46

ENVIROMENT AND NATURAL RESOURCES MANAGEMENT WORKING PAPER

Environment | Climate Change | Energy | Monitoring and Assessment

Bioenergy Environmental Impact Analysis (BIAS):

Analytical Framework

Uwe. R Fritsche
Klaus J. Hennenberg
Kirsten Wiegeman
Rocio Herrera
Oeko-Institut

Bernd Franke
Susanne Köppen
Guido Reinhardt
IFEU

Veronika Dornburg
André Faaij
Edward Smeets
Copernicus Institute

Food and Agriculture Organization of the United Nations, Rome 2010

The conclusions given in this report are considered appropriate at the time of its preparation. They may be modified in the light of further knowledge gained at subsequent stages.

Abstract

The Bioenergy Impact Assessment (BIAS) framework summarizes the major issues related to impact and process based environmental assessments related to bioenergy development and attempts to bring together and evaluate the best available, tested and untested methodologies. It is part of a larger effort of FAO to facilitate decisions at various levels that take their wider impact into consideration, above all their impact on food security (BEFS project) and the environment (BIAS).

In an area of fast development, many investment and land use decisions have already been taken, often in a vaguely defined policy environment and without due consideration of environmental consequences. This framework is intended as a step towards practical decision making tools and to perhaps serve as a benchmark or reference for new methodologies, other evaluation approaches and for future standards development.

The main chapters examine methodological options and their limitations for: GIS applications, risk assessment, water and soil quality, quantity and availability, CBD processes, protected areas, land use changes and GHG. They also examine current databases and platforms that discuss these issues, like: UN-Energy, GBEP, RSB and other roundtables, and the efforts of other institutions and organizations like: EEA, IEA, IUCN, WWF and others.

Newer or still untested methodologies as well as data availability are also discussed. Considerable work remains to fill the data gaps and understanding or measuring of interactions with for example food security, poverty and other rural development processes.

The basic approach in view of highly complex and uncertain interactions and developments is one of precaution and of avoiding areas of development where impact is uncertain and to concentrate on reducing risk, better utilization of already exploited resources and recuperation of degraded resources. To that effect, methods for evaluation and bridging knowledge gaps have been suggested.

Follow up to this framework is envisioned in the form of further testing of the framework, expanding collaboration on the subject, filling some of the gaps, assisting in its application and integration into standard setting and other areas of agriculture.

Bioenergy Environmental Impact Analysis (BIAS): Analytical Framework

by: Uwe R. Fritsche, Klaus J. Hennenberg, Kirsten Wiegeman, Rocio Herrera – Öko-Institut Darmstadt, D
Bernd Franke, Susanne Köppen, Guido Reinhardt – IFEU Heidelberg, D
Veronika Dornburg, André Faaij, Edward Smeets – Copernicus Institute, Utrecht Univ., NL

177 pages, 13 figures, 33 tables

FAO Environmental and Natural Resources Service Series, No. 46 – FAO, Rome, 2010

Keywords:
Environmental impact assessment, strategic environmental assessment, evaluation and assessment methodology and tools, bioenergy, sustainability, biodiversity, greenhouse gas (GHG), water and soil quality, quantity and availability, land use change, models, databases, GIS, lifecycle assessment

This series replaces the following:
Environment and Energy Series, Remote Sensing Centre Series, Agrometeorology Working Papers

A list of documents published in this FAO series and other information can be found at the Web site:
www.fao.org/nr

Acknowledgements

The authors wish to thank FAO colleagues for their support and critical comments on earlier drafts of this report, namely Astrid Agostini, Sally Bunning, Jippe Hoogeveen, Rainer Krell, John S. Latham, Freddy Nachtergaele, Mirella Salvatore, and Jeff Tschirley.

The authors are grateful for advice provided at various stages during the project and preparation of the report by other colleagues, especially from UNEP DTIE (Paris), IUCN, UNEP-WCMC and from Oeko-Institut, IFEU and Copernicus Institute.

Darmstadt, Heidelberg, Utrecht 2010 The Authors

Oeko-Insitut, Rheinstr. 95, 64295 Darmstadt, Germany
Uwe R. Fritsche, u.fritsche@oeko.de www.oeko.de/service/bio

IFEU, Wilckensstr. 3, 69120 Heidelberg, Germany
Guido Reinhardt, guido.reinhardt@ifeu.de, www.ifeu.de

Copernicus Institute, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, Netherlands
André Faaij, a.p.c.faaij@uu.nl, http://www.copernicus.uu.nl

Bioenergy Environmental Impact Analysis (BIAS): Analytical Framework

Commissioned by the Food and Agriculture Organization of the United Nations (FAO), Rome

Executive Summary

The potential role of biomass within sustainable national energy systems is under discussion globally, and especially liquid biofuels for transport receive significant attention.

In general, environmental impacts of bioenergy are considered **smaller** than those of conventional (fossil and nuclear) energy systems, as renewable biomass is CO_2-neutral when burnt, the resource base can be maintained if harvested biomass is re-grown, and residues easily decompose or can be recycled. Bioenergy can have positive employment and income effects, and could increase security of supply. Still, bioenergy crops can cause land-use change with severe environmental impacts, e.g. biodiversity loss and increased greenhouse gas emissions, and might negative impact water resources and soil.

Thus, decision-makers in (national) governments, business, and societal stakeholders need to carefully elaborate the environmental pros and cons of bioenergy in order to develop this resource sustainably.

Given the challenges in addressing the various environmental concerns of bioenergy development, a framework is needed to assist concerned decision-makers and stakeholders, such as project and policy planners, governmental agencies, private sector businesses, and NGOs, in identifying and comparing the environmental impacts of bioenergy development options under consideration.

For that, the BIAS project analyzed, synthesized and recommends environmental assessment methods and tools suitable for bioenergy production chains mainly on a national scale. It also describes data gaps and methodological weaknesses which need further work.

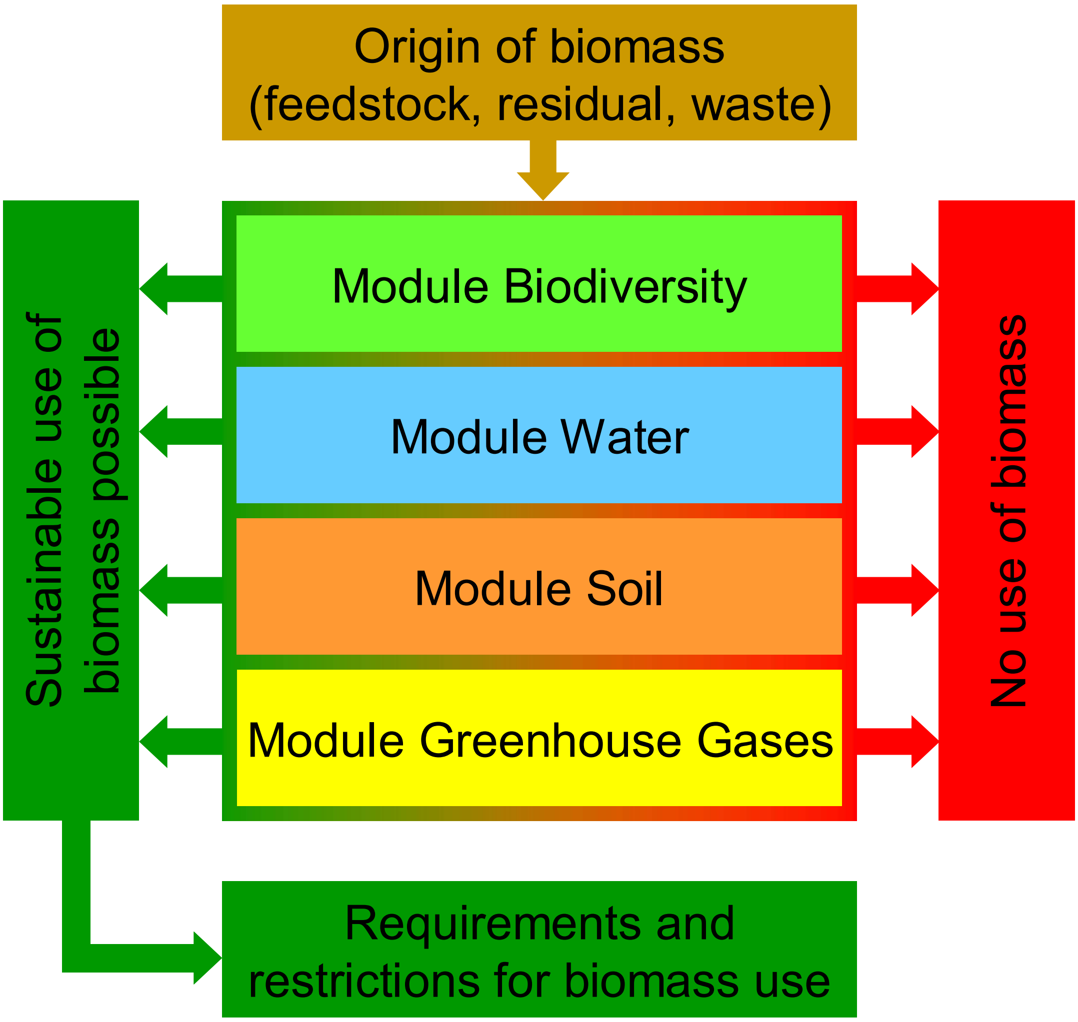
The objective of the BIAS analytical framework is to provide an integrated yet simple approach for the comprehensive analysis of environmental impacts associated with production and use of biomass for bioenergy. It focuses on key impacts, i.e. biodiversity, soil, water and greenhouse gas balances.

The main areas of concern for BIAS are the use of land and related ecosystem impacts, biodiversity, the quality of soils, the availability and quality of water, and greenhouse gas emissions. While some impacts can be quantified, others can only be described qualitatively. For those, the BIAS approach is to seek conditions under which these impacts can be avoided, or at least mitigated.

The BIAS framework combines Strategic Environmental Assessment with life cycle analysis elements, aimed to help decision-makers mainly on the national level to guide bioenergy towards low-risk and environmentally safe development.

For each of the key potential environmental impacts of bioenergy, BIAS offers a “module” in which a risk-minimization strategy for the respective impacts is developed.

The methods, tools and databases in each module are used **as a screen** to identify bioenergy options and conversion pathways which are environmentally compatible under the given (national) conditions.



In most of the BIAS modules, this screening is not a simple “yes” or “no”, but guidance is given to identify restrictions which safeguard against negative impacts, or help to minimize possible effects. Given the variety of possible impacts of bioenergy which are often depending on local specifics, the BIAS framework can only help to screen with regard to “typical” situations. For this, the concept of **settings** is applied

The BIAS framework specifically targets environmental impacts of bioenergy crops in developing countries with regard to biodiversity, water, soils and climate impact. For those, indicators can measure an approximation of the impact or estimate the risk.

For policy-makers and stakeholders, it is import to understand the full range of (net) impacts of bioenergy options before deciding on their actual implementation.

The biomass production system relates to changes in **biodiversity** on the land used, depending on location, crop and agricultural management systems, and previous land use.

The biomass production systems can influence the **availability and quality of water**. The different systems use different amounts of water from surface and groundwater, depending on, among others, the water-use efficiency of the crops and whether the system is irrigated or rain-fed.

Some of the production systems might use and restore degraded lands, while others may contribute to land degradation. Therefore, bioenergy production is likely to change **soil quality** in terms of carbon and nutrient content as well as the risk of soil erosion.

The **climate impact** of production and use of biomass compared to fossil energy is one of its main drivers. The indicator here are life cycle GHG emission balances which depend strongly on the type of bioenergy (e.g. transportation fuels versus electricity), the type of agricultural system (e.g. high versus low input), use of by-products and direct and indirect land use changes associated with bioenergy production. For example, emissions of GHG expressed in CO_2 equivalents are a typical indicator for global warming potential and hence climate change risk.

In the BIAS modules, the selection of indicators for respective environmental impacts is discussed in detail. The extent to which each indicator can be calibrated quantitatively has been explored, but in many cases this proved to be difficult.

Area of concern	Impact	Possible Indicator
Biodiversity	**Protection of existing nature**	**type of land for bioenergy production and risk minimization approach: define “go” and “no-go” areas based on spatially explicit data on relevant biodiverse land**
	Biodiversity on managed land and changes on landscape level	**type of bioenergy production system and adequate management strategies to minimize risks**
Water	**Water availability for biomass production**	**Water stress, i.e. withdrawals per unit bioenergy [m³ per MJ_{bio}]**
	Groundwater depletion	**Water stress in groundwater resources, i.e. withdrawals per unit bioenergy [m³ per MJ_{bio}]**
Soil	**Carbon loss**	**Change in carbon content of soils [t C per hectare in the next 20 years]**
	Nutrient loss	**Changes in nutrient content (N, P, K) in soil [kg per kg soil]**
	Soil erosion	**Loss of soil [kg per hectare per year]**
Climate change	**Global warming**	**GHG emissions [kg $CO_{2\,eq}$ per MJ_{bio}]**
Examples for other possible concerns not covered in the BIAS framework		
Ecosystem resilience	**Freshwater and terrestrial toxicity**	**Ecotoxicity potential [kg 1,4-dichlorobenzene-eq per MJ_{bio}]**
	Eutrophication in aquatic and terrestrial ecosystems	**Eutrophication potential [kg PO_{4eq} per MJ_{bio}]**
	Acidification	**Acidification potential [kg $SO_{2\,eq}$ per MJ_{bio}]**
Resources	**Depletion of natural resources**	**Use of primary non-renewable energy [$MJ_{primary}$ per MJ_{bio}]**
Human health	**Occupational risk of injuries, illness and premature death**	**reduced work time [Person-days lost per MJ_{bio}]**

The indicators for BIAS modules were selected based on "strength" (expression of potential impact), spatial scope (local, regional, global) of impact, and measurability (potential to be treated quantitatively with "field" or average data).

The respective data needs to measure impacts through indicators and related tools (models, databases etc.) are discussed in each of the module chapters.

Table of Contents

1 Introduction: The Context and Content of BIAS 1

1.1 The BIAS Analytical Framework 1

1.2 Environmental Analysis and Assessment Tools 2

1.3 The BIAS Approach 4

1.4 The Setting Approach and the BIAS Framework 7

1.5 Measuring the Impacts: Criteria and Indicators 9

2 Biodiversity Impacts 11

2.1 Approaches to Address and Value Biodiversity Impacts 13

2.2 Risk Mitigation Strategies to Protect Biodiversity 14

2.3 The BIAS Module for Biodiversity 18

2.4 Data Collection and Identification Process 21

2.5 Conclusions and Guidance 26

3 Agricultural Water Use 27

3.1 Approach to Address and Value Water Quantity and Quality Impacts 28

3.2 Risk Mitigation Strategies to Protect Natural Water Resources 30

3.3 The BIAS Module for Assessing Water Needs and Use 34

3.4 Data Collection Process and Available Data and Models 37

3.5 Conclusions and Guidance 37

4 Impacts on Soil 38

4.1 Approach to Address and Value Soil Property and Quality 39

4.2 Risk Mitigation Strategies to Conserve the Soil 41

4.3 The BIAS Module for Soil Conservation 44

4.4 Available Data and Model Choice 46

4.5 Conclusions and Guidance 50

5 Greenhouse Gas Emission Balances 51

5.1 Goal and Scoping Issues 52

5.2 Consideration of By-products 54

5.3 GHG Accounting of Land Use and Land Use Change 56

5.4 The BIAS Module for GHG Emission Balances 60

5.5 Data Issues 61

6 Perspectives for Applying and Refining BIAS 62

7 References 63

8 Glossary 76

9 Abbreviations 80

Annexes

Annex A	Examples for Settings on the Country Level
Annex B	Databases and Data Products
Annex C	Indicators Addressing Biodiversity
Annex D	Tanzania Case Study to Identify Biodiversity-Relevant Areas
Annex E	Description of Water Indices
Annex F	Soil Quality and Risk Assessment for Soils
Annex G	GHG Emission Data
Annex H	Excurse on Pesticides

1 Introduction: The Context and Content of BIAS

The potential role of biomass within sustainable national energy systems is under discussion globally, and especially liquid biofuels for transport receive significant attention[1].

In general, the overall environmental impacts of bioenergy are considered **smaller** than those of conventional (fossil and nuclear) energy systems, as renewable biomass is CO_2-neutral when burnt, the resource base can be maintained if harvested biomass is re-grown, and residues easily decompose or can be recycled.

Bioenergy can also have positive employment and income effects, and could increase security of supply[2].

Still, **land use** is an important issue of biomass supply from energy crops, and land-use change can cause severe environmental impacts, e.g. biodiversity loss, and negative water and soil impacts.

Also, the greenhouse gas (GHG) emission balance of bioenergy systems depends largely on land-use change effects.

Thus, decision-makers in (national) governments, business, and societal stakeholders need to carefully elaborate the environmental pros and cons of bioenergy in order to develop this resource sustainably.

1.1 The BIAS Analytical Framework

Given the challenges in addressing the various environmental concerns of bioenergy development, a **framework** is needed to assist concerned decision-makers and stakeholders, such as project and policy planners, governmental agencies, private sector businesses, and NGOs, in identifying and comparing the environmental impacts of bioenergy development options under consideration.

For that, the BIAS project analyzed, synthesized and recommends environmental assessment methods and tools suitable for the bioenergy production chain mainly on a national scale. It also describes data gaps and methodological weaknesses which need further work.

The objective of the BIAS analytical framework is to provide an integrated yet simple approach for the comprehensive analysis of environmental impacts associated with production and use of biomass for bioenergy. It focuses on key impacts, i.e. biodiversity, soil, water and greenhouse gas balances.

---

1 A summary of key environmental issues under discussion can be found in FAO (2008), UN-Energy (2007), and WRI (2007). More detailed reading is recommended in the subsequent sections.

2 The social and economic impacts of bioenergy development could also be positive or negative, depending on the resources used, their conversion paths, and substituted end-uses. These impacts are not covered in the BIAS framework which only addresses environmental impacts.

1.2 *Environmental Analysis and Assessment Tools*

Since the 1970ies, environmental assessment has been developed as a systematic process to identify, analyze and evaluate the environmental effects of products or activities to ensure that the environmental implications of decisions are taken into account **before** the decisions are made.

Environmental assessment allows effective integration of environmental considerations and public concerns into decision-making (UNEP 2004; World Bank 2008a).

In principle, environmental assessment can be undertaken for individual projects such as a dam, motorway, factory or a bioenergy plantation (Environmental Impact Assessment, EIA), or for plans, programs and policies (Strategic Environmental Assessment, SEA)[3].

These approaches aim at providing a systematic procedure for identifying potential risks to human health and the environment, and a comparison of the respective risks to alternative options for different environmental compartments (air, soil, water).

A specific method developed in the 1980ies for determining and comparing the potential environmental impacts of product systems or services at all stages in their life cycle – from extraction of resources, through the production and use of the product to reuse, recycling or final disposal – is called Life Cycle Assessment (LCA).

It can be applied in strategy formulation, product development, and marketing. The LCA methodology has been developed extensively during the last decade. Moreover, a number of LCA related standards (ISO 14040-14043) and technical reports have been published within the International Organization for Standardization (ISO) to streamline the methodology.

The LCA approach is quite data-intensive since not only direct impacts are included, but also those stemming from "upstream" activities such as mining, processing, and transport, as well as the materials (and energy) needed to manufacture all processes. This approach can be applied to **any** system or set of processes, i.e. it is generic.

