ibid. 267) (or again similar to the landscape category itself between objectivist and subjectivist paradigms, Lothian 1999). Expert approaches rely on trained experts (e.g. landscape architects) to evaluate visual aesthetic quality based on abstract theory and design paramaters (e.g. form, line, texture, unity, harmony etc.). Perception-based approaches use various survey research and psychological methods (including rankings and ratings by human viewers) to obtain (quantitative) measures of *perceived* landscape aesthetic quality. Both approaches and their methodologies are applied in parallel and are somewhat combined in environmental management decisions (Daniel 2001, 268–274).
Broader conceptions of aesthetic landscape quality also involve other sensual features of the landscape, e.g. scent and sound, temperature and texture etc. “The link between the different senses and the landscape is not universally accepted; however aesthetics, an indisputable dimension of the quality of landscapes, cannot under any circumstances be reduced to the aesthetic values of form and the visual. In fact Hegel, in his first-rate treatise on aesthetics, extends the concept of aesthetics to include all sensations of which man is capable” (Luginbühl 2006, 38 with reference to Hegel 1975).

Other authors opt for an even broader understanding of landscape quality. Arler (2000) and Vizzari (2011), for example, suggest that landscape quality could also be a composition of different qualities found in the landscape, wherein aesthetic quality is only one ingredient. Vizzari (ibid.) includes physical-naturalistic, historical-cultural and social-symbolic categories in his multi-criteria assessment of “potential landscape quality” of the territory of Assisi in Italy. Arler (2000) points to the following landscape or nature qualities to be considered in Danish “nature quality plans”:

- Instrumental qualities supporting land use (e.g. water quality or soil quality etc.)
- Qualities related to biodiversity (e.g. rareness, uniqueness, variedness, beauty, and strangeness etc. of species and habitats)
- Atmospherical qualities related to the character of place (e.g. composed of color and light, sound and fragrance, wind and waves etc.)
- Pictorial qualities of scenery along multiple view points

- Qualities related to history and narrativity (e.g. landscape as a medium of common memory, (lost) paradise and wilderness narratives)

In contrast to this comprehensive view, Daniel (2001, 269f) criticizes that “by such accounts landscape quality assessment would expand to encompass virtually every aspect of the environment and all human environmental experience, recollection and imagination” and that very different methods would be required.

However, if one interprets the **landscape as the** perceived 4-dimensional **concretization of the environment** and if one accepts that many qualities may be detected in one and the same landscape according to different human viewers’ value lenses, and that certainly very different methodologies apply for their assessment, then essentially nothing speaks against conceiving of **landscape quality** as **composed of various qualities** (see Section 2.2.6). This would actually be consistent with the understanding of landscape as a part of physical space and people’s day-to-day-surroundings as advocated by the ELC (see page 81f), and its requirement to define a wide range of landscape quality objectives with regard to individual and social well-being and sustainable development.

Common ground seems to be “that landscape quality derives from an interaction between biophysical features of the landscape and perceptual/ judgmental processes of the human viewer” (ibid. 267) or more generally “that **quality of any entity has both a subjective dimension as well as an objective reality**. Central to this assertion is the meaning of quality of both built environments and natural environments” (Marans 2003, 73). On the one hand landscape quality (or *qualities of different kind*) can neither be deduced logically nor determined solely by ‘objective’ scientific procedures, since it requires judgement and taste. On the other hand landscape quality is not subjective in an exclusively private sense. It is a public good, sharable and discussable, and should be subject to democratic deliberative processes among people with shared perspectives, knowledge and experiences (Arler 2000, 293ff, 301).

Thus, **landscape quality,** similar to the concepts of landscape functions and ecosystem services, **is also a category suitable to mediate between value and knowledge systems**. It furthermore **allows qualitative performance judgements**. In the following it will be discussed how the three concepts could relate to each other and form an assessment framework for Landscape Quality Management. In a first step the relation of ecosystem services and landscape functions will be looked at in more detail in the next section and in a second step their relation to environmental and landscape qualities (Section 2.2.6).

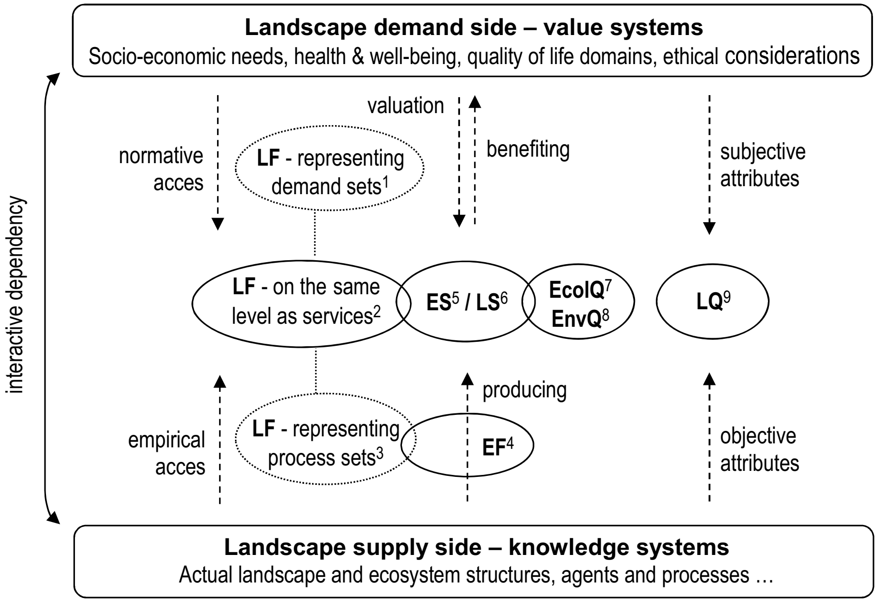
2.2.4 A non-market demand and supply framework

It was argued at the end of the first chapter that a meaningful assessment of sustainable biomass production should refer to a consensus or shared understanding of (1) what is to be sustained in the landscape area (for future generations) and (2) how (well) different biomass forms and producers contribute and perform with regard to this.

The first part of this thesis requires a debate about the demands imposed on the landscape today and in the future arising from different collective and individual needs and moral concepts. This necessitates judgement (Ott, Doering 2004 cited in Biesecker, Hofmeister 2009, 160) and coordinated processes of participation, information, negotiation and consensus building. The second part of this thesis requires a shared and critical understanding of the conceptions of "biomass" and "biomass producers", their roles and activities in ecosystems and landscape processes, and how these may change over time. This involves *acknowledgement* of the respective contributions, as well as different forms of *knowledge* giving information about the present state and past and projected changes of the supply (Chapter 2.3).

Thus, while the first part – the demand side – is mainly determined by value systems and ethical considerations, above all intergenerational equity, the second part – the supply side – needs to be accessed by knowledge systems. Value and knowledge systems, however, are interdependent and are to be integrated and reflected throughout the mechanism (see Section 3.3.1).

Besides the concept of landscape functions, stretching somewhere between the demand and supply side, the concepts of ecosystem services and environmental and landscape quality can also be placed in such an assessment and management framework in different ways. Vandewalle et al. (2009), for example, include the quantification of demand and supply of ecosystem services as a key step in their assessment procedure of Services Providing Units (SPU) for biodiversity conservation policy and management. Burkhardt et al. (2011) suggest mapping ecosystem services demand and supply for sustainable landscape management by linking discrete CORINE land cover data (as proxies for ecosystems providing services) with expert hypotheses on their capacity and demand for services, later to be replaced by measurements of certain indicators. Paetzold et al. (2010) introduce an "Ecosystem Service Profile (ESP) as the match between the societal expectations (including potential future options) for a set of ecosystem services and the realized sustainable provision of those services" (Paetzold et al. 2010, 275) and as a measure of ecosystem quality judgements, there called "ecological quality". Similarly, within the context of German spatial planning, Domhardt et al. (2011, 235) describe environmental quality as "*Verhältnis anthropogener Nutzungsansprüche an den Raum zur Leistungsfähigkeit des Naturhaushaltes dieses Raumes*" (the ratio of anthropogenic use requirements for a given area to the capacity of ecosystems in that area, translation). Weinstoerffer and Girardin (2000) propose a landscape indicator (based on four criteria: openness, heritage, upkeep, and diversity) as a measure of landscape quality inbetween landscape demand and supply and the subjective-objective duality of landscapes (Weinstoerffer, Girardin 2000). As Figure 7 shows, a demand and supply framework may help to clarifiy the relation of concepts and categories to each other.



LF = Landscape Functions, **EF** = Ecosystem Functions, **ES** = Ecosystem Services,
LS = Landscape Services, **EcolQ** = Ecosystem/ Ecological Quality, **EnvQ** = Environmental Quality,
LQ = Landscape Quality

Figure 7: Location of different function, service, and quality concepts within a landscape demand and supply framework (author's portrayal)

(Sources: [1]Wiggering et al. 2003; [2]Haaren et al. 2008, 2011; [3, 4]Groot et al. 2010a; [5]Vandewalle et al. 2009; Burkhard et al. 2012; [6]Termorshuizen, Opdam 2009; [7]Paetzold et al. 2010, 275; [8]Domhardt et al. 2011, 235; [9]Weinstoerffer, Girardin 2000)

The concepts of ecosystem services and landscape functions overlap in many ways and complement each other. In international ecosystem services and landscape research there is a tendency to merge the two. The relationships and differences between ecosystem services, landscape multifunctionality and land use functions have been indicated as most relevant research questions (Burkhard et al. 2010, 257; Groot et al. 2010a). While ecosystem services and landscape services may be used almost synonymously[60], using ecosystem functions and landscape functions synonymously in the same way (Hermann et al. 2011, 9) seems to cause more trouble.

To avoid confusion about "functions" it is therefore suggested here to speak of "landscape functions" as 'demand sets' on the demand side while speaking of "ecosystem functions" as 'sets of specialized activities and processes' on the supply side. Adopting such a terminology, ecosystem functions or functioning then yield or (re)generate ecosystem services from a 'company perspective', and ecosystem services serve, fulfill or sustain landscape functions for society and economy from a 'client perspective' (see page 96).[61] Accordingly, landscapes providing multiple ecosystem services through their ecosystems patches, land use practices and patterns can be considered multifunctional.

While the ecosystem services approach is often used to demonstrate and calculate trade-offs, the multifunctionality approach concentrates especially on synergies and jointness of production between commodity and non-commodity outputs. Both concepts are useful in either way. Ecosystem services, however, are better suited to describe, recognize and discuss diverse activities of living communities as biological-ecological work valuable for economic production and vital for human well-being. They are therefore put in the center of the framework embedded in landscape and ecosystem functions (Figure 10).

An advantage of the landscape demand and supply framework for landscape management is that beneficiaries of landscape functions, services and qualities could be identified on the one side and suppliers on the other side, so that some sort of policy and management could be arranged between them (Vandewalle et al. 2009). "By placing the landscape in a context of supply and demand between suppliers and users, a condition is created for sustainable landscape development. [...] An important part of the landscape-change process is the transfer of money from the demand to the supply side" (Termorshuizen, Opdam 2009, 1047). However, there may also be resistance against placing the landscape and its ecosystems in a demand and supply context. Such a context is usually considered a market situation, which is often criticised for driving decisions for short-term profit rather than long-term benefit. In fact, there is a

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[60] While "ecosystem services" indicates that the services are produced by ecosystem agents, "landscape services" accentuates that they are produced in the landscape area resulting from spatial-temporal ecosystem and land-use patterns.

[61] It is also possible to completely leave out the term "function" and speak rather of the actual needs, requirements and interests when referring to the demand side and of the relevant actors and driving forces and actual landscape structures and processes fulfilling them, when referring to the supply side.

trend in politics to create markets for non-commodity services, like carbon sinks for example, which would then turn into commodity outputs (e.g. carbon credits). While this *may* work for quantifiable services it will be a very difficult and controversy exercise for intangible services such as opportunities for a sense of identity and symbolic meaning provided by landscape features. One may also fear that a demand and supply framework will commodify nature and put ‘price tags’ on species and living communities according to their usefulness and popularity.

It should be pointed out, however, that a constructed landscape demand and supply situation need not neccessarly involve a purely profit-maximizing business logic. The approach advocated here would be instead not to trade ecosystem/ landscape services on the present market, but to invest in their creative, coherent and continuous (quality) management, driven by long-term goals of sustainable development and quality of life. “This may require a fund managed by a local board of representatives of interest groups, financed from both private and public sources” (ibid.) or other institutions like e.g. “common property trusts”, where economic principles could still apply but are embedded in “long time horizons and a legal responsibility to future generations” (Barnes 2006, 84, 87). The issue of common property rights and institutions will be key for sustainable landscape and ecosystem management in general, and Landscape Quality Management as drafted here in particular, but is not subject of this study.

The question still remains, which functions and services in which quantity and quality are to be sustained in the landscape for sustainable development. On the one hand this is to be elaborated during the LQM mechanism to form the basic content of the reference system and to do justice to the local situations and regional, ecological and cultural specifics. On the other hand it cannot solely be an arbitrary matter of negotiations. The standardized part and quality control of the mechanism should take care that the process does not become a pawn of powerful interests and actually leads to a lasting and renewable relationship of humans and other living communities.

As explained in Chapter 1, based on the concept of (re)productivity as a guiding theme, the mechanism should especially focus on the ‘renew-ability’ of living communities, respectively on regenerative social-ecological activities, since these create the sustainable foundations of production, but are missing from the economic logic.

2.2.5 (Re)Productivity of ecosystem services

While there is a clear need to classify ecosystem services in a standardized manner, they may still be grouped in different useful ways according to different purposes (Haines-Young, Potschin 2012, Costanza et al. 1997). **Using “(re)productivity” as a critical-analytical category** (Biesecker, Hofmeister 2010, 1709) an attempt is made in this study **to distinguish ‘production services’ from ‘regenerative services’**. Necessarily such a distinction is unsharp and questionable, since (undisturbed) ecosystems typically are at once productive and regenerative, that is to say (re)productive. However, it is used to make appearent the present unsustainable separation of “the productive” from “the reproductive” in society and economy (see page 111). To overcome this separation, “(re)productivity” is used later on as a visionary category in Landscape Quality Management (see page 114).

‘**Production services**’ is used here to denote the **production of materially usable goods**, such as resources for food, feed, fuel and fiber as well as medicinal and genetic resources, to be harvested or extracted **from ‘biomass**’ – as a collective term for organic substances of many kinds (see also Hermann et al. 2011, 13). ‘**Regenerative services**’ refer to those services of biosynthetic living activities[62] that **reproduce life and health, favorable living & production conditions, and further components of quality of life or human well-being**. The wording ‘regenerative services’ is chosen over ‘reproduction services’ to set it apart from the limited biological understanding of reproduction as mere propagation of populations. **Regenerative services** are further **subdivided into ‘basic services’ and ‘recreational services’**.
This grouping is consistent with the first hirarchy-level of the Common International Classification of Ecosystem Services CICES, classifying three sections: i.e. provisioning services, regulation & maintenance services including habitat services, and cultural services (Haines-Young, Potschin 2012). Figure 8 gives an overview of the grouping used here and its correspondence with CICES.

‘Basic services’ reproduce life in its diverse forms by maintaining (1) basic physiological living and production conditions not only essential for humans but also for other living beings within ecosystem communities (life-support), as well as (2) immediate reproductive processes and properties. Basic living conditions are for instance favorable climatic conditions including no or adaptable global average temperature changes (in terms of climate change), agreeable temperature spans, moderate weather events and relatively ‘reliable’ weather patterns (in terms of climate variability), availability of water and nutrients, disease control, as well as soil fertility in a double sense (a) supporting crops and (b) supporting plant growth in general and therewith again climate, water, soil and habitat services. Immediate reproductive processes and properties are for example pollination, genetic diversity and habitat for migratory species.

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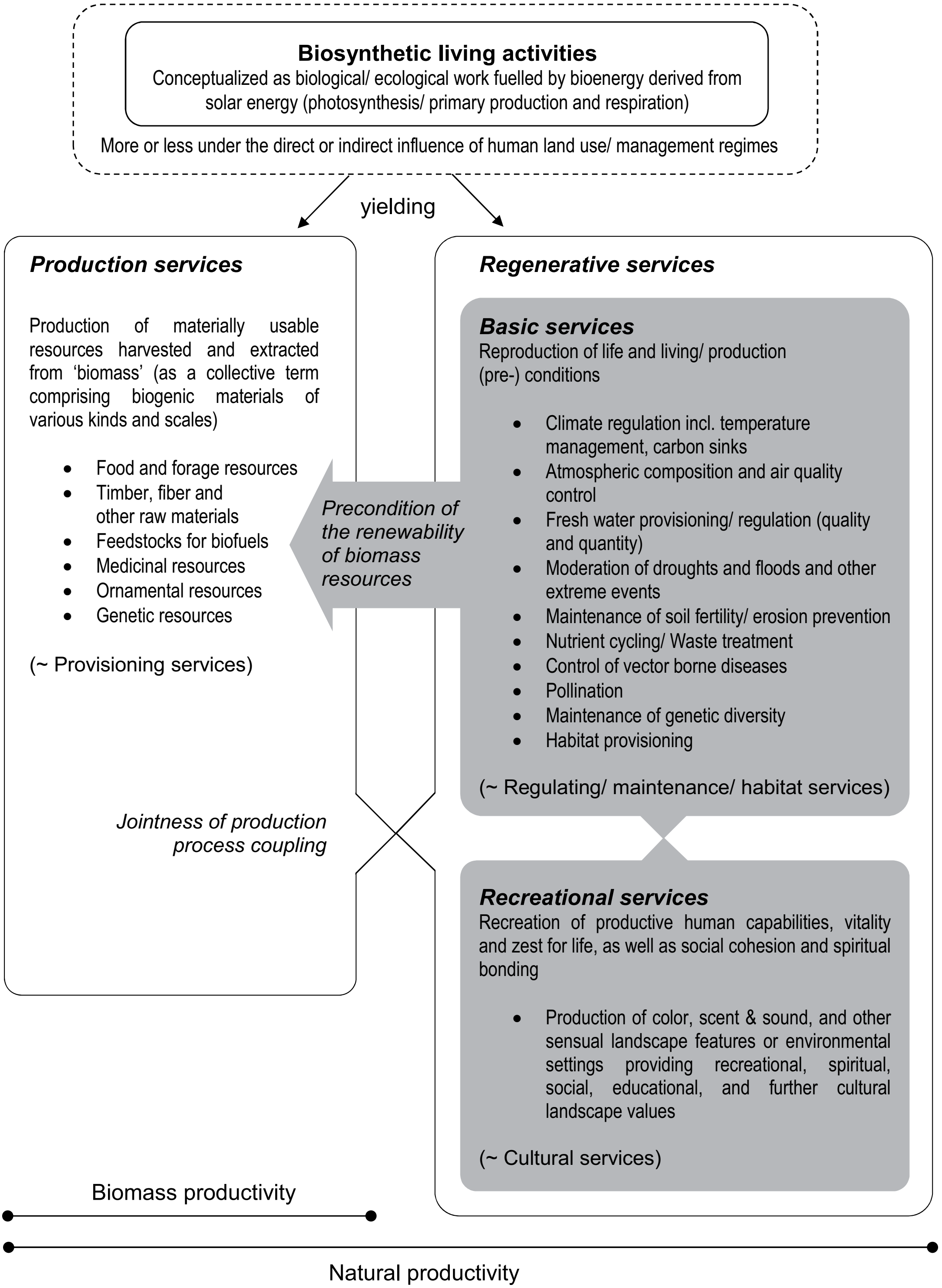
[62] Biosynthetic activities include the decomposing and mineralizing activities of microorganisms, which synthesize their own cells and bodies while breaking down organic material.



Conceptualized as biological/ ecological work fuelled by bioenergy derived from solar energy (photosynthesis/ primary production and respiration)

More or less under the direct or indirect influence of human land use/ management regimes

Production of materially usable resources harvested and extracted from 'biomass' (as a collective term comprising biogenic materials of various kinds and scales)

- Food and forage resources
- Timber, fiber and other raw materials
- Feedstocks for biofuels
- Medicinal resources
- Ornamental resources
- Genetic resources

(~ Provisioning services)

Reproduction of life and living/ production (pre-) conditions

- Climate regulation incl. temperature management, carbon sinks
- Atmospheric composition and air quality control
- Fresh water provisioning/ regulation (quality and quantity)
- Moderation of droughts and floods and other extreme events
- Maintenance of soil fertility/ erosion prevention
- Nutrient cycling/ Waste treatment
- Control of vector borne diseases
- Pollination
- Maintenance of genetic diversity
- Habitat provisioning

(~ Regulating/ maintenance/ habitat services)

Recreation of productive human capabilities, vitality and zest for life, as well as social cohesion and spiritual bonding

- Production of color, scent & sound, and other sensual landscape features or environmental settings providing recreational, spiritual, social, educational, and further cultural landscape values

(~ Cultural services)

Figure 8: Possible grouping of ecosystem services from a '(re)productivity viewpoint' (author's portrayal) (Sources: Listed ecosystem services are extracted from Sukhdev 2010, MA 2005, Costanza et al. 1997)

Regarding the provisioning of food it could be argued that it is a living condition as well. Food resources, however, are directly harvested from biomass and therefore considered a production service here. Furthermore, it is vitally dependent on other basic regenerative services such as climate, water, soil/ nutrient, pollination and genetic services. In contrast to that, the provisioning of water is grouped here solely under regenerative services. Water is a material ecosystem good and could also be labelled a production service. However, water is neither directly produced by ecosystems nor harvested from biomass, but it is managed by biosynthetic living activities. Its quality and quantity show spatial-temporal patterns (Section 2.2.6), which are the results of regulating biological-ecological work. Additionally it is the most essential living and production condition – not only for humans, but for all life forms. In fact, as is explained in Chapter 2.3.1, water plays a double role as an ecosystem service as well as an ecosystem agent indispensible for the provisioning of all other ecosystem goods and services. It was therefore classified as a provisioning as well as a supporting service by the Millennium Ecosystem Assessment (MA 2005, 106). Haines-Young and Potschin (2012, 14) note, that if restricting "the notion of an ecosystem service to the contribution that living (biotic) processes [i.e. biosynthetic living activities or biological-ecological work in this study, author's note] make to human well-being, then the focus in relation to water must be on how effective living processes are in controlling the quantity and quality of water, rather than the availability of water per se. Under this option 'water-related' services would best be situated entirely under the regulating services rather than in the provisioning section." Nevertheless, Haines-Young and Potschin also include water as a mineral ecosystem output in the provisioning section, indicating that there is no scientific consensus on how to deal with water in this context yet. The position adopted here is that the provisioning of fresh water, i.e. the regulation of its quantitative and qualitative spatial-temporal availability in rivers, lakes and aquifers as a regenerative service should not be confused with the actual human (economic) use of the service: the extraction of water for different purposes (drinking, processing, cooling etc.), which may actually be degenerative.

Basic services (re)generate living conditions essential to the renewal of human societies over generations. Basic services also (re)produce preconditions of economic production. Soil/ nutrient, water and climate services are vital for any biomass based material outputs. They are critical for the renewability of biogenic resources and the primary sector on which all other economic sectors rest. When those services degenerate, the "re" in "biomass resource" becomes questionable over time. Consequently, biomass resources can only be regarded renewable if their production (eco)systems maintain basic services over time and space (scales).

Furthermore, basic services provide production conditions in a certain quality which 'save costs' for the entrepreneurial producers compared to a scenario where the services would be lost or degraded. Most industrial production processes for example need water, often in a high quality, e.g. for cleansing, polishing, cooking etc., and thus rely on the services provided by the watershed from which the water is drawn. If the water quality deteriorated, water treatment technology like reverse osmosis or ionic exchange would need to be installed or upgraded.This would not only mean more costs for the producer, but would also require more energy for technical work replacing biological-ecological work.[63] Infrastructural facilities are often designed for 50-100 year weather events. If those 'relatively reliable' conditions change, huge investments for adaptation have to be made. With more frequent heat waves, for example, cooling equipment may fail and need costly upgrades (as happened in German trains in 2010), and so on. Examples like this, where basic services are internalized as site conditions in production infrastructure and process design, can probably be given for most industrial production plants and processes.

'Recreational services' – understood here in a very broad sense – **recreate human bodies, minds and souls as well as social, spiritual and cultural relations.** Ecosystems provide opportunities for classical recreational activities and other non-commercial uses (Costanza et al. 1997, 245). With their biotic and abiotic components they produce 4-dimensional, sensual landscape features and patterns composed of temperature and light, color, scent and sound, wind and water flow (including snow, fog, and dew), relief and rock formations, species and their behaviors, and so on. Those features and patterns are experienced, perceived, felt and interpreted by humans on different scales as e.g. scenery, character and atmosphere, 'soundscapes' and 'scentscapes' etc. in very different beneficial ways and through various activities (Natural England 2009; Luginbühl 2006).

Physical and mental health, for example, may be maintained or restored by outdoor sports or contemplation, e.g. when bicycling or sitting in the sun, enjoying a wide view and listening to the sounds of rustling leaves and gurgling water. Species, ecosystems and landscapes are objects of admiring appreciation, rational observation and sources of inspiration for culture, science, art and design (Kumar 2010, 26, 40). They provide opportunities of 'self-experience' (including positive and negative feelings, see below) or 'rooting' together with or apart from humans (e.g. escapism). Exploring the neighboring forest at dawn, steep terrain in remote mountains or the awakening vegetation after a strong winter, for instance, can (when overcoming potential fears) recreate faith, self-

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[63] The author adopts the position that biological-ecological work cannot be fully replaced by technical work. However, the substitutability debate on natural capital versus technical means is not gone into further here.

confidence, respect and spiritual bonding to 'the whole', or to nature or to the creation and its creator (reconnection).

Besides individual 'self-renewal' and spiritual relations, ecosystems and landscapes also serve to recreate social relations, i.e. by restoring individual capacities for social behavior or by providing opportunities and space for reiterating social activities. 'Fighting against natural forces' (such as wind and waves when sailing and surfing) or enjoying beautiful scenery or a calm remote atmosphere can reduce stress and aggressions and balance moods. Green open spaces decrease density as well as provide spaces for communication, gathering, and games. In urban and peri-urban sprawls they perfectly serve contradictory needs of distance and proximity (Becker et al. 1994; Frankhauser 1991). "Landscapes also form local identity and sense of belonging" (Sukhdev 2010, 34) and thereby support social and cultural cohesion.

Most importantly, roaming the landscape and experiencing plants and animals, or mud and water, supports the physical, mental, and social development of children. The educational value of open spaces, their features and non-human inhabitants is increasingly being recognized by psychological sciences (Gebhard 2009; Louv 2008).

It must be acknowledged, however, that – besides evoking positive feelings and beneficial experiences – species, ecosystems, and other landscape features can also cause negative feelings such as fear and disgust.[64] The experience of positive or negative feelings in the landscape, though, is highly subjective and dependent on zeitgeist (e.g. the Romantic period), attitude towards 'nature', familiarity with the behavior of other beings and environmental forces, etc. Nevertheless, via landscape character assessment, for example, and social and psychological science methods, e.g. involving attitude types, recreational/ cultural services can be linked to specific landscape features and configurations. Methods are also developed for mapping demand and supply of these services as well as tracing changes in non-monetary value, especially in the field of cultural landscape research to be linked with ecosystem services research (Natural England 2009; Schaich et al. 2010).

Altogether, recreational ecosystem and landscape services produce and create anew diverse components of quality of life. They enable children and adults to become 'productive' members of society and its economy. They recreate human labor force, vitality and zest for life, including economically valuable capabilities such as self-motivation, imaginativeness, creativity, perseverance, and concentration etc. Green open areas versus built environments especially serve for the restoration of direct

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[64] The intention of taming 'the wild and unpredictable' potentially posing danger to humans may have actually been a major driver of past land-use changes (e.g. channelling of rivers, eradication of big game, cutting native woods, or drying out bogs) along with the practical need to cultivate land for settlements and food production.

attention, a psychological resource essential for human effectiveness and labor productivity. Letting one's eyes wander over landscape sceneries, for example, enables people to recover from attention fatigue usually appearing in cities and at the work place (Kaplan 1995; Berman et al. 2008). If recreational services degraded significantly, human capital would most likely be quickly exhausted. Needless to say the tourism sector most obviously relying on recreational services is an important income source in many countries and regions.

The grouping of ecosystem services into 'production services' and 'regenerative services' equals to a certain degree the original differentiation of "ecosystem goods" from "ecosystem services" (Daily 1997a, 3), which was abandoned by the Millennium Ecosystem Assessment for the sake of simplicity (MA 2003, 56; Groot, Lars 2007, 17), but is still visible in the classification of "provisioning services" in contrast with "supporting/ habitat, regulating and cultural services" (MA 2005; Sukhdev 2010). Production services basically equal ecosystem goods or provisioning services except that water is taken out here and grouped under regenerative services as explained above. Basic regenerative services comprise regulating, maintenance and habitat services. Recreational services equal cultural services, whereas 're-creation' encompasses here not only physical and mental health, but also social, spiritual and further cultural relatedness, which in turn are vital contributors to physical and mental health and economic productivity.

The language of the multifunctionality approach shows a similar grouping, but partially reiterates the conventional economic understanding. On the supply side, for example, the primary function of agriculture providing material goods such as food, forage or biomass resources is considered "production", whereas other agricultural and landscape functions are considered "non-productive" (Huylenbroeck et al. 2007, 1) or "non-productivity issues of landscapes and ecosystems" (Mander et al. 2007, 2). On the demand side increasing societal interests in recreational landscape values are observed as a trend of rural areas changing from "productive" to "consumptive space" (Huylenbroeck et al. 2007, 5). Recreational activities taking place in the landscape are thereby labelled consumptive and are not regarded productive. This masks the fact that those 'landscape consuming' activities also produce a natural product, thus altering natural productivity, and that cultural ecosystem services vitally contribute to socio-economic productivity by restoring human capital, i.e. recreating productive human capabilities, as mentioned above.

Multifunctionality is also considered a paradigm of moving from "productivism to post-productivism" (Burton, Wilson 2006 cited in Huylenbroeck et al. 2007, 7, 22). From a (re)productivity standpoint one could also say sustainable multifunctional land use should reintegrate 'production and regenerative/ reproduction functions' (Annex 2) and thereby move society and its economy from a mode of unsustainable productivism to sustainable (re)productivity. Landscape Quality Management would initiate and coordinate such reintegration.

The distinction of ‘production services’ from ‘regenerative services’ referring to “(re)productivity” as a critical-analytical category (Biesecker, Hofmeister 2010, 1709) may be unsharp and questionable as the above examples of water and food show. However, as already mentioned, it can cast light on the present unsustainable economic separation of “the productive” from “the reproductive”. Only part of the production services, i.e. “cultivated biological resources”, are considered within the “production boundary” and therewith under the control and responsibility of ‘economic units’.[65] All other natural resources and ecosystem activities are placed in the environment outside the “production boundary” and therewith outside economic control, responsibility and care (Haines-Young, Potschin 2012, 17f with reference to SEEA 2012). Experimental ecosystem accounting is an attempt to account for all ecosystem services as valuable flows *from* the environment *to* the economy. However, ecosystem services are not considered to be outputs of the economy. In contrast, there is a tendency to restrict the ‘service provisioning boundary of ecosystems’ exclusively to non-human activities. In the scientific discussion there is no consensus yet whether ecosystem services should be conceptualized as originating from living activities of other species only, or whether to also include non-living mineral processes and resources as well as human management activities (Haines-Young, Potschin 2012). From a biodiversity conservation perspective only non-human organisms, species, functional groups, populations or communities or their trait attributes are included in the concepts of ecosystem service providers (ESPs) or service providing units (SPU) (Vandewalle et al. 2009, 32f). Haines-Young and Potschin (2013,15-19), with regard to ecosystem accounting, recommend restricting the notion of ecosystem services to outputs of ecosystems dependent on living (biotic) processes beyond the economic “production boundary”, acknowledging that this is a difficult construct. In this way ecosystem services – understood as outputs of organismic processes only – are inputs to economic production systems, but conversely human cultivation actvities are excluded from ecosystem services.

However, from a landscape management or design perspective and (re)productivity standpoint it seems problematic to fully separate ecosystem services from human land management activties. This will be illustrated by a few examples: Picking up the above-

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[65] ‘Cultural biological resources’ are usually well taken care of e.g. through economic breeding, feeding, fertilization, and irrigation activities etc., while the reproductivity of ‘wild harvest and catch’ is mostly taken for granted and not within the realm of ’economic care’.

mentioned 'cultivated biological resources' again, agro-ecosystems most obviously involve both human and organismic land management activities. An agro-ecosystem, which may be considered sustainable, could consist of main crops delivering provisioning services as well as intermediate cover crops, hedge networks and tree groups delivering water regulation and erosion prevention services, habitat and cultural services, etc. While these services can be attributed to specific types of vegetation, they would not be there and able to deliver these services without humans cultivating them. In the case of land abandonment, successional processes would occur and might lead to bush encroachment and the long-term establishment of woodland, which would then deliver a different set of services to different beneficiaries (e.g. climate regulation). However, if the first set of services were to be sustained, then human land management activities would also need to be taken into account. Actually, the concept of multifunctional agriculture and instruments such as payments for ecosystem services presuppose that ecosystem services are conceptualized in that case as joint outputs of organismic and human agricultural activities. In already devastated areas, the restoration of ecosystem services, e.g. by re-establishing vegetation, might require regular human caretaking, like organic fertilization, rainwater harvesting and irrigation for quite a long period of time. Another example is that of constructed wetlands, where human technologies are intentionally combined with the work of living communities to yield water purification services.

For cultural/ recreational services, especially, it seems almost impossible to cut out human contributions. In an urban park or flowering meadow the grass produces the stress-releasing green and the flowers a colorful pattern and fragrance enjoyed by people seeking relaxation there. But without regular human mowing activity, these ecosystems and their services would change quickly. Also for urban habitat services including secondary wilderness on former industrial or mining sites etc. a human component is immanent to those services. Furthermore, where there are no beneficiaries there are no services. Thus, the establishment and maintenance of an access network, e.g. of hiking trails, somewhat contributes to recreational services of e.g. forests and mountain ecosystems. Investigations showed that people tend to link their recreational and spiritual experiences or sense of belonging not to single and exclusively biotic features, but refer to whole landscape configurations also including mineral features such as extraordinary rock formations as well as human artifacts such as stone walls, ruins or architectural style and village views (Natural England 2009, 42ff). The term 'landscape services' capturing both contributions of living communties and humans was used in this investigation (ibid.) and might actually be more appropriate in this regard than ecosystem services.

A distinction could be made between ecosystems and their services existing only with a certain type of constant human management intervention and those underlying processes and stages of succession and climax without constant human intervention. The latter, which usually are called 'natural ecosystems', however, are still influenced to a certain degree by human activities and human induced changes, e.g. climate change or deposition of metabolites travelling on a global scale etc., which in turn may influence their capacity to provide services. This is recognized in the often cited "ecosystem services cascade" as a flow of "pressures" from the social and economic system to the environment (Haines-Young & Potschin 2013, 18).

Another way of looking at it would be to consider **all ecosystems**, just like landscapes, **as nature-culture hybrids and therewith also their services**. This would mean to accept that both biotic processes *and* human/ technical processes *in addition to* biotic processes could generate ecosystem services and vice versa, that both human and organismic processes could substract from service provisioning (Figure 9). Indeed, to look at the ***interaction* of human activities and those of living communities** will be decisive for understanding service provisioning and service degradation. The focus would then shift from accounting for single services to accounting for services bundles, and especially their *qualitative* besides quantitative *performance.*

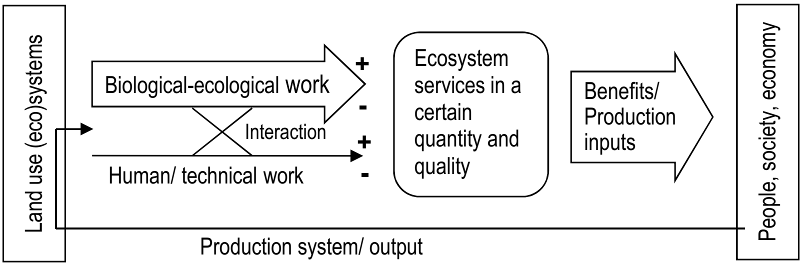

Figure 9: Ecosystem services conceptualized as inputs and outputs of economic production (author's portrayal)

No doubt, the strength of the ecosystem services concept is to highlight the productivity and value-creation of non-human life-forms. Biological-ecological work is thus still to be considered the main component of ecosystem service delivery. However – rather than to tediously segregate organismic from human processes – for the assessment and development of sustainable landscapes and sustainable production systems it will be more important to **distinguish between regenerative versus degenerative processes** – both by living communities and humans, and especially their interactions with regard to the joint co-production of ecosystem service bundles. Additionally, such an understanding may facilitate identifying interactions leading to “land degradation” as “reduction or loss […] of the biological and economic productivity” of land and ecosystems (UNCCD 1996, Art.1(f)).

Using **“(re)productivity” as a constructive category** – i.e. in the sense of a mental and physical reintegration of productivity and reproductivity (Biesecker, Hofmeister 2010, 1709) – would principally mean to fully consider production services *and* regenerative services within the area of responsibility and action of a sustainable (re)productive economy. In line with the above-mentioned ‘sustainable (re)production rule’, i.e. that natural productivity is to be sustained throughout all production activities (page 18), **regenerative services forming the ‘reproductive sphere’ of economic production** (natura naturans) **are then to be consciously shaped as outputs of economic activities in a high quality** (natura naturata). This does not necessarily mean that they must be governed by conventional market mechanisms, but that economic land uses and their production processes are arranged and designed so as to co-produce regenerative services bundles in a high quality.

In this sense one could formulate as a rule for sustainable biomass (re)production and for biomass to be called a ‘regenerative energy source’, that **regenerative services should be jointly co-produced within land use systems providing and using biomass production services**. This also applies to the use of residues for bioenergy purposes also stemming from biomass production services. Alternative uses of organic residues need to be considered, for example with regard to climate regulation, soil fertility, water & nutrient retention, and habitat services (see Chapter 4.3). Thus, **in the reference building LQM mechanism regenerative services will serve as general criteria for the assessment and development of sustainable biomass (re)production**. Important, however, is to understand the kind of ecosystem service output which can be sensed, measured and judged in its quantity *and quality*.

2.2.6 Landscape qualities - product qualities of regenerative services?

The output of production services (provisioning services) are usually tangible, material goods. The performance of these services can thus be easily determined by the amount or yield and quality of those goods (e.g. volume of wood harvested per hectare of a forest and its heating value). The outcomes of most regenerative services (regulating, supporting, habitat, and cultural services), though, are rather intangible. However, their effects can still be observed in the landscape. It is hypothesized in this study that **regenerative services are ‘realized’ as spatial-temporal patterns of various features and quality elements** (quality in a neutral sense) **in the landscape** (in both meanings of the term ‘realized’: perceived and brought about), based on which performance can be assessed (quality in a valuated sense, see below). The biological-ecological work processes underpinning regenerative services result, for example, in the concrete condition of terrain, soil, water and air (water and air regulation, soil maintenance and erosion control), the distribution of temperature and precipitation (climate regulation), population patterns of species and their relationships (habitat services), as well as compositions of color and light, scent and sound, and other sensual or experiential landscape features (cultural services). Sample patterns are listed in Annex 2.

On the one side these **spatial-temporal patterns are perceived in the landscape by human senses and instruments,** either **areal and/or point by point,** either **over time or at certain intervals**. For example, a landscape scenery or rain event at the horizon is visually observed as an areal impression from a specific standpoint in the landscape at a certain moment. The temperature of a rock, when sitting on it, and the smell of flowers growing in its cracks is individually felt at a certain location in the landscape, possibly in spring. Land surface temperature may be measured ‘in different resolutions’ at single weather stations or by remote sensing detecting radiation over the whole landscape area over time (climate regulation, recreational services). Water quality is experienced by the visibility of the bottom of a creek as well as measured by various parameters in the water body at a specific location, e.g. at the outflow of a watershed, in relation to precipitation events and run-off (water regulation). Pollination services are visible in the landscape as the seasonal formation of fruits. Effects of pollination are both tangible goods obtained from fruits like apples, almonds, or sunflower seeds, as well as spatial-temporal population patterns of a multitude of other plants depending on pollination for reproduction as well as animals feeding on those fruits, further providing other services. Even air regulation services and their degradation are, besides being measured high up in the atmosphere, realized in the landscape. Greenhouse gases (climate ‘de-regulation’), for example, are effective through radiation and extreme weather events again observed in the landscape, e.g. as increased temperature values, floods and droughts, or storms hitting coastlines.

On the other side these **patterns are produced in the landscape by a discrete spatial-temporal distribution of living activities and processes** operating over several ecosystems, units and scales in relation to land cover/ land-use patterns**.** Actually, land cover/ land use categories may be used as a proxy for the delineation and distribution of service providing ecosystems in landscapes (Burkhard et al. 2012). Thus, landscapes and their ‘land use (eco-)systems’ provide a place-based context for the assessment of ecosystem services (Natural England 2010a).

If the outputs of regenerative services can be described as processual spatial-temporal patterns of landscape features and quality elements, their actual **quality may be characterized by and judged upon the properties of those dynamic patterns** and their trends. Climate regulation services for instance display *moderate or extreme* patterns of temperature and precipitation over space and time in relation to climate zones. Water and nutrient retention services – respectively their degradation – are e.g. visible as *moderate or extreme* water level fluctuations and *higher or lower* nutrient and particle loads in rivers in relation to relief, soil type and precipitation patterns. Four-dimensional landscape configurations composed of sensual features like terrain and temperature, wind and moisture, light and shade, scent and sound, etc. provide the substance, space and atmosphere for sports, relaxation, contemplation, inspiration, education, identification, as well as social and spiritual relation (recreational/ cultural services). They may be *colorful, unique, opening up wide views or offering skateable sheets of ice in the winter,* etc. Further examples are given in Annex 2.

The spatial-temporal patterns of regenerative services and their characteristics form and qualify the landscape as living and production space. They create more or less favorable living and production conditions and important elements of quality of life. Since the qualities of regenerative ecosystem services, expressed in the properties of spatial-temporal patterns, are perceived and produced *in* the landscape they are therefore labelled **'landscape qualities'** in this study. The emphasis lies on the plural 'qualit**ies**', describing different qualities realized *in* the landscape. They are at the same time qualities *of* the landscape constituting 'landscape quality' in total. Quality in the first instance is meant as a neutral term (i.e. as characteristic, property or feature), which may be described impartially on the supply side. With regard to the demand side 'landscape qualities' obtain a value component and 'landscape quality' a positive connotation. This use of the landscape quality category corresponds with a wider meaning as suggested by Arler (2000), comprising multiple qualities perceived in the landscape through different methodologies and value lenses (page 99).

Qualities of regenerative service outputs could equally be termed 'environmental qualities' as it is usually the case for air, water and soil quality. Some people might prefer to say, for example, that moderate temperature oscillations or an abundant biodiversity are a quality of the environment rather than a quality of the landscape. However, these qualities need to be assessed and managed not in an abstract environment, but in very distinct landscapes. Therefore, with regard to management, the term 'landscape qualities' is preferred here (see also Chapter 2.4), while the landscape is understood as the concrete, sensual and 4-dimensional expression of the environment.

Similarly to qualities of tangible goods, characterized by material properties of the product (such as content of certain substances, solidity, color etc.), one could see **landscape qualities as the product qualities of regenerative services**, characterized by properties of processual patterns (e.g. margin of fluctuation, regularity versus radomness, or uniqueness etc.). Like the quality of marketable goods, the ‘product quality’ of regenerative services equally is a value determinant.

For the assessment and management of ecosystem services, and their quantitative and qualitative performace, indicators are usually required. A standardized set of ecosystem service indicators, however, is not yet available. Various challenges remain, especially with suitable indicators for cultural and regulating services (Layke 2009, 19–22). With regard to the latter Layke (ibid.) point to the difficulties of “measuring ecological processes versus tangible goods”, the “reverse logic of avoided change” and time lags. Other than tangible goods – the outcomes of production services – being produced, consumed and produced again, favorable processual patterns – the outcomes of regenerative services – have to be constantly maintained by reiteration to sustain their ‘product quality’, i.e. landscape quality, over time.

Observation and interpretation of spatial-temporal patterns of environmental and landscape quality elements and features (Annex 2) may thus be a good way to track performance of regenerative services. For example, the interpretation of serial maps of land surface temperature patterns can indicate local and regional climate regulation services. Various parameters are in use to indicate water quality. Their spatial and temporal differences and fluctuations can indicate the performance of water quality regulation. Interviews asking visitors for their impressions of and experiences with landscape features and configurations, a classical method for landscape quality assessment, can indicate the performance of recreational services. Further indicators may be derived from the properties and changes of the patterns (e.g. mean temperature values and temperature amplitudes derived from temperature oscillations, the maximum lengths of drought periods derived from precipitation patterns or rankings of different landscape photographs). Besides ‘pure numbers’, imaging technologies, graphs and sequences, e.g. obtained by remote sensing, will be particularly helpful to display regenerative service outputs in a spatially and temporally explicit way.

However, “the problem is that ‘success’ in preserving a regulating service in a healthy state would, in some cases, not produce a measurable change in ecosystem state, but would appear as simply maintaining the status quo. For example, if nutrient retention services are maintained in a watershed, nutrient levels in the water will remain stable. Similarly, if disease regulation services are maintained, disease levels should remain stable” (ibid.). In these cases relatively moderate fluctuations and avoided undesirable extreme events is a sign of ‘good work’ and high quality. These examples further show that regenerative services, especially those related to regulation of flows, are often realized only when they are already degraded. Like ‘reproductive’ housework regularly maintaining a certain state of order and cleanliness in the house, they are easily taken for granted, since they maintain a favorable status quo of living and production conditions when working well. Only when these conditions and their patterns change in

an unfavorable direction does their former performance come to mind. However, then it may be too late for action. Therefore process knowledge and process indicators are important to detect undesirable trends right in time for preventive or corrective action.
Another issue is that environmental or landscape quality indicators only give information on the 'hybrid' performance, i.e. the combined effects of living activities and human impact or contributions and their interactions. They are not necessarily a measure of the actually accomplished biological-ecological work (cf. Natural England 2010b, 43). If the aim is to quantify the contribution of non-human living activities only, and also with regard to non-linearities and time lags, trait indicators will be particularly useful (Feld et al. 2009). In any case, different types of indicators from the supply to the demand side can complement each other in understanding and assessing the performance of services (UNEP 2009) (see also Annex 2). However, collecting and interpreting data on indicators is a costly task. Therefore, a set of few and significant indicators would be politically desirable.

Indicators alone, though, do not allow for quality and performance judgement. This depends on knowledge about quality-benefit relations, political objectives and individual preferences. Feld et al. (2009, 1868) point out that benchmarking ecosystem service indicators against ecosystem-specific or regional reference values will enhance their significance. **Environmental and landscape quality objectives,** including targets and thresholds, may serve **as benchmarks on the demand side**, against which the qualitative performance of regenerative services could be assessed (e.g. good status of water or aspirations of the public with regard to the features of their surroundings). If not yet given by legal frameworks, quality objectives can be defined for example within participatory landscape visions (Section 3.4.3), which will determine demand based on desirable futures rather than on actual use and reveal potential for improvement. **Against these objectives** different **aspects of landscape quality can be appraised as high or low, their changes and trends as desirable, non-desirable or critical, and the performance of the relating services** – as a hybrid of human and organismic land use/ land management activities – **accordingly as good or bad and improving or degrading.**
Ecosystem services and their quantitative and qualitative changes may also be valued in monetary terms indicating economic losses, potential trade-offs or synergistic gains. This is particularly helpful in illustrating the act of value-creation by living activities which has been globally estimated to be much higher than total GDP (Costanza et al. 1997). However, monetary valuation could also be problematic, controversial and even counterproductive (Haaren, Albert 2011). For LQM it could be sufficient and more practical to rank actual ecosystem service delivery (supply side) against said (political) quality objectives and targets (demand side).

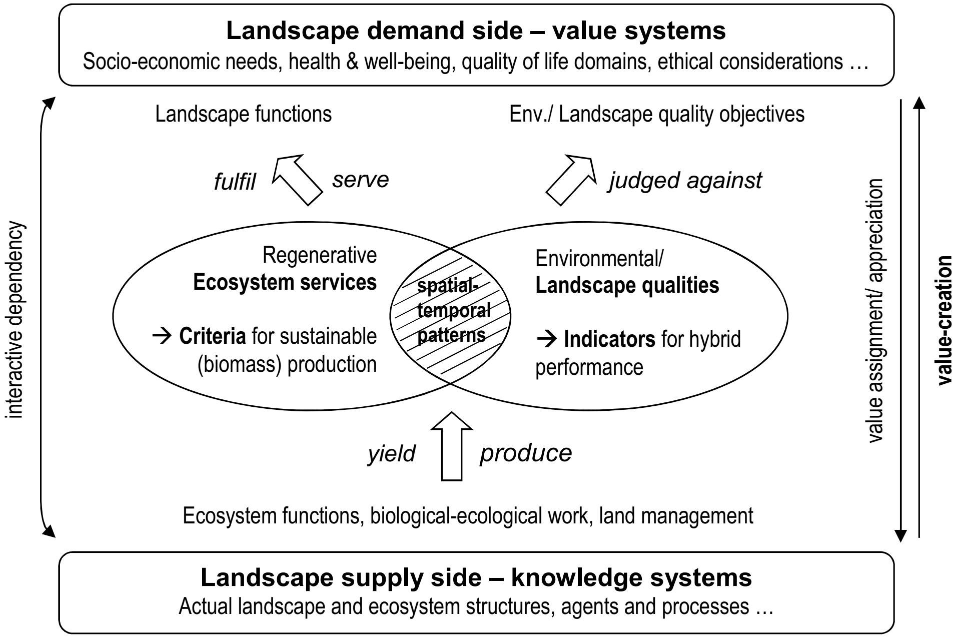

Figure 10: Textual framework of Landscape Quality Management (author's portrayal)

To conclude: What is actually to be judged and managed are the qualities of regenerative ecosystem services realized in the landscape area often as dynamic patterns with specific characteristics, which are called here 'landscape qualities', together constituting 'landscape quality'. The approach developed in this work is thus named 'Landscape Quality Management' (LQM). With the following textual assessment & management framework (Figure 10) LQM is intended to work out synergies through technical and institutional jointness yielding multifunctional ecosystem services bundles wherever possible, before trade-offs have to made and negotiated. The focus should be on regenerative versus degenerative processes and interactions of biotic and human activties. Thereby those processes and interactions producing the service and increasing its quality can be considered regenerative and value-creating. Those processes and interactions diminishing the service and reducing its quality can be considered degenerative and degrading. Thus, both production services and regenerative services are to be considered 'productive' in an economic sense and should be communicated and reflected as such in the mechanism (Section 3.4.1). The category of 'natural productivity' (Biesecker, Hofmeister 2006, 2010) may facilitate this understanding.

Furthermore, ecosystem services cannot be looked at isolated from each other. They typically appear as bundles (Bieling et al. 2013). Production services and regenerative services – respectively biomass production and the reproduction of living conditions and ‘landscape quality of life’ – are physically coupled in ecosystems. Knowledge about this ‘technical jointness’ is essential for any type of landscape management attempting to prevent, or restore from, degradation.

In combination with ‘biomass’ water thereby plays an important role as *the* (re)productive element mediating production and regenerative services, which is highlighted in the next chapter.

2.3 The role of biomass producers as water, land and resource managers

> It would be wise to look at the world
> through a water lens rather than a CO_2 lens.
> *Janos Bogardi, Executive Officer, Global Water Systems Project*

As already mentioned the landscape supply side needs to be accessed by knowledge systems. Specifically, the understanding of the contribution of different biomass forms and producers to the (re)generation of ecosystem services and landscape quality in general and in a specific landscape context is decisive for the assessment and development of sustainable biomass (re)production systems (Conclusions, Chapter 1.8). Furthermore, a comprehension of how processes are coupled to each other and to human biomass cultivation and appropriation is essential. A focus should be on understanding long-term effects with regards to the needs of future generations. On the one hand generic models on 'how ecosystems work and sustain themselves', and thereby (re)generate functions and services, are useful. On the other hand context and site specific knowledge is indispensable. The role of water thereby is of high relevance, since water enables any life process doing (re)productive biological-ecological work.

2.3.1 The (re)productive element water

'Sustain-Ability' of ecosystems according to the ETR Model

The Energy-Transport-Reaction Model, short ETR-Model, a landscape-ecological ecosystem model developed by Ripl (1992, 1995) and colleagues, attempts to explain how ecosystems, respectively life processes on different scales, organize and renew themselves through processes of energy dissipation mediated by water (Ripl 1995b, 1992; Ripl, Wolter 2002). It conceptualizes how living communities as land, water, and resource managers become 'sustainable' under structured time and limited space conditions. It further sheds light on how human land use activities act on the land surface in comparison with living communities, and suggests pathways of degenerating or regenerating human-ecosystem behavior (Ripl 2003; Ripl, Wolter 2002). Recommendations for the management of land and landscapes can be derived from this model with regard to landscape functions (Brüll et al. 2000). Many general and case specific, conceptual and computational ecosystem models exist and attempt to do similar things. This model is selected here, because it highlights the **role of water as a (re)productive ecosystem agent mediating biomass production and the**

maintenance of living conditions. It describes the role of vegetation in combination with soil organisms and detritus – and thus the role of different biomass forms and producers – as water managers and providers of basic regenerative services. Furthermore, the author believes that the associated concept of "landscape efficiency" (see Section 2.3.4) can indicate the performance of basic (re)productive biological-ecological work in a necessarily reductionist, but useful way, and may serve as a suitable complement to powerful and dominating concepts of technical and economic efficiency in decision making.

Ripl conceives ecosystems as energy dissipative[66] structures (sensu Prigogine 1980) **explicitly adding water as a functional agent to the classic ecosystem model** (composed of functional organismic groups, as described in Section 1.3.2). This deductive understanding claims that "energy dissipation mainly accomplished by the medium (agent) water results in dynamic equilibrium patterns of temperature, precipitation, run-off, and subordinate chemical processes with respect to space and time […] differs in some ways from the energy approach expressed in carbon flow expressed in energetic or thermal equivalents as proposed by Odum (1983)" (Ripl 1995b, 63; Odum 1983).

Three special characteristics enable water – the most widely available dynamic medium on earth 'praised as the element of life' – to act as *the* important energy dissipative medium in life processes. "Water, as […] energy processor, shows three dissipative […] properties acting in a recursive way, all three of which involve both cooling and heating respectively: the physical process of evaporation and condensation, the chemical process of dissolution and precipitation, and the biological process of […] water dissociation and association [involved in photosynthesis and respiration, author's note" (Ripl et al. 1996a, 125). By these processes **water and biological cells distribute the daily and yearly modulated solar energy pulse over space and time** (reduction of energy flow density) and partition it into discrete energy potentials useful for further life processes (Ripl 2003, 1922f).

With regard to meaningful timescales concerning the life span of ecosystems and human societies and within a landscape context, **the physical and biological properties of water support cyclic processes**, while **the chemical property in connection with the landscape's water run-off and percolation leads to directed matter losses** out of the terrestrial top soil domains to deeper layers as well as water

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[66] "Energy dissipation (the lowering of energy flux) is the process whereby energy gained by an entity as a pulse (interaction phase and/or from an energy potential) is released, out of phase, both in time as well as in space. In this way, the energy pulse is diminished, tending to a dampened or attenuated value. Thus, the energy potential is reduced, eventually to zero" (Ripl, Wolter 2002, 292).

bodies and finally the sea. Since these matter flows, especially concerning easily soluble mineral nutrients (basic cations) essential for plant growth and soil buffering, become available again only within geological timescales (i.e. rising of the sea bottom through tectonic processes), they can be considered irreversible losses (Ripl 1995b, 64–68). These losses, in relation to the temporality of soil building and weathering processes of bed rock, are a long-range determining factor of the life span of terrestrial ecosystems, as well as the living conditions for aquatic ecosystems, and imply landscape changes over time (Ripl 1995b, 67f), while different sites show different vulnerabilities (Hildmann 1999, 37, 53f; Ripl 2003, 1928f). Maturing ecosystems counteract these losses by establishing and maintaining short-circuited (locally internalized) water and matter cycles, making use of the dissipative properties of water, and dampening temperature extremes at the same time. In doing so they become more persistent and 'stabilize themselves' (ibid. 1922–1925).

Ripl and colleagues claim that increasing energy dissipation and the investment in cyclic over loss processes drive and characterize the development of ecosystems during succession especially "under constraints of space (i.e. they are spatially and/or materially-limited) and time (i.e. they are temporally-structured, or are limited by the energy available)" (Ripl, Wolter 2002, 292).[67] They believe that evolutionary selection may also act upon those principles of reduction of energy flow density and increase in relative material closure. Those coenotic communities, respectively species therein, which manage to achieve even greater internalized water and matter cycles, should be – in evolutionary timescales – more likely to occur than less 'stable' or less 'persistent' communities, characterized by higher losses (Ripl 1995b, 64; Ripl, Wolter 2002, 292f, 298, 301; Hildmann 1999, 11–14).

Ecosystems are here understood as functional groups of organisms, forming – together with water as a cooling, transport and reaction medium as well as the organic debris and humus layer (detritus) as water, nutrient, mineral, carbon and energy storage – "dissipative ecological units (DEU)" (Ripl, Hildmann 2000, 375; Ripl 2003, 1923f) or "core structures" (Hildmann 1999, 9f) which are the smallest entities autonomously controlling the process of energy dissipation via their water and matter budget regimes. The **primary producers**, respectively their main share the vegetation, are ascribed a ***double function*** of (1) producing a bio-chemically bound nutritive energy source (autotrophic biomass production) and (2) acting as a water pump and evaporator (transpiration) as well as condenser. The vegetation thereby manages temperature and further climatic parameters, and also steers the activity of the mineralisers (decomposers) by influencing the level of water saturation and oxygen availability in the soil (Ripl 2003, 1924).

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[67] Corresponding with the concept of r-strategists and K-strategists (Odum et al. 1980, 408, 416)

Both aspects of the second function lead to short cyclic processes on land. **Short water cycles** are basically maintained by the vegetation, especially by the tree vegetation within their canopy (ibid. 1922). The vegetation multiplies the terrestrial surface (estimated by leaf area index), increases the evaporation rate through transpiration, and thereby cools itself as well as the land surface during the day (period of solar radiation input). At night water vapor condenses over the cooled areas, especially again at the leaves' surfaces, warming the surroundings. Small hairs and needles form a condensation surface, where water precipitates without a single rain event (ibid. 1925, 1929). The water vapor is so to speak 'brushed out' of the moving air by the trees (dew building). Such "extremely short water cycles in nature are probably the most abundant water cycles within vegetation structures. Field experiments showed a high range of evapotranspiration rates up to 27mm a day through the advection effects [...] whereas the evaporation and precipitation as measured in various sampling devices represents only a more or less small fraction of these energy dissipative water cycles. This view is supported by close inspection of satellite pictures: showing the distribution of black body radiation of vegetation structures in, for example, landsat TM channel 6 imagery" (ibid. 1925 with reference to Kucerova et al. 2001).

Short matter cycles on land are especially established through a close synchronization of plant and soil organismic processes, again mediated by water. When pumping water the plants lower the water level in the soil compartment, allowing more air to move into the pores, thus enhancing the oxygen dependent respiratory microbial activity. The process of making nutrients available by mineralization thereby corresponds temporally with nutrient uptake by the plants through water uptake. Vice versa the process is inhibited by a more saturated and stagnant water environment (or water scarcity). Through such internalized matter cycles, nutrients and minerals are less freely available to be washed out of the habitat and lost to recipient waters[68] (Ripl 2003, 1924; Hildmann 1999, 9). The organic debris layer (detritus) links and supplies both vegetation and soil organisms and is co-produced by both as a 'joint venture'.

By investing in short water and matter cycles ecosystems create their own local to regional climate and become less dependent on 'random' climate variability (Ripl et al. 1997, 261). Additionally they keep 'their resources' on site (in their living space), reduce losses and become less dependent on geological bed rock conditions (Hildmann 1999, 53). One could also say ecosystems generate and reproduce their own favorable living conditions and make themselves less dependent on 'external', partly unreliable forces or conditions. This may be seen as aspects of achieving greater resilience (Walker, Salt

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[68] Similarly, short matter cycles and high turnover rates in aquatic ecosystems are maintained by organismic communities on solid surfaces in the water (i.e. on pebble stones in rivers, shorelines in lakes, coral reefs in oceans etc.) keeping the moving water body itself relatively clear.

2006) and together with achieving greater persistence, mentioned above, may be interpreted as ‘sustain-ability of ecosystems’, the ability of ecosystems to sustain themselves over space and time. The model thus conceives of ecosystem activities as integrated water, land and resources management activities (Ripl 2003, 1924ff) with an evolutionary ‘**sustainability mode**’ of:

1. Retaining water on land, closing water cycles, dampening temperature fluctuations
2. Retaining matter on land, closing matter cycles, and reducing irreversible losses

The performance of such **integrated, sustainable water, land and resources management**, which is especially performed by a close cooperation of vegetation and soil organisms covering the land surface, can be displayed by two easily monitored parameters:

1. Patterns of land surface temperature
2. Charge loads of catchments to water bodies according to run-off patterns

With regard to these parameters, Ripl and colleagues derive the concept of “landscape efficiency”, in analogy but also in distinction to technical efficiency, as a possible measure of the sustainability of ecosystems (including human activity). How landscape efficiency can inform Landscape Quality Management and complementary biomass stratgegies is further elucidated in Section 2.3.4 and Chapter 4.3.

Green-blue water

A model similar to the one briefly described above is the “green-blue water” concept developed by Falkenmark (1994, 2003) and colleagues also placing water in the center of a so-called “socio-ecohydrosolidaric catchment or landscape management” (Falkenmark, Folke 2002; Rockström et al. 1999; Falkenmark, Mikulski 1994). Falkenmark writes that “after reaching the land surface the rainwater is partitioned into the vapor form *green water flow* and the liquid form *blue water flow*. The former consists of the total evaporation, composed of one non-productive part (evaporation from soil, water or canopy), and one productive part (water taken up by plants and returned to the atmosphere as transpiration). The rest moves as blue water flow in rivers and aquifers from uphill to downhill and from land to water systems (Falkenmark 2003, 2039f). The blue water which runs-off and percolates through the soil is thus to be considered the surplus water of productive ecosystems. While the blue water flow provides humanity with extractable freshwater, the green water flow sustains vegetation and habitats and therewith all other terrestrial ecosystem services generated by them and their living communities. The life-sustaining and service-generating green water flow is dependent on available soil moisture as the “green water resource” (ibid.) (Rockström et al. 1999). The concept was introduced in 1993 to incorporate soilwater and plant water use in the water management discourse with regard to their extraordinary role for our life-support system (Falkenmark 2003, 2040). However, despite its key-role linking water security, food security and environmental security, the green water flow has been largely neglected in water resources management (Falkenmark, Rockström 2006). It seems that this is also the case for the global climate change debate (see below).

The close interlinkage of the litosphere with the troposphere through the green water flow is usually called the soil-plant-atmosphere continuum (Taiz, Zeiger 2007, 102). Vegetation and soil-organismic communities and their production and transformation of biomass determine the partitioning of water and energy flows at the landscape surface (a central argument in both models) and therewith the capacity to provide services. Figure 11 illustrates how the linkages of biomass production with water in ecosystems yield regenerative services, which is further explained in the following sections with a focus on climate regulation.

Water and climate services

Changes of the climate system are observed as changes in temperature and precipitation patterns, extreme events and sea level rise expressed in mean values and/or their variability. Anthropogenic causes of these changes are attributed mainly to the emission of greenhouse gases. Water vapor changes (as increased tropospheric water vapor concentrations expected with global warming) are considered only a feedback but not a forcing mechanism in global climate change. Accordingly, climate change mitigation measures when they involve the landscape usually refer to the production of ‘carbon-neutral’ renewable energy sources and carbon sinks in the landscape, and to the reduction of other greenhouse gases (e.g. methane from wetlands and livestock production), while water management is only part of adaptation measures (IPCC 2007). Consequently, biomass production for bioenergy use is politically promoted as a mitigation measure (which has already been questioned in the first chapter). The second function of ‘biomass production’ in the landscape, i.e. the role of vegetation (living leaf area) and organic debris (leaf litter) for water retention and transpiration with regard to climate is considered, if at all, only within adaptation measures.

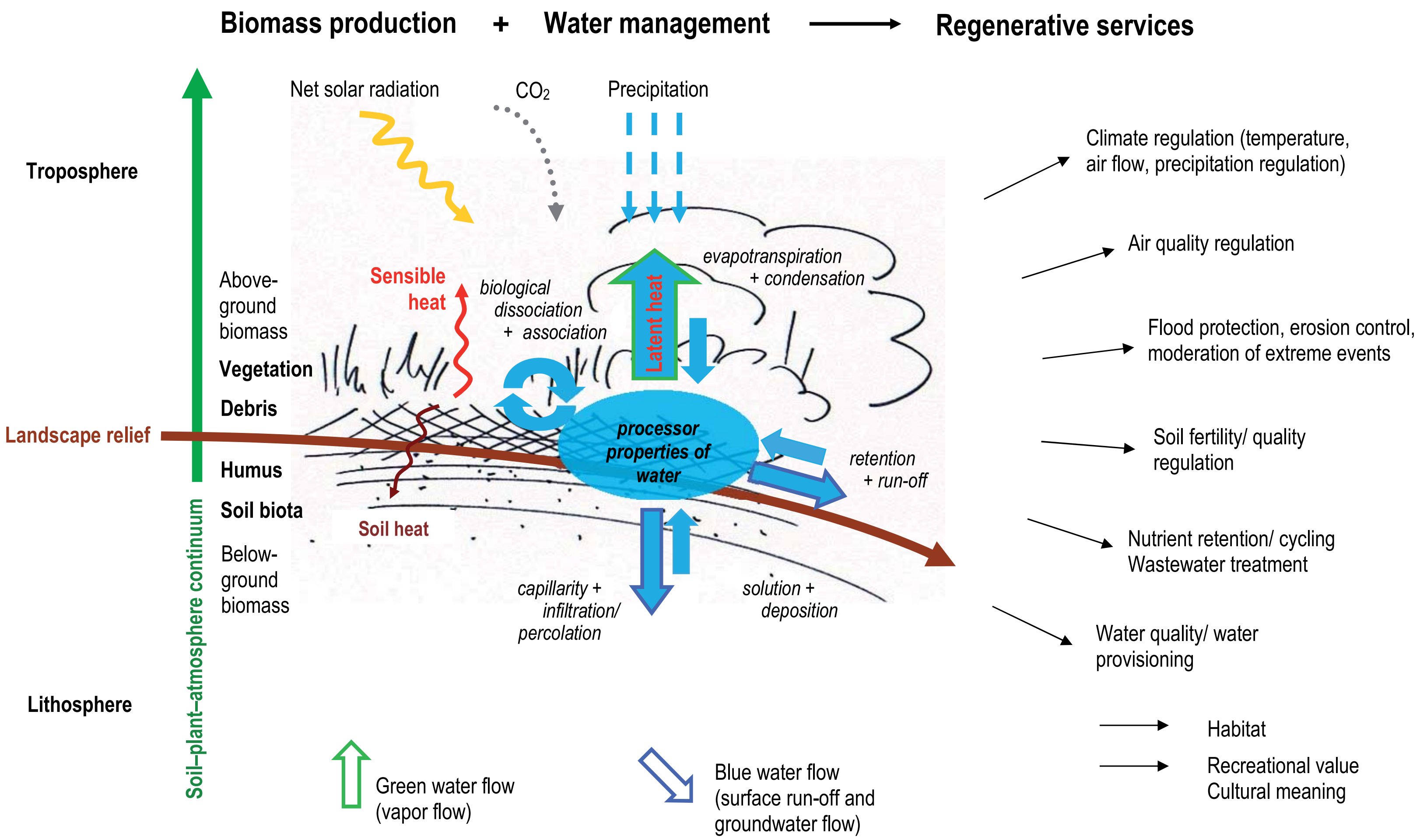

Figure 11: The (re)productive agent water linking biomass production in ecosystems with the provisioning of regenerative services (author's portrayal)

However, it is well accepted that the biosphere is one component of the climate system responsible for the climate and its variations[69], and that landscapes and their ecosystems stocked with moist soils and moistening vegetation provide essential local-regional climate regulation services (MA 2005, 42, 111ff). On the other hand it is increasingly recognized that land use and land cover changes affecting the green water flow and thus the water cycle, like deforestation, extension of crop land, drainage and soil sealing, etc., significantly change regional climate, especially temperature and precipitation patterns. This is mainly due to changes in the surface energy budget, of which latent and sensible atmospheric heat fluxes are a major factor, as well as associated changes in humidity, air pressure and air flows (Hutjes et al. 1998; Mahmood et al. 2013; Makarieva, Gorshkov 2007).

As already mentioned and shown in Figure 11 the rainwater is partitioned at the land surface into vapor flows as well as above-ground and below-ground liquid run-off flows. Also, the solar energy flux is partitioned into various fractions: reflected solar radiation (Albedo), absorbed solar radiation, soil heat flux, emitted longwave radiation, momentum flux, as well as sensible heat flux (warming of surface air) and latent heat flux (heat contained in water vapor which is released when vapor condenses) (Bonan 2008, 1446). In a water-saturated landscape with ecosystems high in soil moisture and leaf area, e.g. forests or wetlands, most of the precipitation is returned as vapor flow to the atmosphere via evapotranspiration from leafs and soil. Thereby a major fraction of the incoming solar energy flux is typically converted into latent heat, while smaller fractions are reflected or absorbed and converted into sensible heat, which we feel in the environment. In areas with little soil moisture and vegetation, like drained crop land or cities, the ratio between sensible and latent heat (Bowen ratio) is usually reversed. Much more solar energy is converted into sensible heat due to a lack of evaporative cooling; i.e. moist environments are characterized by a low, and dry environments by a high Bowen ratio (Mahmood et al. 2013, 4). The partitioning of water and associated energy flows varies according to the bio-physical properties of land cover. Thus, land cover changes can involve major energy flow changes, which may be illustrated by a few numbers.

For example, Kravcik et al. (2007) state: “Sensible heat released from just 10 km^2 of drained land (a small town) for a sunny day is comparable with the installation power of all the power plants in the Slovak Republic (6,000 MW). A fall in evaporation by 1 mm per day over the total area of the Slovak Republic (49,000 km^2) leads to release of sensible heat of around 35,000 GWh for one sunny day. This is an amount of heat larger than the annual power production of all the power plants in the Slovak Republic”

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[69] http://earthobservatory.nasa.gov/Glossary/index.php?mode=alpha&seg=b&segend=d (accessed 9/19/2013)

(Kravcik et al. 2007, 28). One can easily imagine that if such a loss of the evaporative cooling capacity of vegetation were to be replaced by technical means, this would require huge amounts of energy. Höke et al. (2011, 12) calculate, for example, that the sealing of 1 ha of high-quality soil with high water retention capacity in the city area of Stuttgart, Germany releases 9100 GJ of surplus heat due to the loss of the evaporative cooling function, which is equivalent to the annual cooling performance of around 9100 freezers with 270l content and energy efficiency class A, or the annual energy required for air-conditioning of 20,000 m² office area in Germany during the summer. Referring to this particular study, the European Commission's Soil Sealing Guidelines add: "The energy needed to evaporate that amount of water is equivalent to […] some 2.5 million kWh. Assuming an electricity price of €0.2/kWh, one hectare of sealed soil may cause an annual loss of around € 500 000 because of increased energy needs" (European Commission 2012a, 58).

Land degradation also accounts for major changes in precipitation. There is high certainty, for example, that "deforestation and desertification in the tropics and sub-tropics leads to a reduction in regional rainfall" (MA 2005, 113). This effect, known as reduced "moisture recycling" or "moisture feedback", has been attributed to decreases in evapotranspiration (Savenije 1996). "The most important mechanism, in this respect, is the feedback of moisture to the atmosphere through evaporation from vegetation which is required to sustain continental rainfall" (ibid. 507). The change of regional climate towards drier conditions due to a loss of vegetation, partially accompanied by increasing drought periods, has been well documented for the Mediterranean, the Sahel and the Amazon regions (Hutjes et al. 1998, 7). In a recent empirical study Spracklen et al. (2012) found for more than 60% of the tropical land surface that air which has passed over densely vegetated areas produces at least twice as much rain as air that has passed over sparse vegetation (the amount of vegetation being compared by leaf area index). By subsequent modelling they estimate a 12% reduction in wet-season precipitation and a 21% reduction in dry-season precipitation across the Amazon basin by 2050, due to less moisture recycling, if deforestation of the rainforest continues at present rates (business-as-ususal scenario).

The methods and conclusions by Spracklen et al. (ibid.) have been criticized by Makarieva et al. (2013a; 2013b). They suggest it is not only the evaporated moisture content per se which yields more rain, but the creation of low pressure systems by the forests sucking in moist air from the oceans. With their controversial concept of a "biotic pump" Makarieva and Gorshkov (2007) explain how the evaporative force of forests with closed canopy cover transports moisture from ocean to land over thousands of kilometers, while geophysical transport of atmospheric moisture fluxes alone reaches only several hundred kilometers inlands, before it is damped out (Makarieva, Gorshkov 2007). The concept is based on their newly proposed physical mechanism of atmospheric dynamics – i.e. how winds are formed by condensation of atmospheric water vapor rather than by temperature differences (Makarieva et al. 2013a). Conventionally, pressure gradients generated by temperature differences (differential heating) are considered to be the major driver of air circulation. Standard textbook knowledge says that warm light air rises and cold heavy air sinks, forming distinct circulation patterns. Typical patterns are e.g. diurnal land and sea breezes in coastal regions (ibid. 1051f). By applying well established physical principles in a set of equations, Makarieva et al. (2013b) in contrast show that condensation-induced pressure gradients are to be considered the main drivers of atmospheric circulation, an effect so far overlooked or underestimated in climatological and meteorological sciences. When water vapor condenses (i.e. reaches higher density) in moist saturated ascending air, water is massively removed from the gas phase and 'leaves behind' a lower density of the gaseous air. This is associated with a pressure drop which is not compensated for by the simultaneous release of latent heat up to altitudes of a few kilometers (the zone where most precipitating clouds occur). A low pressure system is created, which horizontally draws air from the surrounding areas (i.e. the vertical pressure gradient is translated into a horizontal pressure gradient). Makarievy et al. (ibid.) calculate that the condensation-induced pressure gradients are an order of magnitude greater than gradients by differential heating, which could explain so far unresolved theoretical issues with conventionally estimated versus actually observed velocities of circulation systems, e.g. the Hadley cells of the tropics, or hurricanes. Their theory therewith may close a theoretical gap in the understanding of the climate system, as the *lack of relevant theoretical concepts* with regard to the understanding of atmospheric moisture and its influences in general circulation theories has been identified as a persistent challenge (ibid. 1046, with reference to Schneider 2006b).

Their theory has significant implications for the climatic role of "vegetation and terrestrial evaporation fluxes in determining large scale continental weather patterns" (Makarieva et al. 2013a, 1052). Besides evaporation from water surfaces of the oceans, tropical and also temperate and boreal forests on land deliver the supply of potential energy stored in water vapor by transpiration, which is then converted to kinetic energy (air motion) when vapor condenses (ibid. 1048f). With their multiplied surface area (high leaf area index), forests are able to maintain high transpiration fluxes exceeding evaporation from open water. In this way, they are able to create persistent low pressure systems, which draw moist air from the ocean inlands.[70] Areas with less leaf area (a proxy for the

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[70] Generally evaporation from open water is determined mainly by radiation input and wind, as the surface area changes only minimally with waves. However, it should be noted here that open water bodies are also not homogeneous. As described in Section 1.3.4 plankton patches floating in the sea can significantly influence wind and weather events. It would be interesting to merge the biotic pump hypothesis with the theory developed by Hamilton and Lenton (1998) of "how microbes fly with their clouds".

surface area and amount of physiologically active living mass, i.e. *bio*mass), like grasslands and croplands, are not able to 'switch on' the biotic pump. Also, managed forests appear not to perform as well as self-sustaining forests (Makarieva, Gorshkov 2007; Makarieva et al. 2009). An empirical assessment of the dependence of annual precipitation on the distance from the ocean in 13 continental-scale regions in different parts of the world confirms the significant differences between forested and non-forested regions. "In the non-forested regions, precipitation declines exponentially with distance from the ocean. In contrast, in the forest-covered regions precipitation does not decrease or even grow along several thousand kilometers inland" (Makarieva et al. 2009, 302f).

Makarieva and colleagues conclude that forests sustain their own rainfall, compensating for gravitational run-off losses. This means **forests do not only maintain small water cycles, thereby buffering temperature** (as described in the previous sections), **but even control the large water cycle, bringing atmospheric moisture from ocean to continental land**, which can not be explained by abiotic atmospheric transport processes alone. In this way forests create the basic conditions for terrestrial life to strive on the continents (Makarieva, Gorshkov 2007; Makarieva et al. 2009). In the tropics (e.g. Amazon and Congo basin) they also stabilize dry and wet seasonal variations with growing distance from the coastline and become less dependent on oceanic fluctuations. During dry seasons, their ability to sustain high soil moisture by closed canopy (shading and internalized micro-circulation) and accumulation of organic debris (retention) continuously feeds their productivity. As expected, in the boreal zone summer precipitation was found to remain stable or even grow inwards, while winter precipitation declines according to the seasonally inactive biotic pump. As previously mentioned, forests thus create relatively stable and reliable climatic conditions and weather patterns. In contrast, with large-scale deforestation and forest degradation forging ahead, especially in the coast-to-inland continuum of tropical as well as boreal forests, more extreme and unpredictable events can be expected even on a global scale. Furthermore, coastal precipitation is likely to increase, while continental climates tend to become drier.[71] For deforestation continuing in the Amazon basin Makarieva & Gorshkov (2007, 1018) predict a much higher decline of precipitation than the

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[71] It would be further interesting to apply the biotic-pump concept to a case of regional climate change at the Kilimanjaro. There, a decrease in precipitation of 30% has been observed over the last 100 years, while the Kilimanjaro lost a third of its forest cover during the last 70 years. Due to the drier climate the frequency and intensity of forest fires has increased, which lowered and reduced the cloud forest belt significantly. The drier climate is also responsible for the retreat of Kilimanjaro's glaciers (Hemp 2005). However, the loss of cloud forest has far more dramatic consequences than the loss of the glaciers: "If one assumes that fog precipitation is close to zero once the forest is destroyed, the loss of 150km² of subalpine forests since 1976 [...] corresponds to an estimated loss of 20 million cubic meters of fogwater deposition per year. This is [...] equivalent to the annual water demand of the 1 million inhabitants on Kilimanjaro [...]. In contrast, the annual average water output of the 2.6km² of glaciers can be estimated at only 1 million cubic meters (5%)" (ibid. 1019).

conventional models used by Spracklen et al. (2012). On the other hand a gradual restoration of natural forest cover, especially in coastal arid regions, could reverse processes of desertification by reestablishing the water cycle and regenerating stable precipitation patterns. Makarieva and colleagues thus point to the protection and restoration of distinct areas of dedicated unmanaged forests if climate stability is to be sustained (Makarieva et al. 2006; 2009; Makarieva, Gorshkov 2007).

The "biotic pump" concept – including the theory of condensation-induced atmospheric circulation – has the potential to fundamentally change the view on the role of (virgin) forests and their green water flow in the global climate change debate. So far the importance of the "phase transition of atmospheric water" for "atmospheric dynamics has escaped wide attention" in general circulation and climate models (Makarieva et al. 2013a, 1039, 1051f). The controversy is reflected in an editor's extraordinary comment accompanying the recent publication of Makarieva et al. (2013b) in the internationally renowned journal "Atmospheric Chemistry and Physics" (ACP):[72]

> "The authors have presented an entirely new view of what may be driving dynamics in the atmosphere. This new theory has been subject to considerable criticism which any reader can see in the public review and interactive discussion of the manuscript in ACPD (http://www.atmos-chem-phys-discuss.net/10/24015/2010/acpd-10-24015-2010-discussion.html). Normally, the negative reviewer comments would not lead to final acceptance and publication of a manuscript in ACP. After extensive deliberation however, the editor concluded that the revised manuscript still should be published – despite the strong criticism from the esteemed reviewers – to promote continuation of the scientific dialogue on the controversial theory. [···] The following lines from the ACP executive committee shall provide a general explanation for the exceptional approach taken in this case and the precedent set for potentially similar future cases: (1) The paper is highly controversial, proposing a fundamentally new view that seems to be in contradiction to common textbook knowledge. (2) The majority of reviewers and experts in the field seem to disagree, whereas some colleagues provide support, and the handling editor (and the executive committee) are not convinced that the new view presented in the controversial paper is wrong. (3) The handling editor (and the executive committee) concluded to allow final publication of the manuscript in ACP, in order to facilitate further development of the presented arguments, which may lead to disproof or validation by the scientific community" (Nenes 2013).

Supra-regional climatic effects of large-scale land cover changes, however, have also been described by numerous other studies. Through teleconnections, regions thousands of kilometers away from the origin of land cover change can be affected (Mahmood et al. 2013, 13f). Thus, the changed distribution of (solar) energy and water

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[72] The paper had been under peer-review for an unusually long period of more than two and a half years, receiving extensive criticism but also support, before the editors and the journal's executive board decided to publish it.

flows through partitioning at the land surface by changed land cover is at least an additional factor if not a more important forcing for climate alterations observed in continental-scale regions than additional energy input (radiative forcing) represented by global mean temperature increase (Hutjes et al. 1998, 3f; Savenije 1996, 507; Mahmood et al. 2013, 15). Consequently, there is a “need to broaden the current global climate change agenda to recognize that climate change results from multiple forcings, and that LCC [land cover changes, author’s note] must be included in global and regional strategies to effectively mitigate climate change” (Mahmood et al. 2013, 15). This would require an entirely new approach to climate change (impact) studies, focusing less on global means, trends and predictions, but more on regional rates, thresholds and resulting risks and options (Hutjes et al. 1998, 15). Regional Landscape Quality Management could play an important role in this regard. **For the sustainability of biomass production** – and for bioenergy to be an effective climate change mitigation measure – this means to **take not only carbon balances into account, but also the performance of the biomass production system with regard to its partitioning of water and energy flows** in a regional landscape and climate context.

Water and other basic services

The *management of water by vegetation-soil organismic communities* on the land surface is also critical for other regulating services (Figure 11). A well-watered vegetational land cover largely contributes to *air quality*, for example. It *prevents wind erosion* and dust emissions. Its moist surfaces bind and decompose air pollutants and suspended particulate matter, especially health-affecting fine dust, which is only deposited wet (Höke et al. 2011, 15ff). Generally, a high ecosystem capacity for water retention and evapotranspiration reduces and slows down run-off and percolation. This has positive effects for a couple of other services, e.g. *moderation of extreme events*, *soil and water quality* and *nutrient retention*. Besides the stabilizing effect of the small water cycle on climate and weather, as already described, area-wise water retention of the soil-vegetation-complex *reduces the risk of floods* in the watershed. In contrast, an increased and accelerated run-off from sealed, drained and scarcely vegetated areas intensifies the severity of flooding events. Higher and faster run-off also causes erosion problems. Vice versa, soil covered by vegetation and hold in place by a dense root network is *less vulnerable to water erosion and landslides*, especially on steep slopes. Furthermore, a moist environment also reduces the risk of devastating fires (compare Kilimanjaro case, footnote on page 131).

Slowed and moderated water run-off and percolation is also critical for *reliable fresh water sources and water quality*. The steady flow of springs and creeks as well as low fluctuating surface and groundwater levels are dependent on soil water storage during dry periods. Water transports soluble and non-soluble matter during its passage over

and through soils and deeper layers. The higher its velocity, the more energy is available for solution and transport processes. Thus, high water retention and slowed run-off and percolation principally lead to low particle and charge loads of recipient waters. Higher water retention is associated with higher nutrient retention and lesser eutrophication. Furthermore, a quick turnover of nutrients through coordinated mineralization and root-uptake mediated by the pumping activity of the plants – as already mentioned – keeps nutrients on site and water quality high. How effective these processes work in an ‘unused’ environment may be observed in primary forests. Water quality investigations in remnants of a virgin forest in the dolomitic part of the Austrian Alps showed extremely low charge loads, i.e. conductivities of ca. 150-200 mS cm^{-1} at 20°C (Ripl 2003, 1926).
Water-mediated processes also play a key role in the *formation of soil horizons* and for the *maintenance of soil fertility*, i.e. the capacity of soils to support vegetation and crops. The accumulation of stable forms of organic carbon (e.g. humus, turf) is supported by permanently moist or wet soil conditions (constraints of oxygen availability) while decomposing, mineralization and leaching processes are advanced under fluctuating conditions (ibid. 2927; Ripl et al. 1997, 262; Scheffer et al. 2010, 287). Solution and transport of minerals to deeper soil layers by percolation is responsible for soil development and ageing, partially going along with degradation, e.g. clay illuviation, podsolisation, acidification and salinization (ibid. 5, 288ff). (The latter processes are discussed in more detail in the next section.) Thus, high water retention at the soil surface and slow infiltration counteracts soil degradation. Soils are also depleted via nutrient removal through harvest, which requires continuous replacement by mineral fertilizers or organic sources. After consumption of food the extracted nutrients contained therein are also transported by water, i.e. wastewater. After technical and biological treatment they are released to recipient waters providing further dilution and treatment. ‘Alternative’ systems, like root zone systems of constructed wetlands, directly use the ecosystem service of *wastewater treatment* as secondary and tertiary steps. Such type of (waste) water management and ecological sanitation is often better suited to safely recirculate nutrients back to the land (see Section 4.4.2).

All living beings thrive on ‘the flow of water’. Water acts as a mediator between the solar energy pulse and the mineral earth. Thereby it creates spatial-temporal patterns and conditions in the landscape and synchronizes activities and behavior of adapted species. Water and its dynamics basically “sets the ecohydrological conditions for biological diversity in any habitat” (Rockström et al. 1999, 7) and is therefore a key feature of *habitat services and habitat dependent services*, i.e. the water-vegetation-soil-complex provides reproductive habitat for all animal species which may provide further services, e.g. *pollination and biological control* (Rockström et al. 1999, 8). Water mediated habitat is also important for *disease regulation*. Many emergence drivers of vector borne diseases are associated with deforestation, water projects, irrigation, dam building, poor watershed management and climate variability (MA 2005, 115).

Water and recreational services

Water also plays a major role in recreational (cultural) services. Surface water especially, in the form of springs, rivers, and lakes, has a high recreational value and cultural meaning. In a study of cultural ecosystem services hotspots and coldspots in a German landscape close to the Polish and Czech borders Plieninger et al. (2013, 125) found that "water bodies were of utmost importance for recreation, education, aesthetics, and as heritage sites." Human settlement and urban development has often emerged from local water sources and their provisioning function. The cultural meaning may have co-evolved with this development. Rivers, for example, are given names. They forge identity and are the subject of myths, legends and rituals. Springs are often sacred in indigenous cultures. Lakes are symbols of the soul. Clear water was sung by poets over centuries and is generally associated with health and vitality.