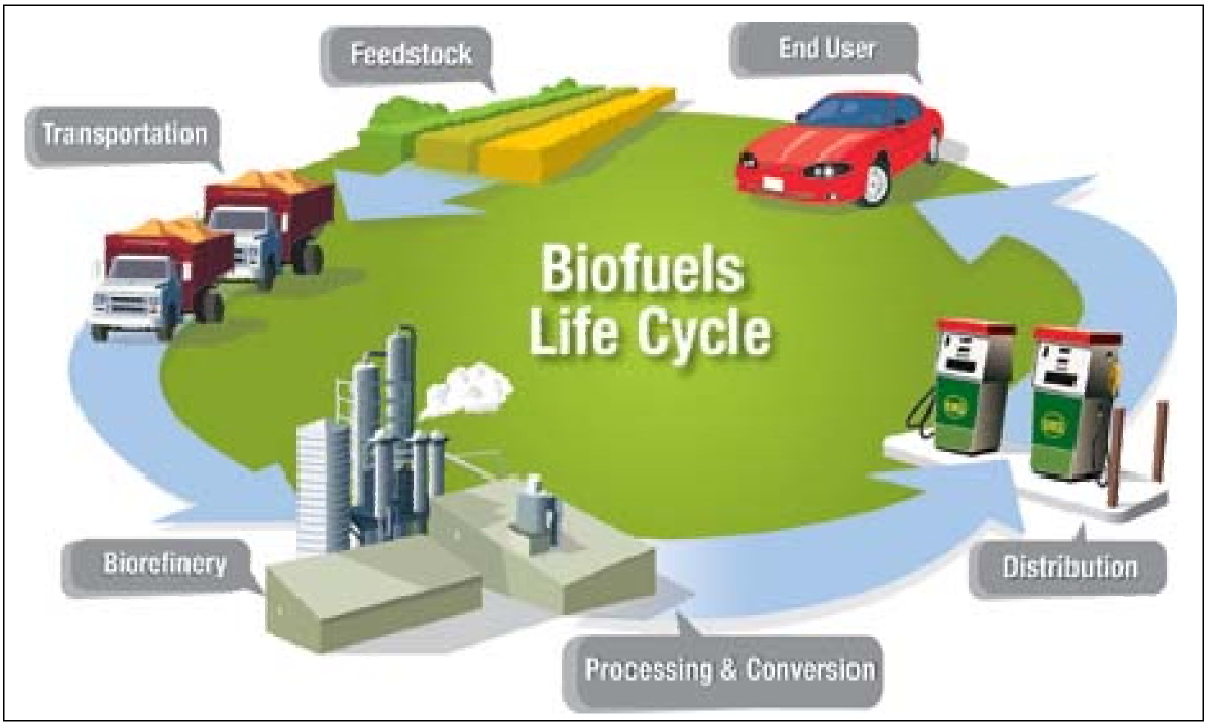
With LCA being developed as a specific assessment methodology to compare products, the formal assessment requirements from the ISO standards for LCA are demanding with regard to time, and resources. Still, the **analytical** approach of comparing "cradle-to-grave" life cycles can be used for any activity, so that in the following, the term LCA is used to describe life cycle analysis.

The principle life cycle for bioenergy – and more specifically: biofuels – is given in Figure 1-1.

---

3 Good examples for some of the many tools for conducting an EIA and SEA can be found at: Open Educational Resource on Environmental Impact Assessment of United Nations Environment Programme (UNEP), the United Nations University (UNU) and RMIT University http://eia.unu.edu/, the World Bank resources on SEA http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/0,,contentMDK:20885949~menuPK:549265~pagePK:148956~piPK:216618~theSitePK:244381,00.html and the European Union resources on Environmental Assessment http://ec.europa.eu/environment/eia/home.htm

Figure 1-1 Principle Scheme of a Biofuel Life Cycle



Source: US DOE (http://www1.eere.energy.gov/biomass)

The life cycles of bioenergy systems can be quite complex, and are interlinked to life cycles of other energy systems (e.g. diesel fuel, auxiliary electricity and heat)[4], and require various materials – from seed to agrochemicals – which have their own life cycles. Furthermore, transport of feedstock and conversion products is also part of the bioenergy life cycles, since the sites of feedstock production, conversion and product consumption are usually distant from each other.

For bioenergy, **land use** and land use changes, respectively, are other critical issues which must be considered in LCA, especially for greenhouse gas balances (see Chapter 5.3).

Life cycle analysis is a valid tool in environmental assessment, but has some limitations, as it was developed mainly to compare products. As already mentioned, it is a data-intensive method, if it is to reflect all relevant steps of the life cycle. On a more general level, material-flow analysis (MFA) aggregates specific products or services into typical "groups" and then tracks the inputs needed to deliver the typical group of products. With MFA, less detail is available to compare specific products, but it allows deriving a more representative view on the environmental impacts associated with the typical use of products in a country or region.

Still, both life cycle analysis and MFA cannot address location- or circumstance-specific environmental problems which occur only at some of the steps in life cycles, and cannot be averaged without loosing their significance. Examples of such "**hot spot**" aspects are biodiversity impacts (Chapter 2), and impacts from pesticide use (Annex G).

4 For a review of biofuel life-cycle analyses, see EMPA (2007); Larson (2005), and UNEP (2008).

1.3 The BIAS Approach

The main areas of concern for BIAS are the use of land and related ecosystem impacts, biodiversity, the quality of soils, the availability and quality of water, and GHG emissions.

While some impacts can be quantified, others can only be described qualitatively. For those, the BIAS approach is to seek conditions under which these impacts can be avoided, or at least mitigated.

Thus, the BIAS framework combines Strategic Environmental Assessment with life cycle analysis elements, aimed to help decision-makers mainly on the national level to guide bioenergy towards low-risk and environmentally safe development.

For each of the key potential environmental impacts of bioenergy, BIAS offers a “module” in which a risk-minimization strategy for the respective impacts is developed.

The methods, tools and databases in each module are used **as a screen** to identify those bioenergy options and conversion pathways which are environmentally compatible under the given (national) conditions.

In most of the BIAS modules, this screening is not a simple “yes” or “no”, but guidance is given to identify restrictions which safeguard against negative impacts, or help to minimize possible effects.

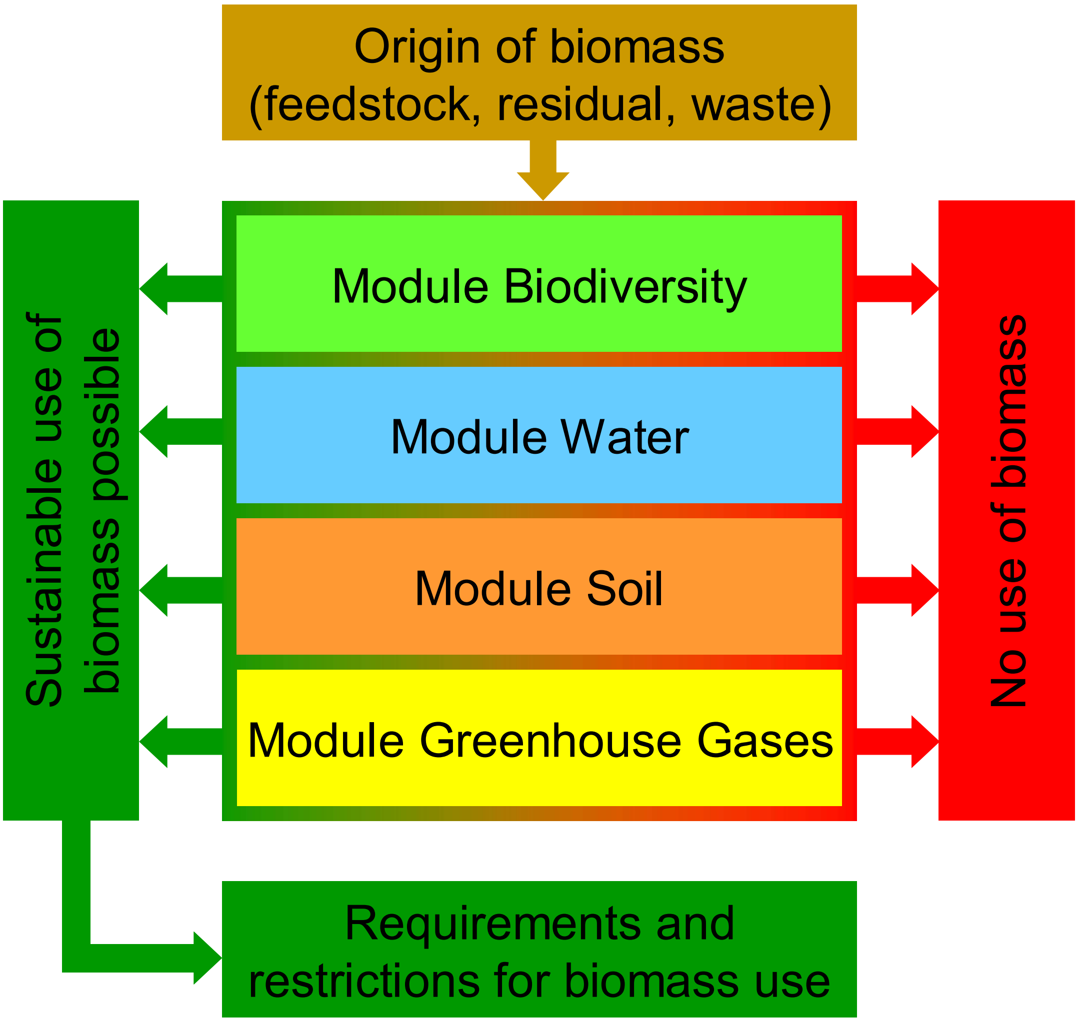
Given the variety of possible impacts of bioenergy which are often depending on local specifics, the BIAS framework can only help to screen with regard to “typical” situations. For this, the concept of **settings** is applied (see Chapter 1.4)[5].

Figure 1-2 depicts the principal flowchart of the BIAS framework and its four key modules.

---

5 Within each of the BIAS modules, more refined tools available from “classic” environmental impact assessment can be used if local knowledge is available.

Figure 1-2 BIAS Logic and Modules



Source: Öko-Institut

Depending on the BIAS module, the result can be either a “green light” for bioenergy development **if all** conditions are met, or some guidance for required restrictions.

If the conditions are not met in **any** of the modules, the respective bioenergy option or pathway is **screened out**, i.e., its development would **not** be environmentally compatible.

It should be noted that this overall framework is meant as a dynamic process which operates on various levels of detail: If only **generic** information is available for e.g., water use or GHG emissions, the modules on biodiversity and soil would still allow deriving results for given situations (settings, see Chapter 1.4).

Once more detail is available for e.g. specific water use or GHG emissions, the respective modules can be re-run with better “resolution” and - thus – more adequate results.

The BIAS framework specifically targets the environmental impacts of biomass production via cropping schemes in developing countries and thus the impact on biodiversity, water, soils and greenhouse gas emissions.

For policy-makers and stakeholders, it is import to understand the full range of (net) impacts of bioenergy options before deciding on their actual implementation. This has become even more urgent with the rapid introduction of various sets of criteria (possibly followed by certification), aiming to secure the sustainability of biomass production.

However, the type of questions and analyses will vary for different actors in the bioenergy arena. Questions for different settings are illustrated in the following table and an example is given in the following.

Table 1-1 Typical Questions of Various Stakeholders with Regard to Environmental Impact Analyses

Stakeholder	Main environmental categories	Typical questions
Policy-makers in developing countries	**Water, soil, land use, biodiversity, other areas**	**Is the bioenergy project fulfilling environmental protection perspectives? Is there a trade-off or synergy between environmental and socio-economic benefits? Do environmental changes influence food production?**
Policy-maker in OECD countries	**Land use, biodiversity, climate change**	**Is the bioenergy project fulfilling environmental protection perspectives? Does the bioenergy project contribute to sustainable development? What is the GHG emission reduction of the projects?**
Non-profit investors	**Land use, ecosystem resilience, biodiversity**	**Is there a trade-off or synergy between environmental and socio-economic benefits? Does the bioenergy project contribute to sustainable development? What is the impact of a changing environment on livelihoods of local population?**
(Large scale) investors	**Land use, water, climate changes, biodiversity**	**Are environmental regulations influencing the envisioned bioenergy project? Do environmental conditions and impact contribute to a loss/increase of productivity?**
Local farmers	**Land use, soil, water, biodiversity**	**What are the costs related to agricultural management that takes into account the environment? Does producing bioenergy change the productivity of other agricultural production systems?**

Source: own compilation

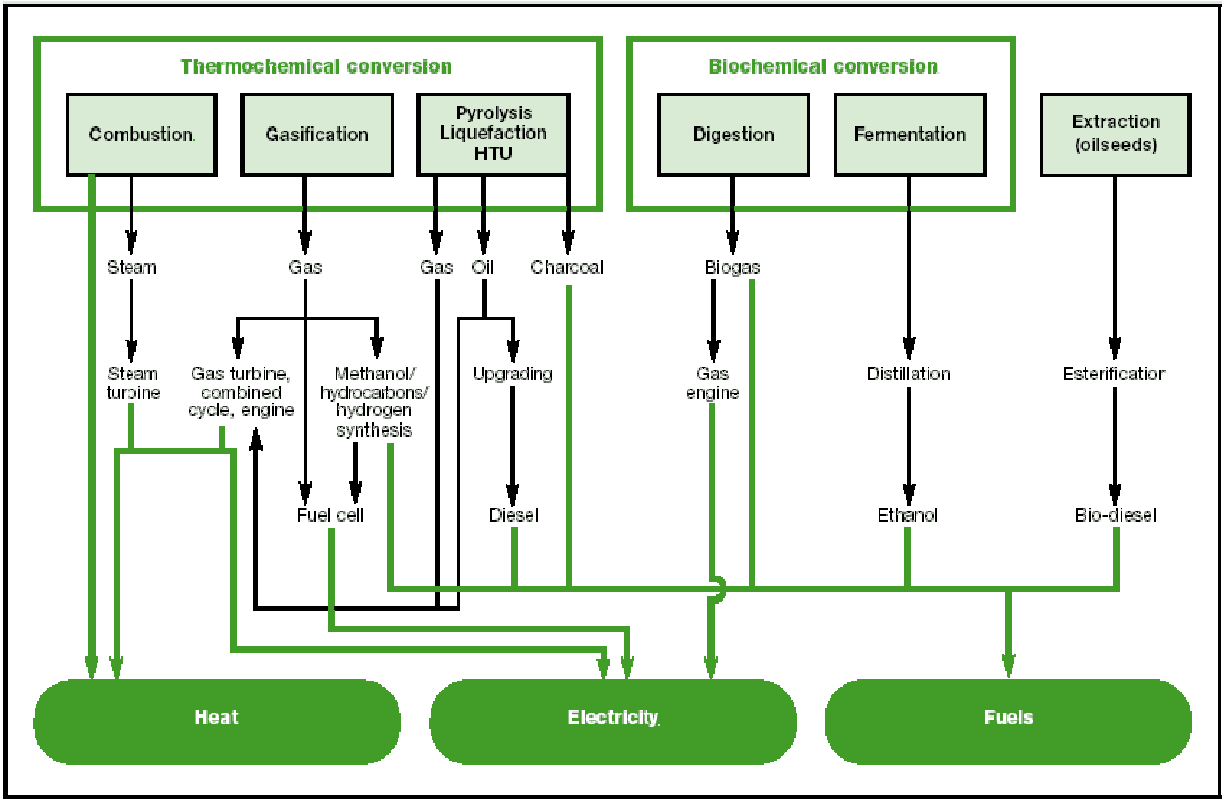
In the BIAS framework, methods are defined to analyze bioenergy for different settings to provide a rational base for decision-making on bioenergy schemes for various stakeholders.

1.4 The Setting Approach and the BIAS Framework

Bioenergy can be derived from a broad variety of farming and forestry systems, residue extraction or waste collection systems, downstream conversion routes, and waste treatment options as well as their respective links to auxiliary energy and material inputs and associated transports – the resulting matrix is impressive:

Different energy carriers can be produced from biomass, i.e. electricity, heat and transportation fuels (see Figure 1-3). The type of conversion technology determines the biomass feedstock that can be used.

Figure 1-3 Different pathways to convert biomass to energy



Source: UNDP (2004)

The production of bioenergy can involve different types of crops and farming systems under different environmental conditions. Nearly all steps of bioenergy life cycles vary with location and time, and each step can be realized with different processes, intensity and efficiency, emission characteristics etc. and under different social and economic circumstances.

To allow for a conceptual framing of this multitude of cases, the **setting** approach was developed.

"Setting" means a generic[6] representation of **combining** life cycles with socio-economic (e.g. ownership structure, intensity and scale of production) and environmental (geo- and

6 i.e. non-localized: area representing several locations, but not referring to any real-world territory.

biophysical, climatic) categories. All settings form a matrix of the multitude of combinations within bioenergy supply chains. In practical terms, this can be represented by a **sequence** of matrices, each valid for a sub-setting (e.g., smallholder farming systems growing a specific feedstock such as sugarcane).

An example of the setting concept is given in Table 1-2 in a simplified matrix.

Table 1-2 Example of a Settings Matrix

SOCIO-ECONOMIC SYSTEM		TECHNOLOGICAL SYSTEM (life cycle)		ECO-SYSTEM	PRODUCTION SYSTEM	
Social	**Economic**	**Technical**	**Fuel type**	**Ecological**	**Crop**	**Practice**
Rural small holder farmers	Subsistence farming	No processing	Unprocessed biomass (dung, wood)	Agro-ecological Zones (AEZ)	Mono crop	very high intensive
Landless rural poor	Viable small to medium scale farms	Household scale processing and use	Charcoal	Landscape level	Multi-crop rotation	GAP
Urban poor	Rural business	Small business processing and use	Liquid biofuels (ethanol, biodiesel)	Watershed system	Perennial	Low input/ traditional
Community	Large scale industrial	Community scale processing and use	Biogas	Soil type	Annual	conservation (no till)
	Export	industrial scale processing	Electricity	Water availability	Agro-forestry	Invasive slash and burn
			(Process) Heat		residues or wastes	

Source: adapted from FAO (2007a); dark boxes indicate selected elements of the setting

The very large number of potential combinations which represent the totality of theoretical settings can be reduced by focusing on the most important or most likely deployed combinations. The settings approach increases the applicability of the framework across countries, regions, and against socio-economic backgrounds. The BIAS modules are, in principle, applicable world-wide, so that the analytical framework can be applied for **any** combination[7]. Two examples of "settings" are given in the Annex A.

7 Note that restrictions exist regarding availability of data, or low resolution of data may induce error.

The approach for BIAS is flexible so that combinations of sub-settings (e.g. feedstock production for biodiesel on marginal lands in dry climates in small-scale farming) can be compared to other sub-settings with different conversion routes of the same feedstock etc.

The **regional** attributes of settings with regard to bio- and geophysical and climate characteristics as well as agricultural management systems should be based on the Agro-ecological Zone (AEZ) concept (FAO 2005a)[8] and the people-oriented farming system approach (FAO 2001). Settings also include combinations of biomass production and use, i.e. supply chains consisting of biomass production, logistic (transport and storage), conversion and end-use.

1.5 Measuring the Impacts: Criteria and Indicators

For the analysis of the environmental impacts that play an important role in bioenergy systems, the core criteria are biodiversity, water and soil, and climate impact. For those, indicators can measure an approximation of the impact or estimate the risk.

The biomass production system relates to changes in **biodiversity** on the land used, depending on location, crop and agricultural management systems, and previous land use. The respective indicators for BIAS are mainly land-use related (Chapter 2).

The biomass production systems can influence the **availability and quality of water***.* The different systems use different amounts of water from surface and groundwater, depending on, among others, the water-use efficiency of the crops and whether the system is irrigated or rain-fed. Respective indicators are discussed in Chapter 3.

Some of these production systems might use and restore degraded lands, while others may contribute to land degradation. Therefore, bioenergy production is in many cases likely to change the **quality of soil** in terms of carbon and nutrient content as well as the risk of soil erosion. The indicators for soil are elaborated and presented in Chapter 4.