Thus, closely linked to its life-giving role on earth, water carries many other recreational, educational, spiritual, symbolic and further cultural values. Similar to water as a resource, the blue water flow seems more important here. However, the provisioning of recreational services by water in the landscape is highly dependent on good water quality and reliable quantitative patterns. A eutrophied lake or polluted river causes disgust rather than pleasure. Too much or too little water can turn murmuring brooks into feared flash floods or picturesque ponds into dried mud holes. Here the role of the green water flow, sustaining regulating services, comes back into play as being indispensable for recreational services, which is also very much true for provisioning services.

2.3.2 Jointness of biomass production and regeneration or degradation

The foregoing exposition indicates how tightly coupled ecosystem processes are. Knowledge about this 'technical jointness' (page 91) – or better, bio-physical jointness – is important for at least two reasons in a LQM context: (1) to avoid or compensate human-ecosystem interactions that lead to land(scape) degradation by applying better design and management practices or 'non-use' respectively, and (2) to be able to manage ecosystem services in bundles, so as not to make the mistake of sectoral improvement of one service at the cost of another.

Production and regeneration

A 'great deal' of jointness in ecosystems is mediated by the dynamic medium water. The maintenance of the short and large water cycles (green water flow), mainly by soil organisms (retention) and vegetation (retention and transpiration), is an essential ingredient of many basic services. Water cycling therefore has been classified as a supporting service in the Millenium Ecosystem Assessment (MA 2005), along with the renewal of freshwater being considered as a provisioning service. Here **water** in itself is considered **an ecosystem agent** providing services within living activities, rather than a resource or service. The water cycle maintained by vegetation and soil organisms is understood as an actual work process. **Water essentially links production and regeneration in ecosystems, i.e. the production of biomass with the regeneration of favorable living & production conditions**. This may be interpreted as the **'(re)productivity of water'**.

First, **transpiration** is a component process of photosynthesis (Falkenmark, Rockström 2006, 129). When opening their stomata at the leafs' surface, plants take up carbon dioxide and release water vapor at the same time, which causes transpirational pull through the stems and water uptake by the roots (Taiz, Zeiger 2007, 85–103). This means that the **primary production of plant biomass is inseparably coupled to water vapor production**, which in turn is responsible for temperature, air flow and precipitation regulation. It further means that transpiration dependent services are provided by certain properties of physiologically active biomass (i.e. leafs' mesophyll and stomata) as well as inactive biomass (i.e. the xylem as part of the plant's vascular system, consisting of dead lignified cells). A high leaf area index and standing biomass may therefore serve as a proxy and trait indicators for these services (Annex 2).

Second, **retention** of soil moisture – necessary to maintain transpiration over dry periods – is also dependent on different forms of biomass, i.e. dead and living soil biomass (e.g. leaf litter, dead wood, humus and soil biota). The organic debris layer increases the infiltration rate and provides the main substrate for humus formation. The properties of humus determine many soil functions. With regard to water, humus has a high water storage capacity (up to 3-5 times its own weight) and increases the field capacity (retention against gravity), especially in soils low in clay. Stable humus aggregates are formed by a wide variety of soil organism decomposing organic matter, producing adhesive substances, and mixing and agglutinating organic and inorganic particles by bioturbation (Scheffer et al. 2010, 66–69). These activities transform the land surface into a sponge, which takes up precipitation, stores water in the upper layers and releases it slowly to recipient waters. Thus, the **secondary production of soil biomass largely accounts for water storage and retention,** which in turn is critical for flood protection, soil and water quality, moderation of extreme events and all other services provided by different types of vegetation and their communities.

Production and degeneration

Being aware of the close jointness of production and regeneration in ecological systems, it is not surprising that the human cultivation and appropriation of biomass and the application of technologies and practices increasing the productivity and yield of certain crops (economic production) – thereby altering the partitioning of water and energy flows at the land surface – has (undesirable) side effects on other services. If neglected, such coupled processes may lead to land/ or landscape degradation.

Humans induce both **land cover changes** and **land management changes**. Land cover changes imply, for example, the replacement of perennial vegetation structures by annual step-like plants used in agriculture or soil sealing for urbanization. Agricultural and urbanized areas are usually characterized by low water retention and transpiration and accordingly high temperature amplitudes, high run-off and high irreversible losses (Ripl 2003) and an associated low capacity of performing regulating services (Burkhard et al. 2012).

Land management changes may involve soil working practices, water withdrawal and irrigation, harvest, vegetation and livestock management, e.g. grazing regimes, etc., which are often not captured by land use/ land cover categories, but also have a high impact on the functioning of ecosystems and landscape configuration. In forested ecosystems, for example, the land cover category 'forest' may not change, but eventually the management practice changes from 'extensive' to 'whole-tree-harvesting', under a program to mobilize bioenergy sources from private forests. However, this changed management method is likely to have critical impacts on the capacity of soils to buffer water flow and pH. In forestry, especially in 'intensive' production systems, forests are kept in a juvenile state (net-productive conditions) by cycles of harvest (take-out) and regrowth of tree-biomass.[73] This **high human-induced biomass regrowth rate**, however, is physiologically **coupled with soil acidification** processes in the root zone: Biosynthesis in plants requires mineral nutrition. Root cells' uptake of basic cationic nutrients (e.g. Ca^{2+}, Mg^{+}) in exchange for releasing protons (H^{+}) to the soil mostly exceeds uptake of anionic nutrients (e.g. SO_4^{2-}, HPO_4^{2-}) in exchange for hydroxide or hydrogen carbonate ions (OH^{-}/ HCO_3^{-}). In mature ecosystems this acidic input is buffered by recirculation of basic cations in organic matter (e.g. leave litter) and other processes over time. Taking out biomass through harvest, though, breaks this cycle and leads to a net-acidic input while weakening the buffering capacity of soils (Scheffer et al. 2010, 155). Bjurström and Herbert (2009, iii) state: "The availability of nutrients for a continued good growth is important, but even more

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[73] Compare the relationship of gross-production with community respiration (P/R ratio) and standing biomass (P/B ratio) in mature versus successional ecosystem stages and the basic human dilemma of "maximizing production" (quantity of yield) at the cost of the "quality of living space" (Odum 1971, 254ff, 267f).

important is the buffering capacity of the soils: forestry is acidifying and even more so if all biomass is removed, as in whole-tree-harvesting." With regard to sustainable biomass production there are several attempts to compensate the acidifying effects of biomass appropriation by ash recycling. However, these show various difficulties and can only make up for minerals extracted by harvest, but not for those lost by leaching as discussed in Section 4.2.2. **Soil leaching and associated irreversible matter losses** are usually increased in such forested systems as less organic debris material is available for building-up the sponge function.[74]

Irreversible losses, especially occurring in humid regions, – not only within forests, but generally by humans' interference with the water cycle – can also be considered as a process of rapid **landscape ageing** and **land degradation** with regard to the long-term usability of landscapes for human needs (Ripl 2003, 1928; Ripl, Hildmann 2000, 373f). In the Stör river catchment in Germany, for example, Ca^{2+} losses have been measured on an average of 263 kg per hectare and year, which cannot be replaced by either fertilizer input (80-90 kg $Ca^{2+}ha^{1-}$ y^{1-}) or weathering processes. Total dissolved mineral ion losses reach up to 500-1500 kg ha^{1-} y^{1-}. Such losses of easily soluble matter flows eroding buffering capacity (especially on hilltops) are characteristic for most of Central Europe and estimated to have increased 50 to 100 times over the last 150 years. Counteracting degradation would require almost area-wide liming with finely ground limestone or chalk (in Germany in an order of 600-700 kg ha^{1-} y^{1-}) at huge energy and monetary cost (ibid. 373, 378-381; Ripl et al. 1996a, 261f).

Somewhat opposite processes operate in arid climates. Eucalyptus plantations for cellulose production in Portugal, for example, showing high transpiration rates but low retention capacity, can deeply dry out soils and significantly reduce water availability, besides increasing the risks of fires and causing other problems.[75] In Australia, on the other hand, where Eucalyptus species are native, the replacement of woody vegetation with shallow-rooted cropland and grassland 'using too little water' led to rising groundwater levels and serious dryland **salinization**[76], a process which can also render soils completely unproductive. There, tree-based biomass production may serve as a socially acceptable way of revegetation. However, it must also be pointed out that this requires thorough understanding of the local context and careful planning to avoid pitfalls like the ones mentioned above (Gordon et al. 2003 with reference to Foran, Crane 2000). This shows that it is critical to consider ecosystem services not separately

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[74] Considering branches, bark and leaf-litter in whole-tree-harvesting an appropriable 'residue' source for bioenergy is to be highly scrutinized in this regard.

[75] http://pdfarchiv.zeit.de/1993/35/eukalypse-now.pdf (accessed 9/5/2013)

[76] Soil salinization is also often associated with improper irrigation systems lacking adequate drainage and maintenance.

but in interaction and to understand the processes and activities generating them in a particular spatial-temporal landscape context.

2.3.3 Ecosystem service bundles and spatial landscape units

“Ecosystems typically deliver multiple services jointly in non-separable bundles. This 'jointness' of the production output is a particularly salient feature of ecosystems” (Heal, Small cited in Hagedorn 2007, 115). Ecosystem services should thus be managed in bundles to avoid improving or even trading one at the cost of another (Bieling et al. 2013). Furthermore, meaningful ‘system boundaries’ or spatial landscape units are to be chosen. It is proposed that the following bundles (Figure 12) and landscape units be simultaneously managed by LQM with a high attention to the relations between them.

(1) Water mediated basic functional service triangle: As shown, the performance of climate and air regulation, soil fertility, erosion control and nutrient cycling as well as flood protection and (blue) water quantity and quality are all strongly dependent on the partitioned water flow through the landscape’s soil-plant-atmosphere continuum. Therefore it seems reasonable to consider these services as one inseparable bundle within **catchments on multiple scales** as meaningful spatial landscape units. As this bundle of climate & air, soil & nutrients as well as blue water quantity & quality provides basic living and production conditions for human societies and their economies as well as life-support-functions for all living communities, it is named here ‘basic functional service triangle’. Essentially, this triangle bundles biotic-abiotic interactions mediated by the water flow. Service providers are vegetation-soil organismic communities including water, especially woodlands, wetlands and to a certain extent grasslands as well as tree, bush and hedge vegetation within agricultural and urban areas (cf. Bello et al. 2008, 12, Appendix).

(2) Reproductive habitat based services: This bundle subsumes regulating services resulting from biotic-biotic interactions as well as habitat services. Common to these services is that they relate to ‘wanted’ (or ‘unwanted’) species, their populations and communities as service providers (partially versus disservices). Species may be ‘wanted’ for their intrinsic value (e.g. rare and endangered species) or for their instrumental value (e.g. symbolic species, pollinators or predators of ‘unwanted’ pest species). The performance of these services highly depends on the condition, i.e. availability and quality, of reproductive habitats of the wanted/ unwanted species. Meaningful spatial landscape units for this bundle may be various **habitat areas and networks** with regard to target species and their communities. Those habitat networks, especially in the case of migratory species e.g. birds, may well extend beyond catchments. However, as already mentioned, water conditions are an important habitat feature. So habitat areas and networks should be looked at in close relation to catchments.

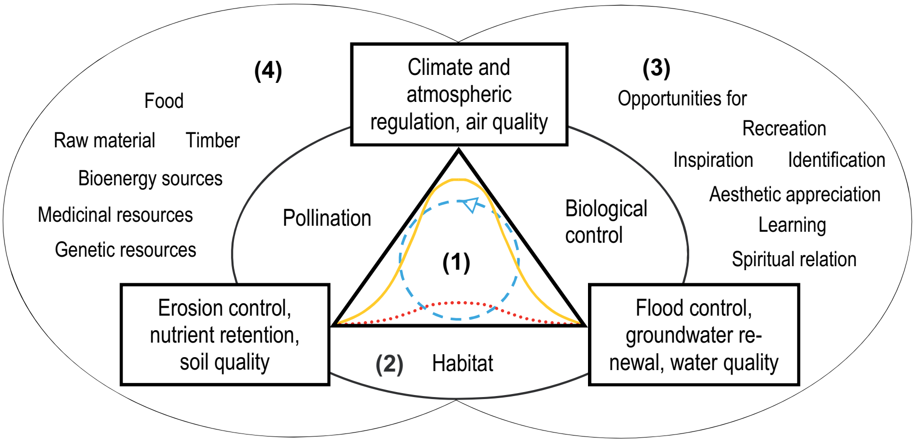

Figure 12: Proposed ecosystem service bundles for LQM: (1) Water mediated 'basic functional service triangle' (biotic-abiotic regulation), (2) Reproductive habitat based services (biotic-biotic regulation) (3) Landscape perception based cultural services (4) Biomass resource based provisioning services (authors's portrayal after Brüll et al. 2000, 100)

(3) Landscape perception based cultural services: Common to the group of cultural services is that they are strongly based on people's landscape perception.[77] They are best assessed with various social scientific and psychological disciplines as well as arts and creative participatory methods. Spatially distinct performance judgements are possible, e.g. in the form of cultural service "hotspots" and "coldspots" (Bieling et al. 2013). In countries subscribed to the European Landscape Convention such assessments may be linked to public consultations within the process of defining landscape quality objectives. Aesthetic appreciation and sense of place, history and identity are obviously related to perception of whole landscapes. For species-related cultural services it may be assumed that their 'recreational effect' is also highly dependent on the landscape setting where the species are observed. For example, people go leisure hunting and fishing or bird watching not only because of the 'trophies' and the fascination of animal behavior, but also because they enjoy being outdoors and

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[77] It should be noted, however, that also regulating and habitat services require perception and interpretation, namely by experts and their different experiences and (research) approaches, as well as normative (political) judgments with regard to desirable or acceptable levels.

in a beautiful environment. Also, emblematic species like eagles or lions display their full symbolic impact through their behavior in the landscape, e.g. flying high in the mountains or running fast in the wide steppe. Thus it seems justified to choose **landscape character or identity areas**, at best landscapes with names common to the public, as appropriate spatial units. For species-related cultural services, habitat areas and networks may be also considered.

(4) Biomass resource based production services: The fourth proposed bundle consists of all provisioning services except fresh water provisioning (and mineral resources) as already explained in Section 2.2.6. They **have in common that they all are dependent on the harvest, extraction and regrowth of phyto- and zoomass** in close interaction with human cultivation (or collection) activities for various uses. They may thus be best assessed on **fields or plots and their spatial pattern**. **In contrast, the basic service triangle is dependent on a high amount of both living and dead biomass *remaining* in ecosystems**. Thus bundles 1 and 4 are principally in a trade-off relationship to one another. Therefore bundle 4 should be also considered by LQM, even if it is not meant to be its primary responsibility. In this regard the role of LQM could be to cooperatively explore with various actor networks a (re)productive mode of agricultural, silvicultural and associated technological practives. Furthermore, the single resource uses of biomass may compete (e.g. material and energy use of wood) but can also complement each other, as demonstrated in Chapter 4. With regard to this bundle in particular, food security should be taken into account by LQM, as it is one criterion of sustainability standards in biofuel certification systems.

As water is indispensable for any kind of biomass production (bundle 4) and rivers and their basins also give identity (bundle 3), landscape character areas and their field pattern should be managed in close relation to catchments as well. Actually, in landscape planning it is common practice to consider **multiple ‘landscape layers’** simultaneously (Chapter 3.1). A normative approach, combining a societal goal of sustenance of regenerative services (potential subject of LQM) with the model knowledge presented in the previous chapters, would require orientation of land use/ land management activities according to the (partitioned) water flow in the landscape (Brüll et al. 2000). In managed ecosystems, land managers should then regain responsibility and compensation for maintaining the basic triangle besides producing food, feed and energy sources internal to their land domain (Ripl 2003, 1931ff). The concept of ‘landscape efficiency’ described below could be used to assess such performance of combined (technical) human and biological-ecological work, especially with regard to the basic service triangle.

2.3.4 Technical efficiency, photosynthetic efficiency and landscape efficiency

Efficiency is a common performance and design criterion for machines and technical installations and processes, all of which generally have an energetic, metabolic and site interface with the landscape and its processes, although this is often not obvious or consciously considered. Also, technologies for bioenergy use, such as biogas plants and combined heat and power plants for example, are usually designed for high technical efficiency.

In classical mechanics 'efficiency' is understood as the ratio of 'useful work' versus 'expended work'. Work can generate a (stored) energy potential (potential energy), which can vice versa drive work processes (at another time and place). Energy can be understood as the capacity of potentials to perform work (Hildmann 1999, 33). Energy and work are in a way equivalent categories measured in the same physical unit Joule. In technology and engineering efficiency is mainly expressed in its energy equivalent as the ratio of "useful energy output" to "energy input" (energy efficiency). In energy and work conversion processes the output is always smaller than the input due to 'loss' in the form of thermal energy not containing potentials and thus no longer being useful to perform work anymore (2nd law of thermodynamics). In a more general understanding efficiency denotes the ratio between wanted (valuable) output and expended (costly) input characterizing a system or timely (work) process, whereas input could be e.g. material resources, energy sources or working time consumed, etc. and output the number of commodities, energy sources or other qualities produced, etc.

The designation of 'utility' versus 'loss' is an essential ingredient when defining 'efficiency', thus implying a crucial value component. For example, combined heat and power plants using the 'waste heat' of the process of electricity generation (usually regarded as a loss) for useful purposes, e.g. near-distance heat supply, are ascribed a higher efficiency that pure power plants. Speaking of efficiency always requires a normative specification of what is regarded as a gainful, valuable output on the one hand, and what is regarded as a loss or costly input on the other hand.

Ripl and colleagues develop the category "landscape efficiency" according to the budget of cyclic over loss making processes (Ripl 1995a; Ripl et al. 1996b; Hildmann 1999; Ripl, Wolter 2002, 293f). As explained above, they see cyclic processes as "useful processes" sustaining ecosystems and habitats, whereas they consider irreversible matter flows out of catchments "loss processes" degrading ecosystems and habitats over time.[78] According to this normative determination "landscape efficiency" is defined as the ratio of energy dissipated in cyclic, life sustaining, 'use processes' to the energy

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[78] These losses are also interpreted as an estimator of the increase of entropy of the system, indicating a higher randomness in its dynamics (Ripl, Wolter 2002, 293).

available by solar radiation; it can accordingly be expressed by the energy dissipated in chemical loss processes (Hildmann 1999, 7,36f):

$\eta = W_D / W_S$ or: $\eta = (W_S – W_C) / W_S$ whereas: $W_S = W_D + W_C$

η: landscape efficiency
W_D : in cyclic processes dissipated energy
W_C : in chemical loss processes dissipated energy
W_S: available solar energy (“solar energy pulse over n •l”)

From these theoretical terms two complementary, measurable indices or coefficients of landscape efficiency are derived: a thermal and a chemical index (Ripl et al. 1997, 259; Ripl, Wolter 2002, 294). The **thermal index of landscape efficiency** is given by the dampening of the daily and yearly temperature amplitude as a measure of the ‘degree’ of energy dissipation. It can be displayed by spatial-temporal patterns of land surface temperature obtained by remote sensing from thermal satellite imagery (e.g. Landsat data) and supplemented by measurements of soil temperature and air temperature above soils, using heuristic methods (Ripl et al. 1996b). This parameter pattern captures the cumulative effect of all energy dissipating processes. However, since the evaporation and condensation cycle usually accounts for the major part of temperature dampening on the land surface – when water and vegetation are available – the thermal index of landscape efficiency primarily can be used to assess the existence and performance of short water cycling activities (Ripl et al. 1997, 261; Hildmann 1999, 41–44; Pokorny 2001, 643). The thermal index does not give qualitative information about the energy dissipation put into effect by the chemical processor property of water. In contrast any chemical energy dissipation should show up as a ‘positive’ contribution towards temperature damping, even if it is comparatively small. The **chemical index of landscape efficiency** can be used to gain better information with respect thereto, putting irreversible matter losses in relation to the total matter turnover.

$\eta = (GPP – L) / GPP$
GPP: gross primary production, L: charge losses, both expressed in proton equivalents

For the total matter turnover gross primary production can be estimated and expressed in the energy unit proton equivalents, whereas the losses can be measured as conductivity and different ionic freights in water bodies and also transferred into proton equivalents (Ripl et al. 1997, 260; Hildmann 1999, 37ff).[79] The chemical index of landscape efficiency is a measure for the degree of matter turnover in cyclic processes versus chemical losses, and thus suitable to assess the performance of matter cycling activities. However, to give useful information with regard to 'ecosystem sustainability', the following conditions need to be fulfilled (ibid.):

- Meaningful spatio-temporal system boundaries are to be set: Spatial boundaries can be drawn where a maximum of relative material closure occurs in the landscape. Since water is the main transport medium in the landscape and accounts as well for the transport of the losses, catchments and sub-catchments on their various scales can serve as meaningful entities of observation. Temporal boundaries should be drawn in accordance with the characteristic time scales of the determining solar energy pulse, i.e. days, years, as well as the characteristic ecosystem components, i.e. generational cycles of trees (Ripl, Wolter 2002, 293, 302).
- Matter reserves and supply via weathering of bed rock and soil building are to be considered: According to the type of soil and bed rock as well as slope, location in the catchment, soil and landscape ageing phases etc., different sites show different vulnerabilities as already mentioned (Hildmann 1999, 37, 53f; Ripl 2003, 1928f; Ripl et al. 1996b, 116–166).
- Matter input (i.e. through air, ground water intrusion and fertilization) is to be considered: Matter input precipitated or deposited from air can be estimated. Statistical data on fertilization is often available.

Since water and matter cycling are closely coupled processes in living systems, both indices should usually correspond with and not contradict each other (Ripl, Wolter 2002, 294; Ripl et al. 1996a, 126). However, the parameters need to be interpreted under local conditions of topography, precipitation, soil types, and land use, etc. (Ripl et al. 1996b). High temperature fluctuations, for example connected with low losses, may indicate aged soils, which are already eluviated (Ripl et al. 1996b, 164f). While the chemical coefficient of landscape efficiency only gives information about the performance of whole catchments and their sub-catchments, the thermal coefficient can give information concerning single land use patches and their patterns. Both can be applied in an area-wide approach to the land(scape) surface and "inform land use management and planning for sustainability" (Ripl, Wolter 2002, 294). The indices of **landscape efficiency** can especially serve **as a trend indicator for the water**

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[79] Historical losses are 'recorded', for example, in lake sediments containing information on the performance of past land management by ecosystem development and human interference. The Swedish Lake Trummen study is a prominent example (Digerfeldt 1972).

mediated basic functional services triangle, as this services bundle is highly dependent on the green water vapor flow and the performance of short water and matter cycling activities.

Hildmann (1999, 7) mentions that other ecological concepts of efficiency e.g. described by Lange (1989), Odum (1999) and Joergensen (1997), neglect in particular the energy turnover by the biologically induced water cycle. Only Bormann and Likens (1994, 43) include photosynthesis as well as evaporation in their efficiency calculations.[80] Mostly, various specifications of ecological efficiencies describe the flow of energy, which is passed on as the carbon related energy content of biomass through different stages of the trophic food chain. Heat released by the respiration of biomass is thereby seen as loss. Odum points out, however, that those ‘respiratory losses’ are necessary to maintain high levels of plant biomass or physiological body temperature of animals as well as to maintain conditions and qualities of the living space (Odum et al. 1980, 408, 435).

According to a carbon-related efficiency understanding the ratio of net primary production to global irradiance is used when calculating the efficiency of photosynthesis in the context of bioenergy use. Lewandowski (2001, 45) indicates that the average efficiency, also called “Nutzeffekt” (‘use-effect’, translation), of net primary biomass production by photosynthesis is only about 1% in forests and grasslands over the vegetation period. Highly net productive agricultural crops such as maize can reach a photosynthetic efficiency of 3-6%. This ‘very low performance’ is due to ‘losses’ appearing stepwise in the process as shown in Table 5. In this (rather technically motivated) definition of energy efficiency of photosynthesis, only the biochemical energy content of the net-product of plant biomass in an ecosystem counts as value or utility. The autotrophic respiratory processes using up about half of the plant’s gross production over time, count as losses. Further ‘losses’ occur over the year or many years, as the net-product of plant biomass is ‘used up’ by respiration of heterotroph organisms. In mature ecosystems net ecosystem production[81] actually tends towards zero, while a high gross-production is maintained (Odum 1971, 252f). However, as described in Section 1.3.4, production and respiration of biomass together provide the bioenergy for productive biological-ecological work with regard to ecosystem services and landscape functions. If the respiratory part of productive work was included as ‘useful output’ in terms of their energy equivalents of biomass consumed, photosynthetic efficiency would need to be related to the gross-product of photosynthesis, as suggested by Odum (1999, cited in Hildmann 1999, 7).

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[80] Sandlerskiy and Puzachenko (2009) include both biological production and evaporation in their consideration of ecosystem exergy understood as the absorbed solar energy spent on ecosystem effective work.

[81] Also called net-community-production or yield

Lewandowski (2001, 43) specifies photosynthetic efficiency related to the gross-product as 15%. However, also this approach somewhat falls short as it still neglects biological-ecological work performed through transpiration, e.g. the management of temperature and other climatic and atmospheric parameters such as patterns of circulation and precipitation.

Energy losses through	**Relative losses in relation to global irradiance**
Wavelengths of solar energy not usable by photosynthesis	50 %
Remission and transmission	5–10 %
Absorption through tissue and structures not photosynthetically active (cell walls, not-sensitive pigments)	2.5 %
Energy losses after absorption of radiation through heat, fluorescence, etc.	8.7 %
Expenditures for electron transports and secondary processes of carbon assimilation	19–22 %
Light respiration	2.5–3 %
Dark respiration C_3-plants	3.7–4.3 %
Dark respiration C_4-plants	4.9–5.8 %
Sum	**91.5–100 %**

Table 5: Energy losses in the course of carbon assimilation in plants
(Source: Lewandowski 2001, 45, translation)

The concept of the ‘biotic pump’ described in Section 2.3.1 offers another interesting aspect in this regard. Makarieva et al. (2013b) propose that the atmospheric circulation system works as a “dynamic machine” driven by phase transition of water rather than as a “heat engine”. They calculate that a condensation-induced pressure gradient converts solar energy into kinetic energy of air movement much more efficiently than a differential heating gradient. This basically means that much of the kinetic energy of moving air is generated by the solar driven water cycle in the following steps:

► Solar power is spent on evaporation.
► Condensation of water vapor produces a pressure gradient (conversion into potential energy).
► The gradient sets air in motion (conversion to kinetic energy, which may be used in the case of wind power).
► Potential energy of atmospheric water vapor is replenished by evaporation.

On land, evaporation from plant surfaces (transpiration) is the most important vapor source. In the case of forests and wetlands with a high leaf area index the amount of evaporation even exceeds that of open water bodies like the sea. The involved mechanism of upward water transport in the plant is actually a ‘passive’ process of transpirational pull solely driven by solar energy (Taiz, Zeiger 2007, 85–103), i.e. the plant does not directly spend (bio-) energy gained by respiration on this process. However, a wide array of functional traits and structural components of the plant (and in the soil compartment) are necessary to maintain and regulate this evaporative force and productive green water flow over time, e.g. a branched leaf system including stomata releasing vapor, a low-resistance Xylem protected from cavitation, and a high surface-area root system, plus structures for water retention in the soil and the property of high surface tension of water itself (ibid.). The various processes involved are enabled by higly differentiated cells, whose formation requires ‘bioenergy’ gained by respiration. Thus, the continual generation of vapor flows through transpiration containing potential energy can be considered work performed by plants and soil-organismic communities.
Makarieva et al. (2013b, 1049) state that during evaporation “work is performed against local atmospheric pressure”. Due to the close coupling of photosynthesis and transpiration through the plants stomata (taking CO_2 in and releasing H_2O), this work may also be considered a result of photosynthesis. The question arises whether this work (or its energy equivalent) with regard to associated valuable regulating services should actually be included in efficiency calculations. **If the potential energy contained in vapor flows was accounted for on the output side**, while the plant did not spent any extra respiratory energy besides maintaining its structure on the input side, **the efficiency of photosynthesis would sharply increase**. This question and speculation cannot be answered or further dealt with here.

However, **the inseparable coupling of solar energy use by plants with water cycling in ecosystems seems to be a fundamental difference to solar energy use in technical systems** (like photovoltaic and concentrating solar power). If comparing efficiencies of a solar PV or parabolic trough field with an energy crop field or even a harvestable forest, then theoretically transpiration work or even the associated regenerative services would need to be taken into account. The thermal index of landscape efficiency may actually serve as a comparable performance criterion not only for renewable (or non-renewable) energy systems, but also for other land uses in this regard.

In contrast to differentiating utility versus loss according to a carbon related energy content, landscape efficiency differentiates utility versus loss according to energy dissipated within ecosystem sustaining or degrading processes. It thereby conceptualizes efficiency closer to its classical understanding, accounting for the energy used in valuable (in this case biological) work processes rather than the energy contained in a material energy source output (useful in this case for technical work processes), the latter being only one aspect of productive work. Certainly this concept of landscape efficiency and its underlying ecosystem model is a rough abstraction devoted to energy dissipation and does not display many other interlacing roles, functions and activities of organismic groups or species. However, in the light of such a model, biomass sources like vegetation and organic residues already receive a meaning quite different than just being a resource for human bioenergy use (or food and material use), especially when looking at how the (re)generation (or degeneration) of vital ecosystem services or landscape functions depends on the "double function" of vegetation and the extraordinary role of water in land management and land use regimes.

But the allocation of ecosystem services depends only to a limited extent on the mass of the living tissue. Decisive are the special capabilities of diverse life forms, performing a wide variety of activities with their differentiated and highly organized cellular organs and tissues.

2.3.5 Biomass, biodiversity, wilderness and irreversibility

Standing biomass in an ecosystem can indicate the 'amount of working tissue' or, in other words, the magnitude of life processes at work in an area. As seen in Section 1.3.3, however, the scientific biomass category actually subsumes the diversity of life forms under a mass parameter. In contrast, the concept of "biological diversity" or "biodiversity" explicitly recognizes the great variety of life forms and communities at various scales. The UN Convention on Biological Diversity defines (CBD 1992, Art.2): "*Biological diversity* means the variability among living organisms […] and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems." Thus, in a sense, '**biodiversity' can be considered the counter-concept to 'biomass'**. Furthermore, since it is an appreciated phenomenon and its protection a political goal due to various values and reasons, '**biodiversity' can be regarded** a desired property or **a quality of landscapes**.

However, high biodiversity, often indicated by the number of species in a given area or ecosystem, does not necessarily mean 'well-functioning' or sustainable ecosystem. There is a long scientific controversy over the role of biodiversity in the functioning of ecosystems (Townsend et al. 2009, 446f). Similarly, there is a lot of discussion about the role of biodiversity in the provisioning of ecosystem services. A conceptual shift from species diversity to functional diversity, understood as the variety and distribution of functional traits in a living community, can be observed (cf. Elmquist et al. 2010; Bello et al. 2008; Norberg 2009). This should not be surprising since the ecosystem model basically entails a functional approach (see page 84), while the identification of various species pursues a taxonomic approach based on morphology, sexual reproduction, genetic code or other aspects (ibid.). The delivery of ecosystem services highly depends on the question of "what do species do in ecosystems" (Lawton 1994 cited in ibid.) or in the landscape and how their activities interact. "Thus, distribution of traits, or so-called trait spectra, in a community is more informative than species richness per se in understanding how a community will function" (Norberg 2009, 593). Adding "some measures of traits to species' identities" could help to better understand the contribution of species diversity to ecosystem services, on the one hand. On the other hand, the ecosystem service approach, eventually broken down to specific traits, service providers or service providing units (Vandewalle et al. 2009), selects species and communities upon instrumental value, i.e. their benefits to humans. The ecosystem services approach should thus not be seen as a replacement, but as a complementary approach, to protecting biodiversity (ibid. 36).[82] However, acknowledging the diverse functional traits of a wide variety of living beings can shed light on the multiplicity of fascinating capabilities with which living communities sustain themselves and perform (re)productive biological-ecological work valuable for human societies and their economies.

With regard to the protection of species diversity and genetic variations in a given landscape area, two types of biodiversity may be distinguished: (1) diversity arising from self-sustaining evolutionary systems eventually under human influence but apart from direct human control; (2) occurrence of species and varieties in co-development with human land-use change, cultivation and land management.

The sustenance of the latter kind of biodiversity usually requires some type of continuous human intervention or care taking, e.g. certain forms of land management and cultivation practices or habitat management, respectively. This may involve e.g. re-establishing certain landscape elements, mowing, removal of trees or alien species etc. These habitat management practices, however, can have synergistic, but also adverse effects on other ecosystem services, especially the functional triangle. For example, the maintainance of extensive grassland as a breeding ground for certain bird species on former moorlands, e.g. through drainage and mowing, may degrade the organic soil and hamper water retention and quality regulation. Therefore, habitat mananagement practices – in the same way as agricultural and forestry production – should principally also undergo a 'sustainability check'.

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[82] It should be noted, however, that lists of rare and endangered species also make selections. Furthermore, regulating services, especially the functional triangle, may be considered not only as benefiting humans but also maintaining life-support functions for living communities in general.

In contrast, the sustenance of biodiversity of ‘type 1’ basically requires as little human influence as possible within a certain area. This includes no extraction of biomass, e.g. no logging or hunting in a forest. Here, the ecosystem services concept can help to make understood that **‘non-use’ of biomass is not ‘useless’, but can be very ‘useful’ and valuable**. As the basic functional service triangle, especially, is dependent on biomass remaining in ecosystems, a high performance of these services may be anticipated in such ‘uncultivated’ areas.[83] However, this highly depends on the landscape context. On hilltops for example, where buffering capacity is lost first, or on coastlines critical for ocean-to-land water transport, unmanaged forests are expected to perform better than cultivated forests regarding climate regulation, water retention and quality, or nutrient retention and soil fertility (Ripl, Hildmann 2000, 383f; Makarieva, Gorshkov 2007, 1029). However, with regard to nutrient cycling and water quality regulation, the management of wetlands may offer advantages over unmanaged wetlands, e.g. established as sinks in the landscape as discussed in Chapter 4.3. Besides regulating services, ‘uncultivated areas’ can provide a variety of ‘cultural services’ (if access is granted). For example, people visit National Parks because of very special recreational, aesthetic and even spiritual experiences, which they only encounter there. In protected ‘wilderness areas’, it is possible to measure one’s strength against Nature, recover one’s inner self or feel the dignity and secrets of centuries-old woods.

These areas can also have a high psychological and educational value. By ‘meeting’ aged trees and wild living animals, children relate to other beings, and may develop their own perception, feelings, thoughts and respect. Increasing offers of wilderness education or self-experience trips indicate the growing appreciation of these services. Also ethical values can plead for non-use of biomass: e.g. moral concepts that other beings should be able to ‘express their own way of life’ or flourish ‘freely’, according to their own dynamics, at least in parts of the territory, even if the global impact of humans can no longer be denied.

In any case, ‘wilderness’ emerges more and more as a ‘cultural value’, as a fantasy of “first wilderness”, i.e. untouched ‘pure’ nature, which has been virtually lost (Hofmeister 2009). Thus, “**secondary wilderness**” (ibid.), i.e. certain areas of **terrain, not taken into or released from direct socio-economic use, could also be regarded as a ‘quality of landscapes’**. Furthermore, areas left to themselves can serve as important “reference areas” (Dudley 2008, 13) of how ecosystems react to human induced change, such as climate change. Observations in such areas can give valuable hints for

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[83] Uncultivated does not mean uncontrolled. In fact “all those “wilderness areas”, large and small, remote and urban, that now dot central Europe, fenced in and fully regulated, are likely to be among the world’s most observed, surveyed, and controlled regions” (Hofmeister 2009, 294).

adaptation strategies as well as sustainable management principles. Or put differently, these areas may serve as exploration grounds to get to know “tertiary wilderness”, understood as the risky, uncertain, and irreversible product and process of globally hybridized culture-nature, which we cannot control, but in which we have to find (re)productive strategies and practices for sustainable development (Hofmeister 2009).

To conclude: Bioenergy use always goes along with the extraction of biomass from ecosystems. However, leaving biomass in ecosystems can provide many services and hold many values, and will thus be very useful and valuable within parts of the overall landscape. Therefore **the use of biomass for bioenergy should be balanced with the benefits of non-utilization of biomass**, especially with regard to irreversible losses, i.e.

- irreversible matter losses and losses of soil buffering capacity,
- species extinction,
- loss of ‘age’ and ‘dignity’ and other cultural values.

It should thus be an explicit task of Landscape Quality Management to care for ‘biodiversity’ and ‘wilderness’ as quality categories of landscapes in relation to both instrumental and ethical values.

2.4 Landscape Quality Management (LQM): Contextualizing knowledge and serving place-based policy approaches

> By dividing information into discrete, disciplinary units,
> we have created what we might call the paradox of knowledge:
> in which we have so much information about the world
> and yet remain so ill-informed about our effect on the world.
> This suggests that we may need to arrange knowledge
> differently in the future not according to disciplinary categories,
> but instead according to spatial phenomena and […] to
> the things without which we cannot live.
> *Thomas Fisher, 2012*

What is inseparably linked in ecosystems is disjoined in society. As shown, production services and regenerative services are physically coupled through a multiplicity of interdependent processes, whereas water plays a (re)productive role. In society, however, production services and regenerative services are divided by valuation and organization. Only production services are recognized as 'productive' and value-creating. Regenerative services are at the same time depreciated as 'non-productive' and simultaneously incorporated for free by production. While production services are mainly managed economically and are 'coordinated' by the market, regenerative services are either not managed at all, or are sectorally administered as 'protection goods' – rather than as products – by public authorities. A coordinated effort to sustain their quality, however, is often lacking and usually not regarded to be a task of economic producers. The areas of responsibility for 'production' versus 'regeneration' are thus clearly separated. Subsequently, economic production systems are being one-sidedly optimized, i.e. with a biased view on maximizing (biomass) production output. The resulting environmental damage is to be reduced by a vast set of restricting regulations. In this logic, environmental and landscape protection are often regarded as limiting economic activities rather than providing services actually enabling economic productivity in the first place.

Need for a coordinating managment activity mediating between field scale and landscape scale (and beyond)

In contrast, the idea of this study is that **regenerative services of a desirable quality** should be co-produced **as conscious products and productivities of economic**

(re)production. Since they are production prerequisites, they should be part of the responsibility of the economy (entailing rights to use *and* obligations to maintain them). As already mentioned this does not necessarily mean that they are to be governed by market mechanisms, but that they deserve equitable management (Costanza et al. 2000). Since regenerative services arise not from a single field or production site, but from a discrete distribution of ecosystems, processes and land uses in the landscape area, a professional **coordinating activity** is needed, which **cooperatively links the decision making level of single land users with the overarching landscape level** in an attempt to reintegrate productivity and reproductivity. However, "landscape scale management is the exception rather than the rule (Selmen, 2006) as it requires co-ordination between land owners and managers at scales rarely operationalized or actively encouraged" (Prager et al. 2012, 244 with reference to Selmen 2006). Landscape quality management will bridge this gap through creating institutional jointness by relating the individual management level of (biomass) producers and other land users with a superordinate cross-sectoral landscape management level.

Landscape management as a continuous adaptive process for sustainable development

"Landscape management" is promoted as a means of landscape policy by the European Landscape Convention (ELC) (Council of Europe 2000, Art. 6E). It is defined as "action, from a perspective of sustainable development, to ensure the regular upkeep of a landscape, so as to guide and harmonise changes which are brought about by social, economic and environmental processes" (ibid. Art. 1e). Landscape management is further specified in the guidelines accompagnying the ELC: "Management of landscape is a continuing action aimed at influencing activities liable to modify landscape. It can be seen as a form of adaptive planning which itself evolves as societies transform their way of life, their development and surroundings. It can also be seen as a territorial project, which takes account of new social aspirations, anticipated changes in biophysical and cultural characteristics and access to natural resources" (Committee of Ministers 2008, I.5). In this sense, landscape management can be understood as a continuous adaptive process of actions for the sustainable development of landscapes with regard to ecological, socio-cultural and economic values, specifically addressing various (land-use) activities, which modify the landscape. Thus, it seems to be the appropriate activity to execute a standardized adaptive mechanism for landscape reference systems and to perform cooperative actions as suggested in Chapter 1.7.

Landscape Quality Management focussing action on the quality of the landscape as common living space, economic space and habitat

Like the two other ELC measures “landscape protection and planning” (Council of Europe 2000, Art. 6E), landscape management is devoted to the improvement of the quality of people’s living surroundings, particularly the achievement of landscape quality objectives (Section 2.2.3). Therefore it may also be termed ‘quality management of landscapes’ or simply ‘landscape quality management’ (LQM). This notion is chosen here to highlight that it is the desired properties of various processual patterns realized in the landscape which should be subject to management. As argued in Section 2.2.6, these patterns can be seen as the perceivable and assessable outputs or product qualities of regenerative ecosystem services. So landscape quality objectives derived from public consultations could be complemented with a set of quality objectives for the hybrid performance of ecosystem services interwoven with human activities. This may involve classical environmental quality objectives like the good status of water, but also more processual objectives like the decrease of temperature gradients and hot spots, as well as improvement of landscape accessibility to allow people to benefit from cultural services. One may subsume ‘landscape quality objectives’ under ‘environmental quality objectives’ or the other way around. Or one may call qualitative goals associated with basic regenerative services ‘environmental quality objectives’ and those related to cultural services ‘landscape quality objectives’. Whatever notion is chosen, they have in common that they are benchmarks for improvement of the quality of people’s living space, as well as the quality of economic space, and the quality of habitat for other (re)producing living communities. Furthermore, as the underlying ecosystem processes serving these various territorial requirements are highly interlinked, they should not be dealt with separately, but in close connection.

Landscape Quality Management as an area-based process with the potential to guide corporate environmental quality management

From a European Union perspective, where improving the quality of the environment is an explicit political goal enshrined in the Treaties (TFEU 2010, Art. 191(1)), it would probably make sense to subsume landscape quality objectives under the notion of environmental quality. In this regard it could be better to call the envisioned mechanism ‘environmental quality management’. However, ‘environmental quality management’[84]

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[84] See e.g. the international journal on “Environmental Quality Management” addressing business organizations: http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%291520-6483/homepage/ProductInformation.html, or the journal “Management of Environmental Quality”, in particular targeting industrial and agricultural bodies: http://www.emeraldinsight.com/products/journals/journals.htm?id=meq&PHPSESSID=flf4keh06tfq43o6cf6tgl3ah2 (accessed 10/18/2013)

and environmental management is a term already much in use in the business world for improving the environmental performance of single organizations, business units or production processes (European Commission 2009b; ISO 2010) mostly assessed in a spatially abstract way by input-output measures like resource consumption and waste release etc. (Kanning 2004, 165, 195). LQM is meant rather as an area-based management system, dealing with the processes and characteristics of a very distinct part of the environment perceived by people, i.e. with landscapes. To repeat, the landscape is understood here as the concrete physical and visible expression of the environment. In this sense, LQM should work towards both environmental and landscape quality objectives (generated by different political agendas) and the improvement of the performance of contributing ecosystem services. It will not deliver abstract environmental standards, but very concrete landscape reference systems according to place-based objectives through a standardized process. These reference systems in turn should guide the improvement of economic production activities with the aim to co-produce environmental/ landscape quality. On the one hand, LQM is therefore to be distinguished from business management. On the other hand, analogy and compatibility with quality management of the business world is an explicit intention, as the target groups of LQM are not only farmers and foresters delivering biomass for bioenergy use and the "bioeconomy" (European Commission 2012b), but more generally economic actors, such as industrial producers and their organizations (see Chapter 5).

Requirements for and components of building an LQM process from the perspective of landscape planning and cooperative regional governance

How to operationalize knowledge of ecological economics and environmental/ landscape planning for corporate environmental management systems (in Germany) has been thoroughly investigated by Kanning (2004). Kanning finds that while corporate environmental management needs to refer to spatially concrete landscape knowledge and goals, landscape planning could learn from process oriented business management. Particularly if landscape planning equipped with ecological-economic knowledge is to play a role of guiding site-specific economic activities in a sustainable direction, it should further develop according to the following points (ibid.167-196, further findings of Kanning are discussed in Chapter 5):

- Discover economic players as a target group to co-produce environmental qualities rather than considering them as a nebulous group causing environmental damage
- Involve participative regional sustainability discourses in the formulation of spatially concrete environmental quality objectives

- Use informal cooperative instruments within open, adaptive, self-reflective governance processes of a ‘new planning culture’
- Develop process oriented tools for continuous improvement of environmental conditions including monitoring systems
- Actively engage in innovation consulting

With regard to a cooperative regional governance process for an environmentally friendly and spatially compatible expansion of bioenergy use, Kanning and Rode et al. (2010, 157-180) identify the following success factors, based on knowledge stocks from the fields of sustainable and innovation oriented regional development, material flow management, stakeholder analysis, network and conflict management:

- Regional Leitbild
- Participation of promoters/ key persons
- Linkage of formal with informal instruments
- Overarching collaboration of all actors
- Spatial proximity of actors, i.e. face-to-face contacts
- Cooperative forms of communication
- Early involvement of stakeholders
- Knowledge transfer and collective learning processes
- Exchange with supra-regional actors
- Process and network management
- Continuous monitoring and evaluation
- Process team with secured financial and human resources

Requirements for and components of building an LQM process from the perspective of land, water and ecosystem related management approaches

A wide variety of approaches which deal with the management of land, water and ecosystems for sustaining or restoring the provision of ecosystem services exist. A brief scan of such land, water and ecosystem related management approaches, i.e Sustainable Land Management (The World Bank 2006; Hurni et al. 1996), Integrated Water Resources Management/ River Basin Management (Agarwal et al. 2000), Environmental/ Ecosystem Management (MA 2005, 92–100; Costanza et al. 2000; Cash, Moder 2000), and resilience focused adaptive governance and management of social-ecological systems (Folke et al. 2005), resulted in the following general requirements for a standardized adaptive LQM process:

- Match political administrative units with ecological processual units
- Integrate different spatial and temporal scales (vertical integration)
- Integrate different sectors (horizontal integration)
- Consider various cultural value systems/ moral concepts
- Involve stakeholders and provide transparency
- Enable and encourage participation (especially of women, youth, indigenous people)
- Build knowledge and understanding of ecosystem dynamics of specific landscapes and seascapes
- Feed ecological knowledge into and generate knowledge through adaptive management practices
- Combine scientific with local, traditional and practitioners' knowledge
- Embrace uncertainty and surprise
- Provide flexibility to react on external drivers and changes
- Focus on irreversible losses and the precautionary principle
- Establish long-term continuous processes including monitoring and feedback
- Establish adaptive management cycles and collaborative learning processes
- Provide leadership
- Provide capacity for creativity, sense making, synthesis, mediation and trust building

Essentially, a management activity within suitable governance arrangements is needed, which will deliver **transboundary, cross-sectoral, and cross-scale communication, coordination and collaboration** on the subject of regenerative ecosystem services and related environmental/ landscape qualities – equipped with the necessary institutional, social and human capital. Cowling et al. (2008), for example, suggest a 3-phase adaptive stakeholder process on a local to regional scale comprising assessment, planning and management as an operational model for mainstreaming ecosystem services in the land-use (and water-use) planning sector to be institutionalized within learning organizations. The assessment phase should include assessment of the social and biophysical system benefiting from and delivering ecosystem services as well as valuation exercises based on both monetary and non-monetary units of value. Because different value systems, research traditions and mental models come together in such a process, excellent facilitation and leadership should be provided. The planning phase is meant to be collaborative planning as a "discourse-based process that comprises the identification of a vision, a strategy to realize the vision, specific strategic objectives, and instruments, tools and organizations for implementing actions" (ibid. 9485). This can entail scenario planning and a variety of imaging tools, such as picture collections, maps, and visual narratives etc. The management phase is to undertake and coordinate actions that achieve the protection or maintenance of those biophysical features and processes that provide ecosystem services and ensure the flow of services to beneficiaries. The whole management framework should embody an action-reflection cycle to provide for learning (by doing) and encorporating changed values and knowledge (ibid. 9486).

Similarly, Boyle et al. (2001 cited in Folke et al. 2005, 444) suggest a triad of activities including (1) governance as a process of resolving trade-offs and providing a vision and direction for sustainability, (2) management as operationalization of this vision, and (3) monitoring providing feedback and a narrative of how the situation has emerged and might unfold in the future.

Requirements for and components of building an LQM process from the perspective of standardized process oriented quality management

Adaptive management systems focussing on the delivery of quality in various fields have been well developed in the area of business and organizational management. The ISO 9000 series provides a standardized framework for process based Quality Management Systems, which can apply to all kinds of organizations and their products, services and management. ISO 9000 defines “quality” as “degree to which a set of inherent characteristics fulfils requirements” (ISO 2005, 3.1.1). “Inherent” means characteristics (permanently) attached to products, processes or systems as opposed to being assigned to them, such as prices (ibid.). Transferring this definition to LQM, ‘**landscape quality**’ can then be understood **as the degree to which the characteristics of various landscape features, processes and** spatial-temporal **patterns** (here: the outputs or product qualities of ecosystem services perceived in the landscape) **fulfill landscape functions** (here: the demands and expectations that people and society impose on landscapes from the perspective of sustainable development, quality of life and individual well-being).

The ISO 9000 standard defines the following eight fundamental principles on which any quality management system should be based (ibid. 0.2, ISO 2012):

- Principle 1: Customer focus (meeting customer needs and expectations including requirements of other interested parties and society as a whole)
- Principle 2: Leadership (including establishing a mission, vision and trust, creating and sustaining shared values, encouraging and recognizing people’s contributions)
- Principle 3: Involvement of people (including creating an atmosphere where people accept responsibility and ownership of processes and problems, freely share knowledge and experiences, and freely discuss problems and issues)

- Principle 4: Process approach (managing activities and related resources as a process with a focus on activities neccessary to obtain the desired results, their capabilities and the interfaces of key activities)
- Principle 5: System approach to management (including understanding the interdependencies between the processes of the system and structured approaches that harmonize and integrate processes)
- Principle 6: Continual improvement (of the organization's overall performance as a permanent objective including goals to guide and measures to track continual improvement, recognizing and acknowledging improvements)
- Principle 7: Factual approach to decision making (taking action based on factual analysis of data and information, balanced with experience and intuition)
- Principle 8: Mutual beneficial supplier relationships (enhancing the ability of both to create value and balancing short-term gains with long-term considerations)

The standard applies a four-phase process model, which is based on the Plan-Do-Check-Act cycle (PDCA cycle) (ISO 2009b). The PDCA cycle – developed back in the 1930s by the physicist and engineer W.A. Shewhardt for problem solving and quality assurance – is a well recognized model for continual improvement processes, especially applied in the automotive industry (Kostka, Kostka 2007, 10ff). Its components in relation to LQM are further described in Chapter 3.5.

LQM contextualizing and spatializing knowledge and knowledge production

The draft LQM process, presented in the next chapter, builds on the above-mentioned requirements, components and principles. The focus thereby is set on where and how the generic ecological, social-ecological and ecological-economic knowledge explored and integrated in the previous chapters can feed into such a draft process. An **abstract generic knowledge core** is considered important for the **'standardized content' of the LQM process** to avoid arbitrary interpretations of sustainable landscape development. Furthermore, **situational knowledge** – i.e knowledge of the specific situation, history, conditions, processes and characteristics in a distinct landscape area – will be highly relevant for LQM. This goes along with a changing role of science in the sense of producing **contextualized knowledge**, i.e. knowledge which responds to societal demand (Nowotny et al. 2002). Cowling et al. (2008, 9483), for example, point out that "mission-oriented ecosystem services research" should be "user-inspired, user-useful and user-friendly" and embedded in a social process designed to ensure their effective management. LQM would basically provide such a process in which different types of knowledge are produced and fed in, in interaction with sharing and defining values according to a specific landscape context. In such a process researchers will be enablers helping stakeholders and managers to understand (long-term) issues and to make informed decisions. However, changing the way of knowledge generation will also mean a changing self-conception and recognition of scientific work. “Researchers will need to be responsive to stakeholder needs, collaborate with many groups with values and norms foreign to their own, operate as facilitators of knowledge transfer to stakeholders, and be prepared to engage in time-consuming processes that are not sympathetic to career aspirations and performance benchmarks predicated by the accumulation of publications in high-impact journals” (ibid. 9487).

Despite these barriers, “**spatializing knowledge**” enabled by geographic information systems and geodesign may induce such a change (Fisher 2012, 5). Rather than sorting information according to disciplines in books and journals, which “enabled us to think of knowledge divorced from any particular physical or conceptual space”, ‘mapping’ information onto places may become the “primary way we organize, access and distribute knowledge in the future” (ibid.). Arranging knowledge in a spatial context and displaying it via multiple thematic layers of a specific territory (as it is typical for landscape analysis and the design profession) will make it possible to see the relationships among disciplines and to focus on the connections as well as to project alternative futures (ibid, 5f). Therefore, however, displaying data and information not only in a spatial pattern but also in a processual time series will be critical.

With regard to biomass production and bioenergy use, a LQM process can also verify and scrutinize general scientific propositions such as the use of perennials and residues as preferred biomass resources. As mentioned on page 138, for example, the use of perennial Eucalyptus trees may offer an option in one area while it poses threats to another. Or, as discussed in Chapter 4.3, the use of residues can save some regions from eutrophication while it can degrade soil functions in another. With the landscape reference systems provided by LQM, general recommendations can be transformed into context-specific local solutions.

LQM serving place based policy approaches

By contextualizing and spatializing knowledge and knowledge production, LQM can furthermore serve place-based policy approaches as promoted by the European Territorial Agenda 2020 for an “inclusive, smart and sustainable Europe of diverse regions” (Informal Ministerial Meeting 2011). Often, general scientific recommendations are picked up in policy making and translated into political norms. This is the case, for example, with the GHG bonus for biomass from ‘restored degraded land’ of the Renewable Energy Sources Directive (European Parliament and Council 2009, Annex V 7.-9.). However, in a local situation, such a norm can be problematic (see e.g. case study Jatropha Curcas, page 221). Furthermore, standard setting policies, which on the one hand are an important feature of European policy, may on the other hand come at the cost of standardization and simplification of landscapes and a weakening of their ability to provide a sense of identity and other services, as has been experienced e.g. with the Common Agricultural Policy (Pinto-Correia et al. 2006, 337f; Lohrberg et al. 2014). In contrast, a place-based policy approach is to avoid ‘territorially blind’ standardization by building on specific regional potentials and territorial evidence, emphasizing vertical integration of levels and scales, horizontal integration of sectors, and territorial integration of different spatial functional units (Informal Ministerial Meeting 2011, §11,12; Böhme et al. 2011, 23–27). Based on their investigation of effects of agri-environmental schemes in different European countries Pinto-Correia et al. (ibid. 343), for example, claim that “the regulations decided at central level should aim less at mass solutions. Rather they should become more flexible and create the conditions for the identification and application of specific solutions to specific places, and in parallel create a basis for developing corresponding instruments.” With regard to the management of rural landscapes and policies for rural development, they point out that “the challenge is to understand ongoing dynamics in a contextual way”. They opt for a “communicative and open-ended approach” with “more flexible frameworks for management” and a “creative and shared process between stakeholders, across disciplines and levels of involvement, within a global framework recognised by all parties” (ibid. 343f). With regard to the need for a collaborative provisioning of ecosystem services on a landscape scale by many different land users, Prager et al. (2012, 245) also criticise that agri-environmental schemes presently “favour a farm scale approach leading to individual disconnected actions”. They stress that the future design and implementation of agri-environment schemes should encourage coordinated action at the landscape scale, whereby “investing in process, i.e. coordination for meetings, facilitation, advice, is as important as direct payments to land managers” (ibid. 246). The same type of landscape based management and planning – especially with regard to a coherent green infrastructure network yielding multiple ecosystem services – would also be desirable for the designation of 7% farm area as ecological focus area, a CAP condition for direct payments (European Commission 2011b, Art.32), presently also working as a single farm approach (Lohrberg et al. 2014).

Rather than incentivising predefined measures, it could therefore make sense for a place-based approach in various fields of EU policy – besides bioenergy policy – to support standardized, but flexible processes of Landscape Quality Management in diverse regions, and thereby invest in building ‘social-ecological regenerative capacity’.

2.5 Summary and conclusions

According to the European Landscape Convention the category of ‘landscape’ – as a nature-culture hybrid – applies in an area wide approach to the whole territory, equally to rural and urban areas as well as to outstanding, everyday and degraded landscapes. It can be understood as the distinctive concretization of the ‘environment’ showing a unique character and an individual history. With regard to considering human and organismic activities on an equal footing, the landscape may furthermore be conceived as the common living and production space of human societies, their economies and other living communities. In this broad understanding, ‘landscape’ essentially is an integrative, inter/transdisciplinary, spatial-temporal, and multi-scale category, which can combine culturalist and naturalist (or subjectivist and objectivist) approaches, rational and emotional access, general and individual aspects, as well as aspects of projection and reflection. With regard to the terrestrial environment these properties seem to make it suitable for a comprehensive standardized adaptive process for reference building, assessment and management as envisioned in this work. (With regard to oceans the term ‘seascape’ may be used analogously.)

At least three concepts, recognized by different political agendas, can be used to build an assessment and management framework as the generic core of contextual landscape reference systems:

1. The *ecosystem services* concept – recently taken up by EU policy as one of several investment priorities of regional/ cohesion policy – allows explicitly describing and acknowledging productive biological-ecological work vital for human well-being and economic productivity. Its strength is that it highlights value-creation by ecosystems and its agents.
2. The concept of *landscape functions/ multifunctional landscapes* – an approach of spatial planning – attempts to reintegrate ‘productive’ with ‘non-productive’ functions in distinct landscape areas. It allows placing land use and land management activities inbetween an empirical side (functions as process sets) and a normative side (functions as demand sets). Its strength is that it focuses on synergies and complementary outputs by analyzing and creating jointness.
3. Improving *environmental quality* is the overarching goal of EU environmental policy enshrined in the treaties, while achieving *landscape quality* objectives lies at the basis of landscape protection, planning and management as a means of landscape policy promoted by the European Landscape Convention. Objective and subjective attributes pertain to the quality category arising from an interaction

> of bio-physical characteristics and perceptual/ judgmental processes. The strength of the concept of environmental/ landscape quality and quality objectives is that it enables qualitative performance judgments.

All three concepts actually bridge between value and knowledge systems by linking environmental, ecosystem or landscape states, structures and processes to societal needs, individual and social well-being, quality of life and sustainable development. However, their linkages with each other do not seem well established yet. An attempt is made in this study to combine the three concepts within one assessment and management framework as the 'standardized part' of the envisioned LQM process, while allowing it to be applied and modified according to the context-specific situation ('adaptive part' of the mechanism):

Setting up a field of action between value and knowledge systems, a 'non-market' demand and supply framework is used to locate the three concepts in relation to each other. The demand side represents requirements to the landscape from the perspective of sustainable development and individual or user group related aspirations – largely determined by different types of values. The supply side represents structures, processes and activities in the landscape fulfilling these requirements (now and in the future) – to be accessed by various types of knowledge. Since value and knowledge systems are interdependent and may change over time, they will be alternated and reflected throughout the mechanism.

As ecosystem services best describe productive biological-ecological work, they are placed in the center of the framework embedded in ecosystem functions as process sets providing services on the supply side and landscape functions as sets of needs and expectations on the demand side. Within this framework a multifunctional landscape is considered an area as perceived by people (and experts) where various landscape functions are fulfilled by the provision of multiple ecosystem services. A landscape of high quality is considered a landscape characterized by distinctiveness and a high match between supply and demand.

To avoid the 'sellout' of the landscape in such a constructed supply and demand framework, which is usually considered a market situation, two points are highlighted by the notion of a 'non-market' approach:

First, it is advocated not to trade ecosystem services on the market in most cases, but to invest in their creative, coherent and continuous (quality) management, within suitable institutional arrangements (not subject of this study) governed by long-term goals of sustainable development and quality of life.

Secondly, the standardized content or value and knowledge core of the LQM mechanism should avoid purely interest-led negotiations and arbitrary interpretations of sustainable development.

Regarding the second point, a distinction is made between ‘production services’ and ‘regenerative services’ by applying “(re)productivity” as a critical-analytical category. ‘Production services’ is the term used here for the production of materially usable goods by ecosystems, such as resources for food, feed, fuel and fiber harvested or extracted by humans from ‘biomass’ as a collective term for organic substances of many kinds. ‘Regenerative services’ – further subdivided into ‘basic services’ and ‘recreational services’ – are considered those services of biosynthetic living activities that reproduce life and favorable living and production (pre-) conditions. ‘Basic services’ maintain (a) basic physiological conditions not only essential for humans but also for other living beings within ecosystem communities (life-support), such as ‘moderate’ temperature spans, soil fertility or disease control, as well as (b) immediate reproductive processes and properties such as pollination, genetic diversity or habitat. ‘Recreational services’, by providing environmental settings which can be experienced by humans in various ways, e.g. as scenery, soundscapes and scentscapes, recreate human and social capital, i.e. productive human capabilities as well as social cohesion (including spiritual bonding).

This grouping makes visible the present unsustainable separation of ‘the productive’ from ‘the reproductive’ in economic theory and practice, as only ‘production services’ are considered within the production boundary and responsibility of economic units. Regenerative services are either taken for granted and not managed at all or at best sectorally administered by the state as protection goods. In any case they are usually not considered as (valuable) outputs of and under the responsibility and care of economic production activities. This is supported also by a scientific view that only organismic activities should be considered in the delivery of ecosystem services, excluding human land management activities and artifacts. For various reasons, however, this is problematic from a landscape point of view, where organismic and human processes are closely interwoven and in many cases together yield certain ecosystem services.

In contrast, applying “(re)productivity” as a constructive category – in the sense of a mental and physical reintegration of productivity and reproductivity – would mean fully considering production services and regenerative services to be within the area of responsibility and action of a sustainable (re)productive economy. With such a shift in thinking regenerative services, forming the ‘reproductive sphere’ and origin of economic production, could then be consciously considered not only as inputs but also as valuable outputs and results of economic activities (as is partly the case with non-commodity outputs of a multifunctional agriculture). This does not necessarily mean that they must be governed by conventional market mechanisms, but that economic land uses and their production processes are arranged and designed so as to co-produce regenerative services bundles in a desired quality at their landscape and ecosystem interfaces. In this way, the dichotomy of utilization and conservation may be partly nullified.

Against this backdrop, it is deemed a rule that, for sustainable biomass (re)production and for biomass to be called a ‘regenerative energy source’, regenerative services should be jointly co-produced within land use systems providing and using biomass production services (including the use of residues). Thus, in the reference building LQM mechanism *regenerative services* will serve as *general criteria* for the assessment and development of sustainable biomass (re)production. Furthermore, they are the *subject matter of collaborative management* as they are not generated on a single plot or field, but by a discrete distribution of processes and activities over the whole land use pattern.

An obstacle to management is that regenerative services are less tangible than ecosystem goods obtained from biomass production. It is hypothesized in this study that regenerative services are ‘realized’ as various processual, spatial-temporal patterns in the landscape in both meanings of the term, i.e. ‘perceived’ *and* ‘brought about’. Following the ISO 9000 definition of quality for process oriented quality management, the “characteristics” of those patterns “fulfilling requirements” may be considered the ‘product qualities’ of regenerative services. They actually qualify the landscape as common living and production space. Here, these characteristics of processual patterns realized in and qualifying the landscape are subsumed under the notion of ‘landscape qualities’ constituting landscape quality in a broad meaning and conferring the name Landscape Quality Management.

With regard to desired characteristics of these patterns, landscape quality objectives may be derived on the demand side involving given policy objectives as well as public and expert participation. Furthermore, *quality indicators* for the hybrid performance of regenerative ecosystem services – arising from (regenerative versus degenerative) hybrid human-ecosystem interactions – may be derived from the characteristics of those patterns and their instrumental and sensual perceptions, complemented with trait indicators of species and functional organismic groups on the supply side.

Both generic and situational knowledge is critical for assessment and management, especially about key processes, process coupling, and joint provisioning of ecosystem service bundles as well as regenerating and degenerating interactions. In this regard knowledge about the role of water as a (re)productive ecosystem agent helps the understanding of how biomass production in ‘natural’ ecosystems is linked with the maintenance of living conditions, since decisive processes of renewal occur through the conversion of solar energy mediated by energy dissipative properties of the dynamic medium water. Key (re)productive joint processes are inter alia: The primary production of plant biomass through terrestrial photosynthesis is inseparably coupled to water vapor production (transpiration). The transformation of organic debris through the secondary production of soil biota largely increases the capacity of soils to retain and store water, thereby maintaining water vapor production over dry periods. This soil-plant-atmosphere continuum partitions the precipitating water flow at the land surface into a “green” water vapor flow returning to the atmosphere (short water cycle) with soil moisture as its “green” water resource, and a “blue” liquid water flow percolating and running off by gravity into the surface and groundwater (large water cycle). While this “blue” water resource – to be regarded the ‘surplus water’ of ecosystems only – provides humanity with fresh water, the green vapor flow sustains the entire range of the basic services: A high performance of water retention and short water cycling closely linked to temperature dampening and short matter cycling are at the base of climate and air regulation, soil quality and erosion control, nutrient retention, water quality regulation, flood prevention and moderation of extreme events. Furthermore, the water-vegetation-soil-complex provides the reproductive habitat for all animal species which may provide further services, e.g. pollination or biological control. Basically, water and its dynamics set the ecohydrological conditions for biological diversity in any habitat. Water also plays a major role in recreational (cultural) services. Similar to water as a resource, the blue water flow seems more important here. However, the provisioning of recreational services by water in the landscape is highly dependent on good water quality and reliable quantitative patterns. In this way, the green water vapor flow, sustaining basic services, comes back into play as being indispensible for recreational services, which is also very much true for production services.

The partitioning of the water flow also means a partitioning of the solar energy flux. This is well accepted e.g. for latent heat carried by the water vapor flow or for more or less kinetic energy carried by accelerated or decelerated run-off. Controversial is the energy potential contained in water vapor – which on the continents is sustained by the green water flow – as a source of energy driving atmospheric circulation by condensation-induced pressure gradients rather than differential heating. Given that this effect has so far been overlooked and not included in global circulation and climate models, the role of water seems currently underrepresented in the global climate discourse. The vegetation can be ascribed a double function as primary producer and water pump/ evaporator in this regard. Both its functional key activities can be considered biological-ecological work. Although the transpirational pull is a ‘passive process’ solely driven by solar energy – meaning the plant does not spend extra respiration energy on it directly – various biomass structures and functional traits are needed to keep transpiration going, which are actively built up and maintained by the plant’s metabolic cellular work. One may also say that, with its specialized tissue taking up and transporting water and releasing water vapor, the plant performs work against atmospheric pressure. Furthermore, by their ability to create low pressure systems, (virgin) forests may play a much greater role in maintaining inland precipitation on continents than previously thought.

In contrast to this conception of transpiration as 'useful work' with regard to even global air flow and climate regulation, it is often referred to as a 'loss' from a biological standpoint of plant physiology, considering the need of the plant to balance CO_2 intake and H_2O release as well as from a blue water resource standpoint of downstream users. Accordingly, water vapor production is usually not included in calculations of photosynthetic efficiency, which is solely based on the ratio of net primary production to global irradiance and estimated to be very low, i.e. about 1-6%. If considering transpiration as a component process of photosynthesis, and the energy potential contained in water vapor as its useful output, however, the question arises whether it should be included in the concept of photosynthetic efficiency, which would then probably sharply increase. In any case, the inseparable coupling of solar energy use by plants with water cycling in ecosystems is a *fundamental difference* to solar energy use in technical systems.

One approach which considers the work performed in ecosystems by maintaining short water cycles is the concept of "landscape efficiency" by Ripl et al. (1995, 1996), which means the ratio of energy disspated in cyclic, life sustaining 'use processes' to solar energy available versus energy dissipated in loss processes, i.e. irreversible matter flows out of catchments. It can be measured in the form of a thermal index based on the spatial-temporal patterns of temperature damping, and a chemical index based on charge loads of catchment outflows in relation to gross primary production in that area. As these two indices of landscape efficiency indicate the performance of short water and matter cycling activities which are critical for various basic services, they may serve as suitable trend indicators.

The following four ecosystem service bundles are proposed for simultaneous management according to different spatial landscape units or landscape layers:

1. **Water mediated basic functional service triangle**: Climate/air, soil/nutrient, and water quantity/quality regulation (biotic-abiotic regulation). Units: catchments on multiple scales. Trend indicator: landscape efficiency
2. **Reproductive habitat based services** related to target species, e.g. pollinators, predators of disease vectors, symbolic or endangered species, etc.: Pollination, biological control, habitat services (biotic-biotic regulation). Units: various habitat areas and networks

3. **Landscape perception based cultural services**: Production of landscape features and settings providing opportunities for recreation, inspiration, identification, aesthetic appreciation, learning and spiritual relation. Units: landscape character or identity areas
4. **Biomass resource based production services** dependent on harvest, extraction and regrowth of phyto- or zoomass: All provisioning services except water. Units: fields/ plots and their land use patterns

As only regenerative services are covered by LQM, the fourth bundle is not directly subject to management. However, it should be observed under LQM with regard to food security as well as synergistic and trade-off relationships. A general trade-off relationship can be principally assumed of the fourth with the first bundle: While all production services result from an extraction of biomass from land use ecosystems, the basic functional service triangle is especially dependent on living and dead biomass *remaining* in ecosystems. This principle shows that ‘non-use’ of biomass is not ‘useless’, but rather can be very useful and valuable in terms of regenerative services. Therefore, the use of biomass for bioenergy – always going along with biomass removal – should be balanced with the benefits of non-utilization of biomass, especially with regard to irreversible losses of soil buffering capacity, species extinction, and losses of ‘age’, ‘dignity’ and other cultural values.

Biodiversity – in a way the ‘counter-concept’ of biomass – will play a twofold role in LQM: On the supply side, the concept of functional diversity in terms of trait spectra helps to understand the capacity of ecosystems to provide services. On the demand side biodiversity represents a value in itself and a quality category of landscapes.

Essentially, a standardized adaptive LQM process equipped with a generic value and knowledge core around

- the theoretical conception of “(re)productivity” and productive biological-ecological work,
- value-creation by regenerative services and their landscape qualities, as well as
- the (re)productive role of the dynamic agent water,

and designed based on the requirements, principles and components of other landscape relevant management systems (like regional management, sustainable land management, integrated water resources/ river basin management, resilience focused ecosystem management and process oriented quality management) will:

- focus collaborative action on the quality of landscapes as common living and production space,
- provide landscape reference systems for sustainable (biomass) production and corporate environmental quality management,
- serve place-based policy approaches, and
- strongly contextualize and spatialize knowledge and knowledge generation.

However, various knowledge gaps remain, especially with regard to the role of water in climate and air flow regulation as well as its meaning for recreational/ cultural services. Also, knowledge about the contributions of ecosystems and their agents to the psychological development of children and adults, in particular the recreation of productive human capabilities, seems a yet underrepresented field. In this regard a closer linkage of research communities dealing with cultural landscape research, cultural ecosystem services research and environmental psychology could be beneficial. Furthermore, knowledge is required on how the main political agendas of environmental quality improvement, maintenance and restoration of ecosystem services and the achievement of landscape quality objectives can be better connected or even merged.

Despite these knowledge gaps the next chapter attempts to anchor the generic value and knowledge core described in this chapter within a draft of the envisioned LQM mechanism.

3 Draft: Standardized adaptive process of LQM

> Because national accounts are based on financial transactions, they account nothing for Nature to which we don't owe anything in terms of payments but to which we owe everything in terms of livelihood.
>
> *Bertrand de Jouvenel, 1968*

Landscape quality management (further referred to as 'the LQM activity' or simply 'the management') is meant to be a professional operational management activity performing according to an agreed standard (further referred to as 'the standard'). The envisioned procedure – named here 'standardized adaptive mechanism of Landscape Quality Management (LQM)' – is to be understood as a standardized process, which contains iterative feedback loops and management cycles and thus provides for an adaptive management. It is conceptualized as a permanent process with a long-term perspective oriented towards sustainable development, trust building, collective learning, and continuous improvement. The standardized adaptive mechanism of Landscape Quality Management is further on referred to as 'the LQM mechanism', 'the LQM process', or simply 'the mechanism' or 'the process'. The standard will predefine certain contents, process steps, criteria, and a few indicators, which can be complemented and adapted in a reasonable way throughout the mechanism. The mechanism is conducted by landscape quality managers (further referred to as 'the LQM team', 'the landscape managers' or simply 'the managers'). Research will feed the process, but not dominate it.

Annex 3 shows the proposed process matrix of the mechanism. Phases one to three are detailed in Annexes 4-6. The mechanism laid out in these figures and described in this chapter is to be seen as a preliminary draft. It is based on the requirements, principles and components extracted from other landscape relevant management approaches presented in Chapter 2.4. It attempts to show how the generic value and knowledge core developed in the previous chapters can shape and be anchored in such a process (see the first line 'Standard' in Annexes 4-6). The form of the process itself as well as institutional governance options would need to be further explored and developed with transdisciplinary expertise from various disciplines, e.g. adaptive participatory planning, political, organizational and communication sciences etc.

Nevertheless, the draft will be partly described in the following as if it were currently happening, in the present tense. This '**envisioning style**' should provide a concrete idea of (or wishful thinking about) the process – like the plan of a building or landscape garden – which can spark further ideas from others. In this way the envisioned LQM process described by graphics and text can become the object of discussion, design and improvement, and hopefully realization in the future (cf. Meadows 2012).

The envisioning style is marked with a different font. It helps avoid too many conditional 'woulds' and 'shoulds'. The explanatory parts, including citations, will be written as before.

3.1 Installing the process within and across boundaries

The overall goal of the LQM mechanism and its professional activities is the maintenance and continuous improvement of regenerative ecosystem services and their landscape qualities. Furthermore, the objective is to provide a concrete reference framework and flexible procedure, which allows the assessment and development of the sustainability of biomass production as well as of other production and land use systems in a standardized but adaptive and locally unique manner.

The landscape reference system is to be considered a normative framework for local action, which could be implemented on a voluntary (e.g. certification system) or legal basis (e.g. like the standardized procedure of the Water Framework Directive). A critical issue is the clarification of responsibilities and decision making competences of the landscape quality managers. This is dependent on how the process will be implemented institutionally. Installing the LQM process thus means installing an operational landscape quality management body within some sort of landscape governance structure.

In the voluntary case the LQM team may act as pure facilitators with low decision making competences, mediating between existing legal institutions and various interest groups and eventually acting as a voice of low impact groups. The reference system elaborated by the stakeholders will provide a vision and orientation with a non-binding status. It may form the starting point of agreements and contracts on a voluntary cooperative basis, initiated and coordinated by the LQM team. A problem of such an option is that not only highly motivated managers, but also highly motivated stakeholders are needed, who invest their work time or dedicate their leisure time to the mechanism. To maintain stakeholders' interest and their long-term participation, the outcome of the stakeholder process should directly and quickly feed back into political decision making processes (Fraser et al. 2006, 126) or create other tangible benefits for the stakeholders (Roux, Heeb 2002).

A more binding option would require a clear legal mandate. The LQM team then may act as operational managers governed e.g. by a board of directors from democratically legitimized institutions. Further research is needed to explore suitable governance options according to different national-regional situations.

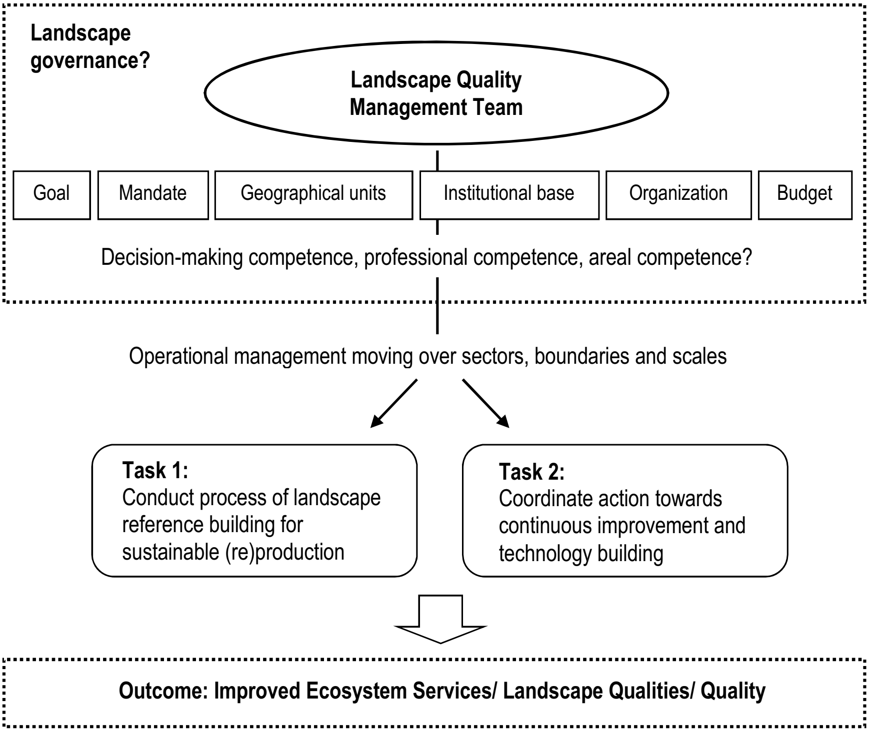

Figure 13: LQM as operational management within landscape governance (author's portrayal, based on matrix shown in Annex 3)

Once a governance structure is set, a professional interdisciplinary landscape quality management team is established. Ideally, the professionals of the LQM team cover different occupational fields and have very good communication and leadership skills. Their competences reach from landscape architecture, geography, ecology, agronomy, and engineering to business consulting, psychology, and communication, to name just a few. Generalists showing education or experiences in management affairs are preferred over specialists. Specialists are consulted on

demand. The landscape quality managers are highly motivated, dedicated to sustainable development and devoted to the overall goal of the mechanism.
The LQM team performs two tasks (Figure 13): (1) It executes a multi-scale stakeholder process developing a regional landscape vision and reference system[85] *for sustainable biomass (re)production or more general sustainable (re)production; (2) It initiates and coordinates various strategies, measures and actions according to the criteria, targets and priority areas etc. laid out in the reference system.*

Along with decision making competences, areal competences need to be clarified. One requirement to the mechanism is that spatial management units should match ecological-processual areas (page 157). Putting ecosystem services and their qualities in the center of the mechanism means that different ecosystem services providing units on multiple scales are to be considered. Furthermore, management units should correspond with units for which meaningful indicators apply and data can be gathered. What does that mean for the installation of the LQM process and its activities? On the one hand the management and its competences should be bound to clearly delineateable, undisputable, spatial units; on the other hand it should be free to communicate and cooperatively operate over different relevant territorial units.

In Section 2.3.3 it was proposed to work with watersheds, habitat (network) areas and landscape character or identity areas as meaningful spatial units for ecosystem service bundles beyond political administrative boundaries. One option could be to closely link LQM to river basin management. The advantages of basins or sub-basins as units are:

- The basic service triangle is closely bound to the water flow in the landscape; there is also a close relationship of other services to water quality and quantity.
- Watershed boundaries are usually undisputed and globally well-recorded.
- Watersheds are realized on nested scales (in drylands as drainage basins with non-permanent water flow).
- Also in cityscapes watersheds can be distinguished as rainwater, drinking water and urban sewer districts.

Another option could be to establish LQM as a full-fledged part of regional management operating in landscape character areas. Although such units may be fuzzier, they also have clear advantages:

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[85] ‘Regional’ and ’multi-scale’ mean here that the stakeholder process is conducted on a ‘regional level’ and simultaneously involves other scales. The multi-scale procedure and reference system is further described in the next chapter.

- Landscape character areas reflect the ‘landscape approach’ well.
- People recognize and identify with them in their daily life. This is highly important for raising public support.
- Cultural services will appear more tangible.
- Well recognized landscape character images may support quality product branding.

In any case, LQM should be clearly linked, but not restricted, to such units. Rather it should be free to simultaneously consider the other units as ‘landscape layers’ and to co-operate across their territorial boundaries. Furthermore, LQM must have a clear organizational structure, an operational base (secretary, facilities etc.) and a budget. This directly leads to the ultimate question of how the whole mechanism and its measures are financed and who pays. This question is closely coupled to the question of institutionalization and can also not be answered in this study.

However, an interesting option could be to embody a LQM activity within watershed trusts or landscape trusts devoted to the long-term sustenance of landscape qualities. Such a trust may be incorporated in the sense of a “common property trust”, as suggested by Barnes (2006, 84, 87), dealing with the issue of property rights of public goods such as ecosystem services. Barnes’ vision is that of a third mode of capitalism “Capitalism 3.0” (ibid.) in which the commons have their own institutions and property rights and are managed with a legal responsibility for future generations beyond the private sector/ state dichotomy. This vision seems very interesting for Landscape Quality Management, since the whole ecosystem services concept has an analogy to economics and economic actors are main addressees of the envisioned LQM standard as well as the underlying (Re)Productivity approach.

3.2 Integrating levels and scales

Another requirement for the mechanism is the integration of various levels and scales (page 157). This basically means to consider multiple spatial and temporal geographical scales and organizational levels in parallel and to link them in communication and organization (Staljanssens et al. 2003). Integrating scales is necessary on both the supply and demand sides. On the supply side the processes and activities providing ecosystem services operate over different spatial scales and time periods. On the demand side weighting and valuation of landscape functions, services and qualities may be different on different societal organizational levels. Furthermore, multiple scales need to be considered with regard to interactions of ecosystem services and land use/ land management activities stretching over a range of scales. I.e. local activities and local changes of ecosystem services can accumulate to global impacts. Vice versa global changes influence local activities and the delivery of services. Therefore, communication should flow in two directions:

The mechanism works both ways, bottom-up and top-down, in the form of three interlinked sub-processes operating in parallel (Figure 14):

1. A regional stakeholder process
2. A local process reaching out to land users and the public
3. A global process on international level

The regional stakeholder process is the core process. It elaborates the landscape reference system and coordinates action. The global and the local processes feed in values and knowledge. They regularly give feedback to (intermediate) outputs of the regional process. A fourth process, which maintains the standard itself and provides for training and quality control, acts on a 'meta level'.

Regional process

The regional scale is ambiguous and may actually span over several scales. Continental UNCCD regions, ecoregions, European political regions, areas of regional planning, landscapes from a high viewpoint or from a birds' eye view, and larger ecosystems like the tropical rainforest, etc., may all be assigned to a 'regional scale'. For the purpose of LQM, however, a level somewhere below European regions or sub-basins and above local community level seems adequate.

A general LQM manager is responsible for conducting the regional stakeholder process and leads the LQM team. In the team there may be designated 'service bundle managers'. However, sectoral splitting of single services and service bundles is avoided. Rather, the managers encourage communication between sectoral institutions and work out synergistic measures. By collaborating with their LQM colleagues from other catchments or regions they make sure that the services are addressed at the relevant spatial landscape units and scales.[86] *Generally, a high level of communication, coordination and cooperation characterizes the working atmosphere between the managers themselves as well as between managers, stakeholders and actors. 'Designated advocates of future generations and other life forms' participate as stakeholders. Further underrepresented groups are supported.*

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[86] In a mountainous area, for example, quality managers of the 'recreational service bundle' from neighboring basins may work closely together. In terms of flood protection, managers of the basic service triangle collaborate in higher-scale watersheds like major European river basins (e.g. Danube, Rhine etc.). Managers dealing with habitat services for migratory animals will coordinate their activities along migratory routes, possibly over far distant regions on the global scale.

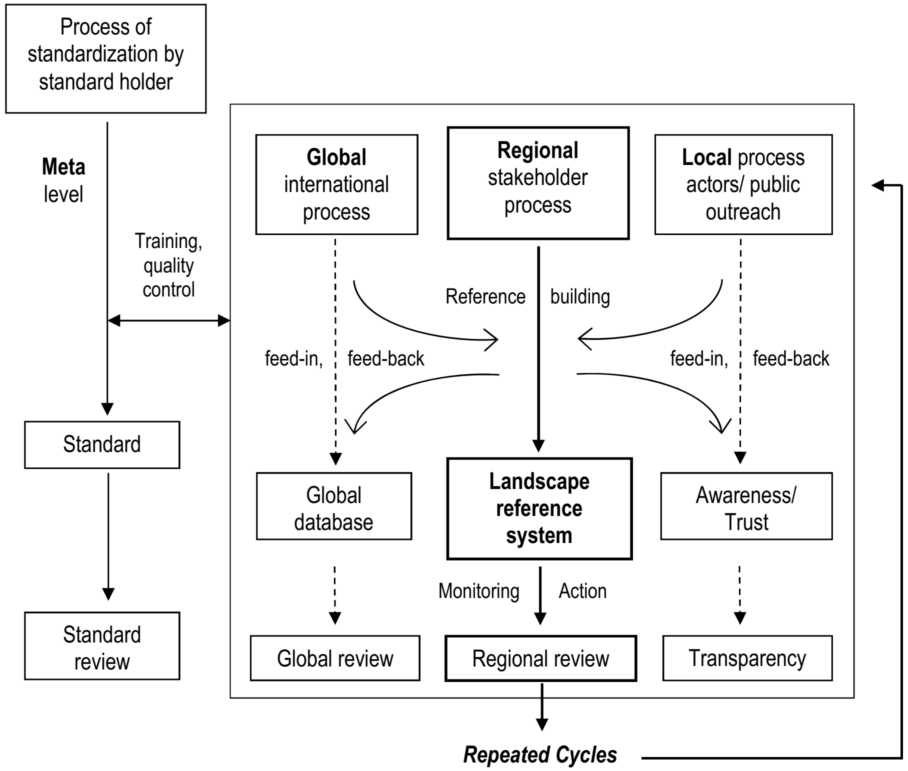

Figure 14: Parallel processes of the LQM mechanism linking levels and scales (author's portrayal, based on matrix shown in Annex 3)

An institutional and stakeholder analysis in the beginning of the process can identify legal institutions actually controlling certain ecosystem services (e.g. authorities dealing with soil protection, flood protection, etc.), as well as further relevant stakeholder groups to be involved. The literature on stakeholder consulting and participation is vast and could not be reviewed here. Only a few thoughts should be explained:

With regard to landscape quality, as the total characteristics of dynamic patterns qualifying the landscape as common living and production space, basically everyone – every physical and legal person, but also other creatures – living in, acting in, using, visiting and appreciating a landscape with its features and resources, is a stakeholder. Public consultation therefore is a major ingredient of the mechanism. As there are various uses and interests 'at stake', different more or less organized land user or interest groups can usually be identified as stakeholder groups to be represented in the regional process. However, according to the requirements on the mechanism, often underrepresented groups like women, youth and indigenous people should be given equal access (page 157). The LQM mechanism will explicitly stimulate and support their participation.