Finally, the **climate impact** of bioenergy production and use compared to fossil energy is one of its main drivers. The indicator here are life cycle GHG emission balances bioenergy production depends strongly on the type of bioenergy (e.g. transportation fuels versus electricity), the type of agricultural production system (e.g. high versus low input), the use of by- and co-products and finally for an important part also on direct and indirect land use changes associated with bioenergy production as these land use changes can result in significant carbon stock changes.

For example, emissions of GHG expressed in CO_2 equivalents are a typical indicator for the global warming potential and hence the climate change risk.

In the BIAS modules, the selection of indicators for respective environmental impacts is discussed in detail. The extent to which each indicator can be calibrated quantitatively has been explored, but in many cases this proved to be difficult. The following table gives a first overview of possible indicators.

---

8 For spatial attributes, the characterization of databases for global land cover should be used (FAO 2005b).

Table 1-3 Environmental Impacts and Indicators for Bioenergy Systems

Area of concern	Impact	Possible Indicator
Biodiversity	**Protection of existing nature**	**type of land for bioenergy production and risk minimization approach: define "go" and "no-go" areas based on spatially explicit data on relevant biodiverse land**
	Biodiversity on managed land and changes on landscape level	**type of bioenergy production system and adequate management strategies to minimize risks**
Water	**Water availability for biomass production**	**Water stress, i.e. withdrawals per unit bioenergy [m³ per MJ_{bio}]**
	Groundwater depletion	**Water stress in groundwater resources, i.e. withdrawals per unit bioenergy [m³ per MJ_{bio}]**
Soil	**Carbon loss**	**Change in carbon content of soils [t C per hectare in the next 20 years]**
	Nutrient loss	**Changes in nutrient content (N, P, K) in soil [kg per kg soil]**
	Soil erosion	**Loss of soil [kg per hectare per year]**
Climate change	**Global warming**	**GHG emissions [kg $CO_{2\ eq}$ per MJ_{bio}]**
Examples for other possible concerns not covered in the BIAS framework		
Ecosystem resilience	**Freshwater and terrestrial toxicity**	**Ecotoxicity potential [kg 1,4-dichlorobenzene-eq per MJ_{bio}]**
	Eutrophication in aquatic and terrestrial ecosystems	**Eutrophication potential [kg PO_{4eq} per MJ_{bio}]**
	Acidification	**Acidification potential [kg $SO_{2\ eq}$ per MJ_{bio}]**
Resources	**Depletion of natural resources**	**Use of primary non-renewable energy [$MJ_{primary}$ per MJ_{bio}]**
Human health	**Occupational risk of injuries, illness and premature death**	**reduced work time [Person-days lost per MJ_{bio}]**

Source: own compilation

The indicators for BIAS modules were selected based on "strength" (expression of potential impact), spatial (local, regional, global) scope of impact, and measurability (potential to be treated quantitatively with "field" or average data).

The respective data needs to measure impacts through indicators and related tools (models, databases etc.) are discussed in each of the module chapters.

2 Biodiversity Impacts

International goals for the protection of biodiversity[9] are ambitious. In 2002, the Convention on Biological Diversity (CBD) introduced the 2010 target for biodiversity protection that was affirmed in the Johannesburg Plan for Implementation[10]. The 2010 target aims to achieve a significant reduction of the current rate of biodiversity loss[11].

Besides net reductions in greenhouse gas emissions from biofuels, food security and income generation, the **conservation of biodiversity** is a key concern of sustainable bioenergy development (UN Energy 2007).

Effects of bioenergy production on biodiversity can be either positive or negative (CBD 2008, CBD-COP Decision IX/2), strongly depending on location, agricultural and forestry practices, previous and indirect land-use, and conversion systems used in the downstream chain (processing, distribution and consumption).

A principle structure to consider land use related biodiversity impacts with respect to specific "settings" and cultivation systems was derived in an extensive project on sustainability impacts of bioenergy (WBA 2007).

The following table gives an indication of the short-term potential biodiversity impacts of key (current and future) cultivation systems for bioenergy, depending on the land characteristics of the production area, and the overall climate zone.

As can be seen from this overall aggregated analysis, all cropping systems show comparatively strong negative impacts when cultivated on land with previously natural vegetation. Still, the impacts of perennial crops grown on existing crop- or grassland, or marginal/abandoned land can be comparatively positive

---

9 Biological diversity (=biodiversity) means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, article 2). http://www.cbd.int/convention/articles.shtml?a=cbd-02

10 This plan was adopted by the World Summit on Sustainable Development in Johannesburg in 2002.

11 See CBD Decision VI/26; sub-targets to achieve the 2010 target are, e.g., the effective conservation of at least 10% of each of the world's ecological regions (target 1.1) and the protection of areas of particular importance to biodiversity (target 1.2; CBD Decision VII/30).

Table 2-1 Short-term biodiversity impact of land converted to annual and perennial bioenergy crops in both temperate and tropical regions.

Land use	Climate regime and cropsystem	Annual crops		Perennial crops		
		Oilcrops (rapeseed, soybean)	**Cereals** (wheat, maize, straw)	**Oilpalm**	**Grass** (miscanthus, switchgrass)	**Woody** (willow, poplar, pinus, eucalyptus)
	Bio-energy Generation	1st	1st / 2nd	1st	1st / 2nd	2nd
Undisturbed Natural vegetation (near pristine)	temperate	from 1,0 to 0.1 result: – **0.9**	from 1,0 to 0.1 result: – **0.9**	n.a.	from 1,0 to 0.3 result: – **0.7**	from 1,0 to 0.3 result: – **0.7**
	tropical	from 1,0 to 0.1 result: – **0.9**	from 1,0 to 0.1 result: – **0.9**	from 1,0 to 0.3 result: – **0.7**	from 1,0 to 0.3 result: – **0.7**	from 1,0 to 0.3 result: – **0.7**
Disturbed Natural vegetation (secondary forest)	temperate	from 0.5 to 0.1 result: – **0.4**	from 0.5 to 0.1 result: – **0.4**	n.a.	from 0.5 to 0.3 result: – **0.2**	from 0.5 to 0.3 result: – **0.2**
	tropical	from 0.5 to 0.1 result: – **0.4**	from 0.5 to 0.1 result: – **0.4**	from 0.5 to 0.3 result: – **0.2**	from 0.5 to 0.3 result: – **0.2**	from 0.5 to 0.3 result: – **0.2**
Existing cropland/ grasslands	Temperate: in rotation intensive	from 0.1 to 0.1 result: **0.0**	from 0.1 to 0.1 result: **0.0**	n.a.	from 0.1 to 0.3 result: + **0.2**	from 0.1 to 0.3 result: + **0.2**
	Temperate: Permanent intensive	from 0.2 to 0.1 result: – **0.1**	from 0.2 to 0.1 result: – **0.1**	n.a.	from 0.2 to 0.3 result: + **0.1**	from 0.2 to 0.3 result: + **0.1**
	Tropical: agro-forestry	from 0.5 to 0.1 result: – **0.4**	from 0.5 to 0.1 result: – **0.1**	from 0.5 to 032 result: – **0.2**	from 0.5 to 0.3 result: – **0.3**	from 0.5 to 0.3 result: – **0.2**
	Tropical: in rotation extensive	from 0.3 to 0.1 result: – **0.2**	from 0.3 to 0.1 result: – **0.2**	from 0.3 to 0.2 result: – **0.1**	from 0.3 to 0.2 result: – **0.1**	from 0.3 to 0.3 result: **0.0**
Set aside land (policy in some developed regions)	temperate	from 0.3 to 0.1 result: – **0.2**	from 0.3 to 0.1 result: – **0.2**	n.a.	from 0.3 to 0.3 result: – **0.0**	from 0.3 to 0.3 result: **0.0**
	tropical	n.a.	n.a.	n.a.	n.a.	n.a.
Marginal land	temperate	from ± 0.3 to 0.1 result: – **0.2**	from ± 0.3 to 0.1 result: – **0.2**	n.a.	from ± 0.3 to 0.3 result: – **0.0**	from 0.3 to 0.3 result: **0.0**
	tropical	from ± 0.3 to 0.1 result: – **0.2**	from ± 0.3 to 0.1 result: – **0.2**	from ± 0.3 to 0.2 result: – **0.1**	from ± 0.3 to 0.3 result: – **0.0**	from ± 0.3 to 0.3 result: **0.0**
Abandoned land	temperate	from ± 0.3 to 0.1 result: – **0.2**	± 0.3 to 0.1 result: – **0.2**	n.a.	from ± 0.3 to 0.3 result: – **0.0**	from ± 0.3 to 0.3 result: **0.0**
	tropical	from ± 0.3 to 0.1 result: – **0.2**	from ± 0.3 to 0.1 result: – **0.2**	from ± 0.3 to 0.2 result: – **0.1**	from ± 0.3 to 0.3 result: – **0.0**	from ± 0.3 to 0.3 result: **0.0**

Source: WAB (2007); values refer to mean species abundance (MSA) and "from 1.0 to 0.1" means a drop from the highest level of biodiversity (1.0) to the lowest level (0.1) and the loss is 0.9

As current bioenergy – and especially liquid biofuels – production is closely related to conventional agricultural crop production, environmental impacts, and their assessment, tend to be similar[12].

[12] see also Box "Bioenergy Cropping Systems" in Section 4.1.

The increasing demand for bioenergy could lead to both direct and indirect[13] expansions of cultivated areas, resulting in further habitat loss and negative impacts on biodiversity, especially if forest, grass-, peat- and wetlands are used for feedstock production and if large monoculture plantations are created (CBD 2008).

Due to more international trade in bioenergy and biofuels (IEA 2008), this may especially be the case in emerging and developing countries that are known to harbor high amounts of Earth's biodiversity.

In that regard, both national and international strategies, guidelines, criteria, and standards for the sustainable production of bioenergy are needed.

2.1 Approaches to Address and Value Biodiversity Impacts

The implementation of conservation goals for the protection of biodiversity requires strategies and approaches for managing whole landscapes, including areas allocated to both production and protection (Margules/Pressey 2000)[14].

Metrics used within approaches to value biodiversity comprise species and ecosystems (all or targeting priorities like endemic species, certain taxa or endangered ecosystems), communities, ecological and evolutionary processes as well as biodiversity.[15] Comparing the approaches according to conservation targets, the question where and how to conserve, the scale of conservation, and the principles that underlie the approach, distinct differences were observed, but there is surprisingly low competition between approach (Redford et al. 2003).

Protection of biodiversity can in general be distinguished in the separation of biodiversity from negative human impacts (segregation; e.g., protected areas) and its protection and sustainable utilization within used areas (integration; e.g., Ecosystem Approach). Today neither the PA network sufficiently covers biodiversity patterns around the world, nor do most land use and management practices respect principles of sustainable use for biodiversity in an appropriate manner (Dudley/Phillips 2006, Langhammer et al. 2007).

Nevertheless, e.g., CBD activities within the Programme of Work on Protected Areas (PoWPA) contribute to improve the situation[16], whereas the CBD Programme of Work on Agricultural Biodiversity integrates issues of biofuel production for the conservation and sustainable use of agricultural biodiversity[17].

---

13 Bioenergy production displaces a former cultivation of food, fodder or fiber (direct land use change) whose cultivation than occurs elsewhere in the world (indirect land use change).

14 For example, Redford et al. (2003) reviewed 21 approaches being implemented by 13 conservation organizations, e.g., hotspots (CI), Global 200 Ecoregions (WWF), endemic-bird areas (BLI), Natura 2000 (EU COM), Ecosystem Approach (CBD) and ecoregional and site conservation planning (TNC).

15 See list of indicators in Annex B

16 See as example the Eastern Europe Regional Workshop "Strengthening the Capacity of Governments to Implement Priority Activities of the CBD PoWPA", Isle of Vilm, 17-21 June 2007 (Gawler 2007).

17 See CBD-COP Decision V/5. Agricultural biodiversity is a broad term that includes all components of biological diversity of relevance to food and agriculture, and all components of biodiversity that constitute the agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at genetic, species and ecosystem levels, necessary to sustain key functions of the agro-ecosystem, its structure and processes.

Further more, CBD-COP Decision VIII/28 provides details guidelines to integrate biodiversity-related considerations into the process of environmental impact assessment that should be considered while planning bioenergy projects.

2.2 Risk Mitigation Strategies to Protect Biodiversity

COP-CBD Decision IX/2 emphasizes the challenge of promoting the positive impacts of biofuel production on biodiversity while minimizing negative effects. A required risk mitigation strategy[18] should ideally remain flexible with regards to the various geographical origins, raw materials and conversion technologies for biomass[19]. Several studies, e.g., (EEA 2006 + 2007) tried to determine sustainable biomass potentials using a risk mitigation strategy to avoid or minimize negative biodiversity impacts from bioenergy development. The strength of a risk mitigation strategy is that it is straightforward in considering various conservation approaches at different scales and geographical situations.

Reflecting the international literature on the protection of biodiversity, sustainable landscape planning as well as sustainable development of agriculture and bioenergy (see citations below) a risk mitigation strategies within national and international policy frameworks to develop the bioenergy sector should focus on four key issues (see Table 2-2).

Table 2-2 Key Issues of the Risk Mitigation Strategy to Protect Biodiversity.

Key issues	Risk mitigation effects to protect biodiversity
Protection of natural habitats (PA, HCV, KBA, etc.)	▪ **Avoidance direct negative effects on biodiversity in sensitive areas**
Sustainable cultivation of biomass	▪ **Reduction of direct negative effects and promotion of positive once in cultivation areas.** ▪ **BUT: risk of negative effects on natural habitats by indirect land use change.**
Areas for preferential biomass production (unused degraded land and abandoned farmland)	▪ **Low direct negative effects and promotion of positive once.** ▪ **Reducing the risk of negative effects of indirect land use change**
Sustainable use of organic residuals and wastes	▪ **No or low direct negative effects.** ▪ **Reducing the risk of negative effects from indirect land use change**

Source: own compilation

---

18 CBD-CPO Decision IX/2 states that policy frameworks should make use of relevant tools and guidances under the Convention like the precautionary approach in accordance with the preamble of the CBD (see also Principle 15 of the Rio Declaration on Environment and Development), and, e.g., according to Annex III of the Cartagena Protocol (http://www.cbd.int/biosafety/protocol.shtml), lack of scientific knowledge or scientific consensus should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable risk.

19 However, as the technologies used in the conversion of biomass into bioenergy material (e.g. biofuels) do not seem to involve the same level of risks to biodiversity as the cultivation of biomass itself (CDB 2008), the risks related to conversion are not addressed here.

Protection of Natural Habitats

Biodiversity is directly linked to properties and quality of habitats (Strand 2007), and loss of habitat as a result of direct and indirect land-use change is still the major thread to biodiversity (Langhammer et al. 2007). The ongoing deforestation in the tropics is a prominent example of the loss of biodiversity-rich habitats (FAO 2006b, Wassenaar 2007). Other prominent factors causing the decline of biodiversity are habitat fragmentation and isolation, land-use intensification and overexploitation, species invasions, and adverse climate change impacts[20].

Protected Areas (PA) defined through their legal protection status are cornerstones of regional conservation strategies as well as global goals such as the 2010 target for biodiversity protection, and they should separate biodiversity, agrobiodiversity, and natural and associated cultural resources from processes threatening its persistence (Margules/Pressey 2000).

The latter necessity should be strongly emphasized in strategies to mitigate biodiversity risks of biomass production. This could effectively be achieved by prohibiting any biomass production (cultivation or unsustainable harvesting, or collection, respectively) in PA, unless the planned biomass extraction conforms to protecting or enhancing biodiversity.

Existing PA throughout the world contain only a (biased) sample of biodiversity, usually that of remote places and other areas unsuitable for commercial activities (Margules/Pressey 2000). Thus, they do not – as yet – come near to fulfilling global biodiversity commitments, nor the needs of species and ecosystems, given that a large number of these species, ecosystems and ecological processes are not adequately protected by the current PA network (Dudley/Phillips 2006)[21].

In a biodiversity risk mitigation strategy for bioenergy, **areas** need to be evaluated that are of **importance for the protection of biodiversity**, but that are currently not protected. These areas should receive the same strict protection status as PA in order to withstand additional direct land-use pressure occurring from biomass production. Moreover, the installation of corridors and buffering zones around important biodiversity areas is desirable and the landscaping opportunities of some bioenergy crops could add to the installation of such zones.

If bioenergy production displaces a former cultivation of food, fodder or fiber (direct land-use change) its cultivation is than likely to occur elsewhere in the world (indirect land-use change). Negative impacts on PA and biodiversity-relevant non-protected areas caused by such indirect land-use change are hardly to be mitigated, and land-use policies executed in a reliable manner on national scale seems to be the most promising attempt.

---

[20] See e.g., Groom et al. (2006), and Lindenmayer//Fischer (2006). Also conversion systems used in the downstream chain (processing, distribution and consumption) may negatively affect biodiversity (CBD 2008). Because these effects are either estimated to be relatively low or are covered by a sustainable management of the recourses soil and water, they are not addressed here.

[21] In this regard, gap analysis is a method to identify biodiversity (i.e., species, ecosystems and ecological processes) not adequately conserved within a PA network or through other long-term conservation measures (Scott et al. 2001, see also Langhammer et al. 2007 and CBD activities within the Programme of Work on Protected Areas PoWPA).

However, as long as each country where a displaced crop – or its substitute – could be cultivated does not implement such a land-use policy, negative indirect land-use effects cannot be excluded. Therefore, displacement of crops for food, fodder or fiber production should be reduced to a minimum.

Cultivation Practice for Biomass Production and Agrobiodiversity

Today, it is widely accepted that the implementation of conservation goals for the protection of biodiversity requires systematic planning strategies for managing landscapes, including areas allocated to both production and protection (Margules/Pressey 2000, Benedict/McMahon 2006, Groom et al. 2006).

The CBD recognizes the limitations of PA as the sole tools for conservation, and promotes a the **Ecosystem Approach**[22] which seeks to mainstream biodiversity conservation into broader land- and seascape management (Smith/Maltby 2003, Dudley/Parish 2006). In this context, the promotion of the positive and minimization of the negative impacts of biofuel feedstock production is needed (see CBD-COP Decision IX/2), especially when based on feedstock production through agriculture (see CBD-COP Decision IX/1), and general principles to address the protection of agro-biodiversity need to be considered as outlined in CDB-COP Decision V/5[23] as well as in the guidelines to integrate biodiversity-related considerations into the process of environmental impact assessment (CBD-COP Decision VIII/28).

In the EU, approaches for environmentally “compatible” biomass production systems which include biodiversity concerns have been suggested (EEA 2006+2007), but are still far from implementation.

Also IAASTD (2008) stressed in its recent Synthesis Report that for successfully meeting development and sustainability goals, a fundamental shift in Agricultural Knowledge, Science and Technology (AKST) would be needed, including science, technology, policies, institutions, capacity development and investment. AKST systems must be developed that enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems (IAASTD 2008). Productivity of these systems will be vital as reduced yields and subsequent cultivation on other lands (indirect land-use change) may case negative effects on biodiversity (Green et al. 2005).

Cultivation practices which respect biodiversity and agrobiodiversity require a number of considerations including, for example, the management of ecosystem services, the use of native species and local varieties of plants[24], avoidance of monocultures, prioritization of

---

22 The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that advances conservation and sustainable use in an equitable way, including ecological, socioeconomic, cultural, and political issues (see overview in Smith/Maltby 2003, Groom et al. 2006, and Hartje/Klaphake 2006). Information on the principles of the Ecosystem Approach is available at http://www.cbd.int/ecosystem/description.shtml and http://www.cbd.int/ecosystem/principles.shtml

23 See detailed information on the CBD Programme of Work on Agricultural Biodiversity (http://www.cbd.int/agro/programme.shtml) as well as related information on Case Studies (http://www.cbd.int/agro/casestudies.shtml).

24 See information on plant genetic resources for food and agriculture at http://www.fao.org/ag/AGP/AGPS/Pgrfa/wrlmap_e.htm. and http://apps3.fao.org/wiews/wiews.jsp.

perennial crops when possible, adequate rotation schemes, low-erosion land-use methods (e.g. no-till systems), low input of agrochemical application and machinery, and minimal irrigation.

Furthermore, the inclusion of specific landscape elements (e.g., stepping stones, corridors, buffer zones etc.) in the cultivation area must be considered or improved.[25]

Due to limited land recourses, cultivation of bioenergy on natural or semi-natural land that is not under production and that is not covered by e.g. PA or KBA, is likely to increase.[26] However, partial or complete conversion of these areas results in habitat loss and fragmentation, and ultimately impacts biodiversity – a process human land-use has induced already in many parts of the world. Thus, cultivation on these areas needs to be embedded in a sound landscape and systematic conservation planning process – considering CBD-COP Decision V/5 and IX/1 – that guarantees that the biodiversity of these areas will not be threatened due to this conversion.

Concerning the use of **genetic modified** crops, there is a wide range of perspectives regarding environmental, human health and economic risks and benefits of modern biotechnology, many of which are as yet unknown. In addition, instruments such as patents on genetic modified crops may drive up costs, especially in developing countries (IAASTD 2008).

These general problems are also valid when cultivating genetic modified crops for bioenergy purposes. Due to a significant lack of transparent communication among actors, and uncertainty on benefits and harms, the use of genetic modified crops for bioenergy production needs to be evaluated carefully.

Cultivation on Degraded Land and Abandoned Farmland

The cultivation of biomass on unused degraded land or (for economical or political reasons) abandoned farmland can be seen as a safeguard against negative **indirect** land use change effects from bioenergy development[27]: As no displacement of previous cultivation occurs, biomass production on these areas will not increase pressure on biodiversity-relevant areas.

However, at least some of these areas might harbor high biodiversity and could belong to biodiversity-relevant areas, and regeneration of degraded land towards natural habitats may be more beneficial (e.g., biodiversity, ecosystem services) than using these areas for bioenergy production.

Unused degraded land or abandoned farmland shall be prior biomass production areas due to the positive effects by avoiding indirect land use change.

---

25 See also strategies to conserve biodiversity in Ecoagricultue (McNeely/Scherr 2003).

26 In addition to the threat posed to habitats and species from unsustainable expansion of bioenergy feedstock production, the degradation of natural areas, including those important in terms of ecosystem functions and services such as the provision of fresh water (Millennium Ecosystem Assessment, http://www.maweb.org), is foreseen as a potential major ecological risk. Any disturbance in ecosystem function or service due to the degradation of these areas may ultimately hold consequences for ecosystem sustainability and the subsistence of human populations.

27 See RFA (2008); Searchinger (2008); WWF (2006); GBEP (2009) and also GHG module in Chapter 5.

Following classification and spatial identification of biodiversity-relevant areas, biomass production, however, should only take place in areas not sensitive to cultivation and that are not used by local people.

Residues and Wastes

Biomass residues (e.g., manure, forest thinnings, rice husks, straw) and wastes (e.g., organic fractions in residential and industrial wastes) are other options for bioenergy feedstocks that can amount up to half of the bioenergy potentials in a country (e.g., OEKO 2004, EEA 2007). The use of residues and wastes has a low risk of causing indirect effects, and could offer positive impacts, e.g., avoided nitrogen leaching, reduced fire risks, revenue from land management (OEKO 2007).

However, the change of natural decay chains in e.g., forests by extracting previously unused organic material such as thinnings could cause negative impacts for local biodiversity, and – in extreme cases – negatively affect soil quality, enhance erosion, and deplete nutrient levels. Thus, national strategies for bioenergy should strongly focus on bioenergy resources from residuals and wastes, and incorporate adequate management rules to safeguard against negative potentials.

2.3 The BIAS Module for Biodiversity

The aim of the analytic framework is to categorize areas into those where **no** bioenergy should come from, and those were biodiversity-friendly bioenergy production or residual extraction could be possible.

A risk mitigation strategy to ensure biodiversity-conscious bioenergy development needs to be part of an analytic framework (Figure 2-1) that should be implemented in national strategies given nations' sovereignty to decide on most land-use related aspects. Nevertheless, the implementation of the analytic framework should be guided by international authorities and institutions.

The following key activities are required and need to be addressed in parallel for areas relevant for biodiversity protection and cultivation areas (see Figure 2-1):

1. Data collection process

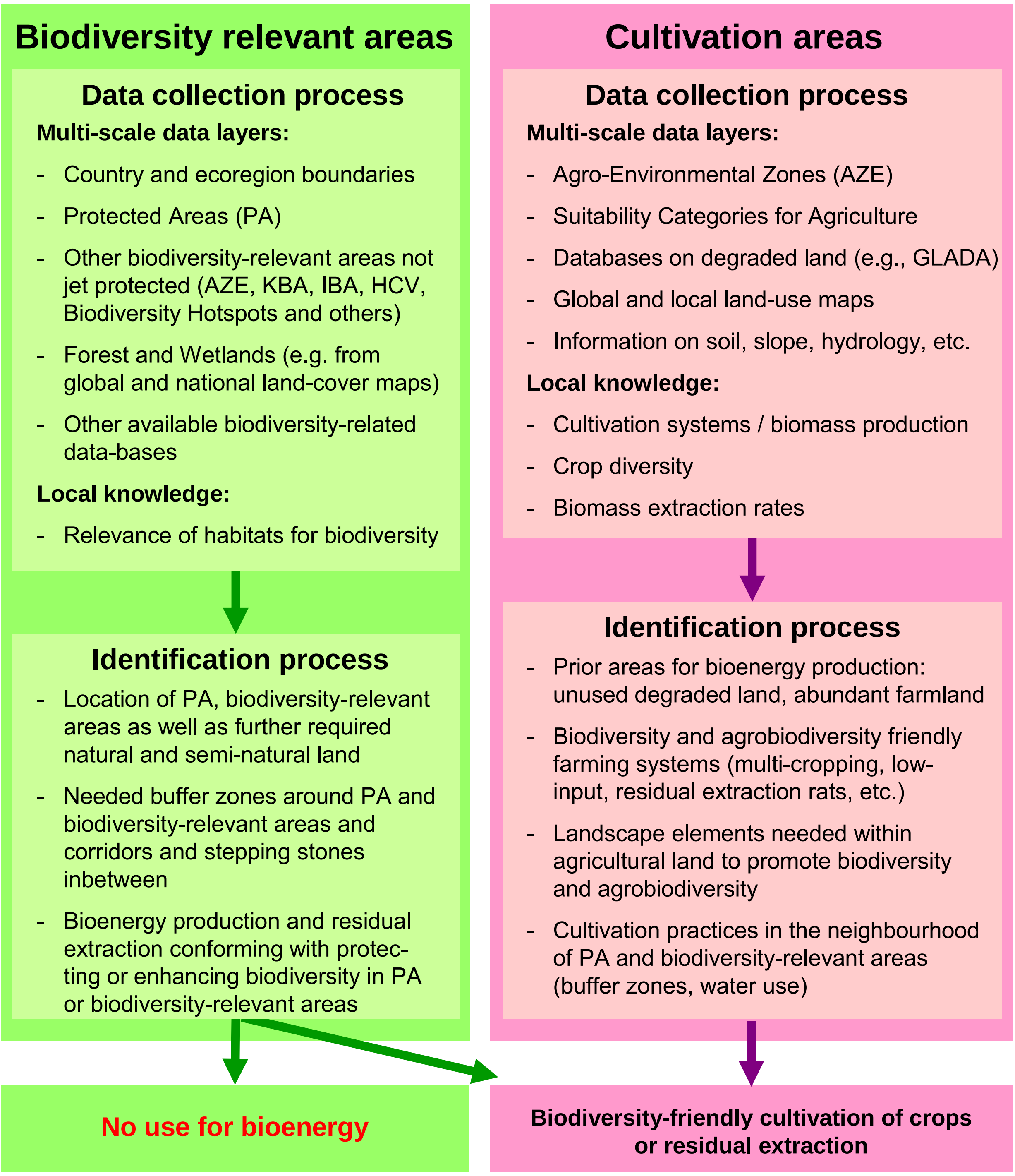
- Available data to characterize areas relevant for the protection of biodiversity
- Information on environmentally "compatible" practices for biomass production

2. Identification process

- Spatially explicit definition of protected and other biodiversity-relevant areas
- Definition of prior bioenergy cultivation systems (including landscape structure) and residual extraction with low negative or positive impacts on biodiversity.

Also other aspects of bioenergy production should - in the longer-term - be integrated into the land use planning, e.g. food production in parallel to bioenergy.

Figure 2-1 Framework to Prioritize Areas for Bioenergy Development



Source: Öko-Institut

Global data relevant for PA, biodiversity-relevant areas, natural and semi-natural land, degraded land, abandoned farmland and cultivated areas should be stored in a comprehensive geographical information system (GIS), and the GIS data should offer the possibility to include further local data as well as to combine this information with requirements and impacts of cultivation practices.

Data configuration and administration needs to be provided in a user-friendly format by an international organization (e.g., FAO), and national administrates should be instructed to use the data.

The identification process for PA and other biodiversity-relevant areas, as well as for biodiversity-friendly cultivation practices, can then be carried out by screening the data collection with (internationally accepted) criteria and indicators. Setting up these criteria and indicator is – nationally as well as internationally – still in progress[28]. This will be the largest challenge and prior work for the further development of the analytic framework that should be embedded in existing international processes, especially the CBD and the Global Bioenergy Partnership (GBEP).

Following CBD-COP Decision IX/2, regional workshops on the sustainable production and use of biofuels aiming at considering ways and means to promote the positive and minimize the negative impacts of the production and use of biofuels on biodiversity are currently carried out by the Executive Secretary of the CBD. Results will be available at CBD-COP 10.

The Global Bioenergy Partnership (GBEP)[29] as an initiative of the G8 develops science-based benchmarks and indicators for biofuel production and use, e.g. to conserve biological diversity, ecosystems and landscapes. GBEP goes way beyond the G8 – in GBEP, partners such as, among others, Argentina, Brazil and China, Ethiopia, Mozambique and Sudan participate, as well as UN and (bio)industry organizations.

The GBEP is the only mechanism that enables global considerations on sustainability standards for GHG as well as biodiversity and social issues (food security, occupational safety and health...) on the basis of mutual exchange and coordination.

It is envisaged to adopt a resolution concerning the “core catalogue” in the scope of the G8 Presidency which would lay the global foundation for implementation.

However, national promotion of bioenergy should follow these international standards and guidelines, but due to the heterogynous and site-specific nature of biodiversity, national adaptations and regional specifications by policies and decision makers are need to identify the above mentioned areas and to define cultivation practices.

A general limitation of the proposed analytic framework is the availability of data with high resolution. Therefore, a combination of top-down and bottom-up approaches should be used to compile information.

Starting with a blank map, first global available data (e.g. PA, wetland, forest, global land cover, suitability maps for agriculture, etc.) are entered (top-down), and for those areas where data resolution is high enough on the global scale, the analytic framework is applied. The other areas stay blank, and still belong to the category “no use for bioenergy”. Bottom-up, the analytic framework is applied to national data (e.g., national land-cover maps, species inventories, land-use data, soil maps, etc.) in combination with knowledge of national and local specialists. For those areas that still stay blank new data need to be collected.

---

28 See, e.g., Round Table on Responsible Soy (RTRS) and Roundtable on Sustainable Biofuels (RSB).

29 http://www.globalbioenergy.org/

2.4 Data Collection and Identification Process

According to Chapter 2.3, the data collection process is specified for the two main fields, protected areas and biodiversity-relevant areas as well as cultivation practices[30].

As outlined above, setting up criteria and indicator that are accepted nationally and internationally is a large challenge that is – however – out of the scope of this study. Nevertheless, in the next subsections, related concepts and needs for local attentions are addressed.

Protected Areas (PA) and Biodiversity-Relevant Areas

Due to the complex distribution of the Earth's natural resources, it is useful to distinguish land- and seascapes with a meaningful biogeographic and/or ecological resolution.

The Ecoregion approach (Olson et al. 2001, Olson/Dinerstein 2002) with its 867 distinct spatial units seems to be most adequate for down-scaling. Implementation, however, is often restricted to political units represented by nations (or groups of nations).

Therefore, the surface of each nation should be stratified according to Ecoregions, and further differentiation on a **national** scale should be carried out within each Ecoregion[31].

Protected areas regulated under a range of legal and customary arrangements are often designed to ensure the conservation of important biodiversity and ecosystem benefits (Dudley/Phillips 2006). Their location is in most cases well-known[32], and they are the starting dataset for the top-down approach to identify **biodiversity-relevant areas**, followed by other internationally accepted areas like Alliance for Zero Extinction (AZE), Important Bird Areas (IBA), Important Plant Areas (IPA), as well as Key Biodiversity areas (KBA). The location of these areas is mainly derived from distribution data of endangered and endemic species (Langhammer et al. 2007).

Also **forests** and **wetlands**[33] often carry natural or near-nature ecosystems, and their importance for the protection of biodiversity is well known. Especially global and national **land cover maps** together with experts' knowledge can be useful to derive further biodiversity-relevant areas (bottom-up).

The High Conservation Value (**HCV**) concept, first applied on forests by FSC, is a promising approach to expand the identification of biodiversity-relevant areas from species (e.g., KBA) to ecosystems[34]. However, currently no internationally accepted definition on HCV exists,

---

30 In Annex E, an overview on available GIS data is given

31 It must be kept in mind, though, that country territories do not necessarily coincide with the natural distribution of species and communities (see e.g., large mammals in Africa - Burgess et al. 2004). Thus, conservation of biodiversity will require cross-border planning.

32 The World Database on Protected Areas (WDPA) based on the UN List of Protected Areas and IUCN Protected Area Management Category System offers the globally most comprehensive GIS based platform; http://www.unep-wcmc.org/wdpa/index.htm

33 For example, Global Forest Resources Assessment (FRA, FAO 2006b) and Global Lakes and Wetlands Database (GLWD, Lehner/Döll 2004)

34 See overview in http://hcvnetwork.org/; HCV is also used from, e.g., the RSB; http://www.bioenergywiki.net/images/b/bf/Env_paper_21_-_6th_virtual_meeting_synthesis.pdf)

and mapping of HCV has only been carried out in some regions. In addition, the needed criteria and indicator should be extended to identify also required buffer zones around areas as well as biomass production and residual extraction forms that conform to the protection of HCV.[35]

Once the location of PA and biodiversity-relevant areas is identified, needed buffer zones around these areas must be specified.

Most edge effects given in the literature vary between 20-60 m (Baker & Dillon 2000, Laurenace et al. 2002, Rees et al. 2004, Hennenberg et al. 2008), but there are also examples that factors like fire can penetrate several kilometers (Cochrane & Laurance 2002), and edge effects strongly depend on conditions at habitat boundaries (e.g. open or closed edges) and on conditions in the surrounding habitats. Thus, the width of buffer zones and also possible land-use forms in buffer zones need to consider the local situation in the view of which negative effects from outside of a sensitive area needs to be mitigated, how deep may such effects penetrate and which land-use forms avoid such possible negative effects.

In biodiversity-relevant areas, any raw material extraction is very likely to endanger biodiversity and should not take place at all, unless there is strong evidence that an extraction is needed to achieve conservation goals, e.g., for species-rich grasslands in Europe (EEA 2004).

Once areas of significant biodiversity value are excluded from potential production plans, the remaining land suitable for cultivation often includes natural or semi-natural habitats. However, partial or complete conversion of these areas results in habitat loss and fragmentation, and ultimately impacts biodiversity – a process human land-use has already induced in many parts of the world. Thus, cultivation on these potentially suitable areas needs to be embedded in a systematic conservation planning process, including management requirements, to guarantee that the biodiversity value of these areas will not be threatened due to poorly planned conversion. Common and well known techniques to minimize extinction risks of species are, e.g., population viability analysis and landscape models (see overview in Groom et al. 2006).

Cultivated Areas

Bioenergy cultivation needs to be carried out in a sustainable manner especially regarding agrobiodiversity which includes all components of biological diversity of relevance to food and agriculture, and all components of biodiversity that constitute the agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem[36], its structure and processes (CBD-COP Decision V/5).

---

[35] The also the overview on priority setting within Ecoregions in Groves (2003). Further more, methodologies of the Rapid Biodiversity Assessment Programme can be helpful to gather species lists of selected species groups of an area in a short amount of time (http://biosurvey.conservation.org/portal/server.pt?open=512&objID=1704&mode=2&in_hi_userid=127583&cached=true).

[36] Regarding the meaning and significance of the biodiversity of soil organisms see http://www.fao.org/ag/AGL/agll/soilbiod/default.stm + ftp://ftp.fao.org/docrep/fao/010/i0112e/i0112e.pdf.

Sustainable cultivation practices are necessary to utilize and manage agricultural biodiversity sustainably. For example, Integrated Pest Management (IPM), Eco-agriculture, Conservation Agriculture or Organic Agriculture[37] – and using the Ecosystem Approach – show a better performance in this field (Groom et al. 2006). Regarding food security, model estimates indicate that organic agriculture could produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base (Badgley et al. 2007)[38].

The main nature of alternative and sustainable cropping systems still guaranteeing high yields is that they need to be adapted to local conditions, and their development is a large challenge for all agricultural sectors including bioenergy (Sagar/Kartha 2007, IAASTD 2008).

As a top-down approach, Agro-Ecological Zones (Fischer et al. 2000, FAO 2005) and especially the more detailed land suitability maps for agriculture (van Velthuizen 2007) appear to be useful to guide the development of priority sustainable cropping systems (bioenergy production as well as residual extraction) together with global and national land-use maps.[39]

Bottom-up-wise, local information on soil, relief, hydrology, land cover and land adjacent to cultivated land providing habitat for agricultural biodiversity (e.g. pollinators) as well as knowledge from national institutions and specialists on cropping systems and biomass-extraction rates should complement the selection of priority cropping systems with low negative impact on biodiversity and agrobiodiversity or its improvement.

As outlined in Chapter 2.3, several basic principles should be considered for the development of priority cultivation systems. The use of native species should always be the first choice to avoid risk of invasiveness of introduced species. However, non-native bioenergy crops often show traits that are characteristic for invasive species like high productivity and absents of herbivores.

Thus, before its cultivation, a Pest Risk Assessment for any non-native species needs to be carried out.[40]

Cultivation of local varieties of plants is often favorable due to adaptations at local condition, and their on-farm conservation is seen as an opportunity to reduce ongoing genetic erosion in crop plants (Hammer/Teklu 2008). As the main requirement of bioenergy crops is the

---

37 According to UNEP-UNCTAD (2008), organic agriculture can especially in developing countries increase agricultural productivity and can raise incomes with low-cost, locally available and appropriate technologies, without causing environmental damage. Furthermore, organic agriculture can improve food security by addressing different causal factors simultaneously.

38 During the last decade several hundred studies on alternative and/or sustainable cropping systems have been published, and excellent project examples are PLEC (People, Land Management and Environmental Change; Liang 2001, Gyasi et al. 2004) and WOCAT (World Overview on Conservation Approaches and Technologies; WOCAT 2007).

39 Agricultural databases on biodiversity that are directly related to the BIAS analytical framework are rare, only data on High Nature Value Area (HNV) farmland in Europe exist so far (EEA 2004, 2005).