Furthermore, there is the problem of how to consult future generations and non-human species. Although it is not possible to speak with them directly[87], it is still possible to at least consider them and their needs from an empathetic human projection standpoint. The question basically is how can the demands of future generations and other living communities in the landscape area be identified and taken into account in the mechanism in a meaningful way. Any assertion stating that this is not possible would render the whole exercise of sustainable development obsolete. While many demands and needs will be unknown or highly speculative, some of those relating to humans and other beings as bio-physical and social members of living communities can be presupposed, like basic needs. However, this whole question has far reaching ethical implications which deserve a broad societal discussion. The reflection part of the mechanism is destined for stimulating this discussion (Section 3.3.3).

One possibility may be to appoint 'advocates of future generations' and 'advocates of life forms' acting 'in their name'. These advocates could be highly respected persons who stand out due to their humanitarian or environmental engagement. Or, existing NGOs 'bearing the future and natural heritage in their title and statutes', like the "Women in Europe for a Common Future"[88] or the "International Union for Conservation of Nature"[89] and their regional representatives, could be entrusted with this role.

The regional core process undergoes a few phases. A reference building phase is followed by a monitoring & action phase. A subsequent review phase opens up a new cycle. The reference building phase works as a series of workshops performing in turn in three sub-phases: (1) brainstorming, (2) knowledge building and (3) vision building (see Chapter 3.4). During reference building and monitoring the process follows a strand of assessment (task 1), and during the action phase a strand of innovative development and regenerative technology building (task 2; see Chapters 4.2 and 5).

The reference system gives a vision of a sustainable and desirable landscape future. It concretely describes which conditions, functions, services and qualities should be sustained or (re)generated in the landscape area to provide a favorable living and production space for current and future generations of humans and other living beings. The reference system contains standardized and context-specific criteria & indicator sets and a monitoring system derived from the best available knowledge of regenerative ecosystem services and their spatial-temporal

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[87] Other worldviews may see this differently, for example in cultures where shamans have 'direct' communicative access to ancestors, reincarnating souls or animals.

[88] http://www.wecf.org (accessed 6/17/2014)

[89] http://www.iucn.org (accessed 6/17/2014)

patterns. Legal standards (e.g. the good status of water required by the WFD) are incorporated as minimum requirements. The services are depicted with regard to their quality, relevance, interdependencies, vulnerabilities and changes over time. In line with the vision, the reference system also indicates needs for improvement, timely targets, and priority areas of action. Not a specific reference state, but a desirable future gives the whole mechanism a direction and intention.

The reference building phase (Chapter 3.4) will allow both retrospection to the past and to qualities already lost or degraded, as well as perspective on yet unimagined possibilities in the nearer or farther future. Via the retrospective view past 'natural or historic reference conditions' can be included in the reference system (Section 3.4.3). The prospective view gives room for creative imagination and conscious design of social-ecological systems which are anticipated to perform well in terms of (re)generating multiple ecosystem services and where humans and nature are not thought of as being separate anymore.

A public campaign introduces the mechanism to the public. An interactive internet platform, reports and maps document the whole process and the landscape reference system, complemented e.g. by video clips, comics, exhibitions, information, training and educational material etc. Easy public access is granted to all documents. After the review phase the reference system is confirmed or renewed in each cycle.

Local process

The local scale usually corresponds with community level. It is considered here the scale of smaller ecosystems and sub-subbasins or the everyday landscape visible up to the horizon from a relatively low (not mountainous) standpoint.

The local process maintains individual communication and cooperation with local land use decision makers[90]*, such as land owners, land managers, industry, municipalities, and local communities etc. as well as contact to the interested public. Local landscape or basin managers run this process. They meet farmers in the field, talk to foresters and hunters in the forest, organize workshops at schools and sports clubs, and accompany volunteer nature conservationists, etc. The local managers help actors implement measures. They are capable of speaking in equal measure to all kinds of people, e.g. to mayors, sewage treatment plant operators, business managers, tourists, and pathfinders alike. They are familiar or familiarize themselves with the local landscape and local actors. They are primary contact persons for civilians when land use conflicts occur. The local (lead) managers (or their representatives)*

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[90] If land users or owners are organized at higher levels, e.g. federal states or multinational companies, communication would most likely emanate from the regional scale.

regularly take part in regional meetings and stakeholder workshops. This ensures that personal experiences and a sense of the local situation directly enter the regional process.

Basically, the local process takes up the needs and aspirations as well as experience and know-how of the local people (Section 3.3.2). It builds trust and raises public awareness. It draws the public attention and respect to regenerative services, the creation of value by ecosystems including the contributions of human land managers, and the key-role of water.

Global process

The global scale basically comprises the entire earth system and is governed at the international level. A global LQM process may be established within an international organization, e.g. in connection with the IPBES or the inter-agency UN water mechanism.[91] The global LQM process should define general and, if applicable, catchment or region-specific demands for the landscape area and its quality management, which arise from international agreements, initiatives and research activities. In the first place there are relevant United Nations and intergovernmental conventions like the UNCCD, UNFCCC, CBD, and UNECE Water Convention, etc. Presupposing good coordination and sufficient staffing, national focal points of these conventions could take part in special regional stakeholder workshops and team meetings and bring in values and knowledge from a global perspective. In return, the regional LQM may act as a catalyst for the implementation of national action programs under the conventions in terms of enhancing soil quality and productivity, carbon sequestration in soils, biodiversity and habitat, water retention and quality. The partly sectoral agendas of the conventions will benefit from the integrated landscape approach.

The global process produces a global value and knowledge base on regenerative ecosystem services and their qualitative changes in relation to global land use/ land cover changes (LUCC). It maintains a LUCC-monitoring system by earth observation and works with national governments towards improving relevant national legislation with impact on ecosystem services and landscape quality. National focal points are invited to the regional processes to feed in their perspectives. The regional management reports the results and findings from the regional processes about the status and trends of regenerative services and landscape quality to the global level, where they are collected and synthesized.

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[91] http://www.unwater.org (accessed 6/17/2014)

Meta level

The LQM standard itself will be developed by a fourth process transcending the spatial scales of the other three processes. Its level of organization is therefore called a ‘meta level’. The standard should be ‘owned’ by an independent organization, here referred to as the ‘standard holder’. This organization could be an inter-organizational roundtable, an intergovernmental initiative, an NGO, a private foundation or an umbrella organization of various watershed and land trusts etc. Again, this depends on how the LQM mechanism will be institutionalized. While LQM is envisioned to work area-wide it is very unlikely to be systematically implemented at once worldwide. It may start its operation as an informal, facilitating management system in regions respectively catchments, choosing to do so for various reasons. One reason could be that severe problems of land degradation, extreme events, water scarcity and eutrophication or problems with other basic services requiring regenerative management are encountered in the region. Another reason may be that the region wants to stand out with a high recreational services profile or attract green business. If those regions are successful with the implementation of Landscape Quality Management, the approach may spread further. Certainly a well thought through version of the standard needs to be ready and operational before a regional core process can start in some area. However, the standard will also be improved in the adaptive cycles according to practical experience gained during operation. The standard holding organization will provide corporate identity, training and support to the management. It is responsible for quality control of the regional and local processes. It may grant quality certificates and awards of excellence for regions or catchments applying the standard (Chapter 3.6).

An initial training familiarizes the LQM team with the mechanism. It introduces the intention of the standard, the subject matter of management and the underlying approaches, i.e. sustainability and renewability, natural productivity and (re)productivity, natural capital and (regenerative) ecosystem services, landscape quality and the (re)productive role of water involving (social-ecological) landscape sciences as well as the categories of biomass, biodiversity and wilderness and other associated categories and concepts. The training furthermore introduces the standardized procedure, its framework, phases, cycles and flexibility to adapt if necessary. The LQM team takes care that stakeholder groups and the broad public are acquainted with the mechanism.

Accompanying the process, further training is provided on methods for compiling the context-specific elements, i.e. on best practices of transdisciplinary work and stakeholder/ public consulting as well as on creative methods of vision, synthesis and consensus building. Special focus lies on methods and tools of quality oriented process management and change management (Chapter 3.4).

As Landscape Quality Management is a highly demanding job – due to the need for integrating many landscape requirements, balancing powerful interests, managing change and knowing a bit of everything – the standard holder also provides personal and motivational support. Individual managers can apply for personal coaching, communication and leadership training. A help desk answers questions and provides ad hoc support to managers in difficult situations and stagnant phases. Professional LQM forums enable exchange of experiences between LQM teams of different regions.

The standard holder may charge external institutes – which are not involved in the process as stakeholders – with the task to externally reflect the process. The reflective work provides continuous consulting to the management, supports internal reflection, and helps to resolve conflicts on a meta level e.g. by uncovering hidden value systems or by clarification of terms etc. (Section 3.3.3). However, it may also provide information for quality control by the standard's auditing system (Chapter 3.6).

Temporal scales

Not only spatial, but also temporal scales are to be integrated in the LQM mechanism. Above all the whole mechanism is conceptualized as a continuous process with a co-evolutionary *long-term* perspective of sustaining natural productivity through a socio-economic mode of (re)productivity. In the case of trusts as suitable institutions, for example, this long-term orientation can be legally fixed in the statutes (Barnes 2006, 84, 87). 'Advocates of future generations and other life forms' will give this perspective 'its own personal' voice. By cooperatively linking decision making processes of land-use, land management and technology development to Landscape Quality Management, its long-term view can influence more short-term economic perspectives. Furthermore, LQM has a focus on preventing irreversible losses (Chapter 2.3.5) determined by time scales relevant for human societies.

Temporal life phases of humans are considered in the process by capturing different needs of differently aged societal groups, e.g. of the elderly and the youth, towards the landscape on the demand side. On the supply side different generational cycles of ecosystem service providers and temporal phases of their metabolic activities are considered, e.g. in model building and monitoring. Reasonable periods of observation and measurement intervals play a role, especially in the determination of indicators and the interpretation of the data. Decisive is whether temporal scales on the demand side match with those of the supply side. For example, rain-fed agricultural production is dependent on regularly recurring rain events on the demand side. It cannot be sustained if drought periods extend over an 'unacceptable' time span. The 'supply of precipitation' by climate regulation services, however, is not ultimately given. Multiple actions may be required for creating storage and buffer capacity e.g. via rainwater harvesting and soil moisture retention through best land management practices as well as for reducing the probability of extreme events toward more ‘reliable’ weather patterns.

Generally, it depends on how spatial-temporal processes of human land use and production activities can be designed and interlaced with those of other living communities and environmental driving forces, so that together they yield high quality services bundles. The spatial-temporal patterns of the water flow thereby play an important role. Water mediates energy and matter flows and synchronizes processes of life. Since most processes are highly dynamic (i.e. non-linear), not only temporal scales are an issue, but also other temporal features such as points in time, breaks, process velocities, and time lags, etc. (Cowling et al. 2008). With regard to substance flow management and the sustainable use of soils, Kümmerer et al. (2008, 2010) therefore suggest a temporal analysis or diagnosis and impact assessment. The knowledge building phase (Section 3.4.2) of the mechanism should thus involve temporal assessments.

The LQM standard establishes a feasible time span for the adaptive cycles of the LQM process, e.g. five years: A cycle starts with the reference building phase in the first year followed by the action phase lasting three years. The review phase in the fifth year opens up a new cycle. Monitoring and action run continuously, but are adapted in the next cycle.

In the beginning, process installation and the reference building phase in the very first cycle may last longer than a year, e.g. three years. In the cycles thereafter, the reference system must probably only be adapted, not completely renewed. There will be no need to synchronize all LQM processes in regional catchments worldwide. On the contrary, if the cycles of neighboring areas run displaced in time, it may be easier for the global representatives to participate in the regional workshops of the reference building/ adaptation phase. The regional management should publicly indicate which phase they are at. The global and standard review, though, should be a fixed milestone setting binding dates for the regional processes to report their findings. Spontaneous feedback between the organizational levels (global, regional, local, meta), however, will need to happen at any time during the phases for the whole system to be truly operational.

3.3 Incorporating three polarities

3.3.1 Values and knowledge

Values and knowledge are both necessary ingredients of decision making processes. Value systems can span over a full range from individual preferences, monetary values and qualitative rankings, judgements of good or bad/ right or wrong, up to ethical values and moral concepts enshrined in societal norms and worldviews. Knowledge systems can comprise purely descriptive observations, daily experiences, intuition and practical know-how as well as explanatory and predictive, conceptual and computational models, etc. However, the derivation of normative statements out of 'value-free' knowledge, theories or models alone is not possible (naturalistic fallacy). There is always a value component in decisions how something should be, even if it is often unconscious. But measures are not derived out of values alone, either. Forward-looking action, which is essential for a sustainable development, always requires a (more or less) conscious idea of relationships. Values and knowledge are usually interlaced and influence each other.

On the one hand knowledge is often contained in values/ valuations. For example, the knowledge that something is rare, e.g. gold or a certain species, lets people assign a high value to it. Or the experience that someone is always supportive enhances my appreciation of that person. Vice versa, if it is not consciously known to people that ecosystems provide vital services for their well-being, they will continue to take them for granted and neglect them in their decisions.

On the other hand values/ valuations are also contained in knowledge and play a significant role in knowledge generation. The example of 'efficiency', described in Section 2.3.4 shows that a judgment of useful outputs versus losses is immanent to this 'objective' category. The type of object construction and the use of terms in science often contain evaluative elements, as in, for example, the 'biomass' catergory, which reduces diverse life forms and activities to a mass parameter (as described in Chapter 1.3 and Section 2.3.5) or the exclusive use of the notion 'productivity' in neo-classical economics for market activities, which depreciates other activities as 'unproductive' (as mentioned in Chapter 1.1). Feminist literature, especially, has long criticized that hegemonial structures influence academic model construction.

What does that mean for Landscape Quality Management? Value and knowledge aspects should be transparently put together in the landscape reference systems. For this purpose a conscious temporary separation of these aspects makes sense.

The non-market demand and supply sides of the LQM core framework (Figure 10) equally represent both value and knowledge systems in the mechanism. Alternating phases and steps in the reference building process set a focus on either side:

Phase 1 'brainstorming' brings together individual value and knowledge aspects on the landscape demand side in a structured way with regard to the question of 'what is to be sustained in the landscape area'. It assembles a preliminary landscape quality profile. The avoidance of evaluation in terms of good or bad/ right or wrong guarantees an open communication in the beginning.

Phase 2 'knowledge building' collects existing data and draws on different types of knowledge to gather information on the landscape supply side. It eventually uncovers hidden values by reflection and generates place-based knowledge on the quality-creating processes in the landscape and their trends over time.

Phase 3 'vision building' consciously integrates the results of the previous phases. Based on the knowledge produced in phase 2 it reevaluates the preliminary profile of phase 1 and builds consensus on a landscape vision as well as measures for action.

3.3.2 General and context-specific aspects

The reference building phase incorporates general and context-specific aspects of both knowledge and value components, such as general and context-specific categories, models, criteria & indicators, ethical and value considerations, etc. 'General' are those aspects which are basically valid and applicable in all regions of the world. They necessarily show a high degree of abstraction and generalization. They make up the 'standardized part' of the mechanism. Context-specific are those aspects which are unique and appear in a specific environment, constellation, phase or situation. They show a low degree of abstraction/ generalization and are concrete/ discrete. They make up the 'adaptive part' of the mechanism.

Examples of general knowledge are the processor properties of water and its 'green' and 'blue' flows in the landscape partitioning solar energy fluxes. In contrast, discrete water cycle dynamics by specific plant/ soil organismic communities in a very specific topographic and climatic situation represent context-specific knowledge aspects. A general value aspect is, for example, the moral concept of intergenerational equity underlying sustainable development. The contribution of regenerative ecosystem services to human well-being and economic productivity is another general value aspect to be recognized during the mechanism. While the protection of biodiversity is a general normative concept given by policy, different, individual, ethical attitudes towards other living beings, their needs and 'rights', may show up in the stakeholder process, which needs to be negotiated context-specifically. Another example of context-specific value aspects are distinct landscape characteristics appreciated by the local people for providing identity and recreational value.

Not only the content but also the form of the LQM process itself involves general and context-specific aspects. The proposed phases and steps constitute a general standardized procedure. However, the procedure is not meant to be perfectly strict. According to the context-specific situation steps can be condensed, further steps inserted and their sequence varied. The management should have the freedom to design ‘their’ LQM process. The standard, however, predefines what is to be covered and worked out, and incorporated at a minimum.

As already mentioned, it is proposed here that the general aspects assembled in Chapters 1 and 2 should largely determine the standardized core-content of the LQM mechanism. How these aspects can apply to the various recommended phases and steps is indicated in the row ‘Standard’ in Annexes 4-6. Furthermore, what will be accepted as ‘general’ (i.e. valid and applicable in all regions of the world) during the global process could be taken into the standard after the review phase. However, general aspects will not simply be prescribed by the standard. Instead, when possible a common understanding should be constructed during the process. As a basic principal, general aspects must be validated within the local context.

To comprehend the context-specific aspects, good local knowledge and long-term observation over time are needed. This is often not possible in temporally limited research projects in which insight into the ‘generally valid’ is sought. For this reason the experience of those with local knowledge and of long-term residents familiar with the particular area and its history, as well as the experiences of observers of nature and practitioners, or traditional know-how, etc., are all valuable sources of knowledge for LQM. Mobilizing this knowledge is a special challenge for the management within the process. For the science this could mean, in contrast, placing more weight on the analysis of place-based relationships. In ecology for example both knowledge strands – general and specific – are present. The knowledge of the specific could attain more significance through LQM.

3.3.3 Projection and reflection

As human products, value and knowledge systems are projections on nature. They draw a picture of nature and determine a relationship with nature. One could say that they form a ‘constructed reality’ (Glaserfeld 2005; Watzlawick 2005), which influences individual and political action to a large extent. A constructed reality should not be confused with the ‘ontic reality’ (which we are not able to fully recognize), but is real in the way that it actually takes effect (ibid.). For example, the construction of the ‘productivity’ category in economics associated with the model of the ‘homo oeconomicus’, independent of social and ecological relatedness, carries such a constructed reality with it. The organization of working environments and market structures within society according to these model assumptions has a great influence on the behavior of people, corporations and politics (Biesecker, Hofmeister 2006; Jochimsen 2005). But ecological categories can also evoke constructed realities – as shown with the biomass category, which supports a massive appropriation of living beings as resources. So too can categories on which LQM will be built shape different constructed realities whose side effects bear watching.

As already mentioned, the ecological-economic construction of ‘ecosystem services’ implies a utilitarian value approach. Relying on this construct, LQM runs the risk of selecting species and living communities according to their instrumental value. Furthermore, the construction of performance oriented ‘biological-ecological work’ in this study may transfer the principle of an achievement-oriented society (meritocracy) to ecosystems and their beings. If one views other life forms in this sense *only* as a useful ‘labor force’, then their exploitation will continue in another form. But if one wishes to recognize the efforts and achievements of other living beings, it makes sense to consider their life activities to be productive work without reducing them to only this. An exploitation of people as mere workers is e.g. countered through the values of human equality and dignity. Although a direct transfer of such concepts to other living beings is difficult, a basic recognition of other beings as independent sentient creatures is needed (cf. Koechlin 2007).

The question is how nature is seen and which attitudes toward it exist. Besides the dominant view of nature as a resource, other well-intentioned attitudes may also contain an in part questionable image of nature. In opposition to the logic of economic utilitarianism, for example, the approach of ‘nature protection’ implies a picture of a vulnerable and needy nature. Or, the also very meaningful approach of “planetary boundaries” (Rockström et al. 2009) enhances the view of a ‘limiting nature’. In contrast, a picture of a powerful, (re)productive and ‘supportive’ nature – enabling human life and economic productivity in the first place – may be more adequate with regard to considering the work of humans and other beings on an equal footing as well as ecosystem services as ‘gifts’.

However, the reflection component of the LQM mechanism offers the opportunity to become aware of such human-nature relationships and to eventually bring about changes in attitude.

Another pitfall is that the generation of general and context-specific knowledge both open the door for manipulations.[92] This must be opposed by an attitude of ‘living relations’, which esteems other life forms as autonomous beings in communities with their own auto-poetic dynamics, and grants them ‘space for acting freely’. A world view in which the focus on objects is replaced by a focus on (respectful) relations (Dürr 2003) could fit this attitude, as e.g. the feministic view of “Freiheit in Bezogenheit” (freedom within relatedness, translation) (Praetorius 2005). Such a reflection on fundamental world views will be difficult and may not be well appreciated. It need not necessarily be cumbersome, however, but can also be shown in a lively way e.g. by comic drawings. If a change of paradigms and attitude were successful, this could mean, according to Meadows (1999), hitting a high “leverage point to intervene in a system”.

However, beyond this rudimentary philosophical excursus, (self-) reflection is regarded as one precondition of collective learning processes, which was identified in Chapter 2.4 as another requirement for, or necessary component of, a potential LQM mechanism (page 156). For example, the steering of individual human action within social structures is supposed to be possible through reflection on the conditions for action and the consequences of action (Giddens 1992 cited in Roux, Heeb 2002, 4/2). Reflection onconditions for action could take place particularly in the LQM knowledge building phase. The vision building phase may be destined for reflection on consequences of action, e.g. through scenario planning.

The LQM mechanism offers various options for reflection and collaborative learning. In a separate reflective process accompanying the whole mechanism, external experts ‘observe’ the process on behalf of the standard holder. They support the management and give feedback on specific issues (grey layer in Annexes 4-6). Moderated internal reflection happens at dedicated steps in the reference building phase. The management maintains a cooperative atmosphere throughout the mechanism. It embodies a respectful attitude towards all participants of the process as well as life and living beings in general.

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[92] I was very impressed by a lecture from a scientist who conducted research on the life habits of an Indian tribe in the rainforest. In order not to put the integrity of their way of life at risk, she decided not to publish her research results.

3.4 Reference building in three phases

Referring to something actually means relating one thing to another. Developing a landscape reference system and managing various qualities of landscapes thus means to actively set things in relation, especially:

- the action space of individuals on a field scale in relation to the landscape as a whole,
- present action in relation to a desirable landscape future and quality vision, and
- human activities in relation to the activities of other living communities.

In this chapter the three proposed phases of regional landscape reference building "brainstorming", "knowledge building" and "vision building" are described in more detail, based on the graphics shown in Annexes 4-6.

Horizontally, each figure outlines a possible timeline of one phase. The array of squares, however, is not to be understood as a fixed sequence of process steps. They are rather meant as building blocks of a series of regional stakeholder workshops giving the process comparable content and structure. Directly biomass related work packages are marked with grey dots.[93] To reiterate, the management will be free to 'construct' the reference building process 'out of these blocks' according to their needs. During the initial training and possibly with the help of external consultants (e.g. process managers, communication trainers, social scientists etc.) the management should plan 'their process' in advance and adapt it while the process is running.

The success of the process highly depends on good leadership and moderation. The process offers many opportunities for the application of methods and tools from the fields of informal planning, participation, process and project management, change management, collaborative learning, visualisation and envisioning, synthesis and consensus building, and conflict resolution etc. (see for example Danielzyk, Knieling 2011; Cowling et al. 2008; Roux, Heeb 2002; Kostka 2008; Kostka, Kostka 2007). The standard, though, will determine a set of textual building blocks which are to be covered. These can be split, assembled, rearranged, reiterated, and complemented as the regional circumstances and the ongoing process require. Further blocks can also be added. However, as the whole exercise is complex enough, the process should not be 'overloaded'.

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[93] Instead of or in addition to bioenergy related work packages, other thematic or sectoral blocks could be included, depending on which activities or leading themes are in the regions' actual focus.

Vertically, i.e. across scales, the building blocks of the regional stakeholder process are linked with:

- the conceptual/ theoretical building blocks of the standard (*meta* level) as supposed and elaborated in the other chapters of this study,
- possible sample components of a *global* value and knowledge base,
- possible methods and tools to grasp and make available *local* values and knowledge,
- possible scientific studies investigating context-specific aspects with regard to the *regional* (evtl. trans-regional) and *local* scale, as well as
- possible topics of reflection (*meta* level).

The process draft and its phases are especially inspired by the principles and components of a quality oriented process management (see right column in Annex 3).

3.4.1 Phase 1: Brainstorming – shared perspectives

A first step of quality oriented process management in the business world is – according to its customer focus (Principle 1, page 158) – to ascertain the client demand, which determines the quality and value of a product (Kostka 2008, 52f). Transferring this principle to LQM means to assess individual and societal needs, requirements and expectations towards a specific landscape with a view to sustainable development. Phase 1 will collect and exchange individual perspectives from the stakeholders (including 'advocates of future generations and other life forms') and the public on the landscape demand side and match it with legal, global and the standard's requirements. It will set the scene for a collaborative learning atmosphere (Principle 2: Leadership, Principle 3: Involvement of people, page 158f).

Introduction of process and landscape category

At the beginning of the workshop series the managers introduce the process to the participating stakeholders and explain its objective, basic structure and phases. In an initial brainstorming participants display pictures, paintings and maps of the landscape they live and work in. They point out typical features and favorite spots, and share landscape names and stories. Via the display the meaning of 'landscape' and its relation to terms like 'territory', 'environment' and 'ecosystem' is discussed along with the ELC definition and the subjective/ objective and naturalistic/ culturalistic aspects of the landscape category given by the standard. The participants also present their individual associations and images of what they understand by landscape quality and the specific qualities of 'their' landscape.

Demand side collection, clustering & rating

A second brainstorming addresses the basic question of what – in the light of sustainable development – should be sustained in the landscape area. Eventually, the brainstorming question is split into a few simpler questions (e.g. what do we need and expect from the landscape, and what do we admire and enjoy in the landscape?) and may also relate to the supply side (e.g. what do we obtain from the landscape and its living communities?). Collected brainstorming results are grouped by perceived associations and similarities and are related to each other. Furthermore, the participants rate the clusters according to their individual preferences and gauge their significance for sustainable development, e.g. by giving points. The results are collected and synthesized by the management.

Biomass sources and technologies survey

The management issues a study on presently used and potential biomass sources in the region, their land-use pattersn and conversion pathways as well as trading schemes and market options. The results of this study are presented in the stakeholder forum. Competitive uses of biomass and existing or potential land-use and land-right conflicts are discussed, especially with regard to the results of the demand side brainstorming.

Relation of brainstorming results to standard framework

The management introduces the standard demand and supply framework with its categories of landscape functions, ecosystem services and landscape qualities/ quality objectives.[94] *It explains the political relevance of these categories with regard to national/regional policy, EU policy and the European Landscape Convention. The participants are asked to locate the brainstorming results on the framework. There usually is a great deal of discussion on classifications, i.e. where things should be placed. However, the discussion helps to clarify relations and sort out the demand from the supply side. Those brainstorming clusters and items that do not at all correspond with the frameworks categories are 'stored' and dealt with later.*[95]

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[94] One could also introduce the framework earlier in the process and, more concretely, ask for functions, services, and qualities to be sustained in the landscape area. An initial introduction of the framework and categories would give a clear structure, but may miss out on some items. The brainstorming in the beginning should provide openness, while the standard with its predefined categories represents structure and more 'closedness', since a question - with more or less predetermined categories - inevitably influences the results. To balance openness, which is essential for the creativity of the process and for capturing stakeholders' perspectives, with the requirements by the standard (structure/ closedness), which is essential for comparability and quality control, will probably be a basic challenge, not only in this phase. However, the implications of a 'more open or closed process' for e.g. stakeholder motivation, collaborative learning and selection of results, which are important issues requiring social scientific competence, are not the subject of investigation here.

[95] In the review phase it should be checked whether and how to include those items in the standard's conceptual basis.

For this step it is assumed that most of the brainstorming results can be related to the categories of landscape functions (LF), ecosystem services (ES) and landscape qualities (LQ) or located elsewhere on the assessment framework (e.g. processes or features supporting ecosystem services on the supply side). For example, in the brainstorming session results like "soil productivity", "soil fertility" and "erosion prevention" may come up. They could be grouped into a "soil services" cluster and located on the 'ecosystem services spot'. Or results like "open views" and "beautiful scenery" may be mentioned. They could be located on the 'landscape qualities spot' and linked with "recreational function" on the 'landscape functions spot'. A result like "old trees", for example, could be linked with educational and spiritual services, but should be placed on the supply side, as old trees are structural landscape features which may provide multiple services at once. Double placements are also possible. In the case of "biodiversity" as a brainstorming result it could and should be placed both on the demand and supply sides as explained in Section 2.3.5.

Reflection on (Re)Productivity and productive biological-ecological work

The management or experts from the standard holder explain the distinction of production services/ functions from regenerative services/ functions by referring to the (Re)Productivity approach, the concept of biological-ecological work and the sustainable (re)production rule. The forum reflects on (non-commodified) value-creation in the landscape and the contribution of landscape-quality-delivering regenerative services to health, well-being and a productive economy and society. It also reflects on how the economy systematically produces nature-culture hybrids, and how natural productivity and ecosystem services are both input and output of economic production and consumption. Based on this reflection the landscape is discussed as a common living and production space of human society, its economy and other living communities.

Agreement on landscape demand and priorities/ output

At the end of the "brainstorming" phase there is some sort of agreement on what is considered most significant on the landscape demand side and is taken into the next phase "knowledge building". Participants give their personal impression of how well the listed functional and qualitative landscape demands are met by the current regional supply. This gives a preliminary landscape quality profile, which serves as a basis to identify priorities for Phase 2.

However, with regard to sustainable development the 'client demand' in this process is not fully negotiatable, but needs to meet the criteria of the standard. As items considered important by the standard could be missed by the brainstorming, the results so far should be compared with a "master list of ecosystem services" (Groot et al. 2010a, 277) including the regenerative services as obligatory items. However, the master list should be general, not habitat dependent as Paetzold et al. (2010) suggest, since as argued here, the provision of regenerative services is dependent on a discrete distribution of processes operating over a variety of habitats and land use patterns.

Local and global input

Many creative tools and techniques can enable and encourage public participation. The establishment of an internet platform and local LQM contact points, which provide interfaces for continuous interaction and keep documents available for public access, should be standard. Furthermore, land art events locally celebrating landscapes, cityscapes or waterscapes and their services and qualities could introduce and accompany the process and stimulate public discussion. Local radio talks and TV series, interactive exhibitions and interpretative field visits or thematic walks offered e.g. by NGOs may have a similar effect. Stakeholders should be encouraged to conduct workshops parallel to the regional process in the organizations they represent. Communal roundtables, school classes and student projects could work in parallel on some of the building blocks. The task of the management will be to carry out a public campaign, coordinate the outreach activities and integrate the findings into the stakeholder process.

Representatives of national contact points from global conventions and other initiatives should be invited to define general and, if applicable, region specific landscape demands from the background of a global value and knowledge perspective: e.g. regarding specific biodiversity hotspots, carbon sinks and sources, water scarcity, globally significant nutrient flows or heritage sites, etc. The global process could support the regional processes with a multilingual glossary of key terms, an overview of classification approaches, a master list of services and a typology of landscape quality aspects, etc. Furthermore, it may present facts and trends of global biomass production, appropriation and trade.

Scientific studies and reflection

Scientific studies from many different disciplines as well as inter- and transdisciplinary cooperation will inform, consult and accompany the whole process at all scales. At the regional and local scale the scientific task would mainly be to capture contextual place-based conditions, situations, knowledge and perspectives as well as reflective investigations. For the first building block of the brainstorming phase this could mean, for example, to geographically determine and visualize different landscape units like watersheds, bioregions, ecosystems, named landscapes etc. and to synthesize available data. In parallel, a social-scientific mapping with lay persons may reveal a perception and appreciation of landscapes and ecosystems at different scales (Grodzynskyi, Grodzynska 2009). A subject of reflection in this regard would be to compare the scientific and lay opinion and, together with the management, find common ground of ecosystem and landscape understandings for process departure. Furthermore, within or before the brainstorming phase, a compilation of legal landscape demands should take place, together with an institutional analysis as well as a collection and review of existing studies and research projects, landscape plans or regional plans, etc. dealing with ecosystem services, landscape functions and qualities in the landscape area of relevance. Besides studies on biomass use and potential, studies dealing with the acceptance of bioenergy and certain technologies could be conducted. Another critical research question could be how the segregation of productivity and reproductivity shows up in land use and people's daily life. A "social assessment" identifying beneficiaries of ecosystem services and the "needs, values, norms and behavior of individual, institutions and organizations in the study area" as e.g. suggested by Cowling et al. (2008, 9484) may also be the subject of reflection and support for the management.

3.4.2 Phase 2: Knowledge building – common understanding

In quality oriented process management a second phase is to describe and make visible the value creating processes (value as determined by the clients' quality requirements), their actors, activities and interdependencies and to identify potentials for improvement (Kostka 2008, 61). This typically also includes the identification of indicators and data which allow an initial performance evaluation or later measuring of success. Applying these principles of a tri-partite process approach, system approach and a factual approach to decision making (Principles 4, 5 and 7, page 158f) in LQM would mean to describe and make conscious the key ecological processes and interactions, ecosystem agents and landscape features as well as human activities which deliver regenerative services and (re)create the various aspects of landscape quality as determined in the previous phase; and to develop a robust monitoring system. Thus, Phase 2 will concentrate on acquiring and sharing (place-based) knowledge, data and information on the landscape supply side.

Pattern and process mapping

The management collects existing geographical data and information which can be associated with regenerative services and landscape quality aspects. With the help of scientists, planners and designers they assemble a landscape atlas. The atlas shows characteristic physical landscape features such as relief, water system, land use/ land cover, and soil types, etc. as well as various functional patterns such as surface temperature distribution and heat islands, direction of water flow with temporal flooding and inundation areas, water quality in surface and groundwaters, soil quality and zones of erosion risks, (protected) habitat areas, recreational hotspots and coldspots, important sceneries and viewsheds, distribution of specific cultural and *spiritual landscape features, etc. Landscape portraits with typical elements, narrative descriptions, poems, photographs and paintings (some of which have been displayed in the initial step of the brainstorming phase) illustrate the atlas and impart an atmospheric impression. Important landscape and ecosystem features, processes or compositions which provide regenerative services are first sketched and described conceptually then located within the landscape atlas and displayed e.g. by time series or video clips.*

Reflection on biomass and (re)productive role of water

As it is impossible to capture all processes, the mapping concentrates on the key activities delivering services and maintaining quality as well as main supporting processes. The management or experts from the standard holder present the (re)productive key role of water for regenerative services and discuss it with the stakeholders. The forum reflects on the meaning of biomass as mass/ tissue of living beings performing productive work with their specialized functional traits. It also reflects on biological-ecological work fuelled by 'bioenergy' versus technical work as well as a broadened scope of 'renew-Ability'. If new insights arise, the pattern and process mapping is revised.

Identification of indicators and spatial units

Following the reflection about water, the stakeholder forum discusses the four ecosystem service bundles proposed by the standard. The management or experts from the standard holder introduce the concept of landscape efficiency and its two indexes as trend indicators for the basic service triangle mediated by water, as well as a few more indicators per bundle given by the standard. Furthermore, indicators defined by European and national legislation, e.g. on water and biodiversity, are collected and related to the landscape demand and supply framework. Beyond these standardized indicators the forum discusses further indicators and monitoring schemes for ecosystem services and various aspects of landscape quality not covered yet. They map points and areas of measurement and suitable spatial units for assessment. Not only quantitative parameters are considered but also qualitative indicators and imaging technologies. Monitoring techniques match data availability. They comprise a broad range of techniques like simple field methods, remote sensing, expert judgements, and periodic interview series, etc. There is an explicit focus on the interpretation of spatial-temporal patterns and their characteristics.

With regard to feasibility the indicator and monitoring set should be manageable and comprehensible for the public. It may help to arrange indicators on a supply-demand scala. Some indicators which allow tracing back past performance, like lake sediment parameters, should also be considered for the landscape history and trend inventory.

Landscape history and trend inventory

The management issues a study on past landscape development. Designers create an exhibition and 4D-animation of landscape history. The study, exhibition and animation display the landscape formation since significant geological time periods, like the ice age, land cover/ land use changes and changes of management practices associated with historical epochs and technological innovations, as well as the associated development of some services or quality aspects. The stakeholder forum discusses the landscape's history, especially processes and activities that led to a degradation of ecosystem services and landscape quality. The management takes care that the discussion is neutral, avoiding blaming certain groups or actors.

Thematic discussions on trade-offs and synergies

The management initiates a couple of thematic discussions on past, present and potential trade-offs and synergies between services, especially between the use of biomass (production services) and regenerative services. Regarding trade-offs a focus is on irreversibility, i.e. irreversible losses in terms of landscape efficiency connected with soil ageing, irreversible loss of precious landscape features like old growth forest, and the irreversible loss of species. The forum reflects on 'biodiversity' as the counterconcept of 'biomass' and the double role of biodiversity as a service provider on the supply side and as a value in itself on the demand side. Another topic of reflection is 'wilderness' and the usefulness of 'non-use'/ 'non-harvest' of biomass.

Synthesis on knowledge base

A synthesis of results at the end of the knowledge building phase gives an overview on the status and trends of the landscape supply side as well as a draft concept for a criteria-indicator-monitoring system. Knowledge and data gaps are identified.

Local and global input

Direct communication of local landscape managers with land owners and land users as well as local authorities, NGOs and local people will be the most important source of gathering situative, traditional and practitioners' knowledge on processes and patterns or indicators and practical field techniques. As in the brainstorming phase, public participation e.g. in landscape history and thematic discussions can also be supported by a variety of creative and interactive methods.

The global level may support the regional level with ecosystem services fact sheets explaining typical processes, functional traits and spatial-temporal patterns, a case study collection (see for example Paetzold et al. 2010, 270), and a database on useful indicator and monitoring schemes. Furthermore, the maintenance of a GIS land use register and global monitoring of land use change, as proposed by the German Advisory Council on Global Change (WBGU 2008, 17), could take place within the global mechanism.

Scientific studies and reflection

Much of the contextual knowledge generated and discussed in this phase will certainly be delivered by scientific studies, e.g. by ecosystem service assessments. Practical and traditional knowledge, however, should be treated as equally significant. With regard to cultural services, design studies, landscape character assessments and perception based interview studies will be particularly helpful. Furthermore, with regard to landscape history and (non-linear) process dynamics, a special focus should be on temporal diagnosis. Topics of reflection could be the observation of scientific controversies and discrepancies between scientific and stakeholders', practitioners' or public opinions. Selected indicators should be critically examined on conveyance of information, model assumptions and political messages. Human-nature relationships and associated constructed realities should be reflected in both people's attitudes and scientific approaches.

3.4.3 Phase 3: Vision building – shared values

A third phase in quality oriented process management includes the (re)orientation of activities according to a corporate vision and goals. The development of a vision and goals will create process coherency with regard to achieving the clients' present and future quality requirements. They can be translated into concrete (indicator-based) targets, strategies and measures for performance improvement (Kostka 2008, 74ff). Transferring this objective and principle of continual improvement (Principle 6, page 158f) to LQM means to develop a landscape vision and establish measures for the improvement of ecosystems services and landscape quality.[96] Accordingly, Phase 3 will focus on envisioning, scenario and Leitbild development and the derivation of targets and strategies which can guide the managements' and individual land users' actions as well as lay the basis for (biomass) technology building.

Review landscape quality profile

Acquired knowledge has possibly changed the basis for valuation. Therefore, a review and completion of the preliminary landscape quality profile takes place at the beginning of Phase 3. The stakeholder forum also reflects on how the new knowledge has eventually changed their views. Based on a sound landscape quality profile (i.e. match between demand and supply) the forum identifies the highest needs / potentials for improvement and priority areas for action followed by a brainstorming on possible measures and project ideas.

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[96] As previously described this will also include biodiversity as a landscape quality category. One may interpret the last principle 'mutual beneficial supplier relationships' (Principle 8, page 158f) in the sense that the living conditions of other species should also be improved.

Vision/ Scenario/ Leitbild development

Participants gather in different work groups. Together with professional landscape architects and artists they envision a sustainable and desirable landscape future. They make collages, draw, paint, describe, and discuss their imaginations. How does the future landscape look, what does it provide, how does it feel, etc? With participative modelling tools they work on different scenarios which pick up trends, scale up project ideas and reveal consequences of action or no-action. They develop Leitbilder and formulate a vision of where they want to be in 2050 and how the landscape as a whole and in terms of different aspects of landscape quality will have developed by then.

Quality objectives and target setting

The forum translates the preferred Leitbild and vision into concrete quality objectives. There are more functional quality objectives which state the improvement of specific services and aspects of quality. For example, we want to achieve bathing water quality in all our rivers and recycle all our nutrients. We want to increase the carbon content of our soils, reduce heat islands and develop a dedicated share of our land area as high-quality habitats for wild living species. Or we want most of the population content with the recreational opportunities of their landscape surroundings and want to be known as one of the most beautiful landscapes in the country etc. There are also more structural quality objectives. For example, we want to increase the tree cover of our land on hilltops and steep slopes[97]*, as they provide many services, and let some percentage of the trees reach their natural age. Or we want to maintain living standards and prosperity without additional soil sealing, etc. In areas where landscape quality objectives have already been defined, these are built into the LQM mechanism from the beginning along with political targets which pose demands to landscapes, like an increased share of renewable energies. The forum defines and maps the quality objectives in a spatially and temporally distinct way. Based on the indicators proposed in Phase 2, as well as possibly new indicators, the most important objectives are converted into concrete targets. The concept of the monitoring system is refined accordingly.*

The landscape vision, quality objectives and targets may involve ‘natural or historic reference conditions’. For example, the water quality which is found in ‘undisturbed ecosystems’ or wilderness areas may serve as a target for comparable areas or catchments under dominant human land management. Or a past cultural landscape character, which was identified in the analysis of landscape history, could be chosen as a reference state for restorative measures. However, it should be discussed how meaningful this is, as the evolution of the landscape and its ecosystems is irreversible. Nevertheless, a return to such reference conditions of a ‘natural or historic state’ could be consciously included in the landscape vision as a societal desire on the demand

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[97] See e.g. “guiding principles” in Lohrberg et al. (2014).

side, rather than being based on problematic concepts of ‘ecosystem or landscape integrity’ (Paetzold et al. 2010).

Project ideas and action plan

Working groups further develop the ideas that arose during brainstorming, envisioning and scenario modelling into synergistic strategies, measures and project concepts. The stakeholders and further partners form interest alliances and project communities. They pick up and create funding opportunities and link with existing initiatives and further partners.

Some stakeholders and partners may form “innovation cooperations” for specific projects, as proposed by Roux and Heeb (2002), to create legally responsible and capable structures. The strategies, projects and measures will be implemented during the action phase.

Complementary biomass strategy

One of the strategies focuses on complementary biomass (re)production. I.e. this strategy selects and supports biomass production practices suitable for the region which do not compete with food production, but complement classical agriculture and other land uses in term of providing and improving regenerative services. A project community brings together interested farmers, farmers associations, researchers, conversion technology firms, water and energy providers, and authorities etc. They investigate various options on field scale and landscape scale and present them to the stakeholder forum. The forum also discusses the use of residues of bioenergy production with regard to soil quality, especially soil carbon content, and recycle-back-to-land technologies.

The concept of complementary biomass (re)production and its implications for technology design are further elaborated in Chapter 4. Here again biomass production stands for various forms of production. Other strategies could address further economic sectors and technologies.