40 For detailed information see The Global Invasive Species Program (GISP, www.gisp.org) and the Global Invasive Species Database http://www.invasivespecies.net/database/species/references.asp?si=77&fr=1&sts=

production of biomass and not a specific product like food, fodder or fiber, a much larger number of potential plants can be considered on a local scale for the development of cropping systems for bioenergy production respecting standards on low-erosion, adequate rotation schemes, carbon sequestration and low inputs (agrochemicals, irrigation).

In addition, diverse cropping systems are known to be more stable than monocultures, and these systems are known to need lower inputs (Smith et al. 2008). In this context, especially perennial crops are favorable that often perform relatively well regarding biodiversity (e.g., agroforestry, see Scales/Marsden 2008).

Cultivation of bioenergy, however, should focus on unused degraded land and abandoned farmland to avoid negative effects from indirect land-use change. For identification of these areas, FAO databases on degraded land (GLASOD, GLADA)[41] together with land use and land cover maps on global and national scale and also the database on global abandoned farmland (HYDE 3, Field et al. (2007) are helpful.

However, due to relative low spatial resolution, results from a top-down analysis can only used to identify potential priority areas, but still ground-proofing involving policy makers, NGOs, local people and other relevant stakeholders is needed to prove if identified areas are really available and suitable for sustainable bioenergy production.

Furthermore, the inclusion of specific landscape elements (e.g., stepping stones, corridors) in agricultural landscapes is well known to enhance the persistence of biodiversity in the neighborhood of agriculture systems as well as within the cultivated systems. Planning of the location and extension of such landscape elements must strongly be interlinked with a systematic conservation planning needed for the protection of biodiversity relevant areas (Section 2.3).

This is also the case for cultivation practices in the neighborhood of PA and biodiversity-relevant areas. The cultivation systems in buffer zones need to be adapted to site-specific requirements to avoid negative effects on biodiversity (e.g., exclusion of fire, reduction of agrochemicals, allowing only perennial crops).

However, internationally accepted criteria and indicators to identify such farming systems are still absent.[42] Their development could adapt to **best practices** proposed in Gemmill (2004) as well as the principal approach developed by EEA to derive a **risk matrix** for bioenergy cultivation systems (see following figure).

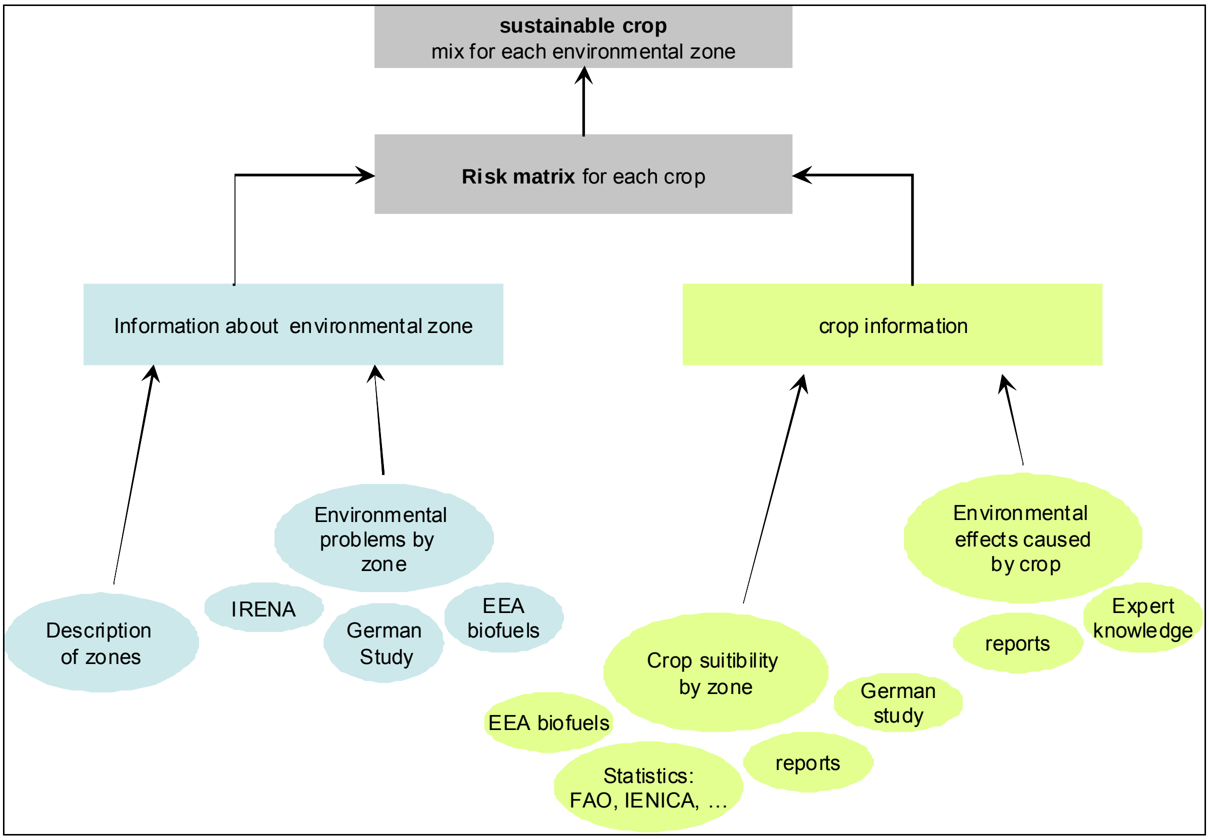
---

41 Global Assessment of Human-induced Soil Degradation (GLASOD) assessed the severity and kind of land degradation for broadly defined landscape units at a scale of 1:10 million. Data with higher resolution are available for Central and Eastern Europe (SOVEUR) and for south-east Asia (ASSOD). A new, quantitative global assessment has started under the GEF/UNEP/FAO project Global Land Degradation Assessment in Drylands (GLADA). GLADA looks at the integrated effect of degradation on vegetation, soil and water resources via remote sensing techniques as well as expert knowledge on national and local scale (see UNEP 2007 and Nachtergaele 2005).

42 For example, Van Cauwenbergh et al. (2007) draw up a hierarchical framework for assessing the sustainability of agricultural systems that considers principles and criteria regarding air, soil, water, energy, biodiversity and economical and social pillars.

To apply the concept globally, though, further data compilation and analyses of environmental risk indicators for "non-EU" cultivation systems, especially for tropical and semi-arid areas (e.g., cassava, Jatropha, palm oil and sugarcane) are need.

Figure 2-2 Framework to Prioritize Bioenergy Cropping Systems



Source: EEA (2006)

The principal approach developed by EEA for Europe to derive a risk matrix for bioenergy cultivation systems which is spatially disaggregated needs further refinement and extension with respect to

- compatibility with globally available biophysical characterization systems, such as Agro-Ecological Zones;
- data compilation and analyses of environmental risk indicators for further cultivation systems, especially for tropical and semi-arid areas (e.g., cassava, Jatropha, palm oil sugarcane); and
- inclusion of socio-economic factors (e.g., impacts on livelihoods, infrastructure requirements, food security links).

The applicability of this approach should be tested, and its function within a system of legal instruments to regulate and stipulate sustainable bioenergy development must be explored.

2.5 Conclusions and Guidance

Biodiversity as a common good serves for various ecosystem services, and its loss bears serious risks for human well-being. Decision- and policy-makers need to consider the protection of biodiversity while developing and implementing regulations, and especially for the development of the bioenergy sector.

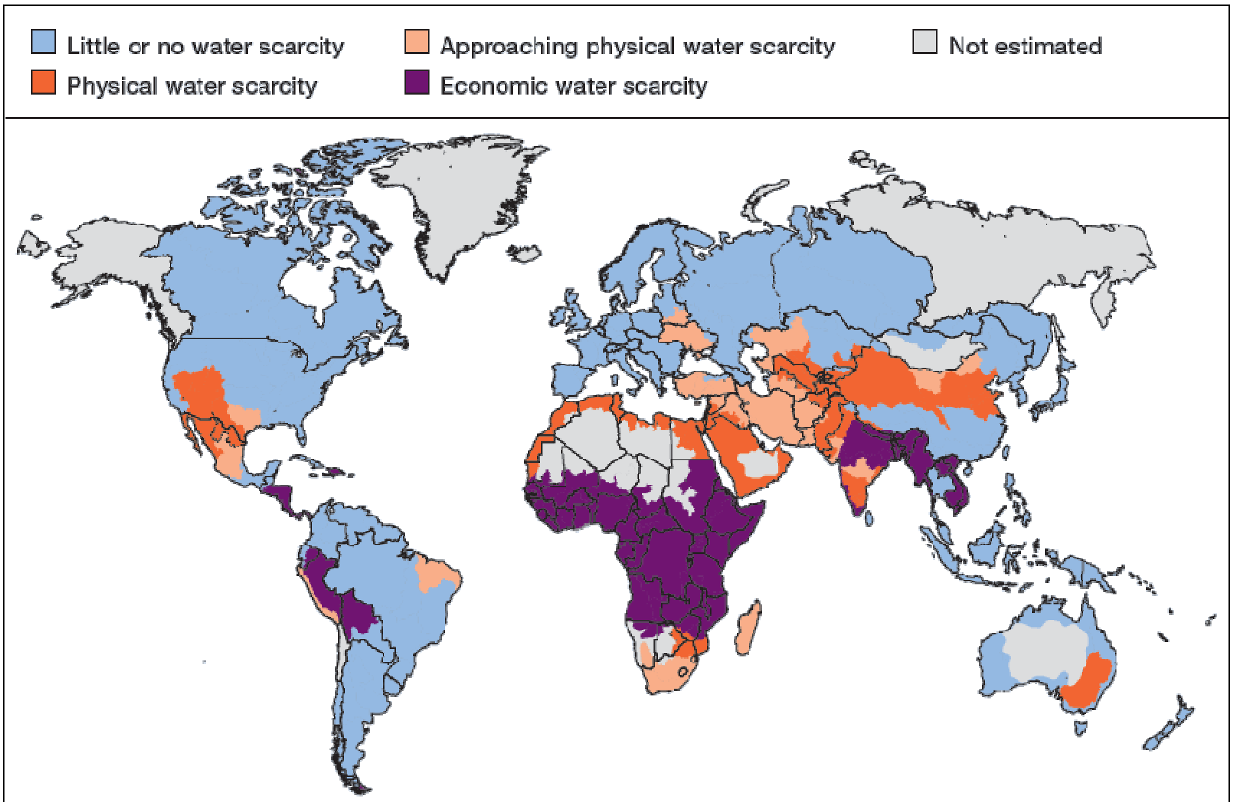
For this, the following steps need to be considered before or while planning to expand bioenergy feedstock production:

- Use of bioenergy with low risks for biodiversity (e.g., wastes and residues)
- Mapping and respecting of biodiversity-relevant areas, i.e., legally protected areas and areas harbouring rare, endangered and threatened species and ecosystems. Making use of existing data sets and use adequate tools for new identification
- Use areas for bioenergy feedstock cultivation with low risk of causing indirect effects (e.g., unused degraded land, abundant farmland)
- Embed bioenergy feedstock cultivation in sound systematic conservation planning (e.g. Ecosystem Approach), integrating biodiversity considerations in environmental impact assessment, respecting CBD-COP Decision XIII/28, and the 10% target of the CBD
- Create landscape elements in cultivated areas to enhance protection of biodiversity
- Avoid the use of GMOs

3 Agricultural Water Use

The unsustainable management of water resources is a key global environmental challenge. Freshwater is already scarce in some regions of the world, and existing freshwater resources are under heavy threat from overexploitation due to growing population and changing diets, pollution, and climate change[43]. The following figure indicates the spatial distribution of several dimensions of water scarcity.

Figure 3-1 Areas of Physical and Economic Water Scarcity



Definitions and indicators

- *Little or no water scarcity.* Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.
- *Physical water scarcity (water resources development is approaching or has exceeded sustainable limits).* More than 75% of river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.
- *Approaching physical water scarcity.* More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.
- *Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands).* Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Source: IWMI (2007) based on analysis using the Watersim model

Access to safe water resources is a limiting factor for sustainable development, and water resources have a key role in socio-economic development: Without better water management, the Millennium Development Goals for poverty, hunger, and a sustainable environment cannot be met (IMWI 2007), as improvements in the water sector will directly

[43] See IWMI (2007), OECD (2008) and WRI (2008) for overall trends, and the comprehensive analysis in the recent 3rd World Water Development Report (WWDR 2009).

improve access to safe drinking water, basic sanitation, food security and poverty reduction efforts (UN WSSD 2002).

Developments in the agricultural sector for food and non-food crops will have important implications for water usage and availability (Royal Society 2007). In this context, water demand for bioenergy feedstock production could lead to increasing agricultural water use worldwide, since bioenergy crops optimized for rapid growth are likely to consume more water than natural flora and many food crops. Agricultural products already take 70% of the freshwater withdrawals from rivers and groundwater (IMWI 2007). In some countries especially in the Mediterranean and Sub-Saharan Africa, this could lead to further water stress in regions where water is already scarce and rainfall is highly variable, which might induce increased competition over water resources (Berndes 2002+2008; OECD 2008; MNP 2007a).

The International Water Management Institute predicts that without further improvements in water productivity and efficiency in the agricultural sector or major shifts in production patterns, the amount of water consumed by evapotranspiration in agriculture will increase by 70%–90% by 2050 (IWMI 2007). The amount of water needed to produce fiber and biomass for energy would add to this, so that competition between agricultural, industrial, domestic and environmental water requirements as well as pollution risks for water bodies could be intensified by bioenergy production and processing (OECD 2008, EEA 2006)[44].

3.1 Approach to Address and Value Water Quantity and Quality Impacts

With respect to bioenergy production, water quantity and quality impacts are covered by water stress and scarcity, and water pollution and contamination.

Water Stress and Water Scarcity

Water stress and water scarcity – where stress is the early stage of scarcity – describe a lack of available water to meet both human demands and environmental flow needs. In general, water stress occurs when demand for water exceeds the available amount during a certain period, or when poor quality restricts its use.

Impacts on water quantity can be described by different indicators[45] which may be applicable to varying temporal and spatial dimensions (WWDR 2009). For the BIAS framework, the following two indicators are used, as they are easy to calculate, well understandable, and applicable on different scales[46]:

- **Water Availability Index (WAI)** according to Meigh et al. (1999) is a global measure for water availability considering its temporal variability and demands from agriculture, industry and municipals.

---

[44] It should be further noted that due to climate change, the overall availability of water as well as regional and temporal distribution of rainfall might change over the next decades.

[45] see details in Annex E. In addition, the Millennium Development Goals water indicator is defined as follows: Surface water and groundwater withdrawal as percentage of total actual renewable water resources.

[46] The practical use of indicators to assess impacts on water quantity in a given region depends on available models and required input data to evaluate the water balance of the region under consideration.

WAI represents the accessible water diverted from the runoff cycle in a given country, region or drainage basin. It is expressed as volume per person per year (m^3/(cap*yr).

- **Water Stress Index (WSI)** describes water withdrawal with respect to total renewable resources. It is a criticality ratio which indicates areas suffering from water stress and should be expressed in a low spatial scale (grid cell or basin). The WSI helps to identify ranges of water scarcity and is used e.g. by World Bank to allocate financial help to developing countries. Water stress is based on expert judgment and experience.

Water Pollution and Contamination

The sources for water pollution and contamination from bioenergy production are agricultural feedstock production and its downstream processing and conversion. Agriculture can affect water quality through leaching or run-off of nutrients (mainly nitrogen and phosphate), and pesticides[47]. Furthermore, re-use of wastewater for agriculture – though potentially beneficial for the quantity of water resources – raises the risk of soil contamination and public health concerns, particularly with respect to pathogens and hazardous substances (EEA 2009).

The UN proposed in the World Water Development Report[48] several indicators directly or indirectly suitable to address water pollution related to fertiliser and pesticides application, and also to waste water use for irrigation[49]. On the European level, indicators to investigate the link between agricultural trends in fertiliser and pesticide use and water quality have been identified by the European Environmental Agency (EEA)[50].

Until now, threshold values to safeguard environmental standards are not established internationally, but three general guidelines on water quality relevant to human health were developed by the World Health Organization (WHO):

- Guidelines for Drinking-Water Quality[51]
- Guidelines for the Safe Use of Wastewater, Excreta and Greywater[52]
- Guidelines for Safe Recreational Water Environment[53].

---

47 For example in Europe, farming is considered as the main source of diffuse nitrogen pollution (EEA 2003). Because nitrate is well soluble it enters water bodies via leaching and run-off while phosphate molecules tend to bind at soil particles entering watercourses by erosion (Young 1986). The presence of pesticides as pollutants of water depends on their mobility, solubility and rate of degradation (UBA 1999).

48 WWDR (2006 + 2009); an extensive description and scope of indicators is given in the Indicator Profile Sheet: http://www.unesco.org/water/wwap/wwdr/wwdr2/indicators/index.shtml

49 E.g. sources of contemporary nitrogen loading (natural and anthropogenic), water reuse Index, dissolved nitrogen and biological oxygen demand (BOD).

50 See “Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy (IRENA)” in which impact indicators to evaluate water pollution, such as nitrates and pesticides in water and the share of agriculture in nitrate contamination, are extracted from the Eurowaternet database. Because of limited data availability and measurability, as well as differences in spatial resolution, the regional application of the indicators is limited even within the European Union (EEA 2005).

51 http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.htm

52 http://www.who.int/water_sanitation_health/wastewater/wwuvol2chap8.pdf

53 http://www.who.int/water_sanitation_health/bathing/en/

These guidelines define an acceptable and realistic level of public health protection which can be achieved through a combination of setting microbial water quality targets, and implementing health protection measures, such as crop restrictions, application techniques, and irrigation timing.

3.2 Risk Mitigation Strategies to Protect Natural Water Resources

As said, water stress and scarcity are critical constraints for agriculture, industries and municipals. Analysis shows that today's food production and environmental trends, if continued, will lead to water crises in many regions of the world.

A growing population with its increasing demands is a major factor, but reasons such as lack of commitment to water and poverty, inadequate and inadequately targeted investment, insufficient human capacity, ineffective institutions, and poor governance are among the key drivers (IWMI 2007).

To mitigate related risks, decision makers should focus on four key areas:

- promotion of rainfed cropping systems;
- fair and good water management where irrigation is needed;
- mitigation of water pollution from bioenergy feedstock production; and
- mitigation of water pollution from bioenergy conversion plants (see following table).

Table 3-1 Key Issues of the Risk Mitigation Strategy for Water Resources

Key issues	**Risk mitigation effect to protect water resources**	**Risk mitigation measures**
Promotion of rainfed cropping system	▪ Safeguarding regional water balances, e.g., level of ground water table, changes to downstream hydrology, size of lakes (water quantity) ▪ Less irrigation needs and leaving more water for food crops or drinking water	▪ Production systems that increase cover crops, low-tillage, soil building, draught resistant varieties ▪ Use of hedges, inter-cropping, riparian protection
Fair and good management if irrigation is needed	▪ same as above	▪ Reducing irrigation losses ▪ Regulate withdrawal by non-agricultural users
Mitigation of water pollution from bioenergy feedstock production	▪ Reduced risk of water contamination (leaching of nutrients and pesticides) ▪ Less waste water ▪ Safer drinking water	▪ GAP and low-input farming ▪ Adequate use of waste water for irrigation
Mitigation of water pollution from bioenergy conversion	▪ Reduced risk of water contamination from waste water (waste water treatment, location of plants)	▪ Water re-use ▪ Less polluting production and treatment technologies

Source: own compilation

Box: Water use of and pollution risks from ethanol production in Brazil

In Brazil, sugarcane occupied 6.1 million ha in 2006, 8% of cultivated area. Almost 60% of the production is located in the São Paulo region (2006). Currently, the sugarcane production area grows continuously (in some town councils more than 50% in relation to 2005; IBGE 2006).