Synthesis/ agreement on landscape development

The end of the vision building phase marks the end of the whole reference building phase. At this point the management presents a synthesis of all the results of the previous phases. Specific outputs are a definite landscape quality profile reflecting the demand and supply status at this time, a landscape vision or development concept, a catalogue of strategies and measures including project proposals or plans, as well as a monitoring plan and action plan for the next phase. The management tries to reach as much agreement as possible on the results, as all this together makes up the landscape reference system. Previous results are also refined and made public, e.g. 4D-animation of historical landscape development, the produced graphics and artworks, evaluation of surveys, and further studies etc. In a final step the forum celebrates *success, reflects on the shortcomings of the whole process, and identifies potentials for improvement for the next cycle.*

Last but not least it is important to note that the landscape vision or concept represents a dynamic development direction rather than a static target state, i.e. an intention rather than a definite goal.

Local and global input

The local management could initiate the development of local visions and measures in compliance with the regional process via inter-communal roundtables and working groups. A public call for projects ideas should be launched. As already mentioned, the direct communication with land users, local authorities, energy providers and other actors will be critical for a complementary biomass strategy as well as other strategies and measures. Just as for the previous phases, the outcomes should be publicly presented and discussed and adjusted if necessary.

Global land use scenarios could be a topic of the global process. The global level may also contribute with a typology of quality objectives and a toolbox of sustainable land management practices. A global synthesis could give recommendations derived from the regional experiences for international policy making.

Scientific studies and reflection

The review of the landscape quality profile could be supported by scientific studies on ecosystem service valuation. Furthermore, scientists may engage in participatory modelling and scenario analysis. Landscape architectural methods will be particularly helpful for Leitbild development and vision building. A continued study on a monitoring concept and feasibility studies for complementary biomass production practices will deliver decisive scientific input.

Possible topics of reflection could be the analysis of valuation and monitoring upon quantitative and qualitative methods, or the analysis of potential conflicts on a ‘meta level’. The investigation of factors of failure and success over the whole mechanism will deliver an important basis for improvement of the regional process as well as the standard itself in the review phase (see below).

3.5 Monitoring and continual improvement of ecosystem services and landscape quality

Continual improvement processes in the business world typically follow a reiterating 4-step procedure, called Plan-Do-Check-Act cycle (PDCA cycle). The planning phase usually comprises problem and state-of-the-art analysis, definition of goals, targets and improvement potentials, as well as development of measures. Measures are implemented in the ‘Do-phase’. The ‘Check-phase’ reviews results and controls success. During the ‘Act-phase’ effective measures are established and standardized. The cycle starts again for adjusting non-effective measures and identifying new potentials for improvement. The whole cycle drives and stabilizes innovation (Kostka, Kostka 2007, 33–41). PDCA cycles are also referred to in standards for quality oriented process management (ISO 2005, 11) and environmental management (ISO 2010). As this cycle actually resembles an adaptive planning and management process, it is used here to structure the draft LQM mechanism (see Annex 3, right column):

‘Plan’ refers here to the whole reference building process including brainstorming, demand specification, process mapping, data collection, status and trend inventory, development of scenarios, ‘Leitbilder’, and targets as well as project ideas and action plans by the stakeholder forum as described in the previous chapter.

‘Do’ refers here to the proactive management activity of the LQM team and the concerted action of single land users, stakeholder groups, project communities, and innovation cooperations etc. to match supply and demand. The LQM team may facilitate the exploitation of existing political programs and instruments like river basin management plans, extension services, rural development measures, intervention and compensation schemes, etc. within strategies and projects. It may also apply other tools e.g. known from regional and ecosystem management like area pools, payments for ecosystem services, or networking firms for regional material flow management, etc. However, there is also the chance to develop tailor-made solutions. In the agricultural sector, for example, one firm is a family farm, one an industrial-scale operation, and another a part-time business. They all have different requirements, motivations, organizational structures and site conditions. One might need investment aid, the other access to machines and the third new ideas. If LQM succeeded in building up its own funds and resources, this would be the most elegant option to implement such individual solutions. But it is also conceivable that funds from regional and rural development programs would be held in trust by LQM under default policy objectives, but not under the stipulation of specific measures or technologies. It would also be interesting to examine whether direct payments to farmers could be coupled to the condition of improving landscape efficiency as a trend indicator. Since local landscape and land managers have the necessary local knowledge and know-how, this would correspond to a true place-based approach, as postulated in Chapter 2.4.

The action of various users and producers on the ground – in bio-physical jointness with the ecological system – will influence ecosystem behavior and induce landscape change, hopefully in the desired direction. Therefore, parallel to coordinating activities and activities on the ground (subsumed under the box ‘Action’ in Annex 3), ‘Do’ also comprises the setup of the monitoring system and the monitoring itself, including collection, administration and interpretation of data obtained from monitoring (subsumed under the box ‘Monitoring’ in Annex 3). The monitoring provides the basis for control of success in the ‘Check-phase’. It is important to note that the management should not seek to optimize single indicators, but instead use the indicator set and monitoring system as a score board. Otherwise, there would again be sectoral management.

‘Check’ refers here to (a) the evaluation of the actual improvement of landscape quality and (b) the evaluation of the quality of the process and standard itself. In this review phase, it is checked first of all on the regional level which improvements on ecosystem services and landscape qualities have been achieved and whether the respective targets described in the reference system in the previous phases were met. During the process, indicators and monitoring techniques are also reflected upon and checked for practical usefulness and conveyance of suitable information. Furthermore the LQM process itself is evaluated, e.g. regarding stakeholder motivation, public participation, strength and weaknesses of steps and tools, etc. Lessons learned should be integrated in the next round. Most likely, many actions on the ground will take a longer time than one LQM cycle to show an effect in ecosystem behavior and landscape quality improvements. Therefore the focus in the first cycle will probably be on the quality of the process itself, while in the continuing cycles ‘landscape quality effectiveness’ (see Chapter 5) will be in the center.

All landscape quality demands and targets as well as the monitoring results should be open to the public. On the local level ‘check’ means to invite the interested public to critically judge the improvement of landscape qualities on a basis of everyday experience, e.g. in public forums, or via the internet platform. Transparency will be a prerequisite of a successful continuation of the mechanism.

The global review may evaluate worldwide trends of ecosystem services and landscape quality on the basis of regionally available data as well as on the basis of global research and land use monitoring where possible. Furthermore, in cooperation with the standard holder and national levels, the global process might check barriers to a widespread application of LQM. These results should be used to review the standard itself and improve its contents, procedure, and quality control mechanisms. The improved standard, adapted to the best available knowledge and experiences, will form the basis for the coming LQM cycles.

‘**Act**’ is understood here in the sense of ‘**adapt**’. It is not thought to be an extra phase, but happens within the next LQM cycle starting with reference building again. ‘Adapt’ can mean to adapt the process itself, e.g. to change procedural steps, to involve new stakeholders, and to expand public campaigns, etc. as well as the reference system and measures. The reference system could be confirmed if no need of change occurs or be adapted to effects of land use changes, actual local to global trends, latest scientific findings, or a shift in value systems. Adaption, however, moves within the textual and structural frame of the standard and its long-term mission of an areawide sustainable landscape development. Indicator sets and the monitoring system may also be adapted according to new knowledge and experiences gained during data administration and interpretation. Measures of the action phase will also be adapted with regard to the new reference building outcomes and changed needs of land use/ land management actors. Additionally, the experiences of the LQM mechanism in several regions may suggest an adjustment of policies including subsidies, if major barriers or contradictions occur between legal demands or incentives and LQM measures, which could be communicated back to policy makers.

The LQM process will never be completed, since ecosystems, societies, markets and technologies, etc. will always change. If a high level of landscape quality is achieved in a region and no change in quality requirements occur, the task is to continuously maintain or reproduce this quality. The LQM activity – continuously caring for the recreation of desirable living and production conditions and landscape quality of life – should be recognized as a vital and valuable, productive and regenerative, societal activity.

3.6 Quality control and the option of regional certification

The landscape reference system is to be considered a normative framework for action, no matter whether ‘solely’ providing orientation, inspiration and a basis for cooperative agreements and projects or having a more binding character. Therefore, the LQM process should undergo an external compliance check and quality control by accredited institutes, besides the self-evaluation in the ‘Check-phase’. Criteria of the quality of the process itself (which are out of the scope of this study) should also be defined by the standard, e.g. equal stakeholder participation, broad public participation, and transparency etc.

Such a **quality control of the process** by an auditory system would open up an option of **regional certification.** This means that the standard holder could grant LQM certificates to registered regions or river basins which prove compliance with the standard’s requirements. A LQM certificate would actually testify that the region provides for a sustainable use and development of its landscapes and resources and that it shows a high ‘landscape quality of life’. Regions could use such a LQM label for regional marketing, attracting visitors, innovative green business and highly skilled professionals, as well as to promote regional quality products. So LQM can be an economic location factor.

For example, regional energy suppliers, e.g. public utility companies, may want to offer their customers electricity from a 100% sustainable renewable energy mix. It would be a competitive advantage for them, if they could transparently prove that the biomass feedstocks they use in the system stem from sustainable production contributing to landscape quality in the region. In such a case, bioenergy suppliers may want to buy their feedstocks from LQM certified local producers. Interested farmers or other land users and production units could register for participation in the LQM scheme, which means that they can test their products and processes against the LQM criteria and the landscape reference system – i.e. their interaction with and contribution to regenerative services and various landscape quality aspects. In return they receive advice and can take part in innovative projects in order to improve their performance in the sense of a co-production of landscape quality. This might result in a win-win situation: LQM helps producers access a quality market segment, and producers help LQM to implement its strategies, e.g. a complementary biomass strategy.

The LQM scheme could also seek approval with regard to the European Renewable Energy Sources Directive and its minimum sustainability standards. I.e. areas with high biodiversity value, high carbon stock value and peatland excluded from biomass production could be integrated within or defined by the landscape reference system according to the Directive’s requirements. Together with GHG calculations and a check of codes of good practice (in cooperation with competent authorities) LQM may attest that individual biomass producers comply with the Directive so that they could receive financial support. Bioenergy from these sources could then count for the mandatory national targets. In this way LQM could also offer low-cost group certification for participating smallholders of the region. Conversely, the definition of the above-mentioned areas would have a solid basis broadly accepted by stakeholders and the public.

As LQM will set quality targets for landscape development, it could provide the necessary reference values for voluntary product certification schemes, especially with regard to trans-regional chains-of-custody. The Roundtable on Sustainable Biomaterials, for example, requires a more or less extensive environmental and social impact assessment, partly involving expert studies and stakeholder engagement, for biofuels operations and feedstock production in its principle 2 with regard to its principles 3-12 (RSB 2013, 2011) concerning:

- greenhouse gas emissions,
- human and labor rights,
- rural and social development,
- local food security,
- conservation (including ecosystem services as conservation value),
- soil, water, air,
- use of technology, inputs and management of waste, and
- land rights.

As argued in the first chapter such an impact assessment should be undertaken with regard to a landscape reference system (such as the LQM system) which displays ecosystem services and quality aspects, their status and trends including cumulative effects in comparison with landscape demand from the perspective of sustainable development. LQM could also take up more social criteria e.g. relating to land rights. For the region this would mean a sound basis for assessment applying equally to different producers. For producers it may reduce complexity and expenditures for expert studies and stakeholder engagement. In this way LQM could ideally complement product-based schemes with its area-wise approach.

However, sustainability assessment, certification and labelling – effective only within a sensitive market segment – is only one aspect of LQM. In the end it will be crucial to design sustainable production systems in connection to an overall management of ecosystem services and landscape quality. LQM thus goes beyond pure assessment in favor of a pro-active landscape and technology development. How this could look for sustainable and complementary biomass production is the topic of Chapter 4.

3.7 Summary and conclusions

The design of a flexible process involving stakeholder, expert and public participation is to assure the ‘adaptive part’ of the LQM mechanism in order to set the general value and knowledge core (developed in the previous chapters) in relation to the specific local conditions, values and knowledge. The draft process presented here is composed of communicative action on three coherently interlinked scales: global, regional, and local plus the meta level of the standard itself; of three reference building phases: brainstorming, knowledge building, and vision/ consensus building; and of three polarities: incorporating general and specific aspects, integrating values and knowledge, and alternating projection and reflection. At the core lies a regional stakeholder process centered on regenerative ecosystem services and their landscape qualities, understood here as the characteristics of spatial-temporal patterns brought about (by ecosystems) and perceived (by humans) in the landscape. With a subsequent phase of action, monitoring and revision, the process forms an adaptive management cycle.

It is envisioned that the process is conducted by a professional Landscape Quality Management activity covering relevant spatial units and equipped with cross-sectoral, transboundary and cross-institutional facilitating and coordinating competences and the necessary resources. The regional stakeholder process elaborates the landscape reference system and initiates and coordinates action. The continual improvement of ecosystem services and their landscape qualities will be the output on this level. The local process collects and feeds in the values and knowledge of land users, practitioners and the interested public and maintains an open information platform. It creates transparency and trust, and promotes awareness of the services and (non-commodified) value-creation of ecological systems including human land managers. The proposed international process – at best hosted by an international organization, such as the International Panel for Biodiversity and Ecosystem Services or the UN – maintains a global value and knowledge base on ecosystem services and landscape qualities. Via its national focal points the organization may feed in relevant global aspects regarding a certain area. The standard setting process itself defines the standard on a ‘meta level’. It further provides assistance, training and quality control to the regional level.

The equal consideration of general and context-specific aspects in the standardized adaptive procedure is to resolve the ‘standardization paradox’. The general aspects actually make up the standard. They provide a sound theoretical basis, set criteria and a few lead indicators. The context-specific aspects provide the entry points for different local-regional conditions. They enable participation, consideration of different value concepts and integration of various situational knowledge types. Value and knowledge systems are equally represented by the demand and supply sides of the LQM framework. As value and knowledge systems are interdependent, alternating and iterative phases and steps of the process focussing on either side enable a conscious and transparent integration of the two poles. A process of reflection accompanies the whole mechanism especially the reference building phase. It serves to reflect on e.g. attitudes towards nature, different moral concepts and knowledge paradigms as well as barriers and success factors. Hence it can provide for conflict resolution on a transdisciplinary meta level and for organizational learning in a self-reflective process.

In accordance with process oriented quality management and continual improvement processes, the whole LQM mechanism is drafted as a ‘PDCA cycle’: with the reiterating phases ‘Plan’, ‘Do’, ‘Check’, and ‘Act’/ ‘Adapt’.

‘Plan’ comprises the whole reference building phase with its three subphases: Phase 1 ‘Brainstorming’ focuses on shared perspectives and sets the scene for a collaborative learning atmosphere. It collects and exchanges individual values and knowledge from the stakeholders (including ‘advocates of future generations and other life forms’) and the public on the landscape demand side and matches it with legal, global and the standard’s requirements. Phase 2 ‘Knowledge Building’ concentrates on acquiring, sharing and synthesizing (place-based) knowledge, data and information on the landscape supply side. This phase attempts to create a common understanding of the service and quality generating processes and interactions as well as trends of degradation. It involves specification of indicators and design of a monitoring system. A common landscape vision based on shared values is the subject of Phase 3 ‘Vision Building’. This phase focuses on scenario and Leitbild development and the derivation of quality objectives and targets. It includes the formation of interest alliances and the layout of a bundle of strategies and measures, which can guide the managements’ and individual land users’ actions as well as lay the basis for (biomass) technology building e.g. through a complementary biomass strategy. Outcomes of the whole planning, i.e. reference building phase are a landscape quality profile (match supply and demand), a concept for an indicator and monitoring system, a landscape vision with spatially and temporally concrete quality objectives and targets, an action plan as well as various documentations, reports and public material, e.g. on landscape history, mappings, processes/ patterns, scenarios, and public campaigns etc. Together they make up the landscape reference system.

‘Do’ consists of monitoring and action: ‘Action’ refers here to the proactive management activity of the LQM team and the concerted action of single land users, stakeholder groups, project communities, and innovation cooperations, etc. – to match supply and demand. The LQM team applies a variety of cooperative tools like area pools, payments for ecosystem services, or regional material flow management, and works on tailor-made solutions together with land users. It may build up its own fund from public and private sources. ‘Monitoring’ comprises the setup of the monitoring system and the monitoring itself, including collection, administration and interpretation of data.

‘Check’ refers to a periodic revision of the interpretated data and the evaluation of the actual improvement of ecosystem services and landscape quality aspects against the vision, quality objectives and targets over time. It means a monitoring of success and effectiveness of strategies and measures. Public transparency is maintained on the local level. ‘Check’ also includes a self-assessment of the quality of the process itself as well as giving feedback to and improvement of the standard.

‘Act/ Adapt’ starts a new cycle, where the landscape reference system or part of it is either confirmed, adjusted or renewed according to the results of the Check-phase as well as according to new developments, trends and potential changes of values and knowledge. Adaption may include e.g. a refinement of indicators, strategies and measures where necessary or may bring up new ideas. Subsequently these adaptions are implemented in the next Do-phase. Those things that have worked well are established on a stable, continuous basis.

The LQM landscape reference system is to be considered a normative framework for action, no matter if legally binding or ‘solely’ providing orientation, inspiration and a basis for cooperative agreements and projects. Therefore the LQM process should undergo an external compliance check and quality control by accredited institutes. For voluntary LQM processes this opens up an option of regional certification, i.e. the standard holder granting LQM certificates to registered and qualified landscape regions or watersheds. Regions could use such a label for regional marketing, attracting visitors, green business and highly skilled professionals, as well as to promote and label quality products and producers in the region. If including peatland and designated areas of high biodiversity and carbon strock value in its reference systems, the LQM standard may seek recognition for the EU Renewable Energy Sources Directive and offer low-cost group certification to small-holders practicing ‘complementary biomass (re)production’ as described in the next chapter. With its area-wise approach LQM could also ideally complement voluntary product-based certification schemes, by providing regional-local reference values for impact assessment with regard to many criteria.

Research is needed on how such a comprehensive LQM process could be institutionalized either in a voluntary or a more binding form, equipped with the necessary long term human and financial resources. Research is also needed on further process design according to different national and regional situations, participatory communicative requirements, and the availability of a broad variety of cooperative instruments and tools e.g. from informal spatial planning, regional and ecosystem management, landscape architecture, or project, process and change management etc. It would also be interesting to investigate to which extent area-based regional certification could mitigate a proliferation of product-based standards.

However, not only assessment of the sustainability of biomass production, but also the proactive development of sustainable (re)production systems is the ambition and chance of LQM, as shown in the next chapters.

4 Application: Sustainable biomass (re)production and regenerative technology design

Sustainable biomass production – the main topic of this study – primarily addresses here the economic activity of biomass production for bioenergy uses, but could include renewable material uses as well. Setting up an LQM process just for safeguarding the sustainability of biomass production would certainly be too costly. Thus the process and resulting reference system should be applicable to **sustainable production** in a more general sense. This means the cross-sectoral transferability to the assessment and development of all kinds of other economic production activities at their energetic, metabolic and site interface with the landscape and its ecosystems (Chapter 5). The term **sustainable (re)production** furthermore denotes the inclusion of the theoretical guiding approach of "(Re)Productivity" chosen in this thesis, as a suggested mode for a sustainable economy, respectively sustainable economic production activities (Biesecker, Hofmeister 2006, 2010). Here the concept is interpreted as consciously internalizing performances and values of regenerative biological-ecological work and the 'renewability' of living communities into the assessment and design of (biomass) production processes and techniques.

4.1 Regional complementary biomass strategies

> "The key task is to transform the uniform and high-external-input-dependent model of quick-fix industrial agriculture (whose health and environmental externalities are largely not internalized) into a flexible approach of 'regenerative' agricultural systems that continuously recreate the resources they use and achieve higher productivity and profitability of the system (not necessarily of individual products) with minimal external inputs."
>
> *Ulrich Hoffmann* (Hoffmann 2011, 16)

Many regions are in the process of or aspire to developing renewable energy visions and strategies or even becoming "100%-renewable-energy-regions" or "bioenergy regions".[98] European funding which is bound to projects and investments fulfilling environmental and social sustainability criteria is available for regional biomass action plans in member states and third producer countries (page 54). The contribution of spatial planning to a sustainable regional energy planning is increasingly discussed (Bundesinstitut für Bau 2011). The LQM process could provide the necessary framework of sustainable landscape development for such initiatives and plans.

The present discussion about bioenergy is highly segregated and predominated by the perception that it competes with food production (as well as raw material use, biodiversity protection, carbon storage in soils, and other ecosystem services (Figure 15)). This is due to the fact that, besides wood, mainly crops well known from food production have been conventionally used for bioenergy so far. Furthermore, the reduction of the biomass category to either a nutritive or technical energy stock, carbon or material stock (as described in Section 1.3.3) might have added to this field of controversy and contradictive action.

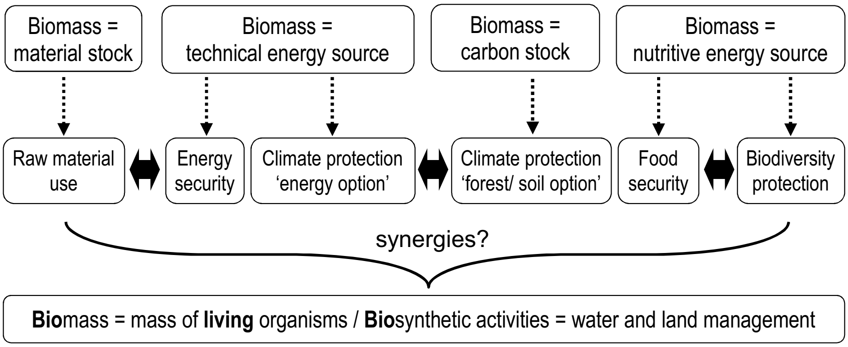

Figure 15: Competitive and complementary biomass use (author's portrayal)

Understanding biomass again as living mass (e.g. in the case of plants and microorganisms) and vital components (e.g. in the case of leaf litter, humus, excrements) of diverse living communities performing biological-ecological work in the form of water, land and resources management activities may then support synergistic measures to multiple demands. If energy crops, for example, were recognized and chosen according to regenerative properties and traits, they could compensate agro-ecosystems and other land uses for their weaknesses in terms of providing regenerative

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[98] See in Germany for example www.100-ee.de or www.bioenergie-regionen.de (accessed 2/6/2012).

services. In this sense a complementary biomass strategy means to strategically integrate bioenergy crops and techniques into present land use systems with the purpose of improving ecosystem services and their landscape qualities, thus improving overall sustainability performance.

A similar approach is being followed by a German research project, called the “ELKE Project” (Heck et al. 2008). ELKE intends to establish an extensive land use strategy in different regions in Germany based on compensatory payments derived from regulations of the Federal Nature Conservation Act. Extensive land use within the project means a variety of agricultural and silvicultural land management practices of biomass production, especially for bioenergy but also material use, which use low input (e.g. mineral fertilizer, pesticides, energy, and soil working), as opposed to intensive (high input) farming. Typically, extensive practices produce fewer yields of commodity outputs compared to their intensive counterparts, but also less environmental damage respectively more environmental benefits. The extensive biomass production practices applied by interested farmers on their field are intended to improve “Naturschutzqualität”. This ‘nature protection quality’ (translation) – previously agreed upon by stakeholders – relates to qualitative conditions of the ‘protected goods’ soil, water and air, as well as fauna, flora and landscape, which are subject to the Conservation Act. Basically, with this “Mehrnutzungskonzept” (multiple use concept, translation) a multifunctional landscape approach is applied by the project. Heck et al. (2008) give a good overview of extensive biomass production practices relevant for Germany (Heck et al. 2008, 23–52) which, implemented and managed by interested farmers during the period of the project and beyond, may prove to be complementary in the sense of this study.[99]

Bioenergy practices and techniques complementarily integrated into present land use systems naturally attain their best effects in regions, primarily agri-industrial, urban and degraded regions that are deficient in regenerative ecosystem services, always subject to landscape demands and conditions, however. A complementary spatial-temporal intergration can happen at the field scale and the landscape scale, which is exemplified by case studies in the next two sections. The case studies represent projects that claim to produce biomass for bioenergy use in an environmentally friendly way or that yield positive environmental effects through biomass production. The cited literature and expert interviews selected for the case studies are interpreted by the author with regard

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[99] The wording ‘complementary’ is preferred here to highlight that bioenergy production does not always neccesarily compete with food and raw material production and can be highly productive in terms of providing other ecosystem services. While the term ‘extensive’ refers to the input side, it is, however, usually associated with a negative image of lower productivity regarding the output side. If both commodity and non-commodity outputs are recognized and treated as of equal value, the distinction of extensive versus intensive farming may disappear.

to a potential improvement of regenerative ecosystem services and landscape qualities by these production systems *compared to a conventional agricultural or other land use system (indicated by italics).* In this way the case studies investigate in principle the feasibility of the Leitbild of 'regional complementary biomass strategies'. Further practical and economic feasibility, however, would need to be explored by applied research in connection to several pilot projects.

4.1.1 Complementary biomass production at the field scale

Mixed cropping

Case 1: Mixed cropping of cereals and oil crops in organic farming / Example: various sites, Germany
Biomass resource: Seeds from oil crops
Conversion technology: Oil pressing
Bioenergy source/ use: Straight vegetable oil for the self-sufficient farm use as biofuel for tractors

Mixed cropping is the cultivation of two or more crops on the same field and in the same growing period. As a special production line, mixed cropping systems give the possibility to spatially combine oil seed crops (e.g. Camelina Sativa L.) with cereals (e.g. wheat) (as well as with grain legumes and others). Seed mixtures and seeding in different rows and depths can be applied. Produced seeds are separated after harvest. This production line is especially relevant for organic and low input farming, where the sole cultivation of oil crops proves to be very difficult. Oil crops, however, are highly appreciated in organic farming for their yield of vegetable oil, which can be used as on-farm fuel, providing better GHG balances and independence from rising oil prices, and for the 'by-product' of oil cake, which can be used as on-farm fodder, giving higher security in feedstuff quality (Paulsen 2011; Heck et al. 2008, 35).

Compared to the sole cropping of each crop, the yield of the main crop is certainly reduced, as only half the number of seeds of each crop is sown. However, in field experiments, relative yields of the main crop proved to be higher than 50%, which means an overall yield gain and a relative increase in food production parallel to the production of biofuel (Paulsen, Schochow 2007, 211). Some farmers even believe that with growing experience, they can grow biofuels in additional to maintaining food yield rates due to mutually stabilizing effects of the crops. Furthermore, quality improvements of the cereals have been observed. The oil cake resulting from oil pressing can be used as high-protein feed and substitute e.g. for soya imports, which means that land for feed production can be saved. The mixed cropping system has a better performance in suppressing weeds and pests. Less soil working – the only method in organic farming to control weeds – is necessary. Additionally, the flowering of camelina provides aethetic effects and feeding grounds for insects (Paulsen 2011; Paulsen, Schochow 2007; Institut für Energie und Umwelttechnik 2011). This means that *compared to sole cropping, improvements of the following ecosystem services and landscape qualities can be expected from mixed cropping systems using energy crops*:

► Biological control, erosion protection/ soil fertility, recreational services/ aesthetic landscape quality, habitat services/ habitat quality, and possibly pollination services

Crop rotation

Case 2: Mixtures of leguminous forage crops and grass plants as winter crops (intermediate crop) complementing maize as summer crop (main crop) / Example: various sites, Germany
Biomass resource: Grass cuttings
Conversion technology: Anaerobic digestion
Bioenergy source/ use: Biogas e.g. for the use in CHPs

Crop rotation belongs to good agricultural practices. On fields where only one main crop (e.g. maize, sunflower) per year is cultivated, energy crops may be temporally integrated as intermediate crops. In Germany traditional field forage mixtures composed of legumes and grass plants (e.g. “Wickroggen” and “Landsberger Gemenge”) are being rediscovered as feedstocks for biogas plants, especially relevant for farms without livestock production. Agricultural associations and advisory services often give specific recommendations.

The cultivation of intermediate winter crops may reduce water availability for the main summer crop, and thus could lower yields of the food crop, e.g. in dry springs. Intermediate crops, however, can provide soil cover, water retention, green manuring, and humus formation (Berendonk 2011; Heck et al. 2008, 32f). *Compared to the sole cultivation of one crop per year in simple rotational systems, improvements of the following ecosystem services and landscape qualities can be expected from intermediate cropping systems with energy crops:*

► Soil services/ soil quality, carbon sequestration, nutrient cycling, water quality, flood protection, and biological control

Case 3: Double cropping / Example: various sites, Germany
Biomass resource: whole plants
Conversion technology: Pressing, thermal gasification and anaerobic digestion
Bioenergy source/ use: Biogas, Syngas

Double cropping is another example where combinations of spatial and temporal intergration can occur. In Germany the so-called “Zweikulturnutzung” (double cropping) is controversely discussed. The principle is to cultivate various winter crop mixes alternated with sommer crop mixes, both harvested as whole plants for bioenergy use. Two yields are possible, since for bioenergy use it is not necessary to await the ripening of grain. The wet harvest can be easily pressed, while the press juice may be used in biogas production and the relatively dry press residue in thermal gasification. A combination of crops for energy and raw material use is also possible. Besides the improvements of ecosystems services already mentioned, this system especially has the potential to increase agrobiodiversity and habitat services, as old genetic varieties may be used and wild flowers can be tolerated (Scheffer 2003, 1998; Heck et al. 2008, 33).

Figure 16: Mixed cropping and agroforestry systems. Left: Wheat and camelina in Germany (Source: Thünen-Institut). Right: Poplar and barley in the UK (Source: Paul Burgess, Creative Commons License CC BY-NC-SA 2.0, https://www.flickr.com/photos/agforward/13968311155)

Agroforestry

Case 4: Alley cropping of poplars in wheat plots / Example: various sites, worldwide
Biomass resource: Wood
Bioenergy source: Wood logs or wood chips
Conversion technology/ bioenergy use: Combustion e.g. in stoves for heating

Agroforestry is the spatial-temporal integration of silvicultural with agricultural or pastoral systems. In silvoarable systems trees are scattered or planted in rows and may be

aligned along contours eventually combined with hedges. In silvopastural systems trees can also be arranged in clumps. Traditional and modern systems are known worldwide.
In agroforestry systems, crop yields may be reduced around trees due to competition of light, water and nutrients. However, depending on climatic and environmental conditions, crops yields may also increase due to positive effects of erosion prevention, moisture feedback, and temperature regulation etc. Furthermore, well planned and well maintained agroforestry systems can show a higher overall productivity than the combined productivity of separate crop and forest plantations. Model simulations of various tree-crop interactions are available. Since, however, high quality timber such as that of walnut and sorbus trees can be produced within agroforestry systems, bioenergy use should instead follow the cascade principle. This means that wood production should first serve raw material use, and bioenergy is then generated from collected and uncontaminated 'waste' wood products (see also Section 4.2.2 Ash recycling). Agroforestry allows for positive aesthetic effects, greater structural diversity and typical characteristics of landscapes and may provide shade for livestock (Dupraz et al. 2005; World Agroforestry Center 2011; Heck et al. 2008, 45–50). *Compared with treeless agricultural or pastural systems, agroforestry usually improves especially tree-bound ecosystem services bundles, such as the following:*

► Climate regulation/ balanced temperature patterns, multiple soil, air and water regulation services, habitat services/ quality (e.g. defragmentation), as well as recreational services, characteristic landscape patterns and aesthetic quality

Integrated farming practices on a field scale are partially covered by codes of good agricultural practices and can be implemented by single land use decision makers. However, such practices need to be tailored to site, farm and landscape specific conditions to actually achieve satisfying yields and the desired effects on ecosystem services and landscape quality improvements. Therefore a period of on-site experimentation over a couple of years seems necessary, which requires time, innovative spirit, and a willingness by the land users to take risks. LQM could pro-actively initiate and support integrated land management practices by encouraging and co-experimenting with farmers, e.g. in cooperation with extension services, local action groups and other organizations promoting these practices. With regard to improving overall landscape quality, best synergistic effects could most likely be achieved when single cultivation systems, land management, and land use practices are coordinated and integrated on a landscape scale.

4.1.2 Complementary biomass production at the landscape scale

Integration at the landscape scale means to introduce biomass production practices into existing land use patterns composed of many (neighboring) plots and production sites as well as land ownerships. Single complementary practices could, for example, be arranged in a biotope network, as intended in the ELKE project and displayed in Figure 17. It could also mean to create new land use patterns better reflecting topography and water flow in the landscape while cooperatively considering land users' property rights and decision making competence.

Figure 17: Model illustration of a potential linkage of ecologically valuable areas with selected agroforestry, SRP and Miscanthus fields to form a biotope network (adapted from Wagener 2008, based on Google Earth, Image © 2007 GeoContent)

Grassland management

Case 5: Different types of grassland areas, parks and gardens / Example: BUND-Hof Wendbüdel, Germany
Biomass resource: Grass cuttings
Conversion technology: Anaerobic digestion or combustion
Bioenergy source/ use: Biogas or hay bales for the use in CHPs

The conversion of grassland into arable land for the cultivation of energy crops is often criticized by NGOs and conservation agencies. In contrast, the management of permanent grassland for the protection of biodiversity and cultural landscapes is part of mostly costly conservation measures. For example, the "BUND-Hof Wendbüdel", a farm managed by the German branch of Friends of The Earth in Lower Saxony, maintains 120ha wet meadows owned by the regional county. Since purchasers for the large amount of hay could not be found, it had to be ‘disposed of’ by composting. The installation of a dry fermentation biogas plant solely processing grass cutting silage from the wet meadows is an attempt to solve this problem and seems to be a successful project synergistically combining conservation measures with bioenergy production. Thereby spatial-temporal aspects of weather and flooding events, phenomenologically determined mowing schemes and reproduction cycles of wildlife are to be synchronized each year (Carius et al. 2008; Gödeke, Hochberg 2009).

The maintenance of recreational urban parks often shows similar issues. While high quality compost generally is a desirable product as a soil conditioner enhancing carbon content and soil fertility, in many municipalities composting facilities are not working profitably, are difficult to manage, are characterized by high carbon losses, and may even pose environmental risks due to leaching. Furthermore, many private garden owners do not practice proper composting, do not use their compost, or just want to get rid of it (Brüll 2005a). The grass can be co-digested with ‘biowaste’, which is practiced in an increasing number of municipalities. In combined biogas and composting facilites in Switzerland, for example, additionally using regionally collected shrub and tree cuttings, high quality compost and manure – even certified for the use in organic farming – is produced parallel to biogas (Brüll 2003). *Through the management of permanent grassland with high conservational or recreational value for bioenergy use, the following ecosystem services and landscape qualities can be maintained*, *which would otherwise be lost if not managed due to high cost, or converted to arable land or building sites in the case of urban parks*:

► Habitat services/ quality, recreational services, nutrient cycling (under a wet management regime water and soil quality, carbon storage, and flood protection may improve)

Case 6: Grassed waterways and filter strips / Example: various sites, USA
Biomass resource: Grass cuttings
Conversion technology: Anaerobic digestion or combustion
Bioenergy source/ use: Biogas or hay bales for the use in CHPs

Grasslands may also be integrated into agricultural landscapes as a water flow related pattern to decelerate run-off, reduce erosion, catch particles and nutrients, and protect receiving waters. So-called “grassed water ways” are a standardized best farming practice in the United States recommended by the National Resources Conservation Services. Its proper installation and maintenance is supported by many extension services of universities. Regular mowing is required for dense sod establishment. Where hay cannot be used as a feed for livestock it may serve as a feed for biogas or combustion plants. Particularly Switchgrass, a native North American prairie grass, is recommended for both use as energy crop and in grassed waterways on steeper sloped terrain, as well as for low wind break and habitat for wildlife (US NRCS 2010; Pfost, Caldwell 1993; Jimmy Carter Plant Materials Center 2011). In Europe also, Switchgrass, along with the giant grass Miscanthus, are expected to yield both bioenergy and positive ecological effects (Heck et al. 2008, 36f). While in the US, grassed waterways can be established by single farms on large plots, on smaller plots in Europe close cooperation of neighboring farms and land owners may be required. LQM could initiate and support such cooperations and coordinate with e.g. research institutions modelling waterways, erosion gullies, and ponding areas etc. *Compared to sole cultivation of annual crops improvements of the following ecosystem services and landscape qualities can be achieved:*

► Erosion control, carbon sequestration, flood protection, water quality, habitat services/ quality, recreational services, characteristic landscape patterns, and aesthetic quality

Figure 18: Grassed waterway in Velm, Belgium (left) on a sunny day and (right) after a thunderstorm. (Source: Wikimedia Commons, GNU Free Documentation License)

Restoration of degraded land

Case 7: Jatropha Curcas / Example: Mali Nyetaa Folkecenter, Mali
Biomass resource: Collected seeds
Conversion technology: Oil pressing or transesterification
Bioenergy source/ use: Straight vegetable oil or biodiesel for the use in diesel electric generators

Jatropha Curcas is a drought-tolerant shrub growing in many soil types, also in those considered infertile or degraded. It produces black seeds with a content of about 35% non-edible oil, which can be pressed and used as straight vegetable oil in small diesel engines and electric generators or processed into biodiesel through transesterification. Due to its multiple functional traits, including a well developing root system capable of acting as a nutrient pump and increasing water absorption, Jatropha has the potential to combat desertification and recover degraded land. However, there are also potential environmental and social risks as Jatropha is toxic, partly recognized as an invasive plant, and often cultivated in large scale plantations (see below) (Brittaine, Lutaladio 2010, 14–25; UNEP 2007, 2ff).

In southern Mali a Jatropha bio-oil project, implemented by the Mali Nyetaa Folkecenter (MFC), provides 300kW of electrical power to the village of Garalo. The project is deeply rooted in local support and ownership, realizes a vision of small-holder production and is designed to benefit the local population in terms of energy supply and additional income. Jatropha is planted as a hedge and living fence to protect food crops from animals and soil from wind and water erosion. Also intercropping of Jatropha with e.g. peanuts is applied, increasing overall farm land productivity. Organic fertilizer is produced from the press cake which in turn is used to increase food production. The Jatropha bushes capture rainwater and run-off in the soils, create a more humid microclimate, and protect the area from desertification (Burrell et al. 2007; UNEP 2007, 7). According to UNEP “the project can serve as a model for sustainable biofuel projects in the future” (ibid.).

Another MFC project, called “Jatropha as a tool to combat desertification, poverty alleviation and provision of clean energy services to women”, has a strong gender focus, as women are traditionally familiar with Jatropha cultivation for the use of making soap. Furthermore, women and young girls carry a high physical work load, e.g. by pounding millet, maize, and shea nuts, which was successfully eased by the installation of a multi-task energy platform through the project. This technical installation, including a Jatropha press, grinders, cereal mills, electric generators and lighting devices, are owned and managed by the womens’ association and also generate income for the use of the association. The project was awarded a UNIFEM price in 2003 (ibid. 17; Mali Folkecenter, 2012). Interpreting the above-mentioned sources, the *following ecosystem* *services as well as livelihoods/ social conditions have been improved through the described Jatropha projects in Mali compared to the situation before project implementation*:

► Erosion control, soil fertility, nutrient cycling, and climate regulation
► Improved living standards associated with electricity, improved living, working and educa-tional conditions for rural women, poverty alleviation (Millennium Development Goals)

UNEP (2007, 11f) suggests a ‘true’ sustainable cost-benefit analysis for Jatropha where the value of environmental and social benefits is factored in, claiming that the economics of small scale projects then look much more promising than large scale projects. Such small scale grassroots projects, however, seem to be the very rare exeption. Im most cases Jatropha is planted in monocultures with the known problems of e.g. biodiversity loss and spreading pests. If Jatropha is to serve commercial interests and to generate returns on foreign investment, then, like any other crop, it needs good soils and/or nutrients and (irrigation) water to thrive and produce high yields. This can lead to displacement effects, where food production is pushed away from fertile soils. If cultivated on ‘marginal land’, high-input Jatropha plantations can indirectly compete with food production for water and nutrient resources, especially critical in food-insecure regions (Pohl 2010). Despite these risks Jatropha cultivation on so-called ‘marginal land’ or ‘wasteland’ is often promoted as a sustainable solution.

Generally, the use of marginal or degraded lands for biomass production is advocated as an option to mitigate indirect land use changes (Dam et al. 2010, 2465). However, NGOs claim that land that has been classified “marginal”, “idle”, “sleeping” or “abandoned cropland” by governments, corporations and scientists (e.g. through satellite based mapping) may include acidic peatland, land previously cleared from rainforests, fragile land managed by long-term rotational cycles including periods for soil regeneration, sacred sites, land under non-formal pastoral community ownership, or land farmed for subsistence by women not given property or inheritance rights (The GAIA Foundation et al. 2008). What is considered “unproductive land” in the reduced economic view is said to be rendered “productive” by biofuel plantations with the promise of benefiting local communties. However, these ‘benefits’ are often not considered beneficial by the people affected. Seasonal farm jobs, for example, cannot offer a stable livelihood and replace land once commonly owned. Thus, “land that might appear to be ‘marginal’ to one person may be a vital resource to another” (ibid. 3). Or as Gilbertson et al. (2008, 18) put it more drastically: “The classification of certain lands as ‘marginal’ or ‘bare’ is often determined more by political considerations than by the state of that land itself, or by whether or not it is actually unused or uninhabited. […] The assumption that ‘marginal’ lands can be claimed to meet rising EU demand for agrofuels is reminiscent of an old colonialist mind-set, whereby the South is depicted as an empty space upon which the North can impose ‘development’ projects to serve its own needs”.

Figure 19: Different ways of Jatropha planting. Left: Commercial Jatropha plantation in Mozambique (Source: Nilza Matavel, Friends of the Earth International). Right: Transplanting of Jatropha as living fence and as biofuel source for a small scale farming community in Kenya (Source: http://www.energyfacilitymonitoring.eu, accessed 01/10/2015)

Another option to restore degraded lands is the use of halophytes (salt tolerant plants) on salinisized soils, e.g. in agroforestry systems, which e.g. was explored by the European research project “BIOSAFOR Remediation of saline wastelands through the production of biosaline biomass - for bioenergy, fodder and biomass” (Biosafor Cosortium, 2011). However, the example of Jatropha illustrates how important it is to consider ecosystem services value, landscape history and trends, and further social-ecological conditions on a local-regional scale when assessing and designing bioenergy systems. Whether land is actually ‘degraded’ or can be considered ‘marginal’ or ‘wasteland’, and what is the best ‘restoration option’, could be regionally verified or clarified in an LQM process, provided that the process as envisioned here gives a voice to all stakeholders equally and runs free from corruption.

Short rotation plantations and agrowood alley cropping

Case 8: Willow plantations with wastewater recycling / Example: City of Enköping, Sweden
Biomass resource: Wood
Conversion technology: Combustion
Bioenergy source: Woodchips, e.g. for the use in CHPs

In short rotation plantations (SRP) fast growing tree species capable of stump shooting or resprouting, like willows or poplars, are grown on fields and managed in short coppicing cycles. After 2-5 years the stems can be harvested either manually or mechanically with specialized machinery. Since those fast growing trees can take up high amounts of water and nutrients, they may be used in combination with pretreated wastewater and sewage sludge application. This is especially interesting for communities with insufficient wastewater treatment looking for cost effective alternatives to conventional secondary or tertiary treatment steps and possibly in water scarce regions.

The European BIOPROS Project[100] investigated opportunities for efficient biomass production with the safe application of wastewater and sewage sludge including field tests on case study sites in Sweden, Northern Ireland, Italy, Spain, and the Czech Republic (Biopros Consortium 2008). In the town of Enköping in Sweden 20,000 inhabitants are supplied with heat (100%) and electricity (50%) from a bioenergy plant. Twenty per cent of the total biomass used comes from SPRs in the form of wood chips. An area of 76ha close to the municipal wastewater treatment plant is planted with willows and equipped with a drip pipe system irrigating the fields with a mixture of supernatant from sludge dewatering and treated wastewater effluent during the vegetation period from May to September. During winter, sewage sludge is stored in lined ponds, which allows for settling of solids and effective decrease of pathogens. The SRP acts as a biofilter for an equivalent of 30t of nitrogen and 1t of phosphorus that would otherwise have been deposited into the adjacent river (Biopros Consortium 2008, 59–63; Brüll 2007). Wood ashes from combustion are separated into a fly ash fraction with high heavy metal contents and a bottom ash fraction with lower heavy metal content. Bottom ashes are mixed with digested sludged and applied as fertilizer to SRPs in other municipalities. These willow plantations showed a high uptake of cadmium and therewith a phytoremediation potential. That means willows managed under short rotation coppice could be used to restore contaminated sites. However, this highly depends on soil characteristics, willow clone type and management regime (Dimitriou 2005; Dimitriou et al. 2006). Herbicides are only used during the first (two) years (establishment phase) of a total economic life span of approximately 25 years. It is anticipated that with suitable intercropping one could even forego them. Willows are also susceptible to pests. Using a genetic variety of clones and planning for habitat of biological control organisms is recommended in this regard. Willow plantations were found to be a rich habitat of e.g. insect, avian and soil micro-arthropod diversity (Biopros Consortium 2008, 17–24). *Compared to the incineration of sewage sludge or its*

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[100] http://cordis.europa.eu/project/rcn/74782_en.html (accessed 12/30/2014). The author was part of the project consortium as a consulting expert of the International Ecological Engineering Society during the years 2005-2008.

disposal on agricultural lands and the discharge of effluent into receiving waters, positive effects on the following ecosystem services and landscape qualities can be expected from wastewater fed SRPs:

► Nutrient cycling, waste treatment, water quality, and habitat services/ quality

However, if not managed properly, the application of wastewater and sewage sludge can also pose environmental and hygienic risks (Section 4.2.2). Therefore it underlies regulations such as the European Sewage Sludge Directive 86/278/EEC supplemented by national legislation. Careful planning, operation and monitoring are required. For a safe application, sludge quality certificates including heavy metals, nitrogen and phosphorus content must be made available to the farmer by the sludge provider. Liability issues may be a point of conflict and should be clarified in advance by solid agreements. It is crucial to involve stakeholders such as local authorities, conservation agencies, municipal energy and water works or private companies involved in wastewater and sludge treatment from the beginning (Brüll 2007). “Projects have proven to be most successful where constructive communication and cooperation links have been built amongst the partners involved” (Biopros Consortium 2008, 28). Such links could be initiated and facilitated by Landscape Quality Management. During the BIOPROS project it became clear that a sustainability assessment of wastewater fed SRPs needs distinct (environmental) quality criteria and reference values at best, which are not readily available. LQM could bridge this gap. SRPs fertilized with pretreated ‘waste’ water are also an option for the re-use of ‘waste’ land (e.g. brownfields and former industrial sites in shrinking peri-urban regions) if the latter is properly determined by an LQM process.

Case 9: Agrowood field strips and contour strip farming / Example: various sites, Germany
Biomass resource: Wood
Conversion technology: Combustion
Bioenergy source: Woodchips, e.g. for the use in CHPs

Rather than again establishing monocultures in large plantations, short rotation coppices, also named agrowood coppices, can also be arranged as field strips in cleared agricultural landscapes. Planted perpendicular to the main wind direction, their main purpose is to reduce wind erosion. Following contours in sloped areas they can reduce water erosion, increase retention capacity and water quality. Both ways they improve the micro-climate and provide habitat services, especially if varieties bred for maximized biomass productivity are mixed with locally adapted varieties. Test applications in Saxony, Germany, showed that they can already be economically competitive. Compensation of services provision, however, would make their implementation more likely. To maintain services during harvest and regrowth, agrowood field strips may be planted in two parallel rows, of which only one is cut at a time (Röhricht et al. 2011; Heck et al. 2008, 45–50). Especially if arranged as contour strips, covering land owned and managed by different land users, coordinating management activity is required, which could be performed by LQM. *Establishing agrowood field and contour strips in formerly cleared agricultural landscapes will most likely improve the following ecosystem services and landscape qualities:*

► Erosion control, climate regulation/ balanced temperature patterns, flood protection, water quality, habitat services/ quality, as well as recreational services, characteristic landscape patterns, and aesthetic quality

Figure 20: Agrowood contour strips providing various ecosystem services.
(Research site: Scheyern, Germany; Source: Frank Wagener, IfaS)

Wetland and pond systems

Case 10: Paludiculture / Example: Region Vorpommern, Germany
Biomass resource: Reed
Conversion technology: Combustion or anaerobic digestion
Bioenergy source/ use: Reed straw, reed pellets or biogas, e.g. for the use in CHPs

'Paludiculture' (*palus* (lat.): mire, morass) is the name of the wet cultivation of helophytes (marsh/ bog plants) on degraded peatlands. Typical plants in northern Europe are e.g. common reed (*Phragmites australis*), cattail (*Typha spec.*), and reed canarygrass (*Phalaris arundinacea*). Harvested in the winter, the straw can be used for combustion. It has a calorific value comparable to wood. Its quality as a fuel is dependent on, for example, the harvest time, water content and processing. Pelletizing is possible and favorable for both fuel quality and transport. Reed can also be mowed in the summer and the green plants used as feed for biogas production (Wichtmann, Wichmann 2011; Kowatsch et al. 2008; Wichmann, Wichtmann 2009). If harvested on frozen ground adapted conventional equipment can be used; if harvested under wet conditions special machinery is necessary (see Section 4.2.1).

In the federal state Mecklenburg-Vorpommern, in northeastern Germany, about 300,000 ha peatlands exist, of which 87-97% have been more or less dewatered. Due to aerobic soil conditions these degraded mires – most of them currently under management as grassland – are characterized by peat mineralisation, settlement, nutrient leaching and a loss of water retention capacity. They account for 30% of the GHG emissions of the federal state (Kowatsch et al. 2008, 4ff; Vorpommern Initiative Paludikultur 2010). Some parts of the fens have been restored and protected for conservation (Wichtmann, Wichmann 2011, 216). Depending on local circumstances rewetting can occur through different means, e.g. refilling drainage outlets, flooding or irrigation with drainage water or pretreated wastewater. Under a permanently wet water regime mineralisation of peat stops and water and nutrients are retained. While emissions of the greenhouse gases CO_2 and N_2O can thus be greatly reduced, emissions of methane usually increase. Estimations based on measurements and extensive literature reviews, however, suggest that a clear net beneficial effect is produced. Rewetting peatland from waterlevel class 2+ to class 5+ can realize GHG emission reductions of 15t equivalents per ha and year (ibid. 226). Under suitable conditions a Phragmites australis stock may even be able to build up peat again, acting as a real carbon sink.

While GHG balances are of great concern in research, the climate regulation effect of a high short-water-cycling capacity of wetlands is mostly neglected (see Section 2.3.1 Water and climate services). Furthermore, through harvesting, combustion and ash recycling, nutrients including base cations captured in the wetland can be recycled back to the land (see Sections 4.2.2-3). Also, from a conservation point of view, the management of reed can be desirable to maintain or restore habitat for target species. It is recommended, however, to combine managed with unmanaged and open water areas to provide habitat for a wide range of species (Timmermann 2009).

Because of its high proportion of drained peatland the region Vorpommern (Western Pomerania) is regarded as a global hotspot of moor degradation. With its Vorpommern Initiative for Paludiculture it wants to establish itself as a worldwide model region for sustainable peatland management.[101] The initiative works on e.g. testing different paludiculture management systems in practice, developing and applying adequate harvesting techniques, developing product lines for energetic and material use, and

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[101] http://www.paludiculture.com (accessed 11/25/2011 and 12/30/2014)

monetarizing ecosystem services, as well as transferring knowledge to Belarus, Indonesia and China (Joosten et al. 2013). The project inter alia draws from long-term experiences of traditional management of high quality reed for use as roofing material, e.g. in the Austrian-Hungarian region of Neusiedler See as well as from the most recent experiences of conservation practices and ecological engineering (page 234), e.g. in the Donaumoos in Southern Germany, which has been partly restored as a wetland habitat (Pfadenhauer 2004) and partly recultivated on a pilot scale with Typha latifolia and angustifolia used for the production of insulation material (Wild et al. 2001).

Compared to continuing peatland degradation under grassland management, the following ecosystem services and landscape qualities can be improved or regained through paludiculture:

► Climate regulation, flood protection, water quality, erosion control, nutrient cycling, habitat services/ quality, as well as recreational services, characteristic landscape patterns, and aesthetic quality

Figure 21: Paludiculture at Ferne and Murchiner Wiesen, Schadefähre, Peene valley, Germany (Source: Benjamin Herold, Greifswald Mire Centre)

Research showed that paludiculture can already be competitive, especially if it is treated equal to agriculture in terms of direct payments. However, while it seems to be a promising approach for complementary biomass production, it is partly faced with resistance by farmers and others. Reasons are for example: Rewetting is a rather irreversible change. Paludiculture potentially requires large investments into specialized machinery. A market is not yet developed. Broad empirical knowledge is lacking. In order to pro-actively introduce such systems, networking farmers, municipalities and energy suppliers, providing information and individual consulting, developing concrete guidelines for the wet management of peatlands with participation of different stakeholders, and considering compensation for ecosystem services are suggested (Wichtmann, Wichmann 2011; Wichmann, Wichtmann 2009, 21; Kowatsch et al. 2008, 49ff; Pfadenhauer 2004): activities all of which could be coordinated by LQM and performed in cooperation with existing institutions active in the region and through interregional exchange.

Case 11: Constructed wetlands / Example: Community of Geuensee, Switzerland
Biomass resource: Reed
Conversion technology: Combustion
Bioenergy source/ use: Reed pellets

Reed cannot only be cultivated on degraded peatland, but also in constructed wetlands. In the community of Geuensee in Switzerland, a wetland was built on former grassland on clay soils to act as a *multifunctional retention system alternative to a conventional technical retention basin made of concrete*. The excavated and levelled area of 3000m², planted with Typha latifolia, receives nutrient rich surface water from a drainage ditch as well as stormwater and diluted wastewater from the overflow of a mixed sewer. *It provides water retention/ flood protection, wastewater treatment, and habitat services as well as recreational services in the form of an aesthetic landscape impression changing with the seasons*. 'Disservices' feared by neighbors such as odor, mosquito breeding or loud croaking of frogs did not occur. Investment costs are 20% and operating costs 30% of those of conventional systems. Typha is harvested in the winter and generates additional income. A cooperation of regional companies works on market and product development, e.g. using fibers as aggregate for clay plaster or pelletizing the straw for bioenergy use (Wyss, Heeb 2004; Wyss 2011; Heeb 2005; Brüll 2006).

Many of the presented examples for a complementary biomass production are based on traditional land management practices and/or require experimental experience and long-term familiarity with specific landscape and site characteristics, including local hydrological and climatic conditions as well as with the behavior of plants, connected microorganismic communities and inhabiting fauna plus cultural habits etc. Thus traditional and practitioners' experiences as well as situative ecological and social knowledge also of non-scientific experts, are valuable assets in complementary biomass strategies, which should be treated as at least equally important as more abstract scientific models.

Merging traditional land management practices with innovative bioenergy technologies offers a chance to revitalize traditional or create contemporary cultural landscapes. Especially water-flow related spatial-temporal land use patterns of ‘retention cultures’ (Chapter 4.3) contain the potential to form more aesthetic identity-giving landscapes in a way that they may be more coherent and intuitively comprehensible than squared land-use mosaics overriding topography and water regime. However, a prerequisite for the development of sustainable contemporary landscapes by means of complementary biomass production systems is that the design of relevant technologies is informed by adequate knowledge such as mentioned above and the intention to improve regenerative ecosystem services and landscape qualities. Thus, the development of conversion technologies for bioenergy supply and others working with biomass resources should go hand in hand with the development of complementary land use systems and land management practices for biomass (re)production, as discussed in the next chapter.

4.2 Landscape quality driven biomass conversion versus technology driven landscape conversion

> “The fulfilment of all these tasks will require the reorientation of
> technology - the key link between humans and nature. [...]
> In all countries, the process of generating alternative technologies,
> upgrading traditional ones, and selecting and adapting imported
> technologies should be informed by environmental resource concerns.”
> *World Commission on Environment and Development, 1987*
> (WCED 1987, 60)

Technological development is a main driver of landscape change intertwined with the availability and structure of energy supply. Through technological means landscapes have been cleared and drained, rivers channelized, dams built, land surfaces sealed, nutrients introduced, and so on. The development of technology, especially production technology, thereby interacts with market developments and is mostly oriented towards technical and economic efficiency to yield the highest possible commodity output and profitability. Such one-sided technology development, as well as technology transfer from one application to another or from one region to another, often leads to an adaptation of the landscape to technical requirements with far reaching impacts on water regime, habitat and linked ecological processes. One example from the past is the melioration of mires for the production of forage grass, as described in the previous section, which required intensive drainage to enable trafficability by common agricultural machinery (Wichtmann, Wichmann 2011, 216). Today, remaining wetlands are mostly protected, because their multiple functions and values have been recognized. However, on unprotected land, technology driven landscape conversion is still the rule, also associated with bioenergy applications. The invention of Haber-Bosch nitrogen largely changed the way how land is cultivated and had an immense deteriorating impact on the quality of water, air and habitats worldwide (Erisman et al. 2008).

For companies investing in large scale bioenergy installations, e.g. biofuel plants, it is important to secure dedicated sources of feedstock supply with long-term confidence in pricing. To feed a cellulosic ethanol plant, which processes 400,000 tons of biomass daily, for example, 17,000 acres of land (approximately 6.8 km²) have been leased under a long-term agreement for 20 years by Verenium Corporation. The company focuses on the cultivation of grasses, such as switchgrass, miscanthus and sorghum, since they are generally regarded ‘sustainable’ non-food energy crops. It contracts for the supply of these with leasing agreements and seeks to be able to control the energy resource (Riva 2009). As a consequence, large plantations of these grasses are presumably being established for a minimum of 20 years. Whether this is a sustainable and desirable development cannot and will not be judged here. This would need to be answered in an LQM process. The example illustrates, however, how a certain type of technology introduced in a region can determine the structure, use and management of whole landscapes.

While adapting the landscape to the requirements of commodity producing technology other non-commodity outputs (i.e. public goods and values) are eventually lost, or in other words undesirable nature-culture hybrids are co-produced. Vice versa: if it has been determined through Landscape Quality Management what is to be sustained in the landscape area, which functions the landscape should fulfill, which ecosystem services are to be co-produced by production activites, and which qualities should be maintained or achieved in general (LQM standard) and in a specific context (LQM process), then technology development could follow a multifunctional pathway serving multiple landscape demands. For the case of sustainable biomass production this means that the development of biomass producing, processing and recycling technologies should be inter alia driven by landscape quality requirements, as discussed in the following.

4.2.1 Land management technology

Integrated and site adapted land management practices co-producing regenerative ecosystem services in a higher landscape quality often require different machinery than conventional agricultural systems. Sometimes common machines can be equipped with new features, and sometimes new constructions are necessary. In mixed cultures, for example, there is the need to sow seeds of different crops and sizes at different depths. Combined seed drill technology has been developed using a second seed drill or additional seed hoppers, and depth-controlled drill coulters on common machinery, which allows sowing mixed cropping systems in one operation and drilling different mixed cropping systems adapted to site conditions (Paulsen, Pscheidl 2007).

Paludicultures under a wet water regime can also not be managed with conventional equipment. Suitable harvesting equipment is the yet missing key link between reed biomass potential and existing conversion options. In conservation projects, on test sites, and in constructed wetlands, mowers with low ground pressure based on snowcat technology have been successfully deployed. However, compaction and transport of the biomass to solid ground remains a challenge. Light-weight transport vehicles are desirable, but counteract the trend towards bigger, heavier, high-output agricultural machines. Nevertheless, suitable equipment is technically feasible and specialized manufacturers exist (Wichmann, Wichtmann 2009, 23–34).

Small, smart and maneuvrable equipment including slope balancers to work on contours would also be needed for the management of water flow related cultivation patterns such as grassed waterways, filterstrips in erosion channels, and contour strips, especially in small-structured terrain. Machinery developed for mountainous regions may serve as a model.

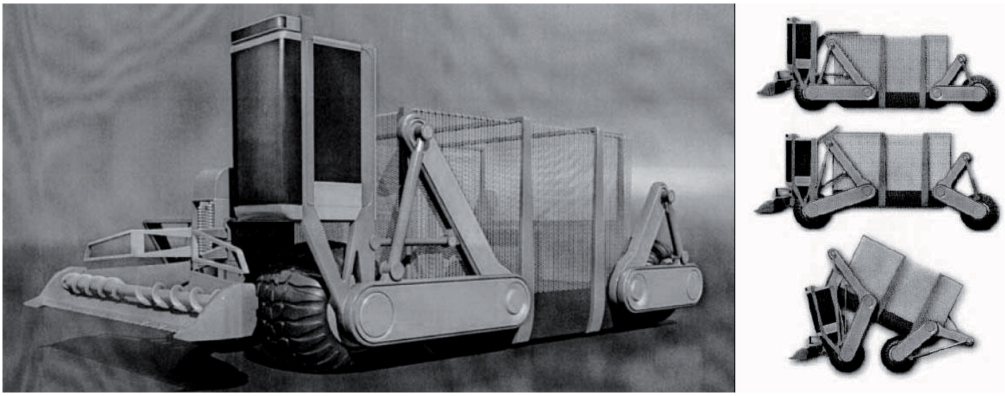

Figure 22: Model of a reed harvester designed by Andreas Grasmück, student of the Kunsthochschule Berlin Weissensee, Germany (Source: Palloks, Mainz 2009)

4.2.2 Nutrient cycling technology

Closing nutrient loops is usually regarded essential to sustainable biomass production, especially if great amounts of biomass are harvested from the landscape as is the case in bioenergy applications. Nutrient cycles in the bioenergy sector can be established through (a) reusing wastewater as a resource, i.e. the nutrients and water contained therein, for the production of biomass as well as (b) recirculating residues from biomass conversion processes back to the land. Regarding humans and their technologies as an integral part of ecosystems, closing nutrient loops basically means an improvement of nutrient cycling services with the objective to improve associated soil, water, and climate services as well as habitat services, especially in aquatic systems. An actual increase of landscape quality, however, depends on how technology and processes are designed and interlinked.

(a) Wastewater recycling: As non-food crops, energy plants such as willows are, along with their physiological characteristics, suitable for wastewater recycling, since the likelihood that pathogens or pollutants will enter the human food chain is minimal. However, for a safe application of treated wastewater and sludge it is desirable to separate harmful from useful substances as far as possible. This can partly be done through source separation, which means not mixing different wastewater fractions in the first place, but collecting and treating them separately. From a nutrient cycling perspective, rather than a purely treatment oriented perspective[102], industrial wastewater as well as water from hospitals, for example, should be separated from municipal wastewater and handled in individual facilities.[103] This may require fundamental changes in sewer infrastructure. Furthermore, by means of suitable sanitary technology and building services (e.g. different toilet systems, multiple piping systems), grey water (e.g. from showers and sinks) could be separated from black water (feces) and yellow water (urine diversion), and stored and treated differently. This could lead to more decentralized and specialized sewer systems or may even render

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[102] Sewer systems and conventional wastewater treatment technology have been developed sectorally to improve hygienic conditions and actually environmental quality, namely water quality and habitat quality of aquatic systems, however at the cost of nutrient cycling and water retention in the landscape and all services and qualities connected therewith. Nutrient availability so far could be partly compensated by artificial fertilizer, but may not be extrapolated into the future (Chapter 1.2.3). Nutrient immisions into receiving waters from sewage treatment plant outlets still account for 20% of the total nutrient load (with 80% from diffuse sources, like agriculture) and are transported to the sea, where they contribute to eutrophication of coastal regions and the formation of dead zones. Advanced tertiary treatment to reducing this load is very costly. The other part of valuable nutrients is bound in municipal sewage sludge, which mostly contains a problematic material mix and increasingly poses a disposal issue. Through conventional wastewater treatment nutrients are continuously lost from the landscape (Lange, Otterpohl 2000).

[103] In many cases industrial wastewater can be cycled in closed systems recovering valuable resources and process water for renewed use.

them obsolete if treatment is realized on-site. Technologies which have been developed for sustainable sanitation and water management (Lange, Otterpohl 2000, 117–231; Tilley et al. 2008) suited to very different regional cultures and circumstances can be partly adopted for biomass production. Source separation allows specifically treating and managing different wastewater fractions according to their characteristic components and properties, and recirculating the resulting products back to the land. In this way ‘productive’ treatment systems can be developed reproducing water, fertilizer, humus and energy (Sustainable Sanitation Alliance 2008) as well as yielding regenerative ecosystem services.

Source separation and productive treatment may also favor biodegradation of increasingly discussed residues of pharmaceuticals and hormones found at the outlets of sewage treatment plants. From root zone research it may be assumed that treatment technologies based on biofilms on plant/ soil surfaces or on submerged plant surfaces perform better than activated sludge in terms of degradation of problematic organic substances, since they provide a greater diversity of organisms, and their metabolic processes and interactions, as well as longer retention time (Lange, Otterpohl 2000, 74; Del Porto 2008 with reference to Kent, Triplett 2002). However, there is an urgent need for research for both the performance of conventional treatment as well as nutrient cycling techniques in this regard. Additionally, in both cases it would be desirable to replace persistant organic pollutants with biodegradable non-toxic substances in the design of products like detergents, cosmetics, and others directly entering domestic wastewater flows.[104]

Wastewater recycling for sustainable biomass production shows that landscape quality oriented technology development can reach as far as **infrastructural engineering** and **chemical engineering** (see also below). Using wastewater as a resource is a classical field of **ecological engineering**, an interdisciplinary approach applying ecological knowledge in engineering (Staudenmann et al. 1996; Bohemen 2005; Brüll et al. 2011).

(b) Ash recycling: The separation of hazardous from useful substances is also an issue for the recirculation of ashes resulting from combustion of biomass. “Biomass ash contains a wealth of macronutrients and micronutrients. Despite the value of the various elements contained in the ashes, their disposal in landfills is still common practice, generating considerable costs for biomass plant operators and negating the recycling potential of ashes. A prerequisite for sustainable use of ashes in agriculture and forestry, however, is their quality in terms of nutrients, on the one hand, and of heavy metals and organic pollutants, on the other. Appropriate combustion and separation

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[104] This is desirable anyway from a public health point of view, since most substances entering the domestic wastewater flow have either been digested by humans or come into contact with skin.

techniques to obtain qualitatively valuable ash fractions are thus highly desirable" (Knapp, Insam 2011, v).

Particularly important in terms of useful substances are cationic nutrients, which can be used for forest soil amendment in terms of retaining buffering capacity and long-term productivity (Insam, Knapp 2011; Bjurström, Herbert 2009). As described in Chapter 2.3.2, net-productive forests are characterized by high irreversible losses and soil acidification, especially on soils with low buffering capacity and under a management of intensive whole-tree farming, a practice which is promoted for biomass production. Wood ashes contain high amounts of calciumoxide and can be applied after treatment (e.g. self-hardening to reduce alkaline reactivity, granulation and pelleting) to increase soil pH, eventually as lime replacement. They are even regarded to be more suitable than lime due to their content of Mg, K, P and trace elements. However, composition and properties depend on plant species, origin of the plants, plant parts used, process parameters during combustion and storage conditions (Knapp, Insam 2011, 2; Bjurström, Herbert 2009, 67ff). Heavy metals and polycyclic aromatic hydrocarbons (PAH) are regarded as particularly problematic in terms of hazardous substances. PAH may be reduced through better controlling combustion performance. In terms of dealing with heavy metals, separation of fly ash and bottom ash has already been mentioned. While an increase in soil pH is usually associated with less solubility and mobility of heavy metals, no accumulation of heavy metals could be found in forest berries, mushrooms, ground vegetation or tree needles on sites treated with ash by various studies (Knapp, Insam 2011, 3, 8), so that the risk of contamination through ash recycling may be less than the risk of soil acidification and increased metal solubility (e.g. of eco-toxic unorganic aluminium) due to lost buffering capacity (Emilsson 2006, 39). However, this is to be assessed context-specifically, e.g. dependent on the quality of available ashes, forest management practices, and soil conditions, downstream water quality and irreversible losses with regard to landscape efficiency.

Acknowledging these issues and potentials, the research program "Environmentally Correct Use of Combustion Residues", also called "Ash Programme", was conducted in Sweden from 2002-2011, mainly with the intention of using bioashes for compensating intensively logged forests, in connection with the European Life-project RecAsh lasting from 2003-2006 (Emilsson 2006; Ribbing, Bjurström 2011). Besides comprehensive technical investigations, the project also revealed economic barriers of implementation. "It was perceived that one essential non-technical barrier is the absence of an economic incentive: spreading ash to soils in doses of a couple tonnes per hectare is costly but the forest owner is not to expect an immediate return as increased growth" (ibid. 156). This means that with ash 'fertilization' overall long-term productivity of forests can be retained, but not neccessarly a profitable increase in production output obtained. However, long-term productivity of forest ecosystems is a prerequisite for many other essential ecosystem services and thus an indispensible component of sustainable landscape development. While ash recycling may be subject to legal regulations, there seems to be a clear need of coordinative management activity involving relevant stakeholders along the supply chain of wood, wood products, combustion for bioenergy and ash recycling, which could be performed by LQM. Furthermore, well-defined quality criteria are needed for investments into improving the properties of ash or combustion residues (Bjurström, Herbert 2009, xi), which may even need to be regionally or locally specified with regard to respective reference systems.

However, rather than separating useful from hazardous substances at the end of the treatment chain, for ash recycling similar to wastewater recycling it is desirable to not mix them in the first place, wherever possible. This is especially relevant for the favored cascade use of woody biomass. High concentrations of e.g. As, Cd, Cr, Pb are attributed to the incineration of surface-treated waste wood and wood treated with industrial preservatives (Krook et al. 2006 cited in Knapp, Insam 2011). This poses a challenge to the design and manufacturing of wood products like furniture, building material, and composite material (e.g. coated boards) etc. if nutrient cycling requirements were to be considered right from the beginning. Thereby it is important to develop techniques for the preservation, processing and finishing of wood products, which allow collection, eventually separation, non-toxic combustion and safe ash recycling after use.

The case of biomass ash recycling shows that landscape quality oriented technology development can reach as far as **process engineering** and **product design**. Overall, the “dichotomy between waste and resource has to be resolved if combustion residues [as well as wastewater treatment residues, author’s note] are to find a place in a sustainable civilization” (Bjurström, Herbert 2009, 1). A very useful approach in this regard based on a vision of eliminating the concept of ‘waste’ and fully realizing biological and technical nutrient cycles is the Cradle to Cradle design concept (Braungart, McDonough 2009).

4.2.3 Biomass conversion technology

Conversion technologies process biomass harvested from the landscape (input) and potentually co-produce nutrient rich substrates returned to the landscape (output). Thus, they need to match both land management and nutrient cycling technologies and align with their landscape interfaces.

Many conversion technologies require homogeneous biomass resources of a certain quality to work efficiently and with reliable bioenergy output. However, in heterogeneous landscapes it is often not possible to produce such homogeneous stocks, unless production conditions are highly controlled, e.g. through monocultures, pestizides, fertilization, and irrigation. From a landscape quality point of view, with regard to working with changing site conditions, weather events and diversity, an aspiration towards technology would be to easily process biomass stocks with fluctuating compositions. Dry fermentation technology for biogas production versus wet processing, for example, can use inhomogeneous biogenic material, which cannot be mixed, may contain mineral substances, e.g. soil particles and stones, and changes with the seasons, e.g. fresh grass cuttings in the summer and solid stable manure in the winter (Meier 2007). Generally, a low volume and a high dry matter content of harvested biomass are desirable to keep transports as low as possible for economic and ecological reasons. This poses challenges to on-site compaction, storage and drying techniques. However, producing high and even dry matter content is not always possible, may require costly facilities or too much energy in case solar drying is not feasible or 'waste' heat (e.g. from CHP) not available.

Another option for reducing transportation of biomass is to develop and establish small conversion units in the vicinity of biomass production sites, increasing the energy density of the original material through the conversion process. Especially pyrolysis – the thermochemical decomposition of organic material at elevated temperatures and under the absence of oxygen – is discussed in this regard in particular (Libra et al. 2011, 71f), e.g. in connection with biomass-to-liquid processing (BTL) and the production of synthetic fuels (Dahmen, Dinjus 2010). Pyrolysis units can be realized on multiple scales from industrial plants to cooking stoves. Even small mobile units for the temporal on-site use in vineyard management are under development (Holweg 2011). Very different biomass feedstocks, especially those presently considered wastes, such as straw, nutshells or pomace etc. can be converted. Pyrolysis co-produces gas and condensed liquid oil which are used for bioenergy capture as well as solid charred black carbon material, also referred to as "biochar". Thereby mass balance, composition and quality of the products greatly vary according to input material and process parameters such as temperature, pressure, and time etc. Biomass may also be completely converted into biochar (carbonization) without energy generation. Hydrothermal carbonization, also called wet pyrolysis, can also process wet biomass, such as manure and aquaculture residues, or biomass with low and varying dry matter content. Depending on the procedure biochar, denoting a broad range of black carbon material with different structure and properties, may be used as high quality industrial material or as soil amendment (Libra et al. 2011; Bridgwater 2003; Biofuelswatch 2011,10f).

The application of biochar to soils scaled up to a global strategy is advocated as a land based solution for carbon sequestration and environmental management with claimed positive effects on soil productivity and food security as well as water quality (Lehmann, Joseph 2009). The use of bioenergy and biochar co-generated from pyrolysis of crop residues are regarded complementary by UNCCD (2008, 4): "Pyrolysis with biochar carbon sequestration provides a tool to combine sustainable SOC management (carbon sequestration), and renewable energy production. While producing renewable energy from biomass, SOC sequestration, agricultural productivity, and environmental quality can be sustained and improved if the biomass is transferred to an inactive carbon pool and redistributed to agricultural fields. The uses of crop residues as potential energy source or to sequester carbon and improve soil quality can be complementary, not competing uses".

However, the biochar strategy is also heavily criticized. Two of the main points of criticism are the questionable cultivation of biochar plantations, which pose issues similar to those of biofuel plantations (as described for Jatropha plantations on page 221f), and the basic assumption of a long-term stability of biochar in soils (Biofuelswatch 2011). This assumption, claiming that the core material of biochar remains recalcitrant in soils for hundreds to thousands of years due to its polycyclic aromatic structure, is solely based on a few laboratory incubation studies, short-term field studies and mathematical models (Major 2010; Biofuelswatch 2011, 10–22). Recent findings suggest that the persistance of soil organic carbon is an ecosystem property rather than a material property predominated by environmental and biological controls (Schmidt et al. 2011). Schmidt et al. (ibid. 52) argue that "the persistance of organic matter in soil is largely due to complex interactions between organic matter and its environment, such as the interdependence of compound chemistry, reactive mineral surfaces, climate, water availability, soil acidity, soil redox state and the presence of potential degraders in the immediate microenvironment". They propose to move on from the concept of recalcitrance of a type or pool of organic material with intrinsic material properties and decay rates to an emerging understanding of soil organic carbon cycling in global models and thereby e.g. to treat microbial *bio*mass, which makes up an important component of soil organic matter (SOM), not just as a pool of carbon, but rather "as an agent that affects the decomposition of SOM" (ibid.). Furthermore they state that "sequestration strategies based on adding recalcitrant material to soils, whether through plant selection for recalcitrant tissues or through biochar amendments, must be re-evaluated" (ibid. 53).

The assumption of long-term biochar stability in soils is furthermore based on an analogy to ancient "Terra Preta (do Indio)", black-earth-like anthropogenic soils occurring in the humid tropics. Terra Preta (*Portuguese*: black earth) has been found as patches of soils with enhanced fertility inbetween a landscape of infertile soils especially in central Amazonia. Terra Preta soils are characterized by deep dark A-horizons, higher soil organic matter including charcoal, higher pH values, and higher nutrient and moisture-holding capacity than the surrounding soils. They are dated back to ages of 500 to 7000 years, thus indicating a permanent stability of soil organic matter. However, simply burying, ploughing or injecting biochar into soils eventually in combination with sludge, ash or fertilizer application is not the same as Terra Preta. Besides charcoal particles, pieces of ceramic pots and traces of human excrements, food wastes, and animal bones have been found at Terra Preta sites (Glaser 2007; Glaser et al. 2001). While the ancient indigenous knowledge of creating Terra Preta soils has been lost, some researchers and developers claim to have been able to unravel its production process and to reproduce a soil substrate with properties (e.g. microbial composition, fertility, stability) very similar to ancient Terra Preta do Indio (Pieplow 2008; Dotterweich, Böttcher 2010). It is supposed that charcoal dust was primarily used for sanitation of source separated human excreta, whereby microbial colonization of the porous charcoal structure and nutrient sorption occurs. The collected substrate was then mixed with organic residues and fermented and preserved under anaerobic conditions in big ceramic pots e.g. by metabolic processes of lactic acid bacteria, while invading soil organisms, e.g. earth worms and fungi, further generated stable humic complexes (Pieplow 2008, 3f). According to the developers, production of “Terra Preta Nova” from organic residues can be easily done on a household to communal scale eventually in combination with sustainable sanitation systems as described above. Instead of conventional charcoal biochar from pyrolytic processes may also be used, with or without bioenergy capture. The developers, however, dissociate themselves from ‘the biochar approach’ for climate farming and point out that **any practices to produce new Terra Preta must be** (and that their research and entrepreneurial activities actually are) **embedded in a sustainable material flow management and land-use management on a local to regional scale** (Dotterweich, Böttcher 2010, 7–10; Pieplow 2008, 4).

Applied research projects using Terra Preta Nova and regional material flow management as key concepts are currently being conducted in Germany under programs for sustainable land management and regional development. A project named “TerraBoGa” for example seeks to establish closed cycles in the botanical garden of Berlin by producing Terra Preta Nova from its landscaping residues and a sustainable sanitation system and applying it as a substitute of purchased commercial soil substrates and soil conditioners.[105] Another project “LaTerra” investigates the ecological potential and economic feasibility of the production of Terra Preta Nova from organic residues and biogas digestate and its use for the restitution of degraded sites in different regions, in particular on brownfields, former military sites, and storm damaged forest areas.[106]

However, the production of Terra Preta Nova as a biomass conversion process including biochar application is a relatively recent development and still has to prove its superiority compared to classical compost, its long-term SOC stability, its harmlessness

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[105] http://www.terraboga.de (accessed 1/2/2012 and 12/30/2014)

[106] http://www.laterra-forschung.de (accessed 1/2/2012 and 12/30/2014)

with regard to accumulation of pollutants, and its sustainability within a land use context. Therefore, developing quality standards for input and output material of biochar production processes as well as **introducing certification schemes for biochar similar to biofuels is under discussion** (Mielke 2011), **which basically leads back to the starting point of this study**. Thus, the argumentation for Landscape Quality Management providing reference values and means for the assessment and development of sustainable biomass production may equally apply to a sustainable biochar respectively Terra Preta production and application.

Investments bound in a certain biomass technology always bear the risk of landscape conversion according to technical requirements. Even developing technologies with potential ecosystem service properties may also involve the removal of technical barriers to ever expanding land and biomass appropriation. Therefore it is most important to join forces for a sustainable landscape development and to link the development and application of such technologies and entrepreneurial activities to a facilitating and coordinating management approach as could be possible through LQM.

4.3 Discussion: Retention cultures, non-use of biomass and the role of LQM

The presented case studies show that a great variety of biomass/ bioenergy production practices and technologies are available, which could be applied in a complementary manner in a regional landscape context. Besides a considerable diversity, they also show similarities. Such different cultivation systems as intermediate cropping, agroforestry, grassed waterways, and constructed wetlands etc. as described in Sections 4.1.1-2 have in common that they – better than conventional agricultural and urban land uses – have the **potential to retain water, nutrients and carbon on site**, properties which are decisive for maintaining the basic functional services triangle as described in Section 2.3.3. Therefore, they are named here '**retention cultures**'. Furthermore, they may provide reproductive habitat for species which are carriers of other services (e.g. pollination, biological control) and values (biodiversity). Retention cultures are not only relevant for the services of terrestrial ecosystems, but also – as they reduce the eutrophying and acidifying transport of soil particles, base cations, nitrogen and phosphorus from land to the sea – for habitat quality and services of coastal and marine ecosystems.

Biomass productivity is usually high where water and nutrients are abundant. It thus makes sense to establish retention cultures for **complementary biomass production**

as sinks in the landscape, where nutrient rich wastewater, run-off and drainage water accumulate. Harvesting such sinks, e.g. retention ponds, is needed to maintain long-term retention capacity (Reinhardt et al. 2006, 653f). Their management for bioenergy use offers the theoretical possibility to recirculate nutrients back to sources. For example, ash recycling as described in Section 4.2.2 from whole tree harvesting of forests on hilltops can only return those base cations extracted with the phytomass and does not account for those which are lost by leaching processes. In contrast, eroded substances can be partly recovered by harvest of biomass and sediment from e.g. constructed wetlands and ponds in depressions and lowlands of a catchment. This means that through retention cultures not only those nutrients extracted by harvest, but also those lost by leaching processes, especially base cations essential for buffering capacity, could be returned to a certain degree. However, ash and sludge recirculation is labor, cost and energy intense and thus limited. Additionally, ash amendments to soils may be regulated and limited by their actual content of undesirable susbstances. For the reason of not accumulating heavy metals and other pollutants in the soils, a "governing principle of balance" is recommended for compensatory doses of ash application in the Swedish Ash Programme, which basically says that only "what has been taken away may be returned, nutrients as well as less desirable constituents. […] To return the desired quantities of mineral nutrients, one needs to keep track of the quantities of logging residues actually removed, which vary depending on soil fertility, essence, etc., and the ash content" (Ribbing, Bjurström 2011, 153f).
Principally, however, **for an even nutrient balance, not only what has been removed and returned, but also what has been mineralized and leached out is to be accounted for.** Otherwise, even with ash recycling, long-term soil (re)productivity, largely governed by the water regime, is neglected similar to what happens with the concept of alleged carbon neutrality (page 48f). Thus, intensive whole-tree harvesting especially in upper areas of catchments is to be reconsidered with regard to irreversible losses.

Furthermore, not only nutrient cycles (and losses) matter, but also the re-etablishement of short water cycles for their importance to climate regulation and disaster prevention. With regard to landscape efficiency as a trend indicator for the basic triangle of water, soil, and climate services, particular attention should be paid to fostering the water retention capacity of the whole landscape area. Thereby not only permanent vegetative land cover (perrenials[107]) is decisive, but especially organic substances on and in soils (organic debris and humus) acting like a sponge (page 136). In contrast to the common

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[107] With regard to the (re)productive role of water and its main manager, the vegetation, bioenergy technologies using perennials pose the opportunity to re-establish permanent vegetation in regions with relatively low vegetative land cover. Conversely that does not mean that technologies based on perennials can be generally regarded sustainable.

opinion that the use of residues is to be favored over the use of energy crops for bioenergy production, from a landscape efficiency point of view the production of energy crops in the form of retention cultures offers complementary potential, while the bioenergy use of residuals especially from forests is to be approached with care.
Generally one could say that **the energetic use of organic residues should be context-specifically weighed against (1) the functional role of residues left in ecosystems** (e.g. 'logging waste')**, and (2) the conversion of residues into high-quality soil substrate returned to the landscape with regard to** maintaining or actually enhancing **regenerative services.** On land which has been exposed to humus decomposition and leaching processes over a long time and which exhibits unsufficient water and temperature buffering capacity, a prevailing recirculation of available organic residues in the form of e.g. Terra Preta Nova as described before could be more sustainable than its bioenergy use. Thus, a complementary biomass strategy in a certain region with e.g. highly degraded soils and good other renewable energy potentials could mean to prefer the conversion of residue biomass into soil conditioner rather than into bioenergy sources in favor of improving basic regenerative services and regaining long-term (re)productivity.

A complementary biomass strategy should also opt for the 'non-use' of biomass in dedicated ecosystems. For example areas of high ecosystem service value or 'wilderness reference areas' (as mentioned in Section 2.3.5) could be established and protected from biomass use. This would mean another protection category of areas, where no harvest of biomass occurs, but the 'production and conversion of biomass' is solely performed by organismic communities. This conscious decision for **'non-use' of biomass** in designated areas, however, **will not be 'useless', but very useful with regard to biological-ecological work**, according to the motto 'let ecosystems do the job'. Since 'non-use', however, seems difficult for many people to accept, the concept of natural productivity and ecosystem services can help again to highlight the value-creating activity of ecological systems.

The multiscale reference building process of LQM would provide the necessary benchmark and knowledge pool to assess the sustainability of biomass production as well as to develop strategies, programs and technologies for complementary bioenergy systems. However, as long as such a comprehensive mechanism is not fully established it is still possible to develop complementary biomass strategies by means of a simpler LQM process, e.g. through a close cooperation of regional and landscape planning with watershed management as well as relevant stakeholders and actors. In such a case, the complementary strategy should at least contain:

- an ecosystem services/ landscape qualities assessment with prioritized needs for maintenance and improvements, eventually with set targets,
- an analysis of landscape history and trends,
- a toolbox of complementary practices and technologies suitable for the region, including a biomass potential analysis and scenario alternatives
- a stakeholder based vision for a sustainable landscape development (where landscape is understood as shared living and production space of humans and other living communities)
- an institutions' and actors' analysis
- a catalogue of measures including existing and potential funding schemes, etc.

For the planning and implementation of a complementary biomass strategy the explicit designation of a management team is required, equipped with a broad range of planning and management instruments and a mandate and budget for coordinative activities. An established LQM mechanism would provide such capacities.

For the success of an extensive land use strategy (comparable to a complementary biomass strategy, page 213) Heck et al. (2008) point to the importance of cooperative actors' management, a long-term continuation of the strategic process, clear and transparent monitoring of "Naturschutzqualität" (comparable to landscape quality) and the development of a regional certification system. A standardized LQM process could provide long-term continuation, avoid proliferation and arbitrariness of regional sustainability certificates, and promote international acceptance. By granting sustainability certificates LQM could enable smallholders especially to be eligible for governmental funding and to get access to high quality market segments.

As already mentioned, further coordinative management activities could include for example pro-actively initiating and supporting integrated land management practices, facilitating contacts and fair agreements between farmers, biomass processing companies, municipalities, authorities and organizations for nature conservation, or co-founding business networks and development cooperations. The management may furthermore organize experience exchange, provide a forum for conflict resolution and support legal permission e.g. if existing land use plans pose hindering barriers as may be the case for agroforestry. Change management competences may prove to be very useful when realizing retention cultures in water flow related land-use patterns or designating unmanaged areas providing ecosystem services.

Since in many cases, however, complementary biomass production systems will not be competitive with conventional production pathways optimized for single commodity outputs over decades (Fachagentur für nachwachsende Rohstoffe 2010, 99–108), other compensation measures for the added landscape quality value have to be found. As already mentioned the management could network and adapt existing funding schemes, e.g. from agri-environmental, regional and rural development programs, carbon certificates or other legal schemes (Heck et al. 2008, 68ff) or eventually use its own funds.

4.4 Summary and conclusions

Not only assessment of the sustainability of biomass production, but also the proactive development of sustainable (re)production systems is the ambition of LQM. Sustainable (re)production denotes production systems that through their production activities maintain favorable social-ecological conditions as the 'reproductive sphere' of economic productivity. In the case of biomass this means biomass production (and conversion) systems that yield simulteneously to bioenergy also regenerative ecosystem services and landscape quality as complementary outputs. When considering *bio*mass (before harvest) as the mass of living beings performing valuable work with their specialized functional traits – and their living activities as integrated water, land and resources management activities – in the design of production systems, then one may arrive at 'complementary' rather than 'competitive' systems. 'Complementary biomass production' is the name given here to a production based on crops and practices that do not directly compete with classical agricultural food production, but can complement it in terms of providing services.