Water use and yields: Sugarcane grows well in regions with an annual rainfall of 1,500-2,500 mm/y which should be uniformly spread across the growing cycle to meet sugarcanes' evapotranspiration rate of 8-12 mm/t (Macedo 2005). Depending of site conditions, sugarcane yields range from 30.4 t/ha in the northern state of Amapá to 85.1 t/ha in the southern state of Paraná (IBGE 2007). Water stress can affect leaf extension sugarcane plants and reduce plant size and total productivity (Taiz/Zeiger 2002). Especially in areas characterized by seasonal droughts (e.g., Northeast basin), irrigation practices are frequently used in order to mitigate shortages of water (Anselmi 2004).

Water pollution risk: The nitrogen-use efficiency of sugarcane with an assimilation rate of about 20-40% is rather low (Oliveira et al. 2000, Basanta et al. 2003). In consequence, contamination of runoff water and groundwater can be significant due to inappropriate application of fertilizer. In addition, the frequently applied burning of sugarcane before manual harvesting can cause an increase in soil compaction leading to higher surface water runoffs and higher contamination risks (Tominaga et al. 2002). Further more, intense application of pesticides can pollute water bodies (Milette 1991).

Water pollution from the industrial processing mainly occurs from the washing of sugarcane stems before they go through the mill and from vinasse, a fluid rich in organic compounds formed during the distillation process of bioethanol. The total water use is calculated to be 21 m^3/t sugarcane. However, with optimized processing, including reuse of water, water-use rates of 1 m^3/t sugarcane and (close to) zero effluent release may be reached (Macedo 2005).

Especially vinasse bears high water pollution risks. The acidity of vinasse and its high biological oxygen demand (BOD) of 18,000 – 37,000 mg/l which leads to reduced dissolved oxygen levels can kill aquatic life when large volumes are dumped in rivers (Pimentel/Patzek 2007). Though irrigation and fertilizing with vinasse can increase productivity (São Paulo region, Varghese 2007), its application can also increase nutrient run-off, acidity of rivers and concentration of magnesium, aluminum, iron, manganese and chloride in groundwater (De Oliveira et al. 2005).

Promotion of Rainfed Cropping System

Options for water use in agriculture stretch from rainfed agriculture with improved storage of water in the soil to supplemental irrigation from water storages[54] and full irrigated cultivation (Figure 3-2). Today, 55% of the gross value of our food is produced under rainfed conditions on nearly 72% of the world's harvested cropland, and 28% are under irrigation (IWMI 2007).

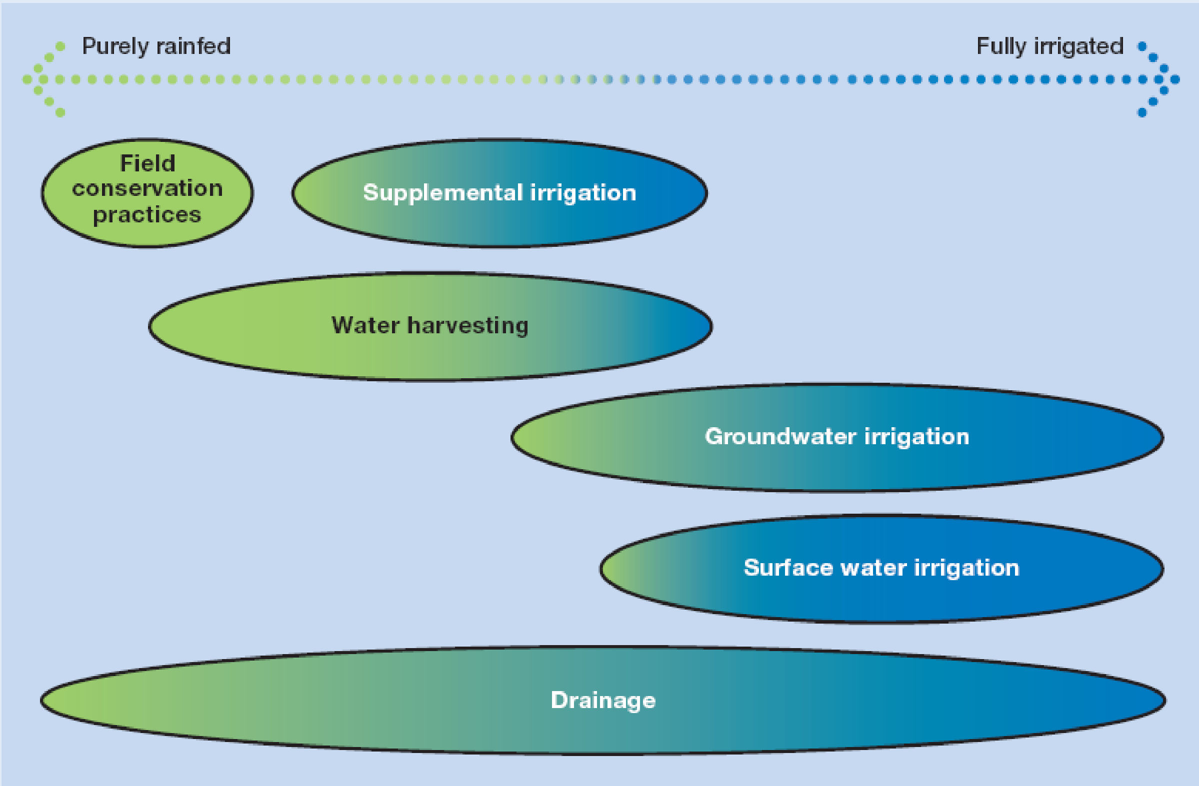
Water withdrawal leads to hydrological changes, i.e. reduction of runoff in rivers and lowering lakes and groundwater level, and – in extreme situations – rivers temporarily do not reach the sea (e.g. Colorado River, USA) or lakes dry up and get salty (e.g., Aral Sea).[55]

In addition, soil salinization often results from inadequate planning and management of irrigation (FAO/IFAD 2008, EEA 2006).

54 Water stored during periods with abundant water supply.

55 See Stockle (2001).

Figure 3-2 Options for Agricultural Management with Regard to Water



Source: IWMI (2007)

Problems caused by irrigation are most often associated with physical water stress or scarcity in arid regions.[56] Sufficient water supply for high-productive bioenergy crops in such regions is very likely to increase existing problems. In consequence, any additional irrigation needs to be embedded in sound water management plans and policies[57] to optimize water use by all relevant sectors - from agriculture to industry and municipals. Furthermore, future demands, environmental constraints, feasibility of water storage as well as water needs in downstream neighboring countries require consideration. This is also needed for regions with abundant water resources to avoid a development towards water stress or water scarcity.

In some cases it might be more beneficial for local people or agriculture industries to shift water use from existing cultivation systems or from industries – especially when producing commodities for international markets – to bioenergy cropping systems. Also improvements in water resources management and water use efficiency may result in "free water" to irrigate

---

56 Water scarcity can also appear where water is apparently abundant, when water resources are overcommitted to various users due to overdevelopment of hydraulic infrastructure like irrigation (IWMI 2007).

57 Among others, several questions need to be covered: Which impacts may be caused by the planned irrigation and what is their extent? How much water is available, how much will be withdrawn and at what scale may water scarcity occur? What are the water needs downstream? How much water is needed for environmental flows? Is the water demand in other sectors supposed to increase in the near future? Could other sectors reduce their water demand? Is the economical return in other sectors higher than in bioenergy feedstock production? Which measurement systems are adequate to monitor water balances and risks of scarcity and are they already in place?

bioenergy crops, and in some cases it may be justifiable to open up new water resources associated with low or medium risks for depletion, or further water stress.

However, as irrigation represents a high risk for negative impacts on water resources, it should not be the standard practice for cultivating bioenergy feedstocks.

Instead, rainfed cultivation should be chosen, as under most circumstances, rainfed cropping systems rely on the water input from precipitation, and competition with other water demands is limited. In addition, greatest potential for increases in yields are in rainfed areas, especially through enhanced management of soil moisture[58] and improving soil fertility management (IWMI 2007).

Thus, decision makers should give strong priority to rainfed bioenergy cropping systems in planning processes and to cultivation practices that improve drought resistance, especially in regions where water is already scarce.

Still, displacement of former natural vegetation (e.g., forests or woodlands) may have decreased evapotranspiration and soil absorption capacities, and levels of groundwater table and water run-offs may have increased. In case that these additional water recourses are used today for purposes such as irrigation or industry, rainfed bioenergy feedstock cultivation with high water use rates similar to former natural vegetation may result in water competition.

For example, short rotation plantations (willow, poplar) cultivated at sites characterized by low precipitation and low water-holding capacity lowered ground water levels (NABU 2008). In consequence, though rainfed cultivation bears lower risks compared to irrigated cultivation systems, there is still a need to evaluate possible effects of cultivated bioenergy feedstock on water balances and potential competitions need be elevated.

Mitigation of Water Pollution from Bioenergy Feedstock Production

The contamination from agricultural – and bioenergy feedstock – production is a major threat to water bodies, especially leakage of nitrogen from fertilizers – whether organic or inorganic – and pesticides[59] to groundwater and surface waters.

The general aim of a risk mitigation strategy is to reduce such leakage of nutrients and pesticides to a minimum without implying significant losses in yields. For this, existing Good Agricultural Practices (GAP) give useful guidance to producers and decision makers. On a global level, FAO provides an internet portal on GAP including a database[60] covering studies, reports and information materials on various agricultural systems from different regions of the world.[61]

Low-input cultivation systems can reduce contamination risks of water bodies, and the challenge is to adopt existing and to develop new bioenergy feedstock production systems to these requirements (see also Chapter 2 and Box in Chapter 4).

---

58 Also supplemental irrigation may be used where small water storage is feasible.

59 Regarding pesticides, see Appendix H

60 http://www.fao.org/prods/GAP/home/database_en.htm

61 Regarding the minimisation of nutrient losses, required calculation of nutrient balances should follow Roy et al. (http://www.fao.org/docrep/006/y5066e/y5066e00.htm).

For example, organic farming practices avoid to a high degree the application of pesticides and chemical fertilizer[62] (UNEP-UNCTAD 2008), leading to significant lower contamination risks.

A further significant source for contamination of water bodies could come from inadequate irrigation with waste water. Besides contamination of soils with e.g., heavy metals, waste water pollutants can be transported to water bodies by direct run-off from irrigation or by washing-out during heavy rain events. Therefore, the use of waste-water irrigation systems should comply with WHO guidelines on the safe use of waste water, excreta and grey water (WHO 2006) to reduce risks for human health and for the environment.

Mitigation of Water Pollution from Bioenergy Conversion Plants

The plants for processing biomass to liquid biofuels, especially ethanol plants and oil milling, imply risks of significant organic discharges due to the high inventory of process water stored on-site. Respective nutrient inputs from non-routine operation (leakage, accidental spills, tank rupture etc.) could contaminate adjacent water bodies (rivers, lakes, etc).

To reduce those risks, the siting of conversion plants should consider adequate distances from sensible wetlands and water protection areas, and licensing procedures should ensure necessary (technical and managerial) safeguards against non-routine discharges.

During typical operation, waste water pollution can be reduced through 1) recirculation systems, 2) waste-water treatment (including potential biogas use from anaerobic treatment) to reduce routine organic loads below critical threshold of local water bodies, and 3) re-use of certain waste-water treatment sludges as fertilizer.

3.3 The BIAS Module for Assessing Water Needs and Use

The analytic framework developed in this study aims at the mitigation of water scarcity and the protection of water resources against contamination (see Figure 3-4).

The mitigation of water scarcity is mainly addressed at two levels, the catchment scale and downstream needs. The catchment scale (up to some square kilometers) is chosen because most water withdrawals and related negative effects occur at this scale.

Considering only larger scales, however, bears the risk that, for example some catchments experience serious water stress though an overall water balance on a river scale is positive.

To the contrary, when water scarcity is avoided at catchment scale, risk of water scarcity at basin scale is relatively low.

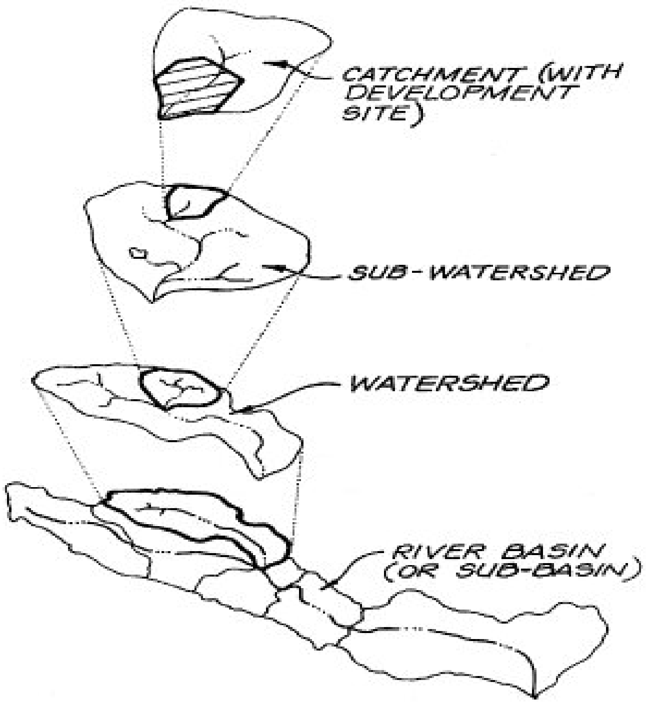
Nevertheless, larger downstream water demands from municipals and industries, but also from environmental flow needs[63] are considered in this framework and may require water-use restrictions upstream and, thus, need to be considered during the planning phases.

---

[62] Nevertheless, also inadequate application of organic fertiliser can result in inacceptable leakage of nutrients.

[63] E.g. peat lands, river food plains; see Section 2.

Figure 3-3 Watershed Management Units



Source: Adopted from Clement et al. (1996), cited by University of Delaware Water Resources Agency, UDEL)

Contamination of water resources from bioenergy feedstock cultivation is mainly related to unsustainable cultivation practices including an inappropriate use of fertilizers and pesticides, but also to the inadequate application of contaminated waste water for irrigation.

Furthermore, the risk mitigation for waste water from bioenergy processing that is mainly contaminated by organic loads is considered in the framework (Figure 3-4).

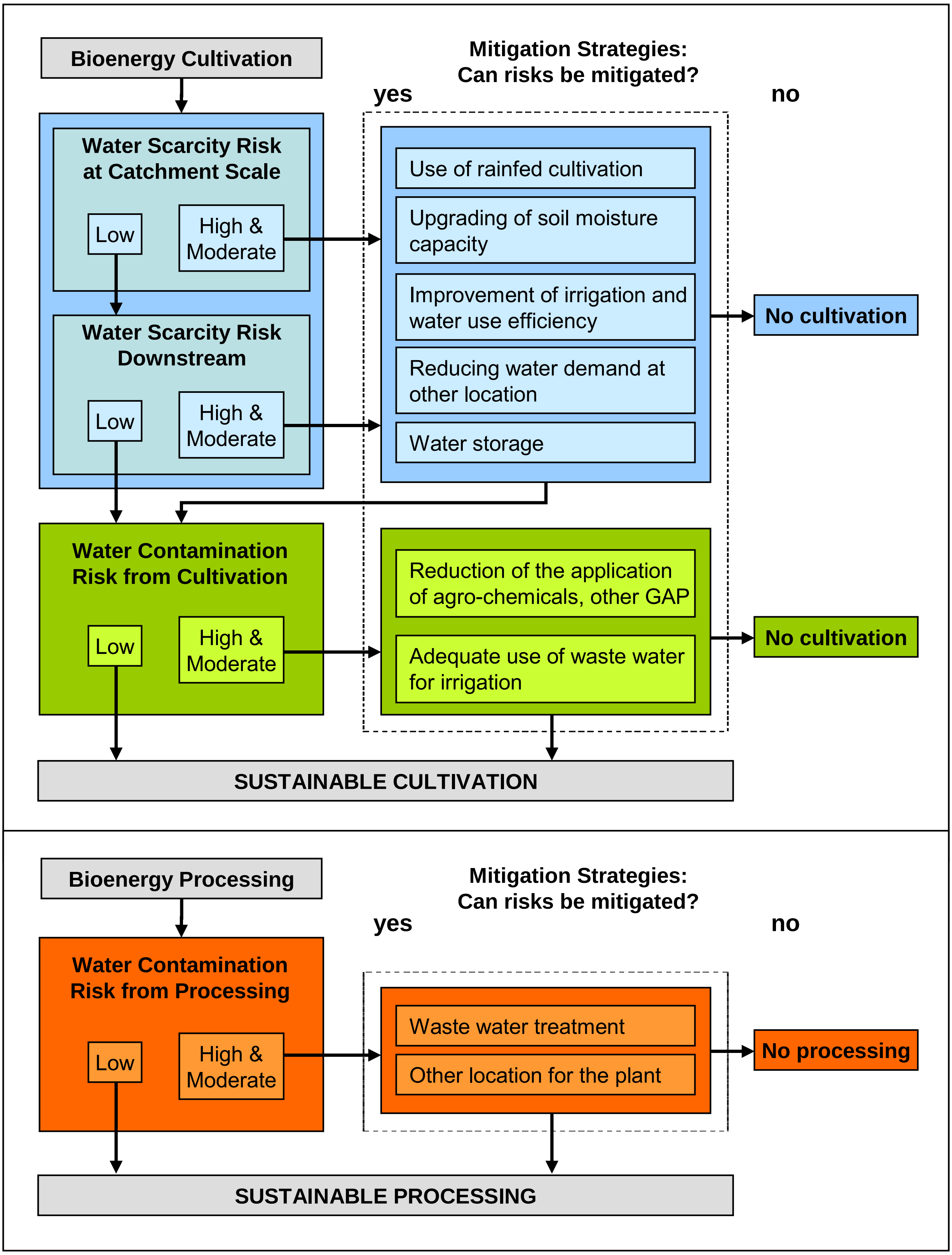
In a first step of the decision tree, risks that may be connected with impact of bioenergy feedstock cultivation and its conversion on water quantity and quality need to be assessed.

In case of a low risk ranking, the planned cultivation is sustainable regarding this parameter. A medium or high risk, however, would require suitable measures to reduce the risk towards the category 'low'. If that is not possible, bioenergy production cannot be recommended.

The logic of the decision tree is rather simple and should be implemented in relevant policies.

However, the most challenging point is to gather needed information to come up with reasonable answers.

Figure 3-4 Decision tree concerning agricultural water use for energy cropping



Source: own compilation

3.4 Data Collection Process and Available Data and Models

Assessment data needs within the developed framework are strongly related to the location under consideration and the selected indicators that address a specific question.

When applying e.g., the Water Availability Index (WAI) which compares the total amount of water resources with the demands of all sectors, the risk of water scarcity may be interpreted as low when the index stays significantly above zero.

In case the index results in a value near zero, i.e. water availability and demands are equal, the risk of water scarcity may be evaluated as medium. Strongly negative values for the index would reflect a high risk of water scarcity.

However, when defining such thresholds, local situations need to be considered. For example, at a location with high inter-annual rainfall variability a WAI of zero may already pose a high risk for water scarcity because in several years the demand is very likely to exceed the available water recourses. In case of very low inter-annual rainfall variability, a WAI of zero may even be interpreted as low risk.

In a similar manner, setting thresholds for the risk assessment regarding the contamination of water resources by both bioenergy feedstock production and processing will **require local adaptation**.

Regarding water quantity impact, most of the datasets and model approaches listed in Appendix B are covering data on a much larger scale as required for the catchment scale, and many parameters are measured on larger grid levels (e.g. precipitation) and for watersheds or river-basins (e.g. run-off).

Nevertheless, data such as the Digital Global Map of Irrigation Areas can be helpful to come up with a **first estimate** of the situation at a catchment level.