Case studies show that a variety of potentially complementary crops and practices exist. They can be integrated in present land use patterns on a field scale or landscape scale. On a field scale, for example, mixed cropping systems, crop rotation and agroforestry may improve soil services, erosion control, pollination, and biological control, etc. On a landscape scale grassland management, short rotation plantations and agrowood alley cropping as well as wetland and pond systems can further enhance carbon sequestration and climate regulation, habitat services, nutrient cycling, water quality and flood protection as well as enrich the recreational and experiential qualities of landscapes. In some cases biomass production can also be used to restore degraded land. However, good knowledge of the local situation, values and processes is required. General claims of available 'abandoned land' or 'wasteland' and recommendations to produce biomass on 'marginal land' should be viewed with scepticism.

Besides a considerable diversity, complementary practices show similarities. Most of them have in common the potential to retain water, nutrients and carbon on site, properties, which are decisive for maintaining the basic functional service triangle. Such 'retention cultures' are not only relevant for the services of terrestrial ecosystems, but also – as they reduce matter transports from land to the sea – for habitat quality and services of coastal and marine ecosystems. Since biomass productivity is usually high where water and nutrients are abundant, it makes sense to establish 'retention cultures' for complementary biomass production as sinks in the landscape, where nutrient rich wastewater, run-off and drainage water accumulate. Harvesting such sinks for biomass use principally offers the opportunity to recover and recirculate nutrients and minerals which have been washed out. However, this can also not serve as a general rule. Whether and how such sinks can be established and managed depends on the particular landscape context and technologies used.

The case studies also reflect that, to realize their beneficial effects, complementary practices require experimental experience and familiarity with specific landscape and site characteristics, the behavior of plants, associated microbial communities, and inhabiting fauna plus cultural habits. Thus many practices are based on traditional land management systems. Merging such systems with innovative bioenergy technologies offers a chance to revitalize traditional or create contemporary cultural landscapes. In particular water-flow related spatial-temporal land use patterns of ‘retention cultures’ contain the potential to deliver landscape identity in a way that they may be more coherent and intuitively comprehensible than squared land-use mosaics overriding topography and water regime. However, a prerequisite for the development of sustainable contemporary landscapes by means of complementary biomass production systems is that the design of relevant technologies is informed by adequate social-ecological knowledge and the intention to improve regenerative ecosystem services and landscape qualities. Thus, the development of technologies for bioenergy supply (and others working with biomass as renewable resources) should go hand in hand with the development of complementary land use systems and land management practices. Especially three fields of technology seem of outstanding relevance for developing sustainable biomass and bioenergy (re)production systems:

1. **Land management technology:** Complementary practices often require different machinery than common agricultural practices, e.g. for sowing mixed cultures, harvesting on contours or mowing under a wet management regime. In contrast to a trend towards bigger, heavier, high-output machines, the development of small, adaptable and maneuvrable equipment would be desirable from a landscape quality point of view.
2. **Nutrient cycling technology**: Closing nutrient loops is usually regarded essential to sustainable biomass production. Nutrient cycles in the bioenergy sector can be established through (a) reusing wastewater, i.e. the nutrients and water contained therein, as a resource for the production of biomass and (b) recirculating residues from biomass conversion processes back to the land. Thus the co-development of complementary practices with suitable wastewater, sludge and ash recycling techniques will be critical for sustainable biomass production. This can reach as far as infrastructural engineering for source separation, sustainable sanitation and safe wastewater reuse or chemical engineering for the

design of products entering domestic wastewater flows. Furthermore, the design of non-toxic wood products is desirable with regard to their cascade use for bioenergy and the recycling potential of combustion residues. Also the control of combustion via process engineering and the development of separation techniques (e.g. of fly ash from bottom ash) is essential for separating useful from harmful fractions contained in ashes. However, (context-specific) quality criteria for ashes and incentives for 'ash-fertilization' of intensively logged forests are yet lacking.

3. **Conversion technology**: Combustion is only one possible biomass-to-bioenergy conversion technology. Other conversion technologies are e.g. anaerobic fermentation and pyrolysis. Generally, conversion technologies process biomass extracted at some point from the landscape (input) and eventually co-produce nutrient rich substrates returned to the landscape (output). Thus, they need to match both land management and nutrient cycling technologies and align with their landscape interfaces. This is especially valid for pyrolysis technologies and biochar-to-soil or Terra Preta Nova applications. Experts suggest that such practices and associated research and entrepreneurial activities must be embedded in a sustainable material flow management and land-use management on a local to regional scale. Due to very uncertain and problematic effects, especially of a promoted pathway of carbon sequestration based on 'biochar', experts furthermore discuss quality standards for input and output material of biochar production processes as well as to introduce certification schemes for biochar similar to biofuels. This basically leads back to the starting point of this study. Thus, the argumentation for Landscape Quality Management providing reference values and means for the assessment and development of sustainable biomass production may equally apply to a sustainable biochar respectively Terra Preta production and application.

Nevertheless, such technology development with an eye on its metabolic, energy and site interfaces with the landscape would mean to design technologies not only for their primary commodity output, but also according to landscape quality requirements, instead of converting the whole landscape to fit technology requirements as it is usually the case. However, before grounding new technologies in an expected (large scale) supply of biomass resources, technology development in cooperation with LQM should consider the following two rules: Firstly, the energetic use of organic residues should be context-specifically weighed against the functional role of residues left in ecosystems and the conversion of residues into high-quality carbon-rich soil substrate to be returned to the landscape for maintaining or enhancing regenerative services. Secondly, for an even nutrient balance of bioenergy systems, not only what has been harvested and recycled to the land (e.g. via ash application), is to be accounted for, but also what has been mineralized and leached out of the watershed (irreversible losses). These rules challenge general recommendations claiming that the use of residues and ligno-cellulosic material is principally to be favored over the use of energy crops.

The development and application of complementary biomass/ bioenergy practices and technologies on the landscape scale but also the initiation of field scale measures require good coordination and cooperation across administrative and property boundaries. Regional complementary biomass strategies, developed by LQM together with the relevant stakeholders and actors, can be a tool for a coordinated, widespread and place-based implementation of these practices. Via such strategies, suitable sites, practices and technologies for complementary biomass (re)production can be identified and tested as well as projects, measures and programs launched. Furthermore, complementary biomass strategies may also opt for the ‘non-use’ of biomass in sensitive areas. This should include an open public communication that ‘non-use’ is not ‘useless’, but very useful with regard to productive biological-ecological work.

Another role of LQM will be to care for compensation and financing of complementary practices and technologies, which in the beginning may not be competitive with conventional production pathways optimized for single commodity outputs over decades. For this purpose the management could network and adapt existing funding schemes, e.g. from agri-environmental, regional and rural development programs, carbon certificates and other legal schemes or eventually use its own funds. However, another option rather than expensive financial means compensating for better social-ecological performance is to transfer sustainability standards and LQM requirements to all kinds of technologies and production practices, in order to create an even playing field.

The last chapter points to the potential transferability of the LQM process and to the assessment and development of sustainable production in other fields, and gives a brief outlook on how LQM may drive sustainable innovations.

5 Outlook: Embedding innovation in renewability

Research, innovation and technological development are regarded as important drivers of economic growth, especially with regard to a European knowledge economy, and therefore receive strong political support. While it would be desirable and logical from an LQM point of view to arrive at some point at a ‘post-growth paradigm’ (Merritt, Backer 2011; Jackson 2009; Costanza et al. 2014) due to finite land area, innovations in all societal fields will be necessary to deal with the social-ecological crisis of “the reproductive” as described at the beginning of this study (Chapter 1.1). However, innovation per se does not guarantee a sustainable development. On the contrary, history is filled with examples of innovations, especially technological inventions, which had unintended side-effects, e.g. negative environmental impacts. These are usually tackled by policy at a later point in time. The push for biomass-for-biofuel use and associated technological development with a delayed reaction on minimum sustainability standards (as described in Chapter 1.5) is just one example. Often, innovations happen so fast that policy cannot keep up with regulations.

Therefore it would be desirable for sustainability standards and a territorial dimension to be integrated in innovation processes and processes of technological and business development right from the beginning. Policies for eco-innovations and corporate environmental management systems aim in this direction. Especially noteworthy here are the international ISO 14000 series and the European Eco-Management and Audit Scheme (EMAS). EMAS and ISO 14001 are voluntary instruments to promote continuous improvements in the environmental performance of organizations. They require the establishment of a standardized environmental management system as part of the overall management of the organization. The system manages the organizations’ environmental aspects and impacts according to an environmental policy to be determined by the organization (ISO 2009a, 3.8, European Commission 2009b Art.1, 2/1, 2/13).

Kanning (2004) investigated these corporate environmental management systems in terms of possible interfaces with knowledge stocks and practices from ecological economics and spatially oriented environmental planning (i.e. landscape planning). She found critical areas for potential synergies regarding the following points:

(a) Determination of significant environmental impacts
(b) Actual eco-effectiveness
(c) Diffusion
(d) Closer coupling of environmental management with quality management
(e) Sustainable innovations

(a) For the identification of **significant environmental impacts** of their registered production sites companies need to refer to external information on the fragility and conditions of the environment on multiple scales, consult views of interested parties, and cooperate with (a multiplicity of sectoral) public bodies (European Commission 2009b, Annexes I.2, I.3). With regard to production sites as units of assessment Kanning (2004, 159-189) also points out that the determination of significant impacts should be guided by spatially explicit (regional) environmental quality objectives obtained from participative sustainability discourses involving expert knowledge on accumulating impacts and complex ecological interactions. She shows that landscape planning (in Germany) has some suitable methods and information to offer, but needs to develop in a more process oriented direction. Furthermore, sustainable regional development processes should include the following elements comparable to components of corporate environmental management systems: action targets based on quality objectives, indicators, monitoring and reporting, measures and control of success (ibid. 170).

Landscape Quality Management could fulfill these requirements by providing a landscape reference system including a development vision and quality objectives, an indicator and monitoring system, a knowledge and expert pool as well as bundled stakeholder opinions and information on environmental conditions, trends and vulnerabilities, etc. Furthermore, LQM is designed as a continuous self-reflective process. Companies could thus ideally link the environmental management of their production sites to an LQM process in their region.

(b) Companies measure the improvement of their environmental performance on the basis of their self-defined environmental objectives, which often refer simply to input-output parameters. But this does not allow an assessment of **eco-effectiveness**, i.e. whether the environmental management actually brings about improvements of the environmental quality, which is what EMAS has declared its goal to be. In the end, success can only be measured on the basis of tangibly achieved environmental improvement (ibid. 157f), i.e. in the landscape and its perception.

With its monitoring LQM offers the opportunity to indicate improvement or degradation of different aspects of environmental or landscape quality, although this does not always provide a good indication of the performance of individual firms. However, if landscape managers, corporations and eventually consultants would cooperate within a trusting atmosphere, it could be possible in many cases to design tailor-made measures and to follow their effects (see sustainable innovations below).

(c) Another reason for unsatisfactory effectiveness is the low **diffusion** of environmental management systems. The share of EMAS registered companies and sites in Europe in 2003 was located in the vicinity of tenths of one percent. (Since then their number has doubled[108], but it is still an extremely small proportion of the total number of corporations.) The diffusion of ISO 14001 is probably higher. However, there is a great need to increase the application of corporate environmental management, especially within small and medium sized enterprises, and to make it more known to the public (ibid. 154f).

Equipped with sufficient capacity, LQ managers could actively approach land users and corporations, and give them the initial impulse for environmental management by inviting them to participate in the LQM process. In return, LQM could offer support for certification, or even apply to become an accrediting authority themselves, carrying out (group) certifications, e.g. for small holders. The EMAS cluster approach and required national support for small organizations seem favorable in this regard (European Commission 2009b, Art. 36, 37). In addition, through its public campaign and the creation of a public awareness, LQM could raise the demand for certified products in the region, in which landscape qualities are co-produced in the production process, and pursue development of transparent quality markets.

(d) A broader application of **environmental management** systems could be possibly achieved, if they were more closely **coupled with** the widely practiced **quality management**. Combining them in the sense of a Total Quality Management has been discussed in the course of the process oriented transformation of both management systems. This should open up possibilities to better integrate environmental management into the core processes of a company (Kanning 2004, 163f). Today environmental management and quality management are aligned, but still separate systems (cf. ISO 2009a, 6, Annex B).

LQM with a clear relation to quality could facilitate a closer connection of the two systems, e.g. under the key word of “sustainable excellence” (SEG & DBU 2006, EFQM vision[109]). For example, what if the excellence model of the European Foundation for Quality Management (EFQM) were to include the contribution of a company and its production sites to regenerative ecosystem services and various aspects of environmental/ landscape quality under its output criterion “society results” (Figure 23)? On the one hand this would support the ‘sustainable (re)production rule’, i.e. that the preconditions of production – namely natural productivity and favorable social-ecological conditions – are to be sustained or reproduced throughout all production processes (Chapter 1.1). On the other hand this would make clear that corporate environmental (and quality) management needs to take into account a stronger territorial place-based dimension (cf. Kanning 2004, 207ff).

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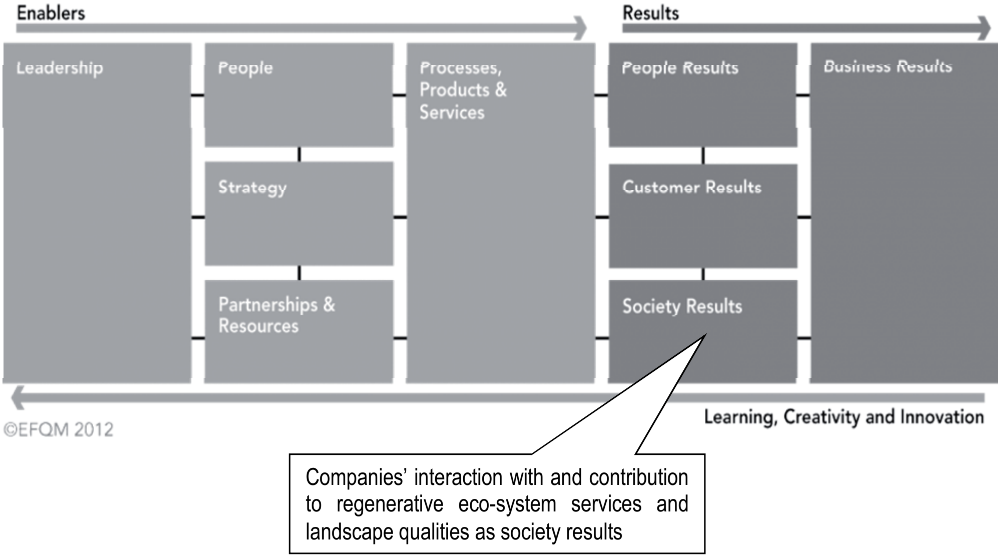
[108] http://ec.europa.eu/environment/emas/documents/articles_en.htm#statistic (accessed 3/6/2012)

[109] http://www.efqm.org/about-us/our-mission-vision-values (accessed 11/14/2013)



Companies' interaction with and contribution to regenerative eco-system services and landscape qualities as society results

Figure 23: EFQM excellence model with extended society results
(Source: EFQM 2012, adapted)

(e) However, as long as the continuous improvement of environmental or sustainability performance is a voluntary and non-binding task for corporations, the application of environmental management systems will strongly depend on cost-benefit considerations. Besides internal factors, like quick resource efficiency gains, the importance of environmental management in the long run is especially seen in the company's improved innovation capacity and strategic positioning in the market (Kanning 2004, 155ff). Kanning (ibid. 164ff, 177) points out that for advanced sustainable innovations it will be important to incorporate into organizational learning not only abstract input-output knowledge but also place-based ecological process knowledge about interactions and changes in specific environments. She furthermore suggests that (process oriented) landscape planning with the help of regional management should actively engage in innovation consulting and the organization of regional (eco-) innovation platforms (ibid. 190-193, 211-230). Roux and Heeb (2002), for example, show how regional landscape development processes can lead to the formation of "innovation cooperations" as legal structures to bring sustainable innovations to application and the market.

Organizing platforms, consulting and training for **sustainable innovations** could thus be another role for LQM in its action phase. Further experts (e.g. from the fields of Ecological Engineering, Industrial Ecology or Cradle to Cradle Design etc.) could be involved to tackle the knowledge interface of landscape processes with companies' internal metabolic and management processes. In the case of business secrets, LQM workshops with the companies' key persons like managers, developers or operators etc. could initiate a company-internal change management and give its strategic and creative processes an orientation towards regenerative services and landscape quality outputs.

Technological innovations and innovations towards a (re)productive mode of the industry, however, will be only part of the solution. An approach encompassing the whole landscape, and its functions, services and qualities is necessary for sustainable development. One must know where utilization is sensible and desired and where it is perhaps not. In the case of biomass this can mean, for example, establishing a balance between utilization of biomass and returning it to or leaving it in ecosystems. With regard to the green water vapor flow and its associated vital services, for example, it may be more sustainable to reafforest a degraded site by means of organic residues instead of constructing a solar power plant there and using the residues for bioenergy.
Another example in connection with renewable energy is hydropower and ecological pump storage systems. While it is partly possible to design them in a way yielding contributions to regenerative services and landscape quality, e.g. increased water retention and biodiversity, a region may decide not to dam up all its rivers and creeks with regard to an experiential or ethical desire for free flowing water. In such cases classic land use planning is needed. But it should be complemented with innovative tools for financial compensation, such as that between communities that grant usage rights and communities that consciously refrain from doing so (Brüll 2005b): possibly a further mediator task for LQM?

Considering all these points, Landscape Quality Management could play a key role in embedding innovation in the long-term 'renew-ability' of ecosystems, landscapes and societies. It may provide a solution for the necessity to find a balance between novelty and change on the one side and conservation and regeneration on the other side – as stated in the very beginning of this study (Chapter 1.1). Hence, with its approach for innovative societal renewal, LQM may help to sustain the conditions and capacities vital for the survival and quality of life of future generations of humans and other living beings.

However, all this will require further research. First of all the draft of Landscape Quality Management itself is to be tested in pilot projects and further refined with 'true' transdisciplinary research involving various stakeholders and experts. Also, complementary biomass practices should be developed in pilot projects before being upscaled to a regional strategy. Dependent on promising research results, how the sustainability of other production systems could be assessed and developed with LQM, how LQM could complement product certification as well as corporate environmental and quality management, and how it may support quality markets and sustainable innovations should be further investigated.

In my vision for *2070 Landscape Quality Management is successfully established and broadly applied. Complementary biomass provides a small, but essential, buffering component to a regional 100% renewable energy mix. Furthermore, LQM largely contributes to the assessment and development of sustainable production. As an innovation itself to strengthen "(re)productive" societal capacity in the beginning, LQM now accompanies the development of many technological and other innovations. Hence innovation processes occur in a broader context of the 'renew-ability' of landscapes, ecosystems and their services, and thus support the long-term renewability (i.e. sustainability) of society and economy. Looking back from a sustainable society in 2070, LQM – with its focus on 'productive biological-ecological work', regenerative ecosystem services and landscape qualities – helped to find a new balance between the use and 'non-use' of land and natural resources, as people increasingly realized that natural productivity – even if not directly exploited – 'does an amazing job'.*

Acknowledgements

While I was writing this dissertation, it became increasingly clearer to me that being 'productive' is not possible without being enmeshed in 'regenerative' spheres and activities. Although this is a commonplace, it does not seem to be consciously anchored in our society. Or perhaps exactly because it is self-evident, the permanent existence of an effective reproductivity – in the sense of a continuous maintenance of productivity – is simply assumed, or at least not adequately appreciated and cultivated. It became clear to me that the regenerative areas of home life as well as of ecology and society require not only an investment of time and other resources but also a particular attention and recognition, whether it is the daily moments of one's own mental-physical renewal, child care and other care-taking activities or the indispensable and restorative environment of productive ecosystems and high quality landscapes.

That is why I would like to begin by thanking my family: my son Bennet, who lets me experience what pure life is; my husband Dirk Bartz, my father Alfred Brüll and his wife Mechthild Lohmann, as well as my sister Janine Brüll, all of whom had my back and supported my dissertation project with conversations and delicious food, long-standing patience and love, child care and zest for life and a great deal more.

I would also like to express my deep gratitude to all the other relatives, friends and the staff at various institutions, who lovingly cared for Bennet in the many days and hours that I was able to work and earn my doctorate: especially Edeltraud Dohmen, Christa and Peter Hein, Véronique and Kai Bartz, Ingrid and Murielle Beyel and Eva Schubert-Maas, our daycare provider Tatjana Désy, who was always in a good mood, the nursery team from the Henri Chapelle nursery school and the La Chenille daycare center as well as the whole team of Haus Kühberg in Blaichach. Without their responsible care-taking, no long and concentrated work would have been possible for me! My friend Eva Schubert-Maas opened my eyes to the unbelievable accomplishment of care-taking activities not only at the beginning but also at the end of a life, and enriched my work with philosophical reflections.

I am also grateful for the plants, animals and other elements that comprise the beautiful landscape in which we live. The lush green of the grass, the lively chirping of the birds, the tranquility of the trees, the burbling of water: all this and much more uplifted my weary spirit time and time again, brought (back) perseverance, motivation and ideas and renewed my capacity for concentration.

Here I would like to remember my deceased mother Inge Brüll. Above all I have her to thank for the respect towards nature upon which this work is based, as well as other values and fundamental knowledge.

Naturally I would like to thank very warmly my advisor Prof. Dr. Sabine Hofmeister, who inspired me deeply through her theoretical approaches, always motivated and never pressured me and accompanied my work academically through critical suggestions. My thanks go also to my co-advisor Prof. Dr. Helga Kanning, who also encouraged me through her writings and brought clarity to my thoughts. I would also like to thank Prof. emeritus Wolfgang Haber particularly, for his professional recognition and praising motivation for my work “at the halfway mark”.

For twenty years, a close friendship and professional cooperation has connected me with my colleagues Dr. Grit Bürgow and Ina Küddelsmann, who certainly influenced this work in a crucial way. I thank them for the many years of collaboration in projects, for sharing thoughts and being soulmates and for inspiring ‘landscape tours’. I would also like to thank my colleague and friend Günther Kunz for our long-standing collaboration in construction projects and the chance to get insights into the world of technological development and renewable energy. In the process he deepened my admiration and understanding for the intelligence of nature and her ‘constructive solutions’.

I would like to express my deep gratitude to the Reiner Lemoine Foundation, especially to Dr. Annegret Jatzkewitz and Clemens Triebel, for the very generous financial and also the non-material support in the spirit of Reiner Lemoine, an always friendly and unconventional soul whom I had the privilege of getting to know. I also thank Leuphana University for a final grant and the uncomplicated administration of my doctoral program.

I would like to thank Prof. Dr. Frank Lohrberg and my colleagues at the Chair of Landscape Architecture at RWTH Aachen University, especially Matti Wirth, and also colleagues at Euregio Meuse-Rhine and the Three Countries Park for a pleasant working atmosphere and flexible working hours at my job and also for content-related inspirations, fresh ways of thinking and a practical orientation to applications, all of which left their mark on this work. I am grateful to Prof. emeritus Wilhelm Ripl for teaching us in the course of our studies about the meaning of water in the landscape and how to read patterns.

Last but not least I would like to express special thanks to my reader Dr. Paula Niemietz for her careful correction of the English in my work, which she accomplished with patience and a wonderful feeling for language in both English and German.

Danksagung

Während ich diese Dissertation schrieb, wurde mir immer deutlicher, dass ‚produktiv’ zu sein nicht möglich ist, ohne eingebettet zu sein in ‚regenerative‘ Sphären und Tätigkeiten. Obwohl dies eine Binsenwahrheit ist, scheint es in unserer Gesellschaft nicht bewusst verankert zu sein. Oder vielleicht gerade weil es eine Selbstverständlichkeit ist, wird der dauerhafte Bestand einer wirksamen Reproduktivität – im Sinne einer beständigen Unterhaltung der Produktivität – einfach vorausgesetzt, zumindest nicht adäquat gewürdigt und gepflegt. Mir wurde klar, dass die regenerativen Bereiche sowohl im privaten Leben als auch in Ökologie und Gesellschaft nicht nur einer Investition an Zeit und anderer Ressourcen sondern auch einer besonderen Aufmerksamkeit und Anerkennung bedürfen, ob es nun tägliche Momente der eigenen geistig-physischen Erneuerung, Kinderbetreuung und andere Sorgetätigkeiten oder die lebensnotwendige und erholsame Umgebung leistungsfähiger Ökosysteme und hochqualitativer Landschaften sind.

Daher möchte ich mich an aller erster Stelle bei meiner Familie bedanken: bei meinem Sohn Bennet, mit dem ich erleben kann, was Leben pur ist; bei meinem Mann Dirk Bartz, meinem Vater Alfred Brüll und seiner Frau Mechthild Lohmann, sowie meiner Schwester Janine Brüll, die mir jederzeit Rückhalt gaben und mein Promotionsvorhaben immer unterstützten, sei es durch Gespräche oder leckeres Essen, langjährige Geduld und Liebe, Kinderbetreuung und Lebenslust und vieles mehr.

Auch allen anderen Familienmitgliedern, Freunden und Mitarbeitern verschiedener Institutionen, die sich liebevoll um Bennet gekümmert haben in den vielen einzelnen Tagen und Stunden, in denen ich arbeiten und promovieren konnte, möchte ich meinen tiefen Dank aussprechen: insbesondere Edeltraud Dohmen, Christa und Peter Hein, Véronique und Kai Bartz, Ingrid und Murielle Beyel und Eva Schubert-Maas, der immer gut gelaunten Tagesmutter Tatjana Désy, der équipe der Ecole maternelle Henri Chapelle und der Garderie La Chenille sowie dem ganzen Team des Haus Kühberg in Blaichach. Ohne ihre verantwortungsvollen Sorgetätigkeiten wäre kein langes und konzentriertes Arbeiten für mich möglich gewesen! Meine Freundin Eva Schubert-Maas öffnete mir zudem die Augen für die unglaubliche Leistung von Tätigkeiten der Fürsorge nicht nur zu Beginn, sondern auch am Ende eines Lebens und bereicherte meine Arbeit mit philosophischen Reflexionen.

Ich bin auch voller Dank für die Pflanzen, Tiere und anderen Elemente, die die schöne Landschaft ausmachen, in der wir wohnen. Das saftige Grün des Grases, das muntere Zwitschern der Vögel, die Ruhe der Bäume, das Plätschern des Wassers, all dies und vieles mehr erfrischte immer wieder meinen müden Geist, brachte Ausdauer, Motivation und Ideen (zurück) und erneuerte meine Fähigkeit zur Konzentration.

An dieser Stelle möchte ich meiner verstorbenen Mutter Inge Brüll gedenken. Den Respekt vor der Natur, auf dem diese Arbeit fußt, sowie andere Werte und grundlegendes Wissen verdanke ich vor allem ihr.

Dann möchte ich natürlich ganz herzlich meiner ‚Doktormutter' Prof. Dr. Sabine Hofmeister danken, die mich durch ihre theoretischen Ansätze besonders inspiriert hat, mich immer motiviert und nie gedrängt und durch kritische Anregungen meine Arbeit wissenschaftlich begleitet hat. Mein Dank gilt auch meiner Zweitgutachterin Prof. Dr. Helga Kanning, die mich ebenfalls durch Ihre Schriften sehr bestärkt und Klarheit in meine Gedanken gebracht hat. Ganz besonders danken möchte ich auch Prof. emeritus Wolfgang Haber für seine fachliche Anerkennung und lobende Motivation ‚auf halber Strecke' meiner Arbeit.

Mit meinen Kolleginnen Dr. Grit Bürgow und Ina Küddelsmann verbindet mich seit 20 Jahren eine enge Freundschaft und fachliche Kooperation, die diese Arbeit sicher auch entscheidend geprägt hat. Ihnen danke ich ganz herzlich für die langjährige Zusammenarbeit in gemeinsamen Projekten, für Gedanken- und Seelenaustausch und für inspirierende ‚Landschaftstouren'. Meinem Kollegen und Freund Günther Kunz möchte ich auch ganz herzlich danken für unsere langjährige Zusammenarbeit in Bauprojekten und die Chance Einblicke in die Welt der Technologieentwicklung und erneuerbaren Energien zu erhalten. Dabei vermittelte er mir immer wieder Bewunderung und Verständnis für die Intelligenz der Natur und ihrer ‚konstruktiven Lösungen'.

Bei der Reiner Lemoine Stiftung, insbesondere Dr. Annegret Jatzkewitz und Clemens Triebel, möchte ich mich sehr für die großzügige finanzielle aber auch ideelle Unterstützung im Geiste Reiner Lemoines bedanken, dessen immer freundliches und querdenkerisches Wesen ich noch kennenlernen durfte. Auch der Leuphana Universität Lüneburg danke ich für ein Abschlussstipendium und die stets unkomplizierte Verwaltung meiner Promotion.

Prof. Dr. Frank Lohrberg und meinen Kolleginnen und Kollegen des Lehrstuhls für Landschaftsarchitektur der RWTH Aachen, insbesondere Matti Wirth, sowie Kolleginnen und Kollegen der Euregio Maas-Rhein und des Dreiländerparks möchte ich danken für eine angenehme Arbeitsatmosphäre und flexible Arbeitszeiten im Rahmen meiner Erwerbsarbeit sowie für inhaltliche Impulse, Gedankenanstöße und einen praktischen Anwendungsbezug, welche diese Arbeit auch mitgeprägt haben. Prof. emeritus Wilhelm Ripl danke ich dafür, dass er uns während der Studienzeit die Bedeutung des Wassers in der Landschaft und das Lesen von Mustern gelehrt hat.

Last but noch least gilt mein ganz besonderer Dank meiner Lektorin Dr. Paula Niemietz für Ihre sorgfältige Korrektur der englischen Sprache meiner Arbeit, die sie immer mit Geduld und wunderbarem Sprachgefühl sowohl für das Englische als auch das Deutsche bewerkstelligte.

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ANNEX 1: Sustainabillity concerns and measures in EU bioenergy policy

Date issued	Policy document	Addressed sustainability/ environment concerns/ impacts with regard to bioenergy	Actions/ measures concerning bioenergy/ biomass sustainability	References
13.12.1995	White Paper on Energy Policy COM(95)682	Renewables not differentiated, seen as generally having few hidden environmental costs (pollution). Environmental protection to be best achieved by market based instruments internalizing external costs. CO_2/energy tax is higlighted as relevant for the energy sector, but to be complemented with policy measures offsetting adverse effects on competetiveness. Important role of rural areas seen in contributing biofuels thereby increasing their economic viability.	—	104.-121.
26.11.1997	White Paper on Renewable Energy Policy COM(97)599	Mentions that overall environmental effects of biofuels vary on crops cultivated and crops replaced. Promotion of biofuels should take account of the full cycle of environmental costs/benefits. Internal market: Agri-environmental schemes, forest measure and non-food set-aside regulations should be used to promote value of biomass and reduce environmental pressures from biomass-production by giving incentives to those practices using organic or low input methods, reducing water consumption and increasing biodiversity. External relations: RES should be promoted to ACP countries to resolve problems of overconsumption of fuelwood, development of suitable fuelwood species plantation should be encouraged. General: - preference should be given to high yielding, low-input (concerning water, fertilizer and pesticides) crops, which respect biodiversity best on marginal land, safeguarding of biodiversity needed - any biomass development strategy shall set an upper maximum limit for land use, - growth of biomass sector needs to be compatible with sustainable development	Action plan includes a bio-energy initiative: Developing market for biofuels through large scale detaxation; market for solid biomass through promotion of co-firing, district heating or cooling networks and CHP for co-generation with biomass; Directive proposals: Promotion of Biofuels in transport fuel and in low-sulfur liquid fuels. Member states to increase the market share of biofuels. Integration in CAP and regional policies/ funds as well as member state strategies and co-financing programs (both promotion of biomass use and measures for environmental effects)	p16, p22-23, Annex I p34-36, Annex II p37-39
27.09.2001	Renewable Energy Sources Directive 2001/77/EC	No differentiation between renewable sources. RES promoted as priority measure "given that their exploitation contributes to environmental protection and sustainable development" (1).	Producers required to give guarantee of origin of electricity produced from RES. Biomass counts as RES, defined as biodegradable fraction of products, waste and residues from agriculture, forestry, industrial and municipal sources. No further differentiation or sustainability safeguarding measures.	(1), Art 2 Art 5

08.05.2003	Biofuels Directive2003/30/EC	b) the environmental impact of further increasing the share of biofuels and other renewable fuelsc) the life-cycle perspective of biofuels and other renewable fuels for the future promotion of those fuels that are climate and environmentally friendlyd) the sustainability of crops used for the production of biofuels, particularly land use, degree of intensity of cultivation, crop rotation and use of pesticidese) the use of biofuels and other renewable fuels with respect to their differentiating effects on climate change and their impact on CO2 emissions reductionMember States should consider the overall climate and environmental balance of the various types of biofuels and other renewable fuels.	Commission to report on points b) - e).Adaptation of list of eligible biofuels according to environmental effects experienced.Member states to set individual indicative targets for the minimum share of renewable transport fuels and implement suitable measures (i.e. tax incentives) incl. climate and environmental balance considerations. Member states are allowed to give priority to those renewable fuels which show a very good, cost-effective environmental balance.	Art 3,Art 4,Art 5
07.12.2005	Biomass Action Plan COM(2005)628	185 Mtoe is estimated as EU's domestic biomass potential to increase with accession of Bulgaria and Romania while a) complying with good agricultural practice b) safeguarding sustainable production of biomass c) without significantly affecting domestic food supply Three environmental impact areas identified (but not addressed in impact assessment): - greenhouse gas (GHG) emmissions - production of raw material - can have significant positive or negative effects on the environment - use of biomass (burning/ air quality) > need to guarantee that site-specific environmental requirements are observed when producing biomass – will be addressed in the Commission's 2006 report on the implementation of the biofuels directive as well as possibilities of a certification system and minimum sustainability standards for biomass produced for biofuels (and other bioenergy uses)	Heating sector: - set up legislative framework for RES in heating + cooling, - promoting biomass use through district heating and combined heat and power plants Transport sector: revision of biofuels directive concerning - (binding) national targets for market share of biofuels, - encouraging member states to use biofuels obligations (blending with conventional fuels) and give favorable treatment to second-generation biofuels, - introduction of certification schemes to ensure that only biofuels produced according to minimum sustainability standards count towards targets, - set up legislation promoting public procurement of vehicles using high blends of biofuels, - balanced approach concerning domestic biomass production and imports (incl. certification) Cross-cutting sectors: information campaign for farmers about energy crops, - forestry action plan for energy use of forest material, -member states to establish national biomass action plans, -promote research in bio-refinery and second-generation biofuels	p5, 9-10, Annex p17-19, Annex 4 p23-24
07.12.2005	Biomass Action Plan Impact AssessmentCOM(2005)628	2 policy scenarios analyzed upon following impacts:- GHG emmissions- Diversification of energy mix/ security of supply- Direct and indirect employment effects and cost for societyLife cycle analysis shows significant reduction of GHG potential. Competition of biomass for energy with food, materials, bio-chemicals and carbon sinks expected not before 2020 with international trade beyond 2050. Environmental concerns must be addressed for any type of biomass use for food, materials or fuels.	—	p25, 32,Annex 3p54

08.02.2006	Biofuels Strategy COM(2006)34	Capturing environmental benefits of biofuels identified as 1 of 7 key policy axes to develop biofuels. Section 3.2 (2): "Environmental standards shall apply to feedstock production for biofuels, concerning biodiversity, water and soil in EU and thrid countries. Sustainability criteria in EU countries should not only apply to energy crops but all agricultural land as required by cross compliance." Environmental concers expressed for developing countries relating to rainforests, soil fertility, water availability and quality, and pesticide use > Balanced apprroach: developing domestic industry and allowing for imports, supporting developing countries to integrate environmental and social aspects	Revision of Biofuels Directive in 2006 will adress national targets and biofuel obligations requiring that only biofuels whose production complies with minimum sustainability standards will count towards targets coupled with a certification system. Member states to be encouraged to give preference to blending quota obligation over tax reliefs (under the Energy Tax Directive 2003/96/EC). Commission to monitor impacts of biofuels demand increase on food prices and competition with raw materials for industries. Commission will develop forestry action plan with energy use of forestry material playing an important role for second generation technologies. Commission will develop a Biofuels Assistance Package to help third producer countries to develop national biofuels platforms and regional biofuel action plans that are environmentally and economically sustainable.	p4,7-10, p13, 15
08.02.2006	Biofuels Strategy Impact Assessment COM(2006)34	3 policy scenarios analysed upon following impacts: - environmental impacts: GHG emmissions, feedstock cultivation, use of biofuels (air quality), - impact on agricultural markets and land use - impacts on international effects, fuel supply, employment, competitiveness & innovation, cost. Acknowledgement that biofuels are not carbon neutral, but life cycle assessments show positive GHG impacts. Many positive and negative effects on water, soil and biodiversity could result from biofuel feedstock cultivation and use of set-aside land. Complementary to a life cycle approach a farming system approach is needed on the overall ability of the farm to provide environmental services. Monitoring scheme for environmental standards proposed. Posistive and negative international effects expected. Domestic production easier to monitor than international imports.	—	p13-18 p29-33 p36
08.03.2006	Green Paper on Energy PolicyCOM(2006)105	Sustainability here is basically seen in connection with policy commitments towards climate protection and developing a low-carbon economy bringing together the objectives of environmental protection, competitiveness and security of supply.	Commission to develop Renewable Energy Roadmap to meet policy targets and go beyond including a plan to gradually reduce EU's dependency on imported oil by building on the existing Biomass Action Plan and Strategy for Biofuels.	p5,12,19
10.01.2007	Renewable Energy Road Map COM(2006)848	Biofuels regarded the only available large scale substitute for petrol and diesel in transport. Consideration of environmental and social aspects identified as 1 of 7 key principles for future RES policy framework. Impact on GHG emissions and other environmental impacts: Only positive effects of RES on GHG emission and air quality mentioned. Road map considered a major step along the road to sustainability.	Commission to develop proposal for incentive/support system for biofuels that discourages the conversion of land with high biodiversity value or "bad systems" for biofuel production and encourages second-generation production processes. To develop network of regions on best practices of sustainable energy use. Full implemention of Biomass Action Plan	p7,9, p12-14, p18

10.01.2007	Renewable Energy Road Map Impact Assessment COM(2006)848	2 policy scenarios analyzed upon following impacts: - feasibility and achieveability risks - costs (in the absense of full internalization of external cost) - benefits: GHG emmissions, security of supply, employment, GDP and export opportunities, biodiversity impacts, regional development and rural economy No differentiated between RES, only positive effects expected under benefits. Tackling climate change with RES policy will automatically lead to positive effects on biodiversity, since climate change is regarded as main driver of biodiversity loss. Local biodiversity impacts of biofuels production are considered but seen as minor and avoidable problem.	—	p7,18-22
23.04.2009	Renewable Energy Sources Directive 2009/28/EC	Minimum sustainabilty criteria for biofuels and bioliquids binding to targets: a) GHG saving level to be achieved; b) exemption of land with high carbon stock and biodiversity value for production of biomass; c) cross compliance rules; Reporting requirements with regard to member states and third countries representing a significant source of biofuels; d) national measures concerning criteria above and soil, water, air protection; e) impact on social sustainability, commodity prices and food security, land-use rights; f) countries state of ratification and implementation of ILO Conventions, Protocol on Biosafety and Convention on International Trade in Endangered Species; h) impact of indirect land-use changes on GHG emissions; g) biodiversity impacts, displacement impacts, other indirect land-use changes	Producers of biofuels required to show certification documents on compliance with a)-c) to be eligible for financial support. Member states required to control and verify certification of producers to count biofuels towards the mandatory target. Commission to report on points d)-g) every 2 years earliest in 2012 Commission to report on point h) at the end of 2010 including a proposal on measures to minimize this impact Commission to report on requirement of sustainability scheme for other energy uses of biomass until end 2009. Contribution of biofuels produced from waste, residues, non-food cellulosic + ligno-cellulosic material towards target in transportation count twice of that of other sources	Art 17.7 Art 19.6 Art. 23 Art 17.9 Art. 21.2
02.07.2010	Report on sustainability requirements for solid and gaseous biomass use in electricity, heating and cooling COM(2010) 11	Addressing the sustainability of the use of solid and gaseous biomass in electricity, heating and cooling:Impacts on biodiversity and soil carbon stocks; Deforestation and forest degradation at global leve; Life cycle greenhouse gas performance and energy efficiency	No binding criteria at EU level but recommendations for Member States on the development of their sustainability schemes for solid and gaseous biomass used in electricity, heating and cooling to apply similar criteria and conditions as laid out for liquid biofuels in the Renewable Energy Sources Directive.	p3-9
15.12.2011	Energy Roadmap 2050 COM(2011)885	Indirect land use change and associated GHG emissions	ongoing work on the issue of indirect land use change continued promotion of biofuels based on waste, algae, forest residues	p11

17.10.2012	Proposal for a directive amending Directives 98/70/EC and 2009/28/EC COM(2012) 595	Indirect land use change and associated GHG emissions	5% cap to the contribution made from biofuels and bioliquids produced from food crops, such as those based on cereals and other starch rich crops, sugars and oil crops, to the 10% Renewable Energy Directive targets in the transport sector. Enhanced incentive scheme to further promote sustainable and advanced biofuels from feedstocks that do not create an additional demand for land. Reporting of estimated emissions from carbon stock changes caused by indirect land-use change, for the purposes of the calculation of the life cycle greenhouse gas emission savings from biofuels and bioliquids. Increase of the minimum greenhouse gas saving threshold for biofuels and bioliquids produced in new installations	p3-4 p13-16

In its original sense *bio*mass denotes *living* mass. Through *bio*mass not only is a bio-chemical energy potential being renewed, but also vital living conditions and quality of life domains: for example a favorable climate, water and soil quality as well as spaces for habitat, recreation and a sense of belonging. How to retain the capacity for such (re)productive and value-creating 'biological-ecological work' needs to be considered when using bioenergy for 'technical work'. Hence, the design and application of bioenergy technology should involve a place-based landscape context.

Based on this argumentation Anja Brüll unfolds in this book the concept of 'Landscape Quality Management (LQM)' – a standardized adaptive stakeholder process to continuously improve various quality aspects of the landscape. The process also serves to assess and develop the sustainability of biomass production and eventually other land uses.

The author goes on to develop 'complementary biomass production' as a regional guiding principle. This means using biomass sources and practices which do not compete with agricultural food production, but complement it in terms of providing ecosystem services and contributing to landscape quality. Several case studies illustrate this convincing approach. At the end, the author shows how LQM can provide a source of innovation for sustainable production by linking it with corporate environmental and quality management.

Dr. Anja Brüll is a landscape planner with a background in biology, ecological engineering and management. She is cofounder of the Aquatectura - Studios for Regenerative Landscapes, a team active in practical projects from the local to international scale in the field of sustainable water, land and resources management. She has worked as a researcher and lecturer at the Institute of Sustainability Governance at the Leuphana University Lüneburg and the Chair of Landscape Architecture at the RWTH Aachen University. Presently she is project leader of the Three Countries Park, a cross-border platform for maintaining and developing the quality of the landscape in Euregio Meuse-Rhine at the tri-border area of Belgium, The Netherlands and Germany.

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ISBN 978-3-8440-3959-7