Such data, especially in case of the assessment of high or medium risks, need to be confirmed by local measurements (field data), though.

This is also the case for the evaluation of downstream demands.

3.5 Conclusions and Guidance

The choice of biomass crops, especially in arid areas, should aim for low water demanding crop types that do not require irrigation.

Hence, the **standard** for bioenergy crops should be represented by **rainfed** cultivation.

The choice of crops should consider the following aspects and criteria:

- Cropping systems optimized for water efficiency, e.g. agro-forestry systems in dry regions, farming practice increasing soil organic carbon and water holding capacity
- No drainage of wetlands, e.g. by planting moisture-tolerant crops on sites where water logging can occur.

In case **irrigation** is used, a **hydrologic impact assessment** has to be performed to give evidence on compliance with actual water resource conservation.

The water availability for energy crop production should be determined on a catchment scale in order to assure the examination of related upstream and downstream water availability and needs[64].

The degree of water stress, evaluated through the Water Stress Indicator[65], is assumed to be proportional to the ratio between annual average water abstractions and annual average water availability on the catchment or basin-scale.

In most water scarce regions, water stress occurs seasonal – depending on climate and hydrology regime whereas the water stress indicator does not take account of seasonal patterns in water supply and demand (Alcamo et al. 2003).

In case of more than one cropping season, the calculation of separate indicators for each season may be reasonable. This is recommended to be a concern for further elaboration.

4 Impacts on Soil

Apart from providing food, biomass and raw materials, soil also performs numerous environmental functions such as storing, filtering and transformation of substances (nutrients, contaminants and organic carbon) and serving as a habitat for species as and as a gene pool.

These essential functions must be protected. Since soil formation and regeneration processes are extremely slow whereas degradation[66] rates can be very rapid, soil is considered a non-renewable resource (COM 2006a).

Soil degradation defined as the loss of the soil's ecosystem functions and services has a major impact on other sustainability aspects, e.g., surface and groundwater quality, climate impacts due to losses in soil carbon stocks, and food insecurity as a result of a decline in soil fertility.

For example, the loss of organic matter – caused by several degradation processes – is important not only because the soil is a significant carbon sink but also because soil organic matter is critical for soil productivity:

Soil organic matter affects soil water holding capacity, soil density, aeration, soil biodiversity and cation exchange capacity[67].

Land conservation and rehabilitation are an essential part of sustainable agricultural development. The feedstock production for bioenergy might lead to changes in crop rotation and cultivation practices.

---

64 Selected available data and models useful for the BIAS Analytical Framework are listed in Annex B.

65 The Water Stress Indicator appears most suitable for the BIAS Analytical Framework. For a detailed description on calculating the WSI, see Alcomo et al. (2003), and Annex E

66 Degraded land is characterized by a long-term decline in ecosystem function and productivity and measured in terms of net primary productivity (Bai et al. 2008; GLADA project). Soil degradation is understood as the human-induced worsening of soil quality, meaning the partial or entire loss of one or more functions of the soil. The final phase of the degradation process is land desertification (Ecologic 2004).

67 Cation exchange capacity characterizes storing and buffering of nutrients in soils, see MNP (2007b).

To prevent soil degradation from agricultural changes, improved agronomic practices will play a key role[68].

The objective of this chapter is to formulate a number of soil conservation considerations to be incorporated into the proposed analytical framework for sustainable bioenergy feedstock production.

Box: Bioenergy Cropping Systems

Today, most bioenergy is still derived from woody materials (firewood collection, charcoal production). The majority of current liquid biofuels is produced from feedstocks also used for food and feed, e.g. ethanol from sugarcane, maize or wheat, and biodiesel from rape seed or palm oil (so-called first generation feedstocks). Cropping systems for first generation biofuels already started to change e.g. feedstock for biogas plants in Europe use new maize species with high mass yields instead of high starch content. In addition, new cropping systems are used to cultivate perennial crops (energy grasses, e.g. *Miscanthus, switchgrass,* or short-rotation coppice, e.g. poplar or willow) as feedstocks.

Furthermore, the development of advanced (so-called 2nd generation) biofuels opens possibilities to use cellulosic plant materials not only for combustion, but to convert solid biomass into liquid fuels. Typically, 2nd generation feedstocks are characterized by high yields and are not cultivated for food and feed.

Changes in cropping systems, however, may result in both positive and negative impacts. For example, yield increases due to optimized overall growth of plant mass may lead to an increased soil compaction risk through larger loads and heavy machinery. On the other hand, perennial cultures may reduce erosion risks due to less tillage. The challenge is to develop cropping systems and related good agricultural practices so that they produce both environmental and economic benefits.

Another challenge is the cultivation on degraded and marginal land. These lands are often unsuitable for food and feed production under the current circumstances, but some bioenergy feedstocks which have different requirements (e.g. Jatropha) may be feasible, although they will have to be competitive with the same crop produced on more fertile lands. Degraded and marginal lands are also often sensitive sites, e.g. with high erosion risks and low nutrient contents, and cultivation systems need to be carefully adapted to site conditions to fulfill their sustainable potential.

4.1 Approach to Address and Value Soil Property and Quality

An important goal of soil conservation is to maintain the functional capacity of soils. Compared to, e.g. water and air, the valuation of soil properties and quality is much more difficult due to the complex nature of soils. Soil characteristics comprise physical, chemical and biotic components that interact intensively, and their dynamics strongly depend on land use and soil management.

Soil scientists developed numerous indicators and methodologies[69] to value different aspects of soils like organic content, erosion rate, aggregate stability, nutrient content, soil reaction, available water capacity, and microbial biomass and soil biology[70].

---

68 See EEA (2006), Royal Society (2007), IAASTD (2008) and UNEP-UNCTAD (2008).

69 Soil description as a basis for the valuation of soil quality should follow the FAO guidelines for soil description (FAO 2006).

70 Comprehensive examples are the Revised Universal Soil Loss Equation 2 (RUSLE2) that estimates rates of rill and inter-rill soil erosion caused by rainfall, and methodologies to assess soil nutrient balances; see http://www.fao.org/docrep/006/y5066e/y5066e00.htm.

Soil management practices often focus on erosion rates and annual tolerance values for soil losses (Andrews et al. 2004).

Throughout the 1990s, soil scientists emphasized that sustainable soil management requires more than soil erosion control (Karlen et al. 1997, 2008) being addressed in the concept of soil quality[71].

Besides erosion problems, also other important soil parameters and functions are considered in the soil quality concept, e.g. losses of organic matter, reductions in biodiversity, fertility and productivity, and chemical and heavy metal contamination. The loss of soil quality can be interpreted as soil degradation.

The general nature of most soil quality indices is that they select appropriate indicators for single parameters and often aggregate them to an overall index. However, until now, no universally applicable methodology to measure soil quality is available (Bastida et al. 2008). One reason is that the target or optimum of soil quality is not one standard for all soils, but a series of thresholds defined by limiting factors and user needs (Andrews et al. 2004).

Numerous indicators have been proposed to evaluate soil quality[72]. For example, Mueller et al. (2007) prepared a field manual to derive a soil quality index using scoring tables for various soil indicators, and the authors suppose that this method is applicable globally to arable and pasture land.

Andrews et al. (2004) offer a generalized computer-base assessment tool that assists to select from more than 80 soil indicators those that are most suitable to assess soil quality depending on inherent capabilities of soils, intended land use and management goals.

A more simplistic approach is the soil quality card[73] developed by a group of farmers together with soil scientists for Willamette Valley, Oregon (USA) covering 10 simple indicators that are suitable to monitor soil quality from year to year and to identify its changes due to management effects.

The advantage of an overall index for soil quality is that it might be better understood by non-soil scientists.

However, its disadvantage is that detailed information for single parameters may get lost.

Instead, it can be much more straight forward to select a small set of parameters of highest importance and related indicators, depending on national or local conditions, and to evaluate the influence of land use and soil management on each factor on its own.

---

[71] The Soil Science Society of America (SSSA) has defined soil quality as “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health” (SSSA 1997).

[72] See overview in Bastida (2008) and Annex E.

[73] Willamette Valley Soil Quality Guide: http://extension.oregonstate.edu/catalog/pdf/em/em8710-e.pdf; Willamette Valley Soil Quality Card: http://extension.oregonstate.edu/catalog/pdf/em/em8711.pdf

4.2 Risk Mitigation Strategies to Conserve the Soil

The risk mitigation strategy drawn up in this chapter evaluates the conservation of soils against degradation risk that may be related to bioenergy feedstock production[74]. According to Liniger et al (2008), soil degradation[75] can be classified in four groups:

- **Soil erosion by water:** Loss of topsoil and surface erosion; gully erosion and gullying; mass movements and landslides; riverbank erosion; coastal erosion; and offsite degradation effects
- **Soil erosion by wind:** Loss of topsoil; deflation and deposition
- **Chemical soil deterioration:** Fertility decline and reduced organic matter content; acidification; soil pollution; and salinization and alkalinization
- **Physical soil deterioration:** Compaction; sealing and crusting; water logging.
- **Soil biodiversity loss:** loss of micro- and macro-organism abundance and diversity[76]

Various types of human activities and natural causes may result in direct soil degradation impacts, and they need to be evaluated in the light of bioenergy feedstock production. Following the systematic given in Liniger et al (2008), direct impacts from bioenergy feedstock production occur most likely from improper soil and crop management, as well as from deforestation, removal of natural vegetation and overexploitation of vegetation. Negative impacts from conversion and overuse of natural habitats on ecosystem functions have already been discussed in Chapter 2, and soil degradation from opening up these areas is one component of the loss of ecosystem functions.

The risk mitigation strategy to conserve the soil does not cover the protection of natural habitats, but it focuses on the mitigation of soil degradation that emerges from soil and crop management while cultivating bioenergy feedstock. The selection of key issues given in Table 4-1 aims to represent the most important factors causing soil degradation.[77]

Soil erosion represents the most prominent degradation factor in agriculture that leads to loss of fertile top-soil within in periods of several years – in extreme situations, within a few hours - whereas soil formation by natural processes can take thousands of years. Any bioenergy feedstock cultivation practice should reduce soil erosion to a level near or below the natural erosion rate.

The **decline of soil carbon** due to improper soil and crop management impacts the fertility of soils, but also the environment (e.g. nutrient leakage into water bodies, GHG emissions from soil carbon loss). For example, at pan-European scale, recent trends in land use and

---

74 see Box “Bioenergy Cropping Systems”

75 Beside soil related types of land degradation, Liniger et al (2008) also cover water degradation and biological degradation.

76 This parameter is not included in Liniger et al. (2008), but represents an important aspect of soil fertility for natural ecosystems as well as for agricultural systems (Ingham 1998).

77 The selection of key issues was adopted from Eckelmann et al. (2006) and Louwagie et al. (2009).

climate change resulted in soil organic carbon loss at a rate equivalent to 10 % of the total fossil fuel emissions, and these losses are mainly related to cropland (Louwagie et al. 2009).

Factors leading to soil organic matter decline due to an imbalance between the build-up of soil organic matter and its decomposition rate are climate, soil characteristics, natural vegetation type, topography, land use and land management (Eckelmann 2006). Good agricultural practices for bioenergy feedstock production systems need to guarantee balanced soil organic matter processes or even an increase of carbon in soils.

A major cause of **soil compaction** is the use of agricultural machinery. The degree of compaction depends on the type of machine, the applied loads and the frequency of use, which are related to the production system and the type of bioenergy feedstock. The impact of machinery on soil also depends on the soil type and especially its wetness, i.e. the timing of machinery use is an important factor (Eckelmann et al. 2006).[78] Thus, soil compaction may especially be a risk for high yield bioenergy feedstock harvested under wet soil conditions.

Soil **salinization**[79], e.g. due to inefficient irrigation systems, poor on-farm management practices and inappropriate drainage management, is also reducing crop yields.

Table 4-1 Key Issues for the Risk Mitigation Strategies to Conserve the Soil

Key issues	Risk mitigation measures to conserve the soil
Minimizing erosion	▪ Enhancing soil cover (e.g. mulch, perennial crops and agroforestry, multi cropping ▪ Mechanical soil protection (e.g. cultures in rows/strips, wind breaks) ▪ Avoiding cultivation at unsuitable sites (e.g. slope)
Minimizing organic matter decline	▪ Recycling of organic matter (use of residues and organic fertilizers, mulching) ▪ Reducing carbon mining (excessive removal without appropriate replacement of organic material, destructive management of soil fauna and flora) ▪ Enhancing soil carbon (soil cover, minimum extraction rates) and reduced tillage
Avoiding physical compaction	▪ Using suitable machinery (weight of the machinery, load per axle (tire)) ▪ Considering weather (moisture and temperature of soil) while using machinery
Avoiding salinization	▪ Avoiding inappropriate irrigation/ inappropriate use of water in rainfed agriculture ▪ Avoiding waste water with high salt or pollutant content ▪ Minimizing water application by use of efficient irrigation methods ▪ Guarantee sufficient drainage of irrigated soils

Source: FAO (2000), EEA (2006), WOCAT (2007), Liniger et al. (2008), Louwagie et al. (2009).

78 Animal movement and density is also an important cause of soil compaction and similarly is variable depending on soil type and wetness (Eckelmann et al. 2006) while proper animal management can be used to decompact soil (Butterfield et al. 2006. Also soil crusting can be an important soil degradation factor especially on soils low in carbon content with poorly sorted sand fractions and appreciable amounts of silt if soil cover does not provide sufficient protection to the impacts of raindrops (Oldeman 1991).

79 Salinization is the process that leads to an excessive increase of water-soluble salts in the soil. Primary salinization involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater. Secondary salinization is caused by human interventions such as inappropriate irrigation practices, e.g., with salt-rich irrigation water and/or insufficient drainage (Louwagie et al. 2009).

However, this list should not be interpreted as being exclusive, as soil properties and degradation factors strongly depend on site conditions (e.g., nutrient decline[80], pollution of the soil[81] and loss of biological activity in soils[82]).

Soil conservation measures[83] can contribute to different conservation goals. For example, increasing soil cover – according to FAO (2005) the most important principle for sustainable soil management – brings multiple benefits like the reduction of water and wind erosion, increase in rainfall infiltration, reduced moisture loss by evaporation, improvement of germination conditions, increase in organic matter (surface soil layer), stimulation of biological activity, and suppression of weed growth.

Table 4-2 Case Studies and Technologies by Group of Conservation Measures

Group Case study/technology	Country zone	Climatic				Land use type						Degradation type						Conservation measure				Inter-vention type		
		arid	semi-arid	subhumid	humid	annual crops	perennial crops	grazing land	forest	mixed	other¹	water erosion	wind erosion	chemical degrad.	physical degrad.	vegetation degrad.	water degradation	agronomic	vegetative	structural	management	prevention	improvement	rehabilitation
1 Conservation agriculture																								
No-till technology	Morocco		■	■		■						■	▒	▒	■			■			■		■	
Conservation agriculture	UK			■		■						■		▒				■					■	
Small-scale conservation tillage	Kenya		■			■						■			▒		■	■	▒				■	
No-till with controlled traffic	Australia	■	■			■						■	▒		■			■					■	
Green cane trash blanket	Australia				■		■					■		■				■					■	
2 Manuring/ composting																								
Vermiculture	Nicaragua			■	■	■	■							■				■					■	
Composting/ planting pits	Burkina Faso		■							■		■		■	▒			■					■	
Improved trash lines	Uganda			■		■						■		■				■					■	
3 Vegetative strips/ cover																								
Natural vegetative strips	Philippines				■	■						■		▒				■	■				■	
Green cover in vineyards	Switzerland			■			■					■		▒				■	■				■	
Vetiver grass lines	South Africa			■			■					■	▒					▒	■	▒			■	
4 Agroforestry																								
Shelterbelts	P.R. China		■			■				▒			■				■		■				■	
Grevillea agroforestry system	Kenya			■		■	■			▒		■		▒			■		■			■		
Poplar trees for bio-drainage	Kyrgyzstan		■			■				▒	■			■	■			■	■					■
Multi-storey cropping	Philippines				■	■				▒		■		■				■	■			■		
Intensive agroforestry system	Colombia			■						▒	■	■	▒	■				■	■	■			■	
Shade-grown coffee	Costa Rica				■					■		■		■				■	■	▒		■		
Conversion of grazing land	Tajikistan			■				■		▒		■			■	▒		■	■	■	■			■
Orchard-based agroforestry	Tajikistan			■			■			▒		■	▒	▒				■	■	■			■	

Source: WOCAT (2007)

The production of bioenergy feedstock – in the same manner as food and feed cultivation – should make use of soil conservation measures where possible.

---

80 For the assessment of nutrient balances see http://www.fao.org/docrep/006/y5066e/y5066e00.htm

81 Sources for soil pollution are, e.g., pesticides, waste water and contaminated sludge. As an example, Annex H gives an overview on the effects of pesticide use.

82 See overview on negative affects related to the loss of biological activity in Louwagie et al. (2009).

83 For example, WOCAT (2007) provides an overview of the application of 42 different soil conservation measures in 23 countries, grouped as follows: Conservation agriculture; manuring/composting; vegetative strips/ cover; agroforestry; water harvesting; gully rehabilitation; terraces; grazing land management; and other technologies. See also Junge (2008), de Graaf (2007), and the discussion of organic agriculture in Chapter 2.

However, cultivation technologies and cropping systems already started to change and new systems are under development aimed to optimize biomass yields instead of starch, oil or protein[84]. This new goal offers the opportunity to consider soil conservation (and soil carbon) from the beginning, especially as bioenergy feedstock cultivation can use a larger range of species and is more flexible, e.g. regarding harvesting time.

4.3 The BIAS Module for Soil Conservation

The main aim of the analytic framework of this study is to mitigate risk that may arise from bioenergy feedstock production. In such a context, overall soil quality indicators appear less suitable because of the risk that single soil parameters being under pressure are not well visible. More straight forward is the evaluation of the most important parameters related to soil degradation (see parameter selection in Chapter 4.2), and to apply for each parameter the logic of the decision tree drawn up in Figure 4-1 to judge the sustainability of a planned bioenergy feedstock production system.

In the first step of the decision tree, the site specific vulnerability of the soil regarding a single parameter needs to be identified (Figure 4-1), and the risk that a planned bioenergy feedstock cultivation may lead to its degradation is judged. Such judgment requires a soil expert. A low risk ranking indicates that the planned cultivation is sustainable regarding this parameter. In case of a medium or high risk, conservation measures need to be identified that can mitigate, i.e. lower, the risk. If this is not possible, bioenergy feedstock production should not be carried out. This procedure needs to be applied to all soil parameters of importance. A sustainable bioenergy feedstock production requires low risk judgment for all soil parameters.

A similar assessment and categorization of soil vulnerability has been applied, e.g. to identify bioenergy production areas with low risks for the environment (EEA 2006 + 2007) and for generating suitability maps of different cultivation systems (van Velthuizen et al. 2007).

Though the logic of the decision tree is simple, the assessment of the vulnerability of the soil as well as the definition of thresholds[85] for the risk categories is challenging. Both aspects will strongly depend on soil and site conditions as well as on national targets for soil conservation (Eckelmann et al. 2006).

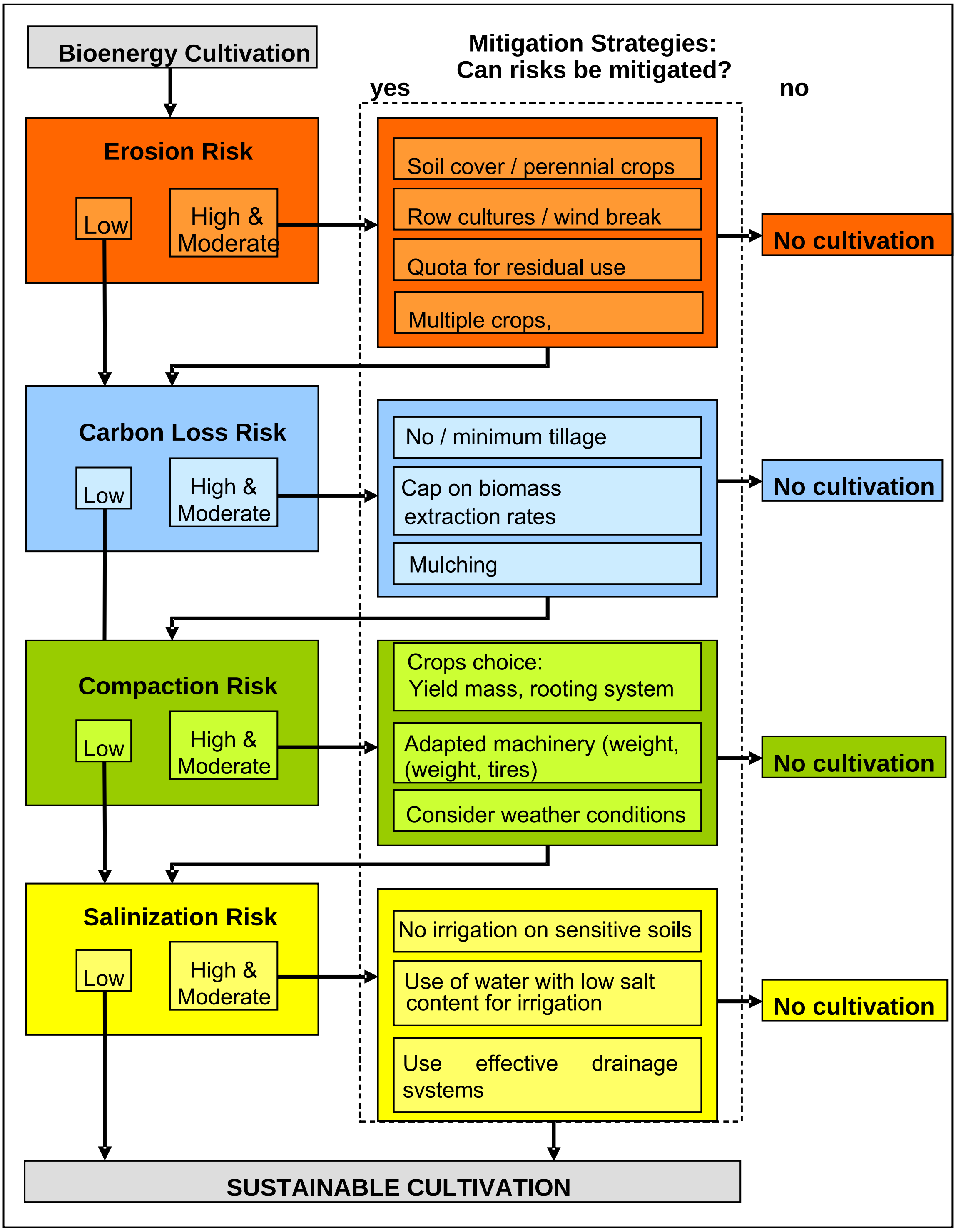
Nevertheless, several models and databases are available to guide and facilitate the vulnerability and risk assessment, and a selection is described in Chapter 4.4.

---

84 See Box “Bioenergy Cropping Systems”.

85 Thresholds initially require that reasonable values are available beyond which degradation of soil properties limits sustainable functioning of the soil.

Figure 4-1 Decision Tree for Soil Conservation



Source: own compilation

4.4 Available Data and Model Choice

Soil assessment should follow international accepted guidelines for soil description (e.g. FAO 2006) and nomenclature (WRB 2006). On a global scale, the Harmonized World Soil Database with its site-specific resolution of 1 km² is a very valuable tool (Nachtergaele et al. 2008; see Appendix B).

Monitoring of the development of soils – based on a regular soil assessment at long-term plots – is fundamental for all identified key issues, and especially in areas where a parameter is expected to come close to a defined threshold. Preferably, soil monitoring would also cover different types of bioenergy feedstock production under various site conditions. Depending on available resources and education levels of personnel, the required assessment could be carried out at different levels of intensity (see examples in Chapter 4.1).

For the identification of risk areas according to threats to soils, Eckelmann et al. (2006) presented a comprehensive approach including definitions and methodologies for soil risk assessment and management for the EU. The authors proposed a first-level assessment based on existing data to identify broad areas within which further measures are required for a 2nd level assessments using, e.g. more detailed data, appropriate regional thresholds and possible management measures. Outside of these areas, no further measures have to be taken.

The 1st level assessment of Eckelmann et al. (2006) – covering erosion, loss of soil organic matter, compaction and salinization – mainly requires data with a resolution of 1 km² (soil maps) to 250 m (land cover)[86]. The generation of 1st level risk maps incorporates a qualitative approach (expert knowledge) and a quantitative approach (e.g. using pedotransfer rules, extrapolation techniques and modelling approaches). Most of the required data are available at a global scale, and, e.g. IIASA/FAO (2008) already prepared a global map of soil erodibility[87]. The main gap is data availability in higher spatial resolution.

Datasets for the other key issues of the decision tree drawn up in Figure 4-1, are not available on a global scale, but for most required data, compilation is under development (Annex D).

The following sections provide more detailed information, mainly taken from Eckelmann et al. (2006) and Louwagie et al. (2009), on the selected key issues with a focus on approaches and models that are also applicable for more detailed assessments at a local scale.

Soil Erosion

Soil erosion caused by physical factors like rainfall, flowing water, wind, ice, temperature change and gravity occurs naturally over geological timescales, but soil erosion can be significantly increased due to unsustainable anthropogenic activities. A threshold value to define low, medium and high soil erosion risks needs to be compared to the natural “background” erosion.

---

86 See overview on required data in Annex D; detailed information including maps is re available at http://eusoils.jrc.ec.europa.eu/ and in Louwagie et al. (2009).

87 K-factor is used in the Universal Soil Loss Equation USLE (see Chapter 0).

As a generic threshold, soil erosion caused by bioenergy feedstock production should **not exceed 1 to 2 t per ha and year**. However, the threshold needs to be adapted to national conditions and political targets.

No single method or model can be used to define the loss of soil caused by all different types of erosion. Most available soil erosion models address water erosion as the most widespread form of physical soil loss. A common and worldwide applicable model is the Universal Soil Loss Equation (USLE, Wischmeier/Smith 1978)[88] and its revisions (RUSLE, Renard et al. 1997; RUSLE-2)[89].

Also wind erosion models exist[90], but required input data on wind strength and direction to run the model are often missing. As approximation, the calculation of erosive days per year is useful (page 16 in Louwagie et al. 2009).

Furthermore, soil erosion can substantially vary during the year due to, e.g. soil cover and rainfall patterns, and consequently, erosion risk assessment must consider seasonal variability.[91]

Carbon Balances

The calculation and/or modeling of carbon balances is not yet sufficiently advanced on a global scale. In contrast to water and soil erosion, existing model approaches require representative long-term plot-data for calibration. Consequently, a global risk assessment should be based on the identification of “at-risk” soils from expert knowledge in combination with spatial information on soil types, land cover and climate (Table 4-3).

Soils and their organic matter content are highly variable all over the world, and thresholds to identify at-risk soils need to be very general and reflect national conditions.

Thresholds could focus on two categories for the upper soil horizons (A, A_p), that need to be adapted to national and local conditions (Eckelmann et al. 2006):

- **Soil with < 2% soil organic matter content** (arable soils, in particular those that are managed in continuous arable production, and especially where tillage is intensive)
- **Soil with > 8% soil organic matter content** (Drained, current or formerly wet soils under arable crops or intensive livestock management)

However, soil types with intermediary soil organic content may also be at risk, especially when land management systems with high oxidation rates are applied. Some soils may have

---

88 Universal Soil Loss Equation (USLE): A = R * K * LS * C * P. R is the rainfall and runoff factor; K is the soil erodibility factor; LS is the slope length-gradient factor; C is the crop/vegetation and management factor; The generalized C factor provides relative numbers for the different cropping and tillage systems; and P is the support practice factor. See more details at http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm.

IIASA/FAO (2008) derived a global map for the K-factor used in USLE.

89 See also http://www.iwr.msu.edu/rusle/ (RUSLE) http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm and http://www.ars.usda.gov/Research/docs.htm?docid=6010 (RUSLE2);

90 For example, Wind Erosion on European Light Soils (WEELS, http://www2.geog.ucl.ac.uk/weels/).

91 See as example seasonal erosion risk assessment in Europe: http://eusoils.jrc.ec.europa.eu/ESDB_Archive/serae/grimm/erosion/inra/europe/analysis/maps_and_listings/web_erosion/index.html

already lost most their needed functions at a threshold above the 2% soil organic matter content. Thus, each soil type needs to be evaluated at a national or local scale to draw up a list of at-risk soils.

In addition, a monitoring system is required to gather information on risks of carbon loss for each soil type under specific land management conditions.

Table 4-3 Soil, Land Cover and Climate Combinations Giving Rise to Higher Risks of Soil Organic Matter (SOM) Decline

Soil Description	Land Cover	Climate	Description	Threat
Soils with a histic (organic) top soil horizon	Arable, grassland	All	Drained, current or formerly wet soils under arable crops or intensive livestock management	Rapid SOM minera-lization after drainage and/or tillage and/or nutrient additions
Soils with a mollic (dark, base saturated, higher organic matter content) top soil horizon	Arable	All	Soil in exposed, large open fields (arable land with low proportion of adjacent forest cover)	SOM decline and linked to accelerated water and wind erosion
Permanent or temporary wetness (Fluvisols, Gleysols, Vertisols)	Arable, grassland	All	Wet soils with higher SOM contents, under arable crops or intensive livestock management	Rapid SOM decline after cultivation, increased by field drainage
Shallow or weakly developed soils, found mainly in upland areas (Leptosols and Regosols)	Arable, grassland, forest	Abrupt and heavy rainfall	Bare, poorly structured soils on steeper slopes e.g. subject to overgrazing, inappropriate tillage or deforestation	Loss of soil and SOM via erosion of top soil
Sandy soils with naturally low levels of SOM in topsoil (Arenosols, Regosols and Podzols)	Arable, grassland, forest	All	Tillage and intensification of agriculture (e.g. by fertilizer applications) and forestry on fragile soils	rapid loss of SOM because of weak stabilization of SOM
Man-made soils (Anthrosols)	All	All	Man-made soils in which SOM has accumulated under one land use, and where the land use has changed.	Rapid loss of SOM as response to altered land use and changed conditions, e.g. water regime

Source: Eckelmann et al. (2006)

Soil Compaction

In the light of bioenergy feedstock production, risks of soil compaction – a process of densification and distortion in which total and air-filled porosity and permeability are reduced – are mainly related to impacts of heavy machinery. However, both details of machinery used as well as information about soil mechanical properties are scarce. Approaches to modelling soil deformation are limited because they require input data on mechanical properties for a large range of soils.

The compaction risk depends mainly on three factors: the characteristics of the applied stress (e.g. type of machinery), the sensitivity of the soil to compaction, and on periods when soil moisture is above a critical soil water content.

Stress characterisation can be derived from expert knowledge on land-use practices (period and type of machinery used), and this information can be linked to spatial information on land cover, land use and topography. Information on soil sensitivity can be gathered from soil maps by means of pedotransfer rules.[92] Periods of critical wetness can be derived from different sources: from climatic zoning with characterisation of seasonal wetness; from climatic water balances based on rainfall and potential evapotranspiration[93]; from simple soil water balances based on available water capacity, rainfall and potential evapotranspiration (irrigation can be included); and from crop growth models for annual or perennial crops.

The current state of the art of soil-compaction risk-assessment strongly depends on expert knowledge. Further research on effects of machinery and sensitivity of different soil types is needed to enhance the prediction of at-risk soils.

Salinization

The main natural factors influencing the salinity of soils are climate, soil parent material, land cover and/or vegetation type, topography and soil attributes. The most influential human induced factors are land use, farming systems, and land management. The degree of salinization of the upper horizons, measured as electrical conductivity (Rhoades et al. 1999), represents a good indicator to identify at-risk soils that are vulnerable against further salinization. Three classes of soil salinity are proposed by Louwagie et al. (2009):

- **Low risk:** ECse < 4 dS/m (deciSiemens per meter)
- **Medium risk:** 4 < ECse < 15 dS/m
- **High risk:** ECse > 15 dS/m

where ECse is the electrical conductivity of the soil saturation extract from the root zone.

At-risk soils can be identified and mapped by means of pedotransfer rules applied to existing soil inventories and maps like the Harmonized World Soil Database (HWSD).[94] Following this system, saline soils have already been mapped in Europe, and similar exercises could be carried out for other regions by national institutions or international organizations.

However, as salinization is a site-specific effect, it should be monitored and trends should be modeled to avoid negative developments. A list of required data is given in Annex D. WATSUIT, for example, is a model which predicts the salinity, sodicity and toxic-solute concentration of the soil-water within a simulated crop root zone resulting from the use of a particular irrigation water of given composition and at a specified leaching fraction[95]. It can be used to evaluate the effect of a given salinity level (or solute concentration) on crop yield and of a given sodicity level on soil permeability.

---

[92] See as example page 27 ff. in Louwagie et al. (2009). Susceptibility of soils to compaction depends on soil texture. It ranges from sand (least susceptible) – loamy sand – sandy loam – loam –clayey loam – loamy clay – to clay soils (most susceptible to natural compaction).

[93] See estimation of machinery work days in Rounsevell/Jones (1993).

[94] See also Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils (http://www.fao.org/ag/AGL/agll/spush/).

[95] http://www.ars.usda.gov/Services/docs.htm?docid=8968

4.5 Conclusions and Guidance

Agricultural activities already lead to the degradation of soils worldwide. In general, bioenergy feedstock production bears similar risks for soil degradation as food and feed production, and therefore requires the same application of good agricultural practices and conservation measures developed for the latter.

There is a need to develop new bioenergy cultivation systems to optimise yields, because bioenergy production – especially cellulose production for second generation liquid biofuels – aims no longer at high yields of oil, starch or protein, but at high yields of carbon. The challenge is to design such systems in a sustainable manner[96] and to make use of opportunities for soil conservation from the beginning (e.g. larger choice of species, low input systems and flexibility regarding harvesting time).

Each bioenergy production system must be evaluated for its risk to cause soil degradation, and a monitoring system of soil parameters should be installed at least for enough sites representing the variety of national site conditions.

In case of high or moderate risks, soil conservation measures need to be applied. If those risks cannot be reduced sufficiently, bioenergy feedstock production and other similar agricultural production should not be allowed at that specific site[97].

The identification of at-risk soils and their mapping is of high importance. Due to improvements in global soil databases, analyses can be computed and can form the basis for the evaluation of bioenergy cultivation systems.

Threshold levels need to be established for specific local conditions, judged from expert knowledge where sufficient data are not available. This should be a strong focus for future work of national and international soil scientists and institutions.

---

96 see Box “Bioenergy Cropping Systems”

97 The relevance of degradation at a specific location strongly depends on site conditions. In consequence, the given list of key issues and thresholds need to be adopted by national experts also considering other issues such as activity of soil biology, soil pollution, or loss of nutrients.

5 Greenhouse Gas Emission Balances

One of the key reasons for pursuing bioenergy is their potential to reduce GHG emissions when displacing fossil fuels. Bioenergy crops could offset their life cycle GHG “burden” in three key ways:

- removing CO_2 from the atmosphere and (temporarily) storing it in crop roots and soil as organic carbon;
- producing co-products such as protein for animal feed, which could avoid GHG emissions from activities needed to provide feed by other means; and
- displacing fossil fuels.

On the other hand, greenhouse gases are emitted in the production life cycle of bioenergy crops:

- in using fertilizers, pesticides, and fuel in farming,
- conversion/processing, transport and distribution up to combustion of the bioenergy product
- direct and potentially indirect land-use changes.

In determining the potential GHG emissions, it is important to consider all relevant steps in the life cycle.

With respect to biofuels, regulations in the EU and currently under consideration in the US require that importers certify the sustainable cultivation of agricultural land, the protection of natural habitats and a minimum level of CO_2 savings for the biofuels, ranging from minimum net savings of 20% (U.S. State of California[98]) to 35% (EU[99]).

With effect from 2017, the EU requires GHG emission saving from the use of biofuels and other bioliquids of 50%.

Successful marketing of bioenergy in the EU and the US will, therefore, require a verifiable GHG balance.

Numerous studies have been performed worldwide on a large array of energy crops looking at this issue with differing results. The results of previous studies show differences strongly depending on the assumptions made for the calculations. Also the level of transparency varies considerably between studies. Thus, there remains some ambiguity and uncertainty in how different biofuel GHG analyses are conducted.

A prerequisite of GHG balancing is the harmonization of methodologies and important default values; national and international efforts are currently underway to standardize GHG emission for energy (and also bioenergy) systems.

---

98 Low Carbon Fuel Standard (LCFS), Executive Order S-1-07, issued on January 18, 2007

99 European Commission (2008): Directive on the promotion of the use of energy from renewable sources; Brussels, December 17, 2008 (version adopted by the European Parliament, and the EU Council)

5.1 Goal and Scoping Issues

Goal of the GHG balance method

The main objective of the GHG balance method within the BIAS framework is the definition of a clear methodology and data requirements in order to perform verifiable lifecycle analysis of energy crops. It should build on harmonized methods and take into account ongoing efforts such as the Global Bioenergy Partnership (GBEP) taskforce that will develop recommendations on the methodology used to conduct this type of analysis. It should also be suitable to provide information that is required to comply with international certification schemes for bioenergy and should therefore conform to requirements laid out in such regulations (e.g. by the European Commission).

Greenhouse Gases to be considered

The following greenhouse gases are relevant for production of energy crops: carbon dioxide, methane and nitrous oxide. The impact from other greenhouse gases is of minor importance.

For the purpose of comparing the global warming impact of different greenhouse gases, the time horizon should be taken as 100 years; the conversion factors relative to CO_2 are taken from the most recent IPPC report and shown in Table 5-1.

Hence, one kg of nitrous oxide has the value of 296 kg of CO_2 equivalents (CO_2-eq.).

Table 5-1 Greenhouse Gases and Conversion Factors

Greenhouse Gas	Conversion Factor (mass based)
Carbon dioxide (CO_2)	**1**
Methane (CH_4) fossil [a)]	**23**
non fossil [b)]	**21.25**
Nitrous oxide (N_2O)	**296**

a) includes the impact of CO_2 after CH_4 has been oxidized in the atmosphere
b) does not include the impact of CO_2 after CH_4 has been oxidized

Source: IPPC (2006)

System Boundaries

In determining the potential GHG emissions, it is important to consider more than just the combustion of the finished product - the full life cycle impact which includes production of the fuel feedstock, transportation of the fuel feedstock to a processing facility, fuel processing, distribution of the fuel to the retail outlet, and waste treatment should be considered.

The GHG balance is the balance between all greenhouse gas emissions from production to use of a biofuel and those emitted from produce to use of the equivalent energy amount of the respective fossil fuel. Figure 5-1 shows the processes using the case of palm oil methyl ester (PME) production as an example.

Many processes produce not only the desired product but also other streams or “by-products”. For example, in the production of bio-diesel from oil seeds, protein-rich material from e.g. oil seed pressing are likely to be used as animal fodder displacing soy meal. This implies that the reference scenario must include either an existing process to generate the same quantity of by-product as the alternative scenario, or another product which the by-product would realistically replace.

Growing energy crops may trigger direct and indirect land use changes that have to be accounted for. Emissions or savings from these land use change can be a major factor in the overall greenhouse gas balance of bioenergy.[100]

Bioenergy Systems

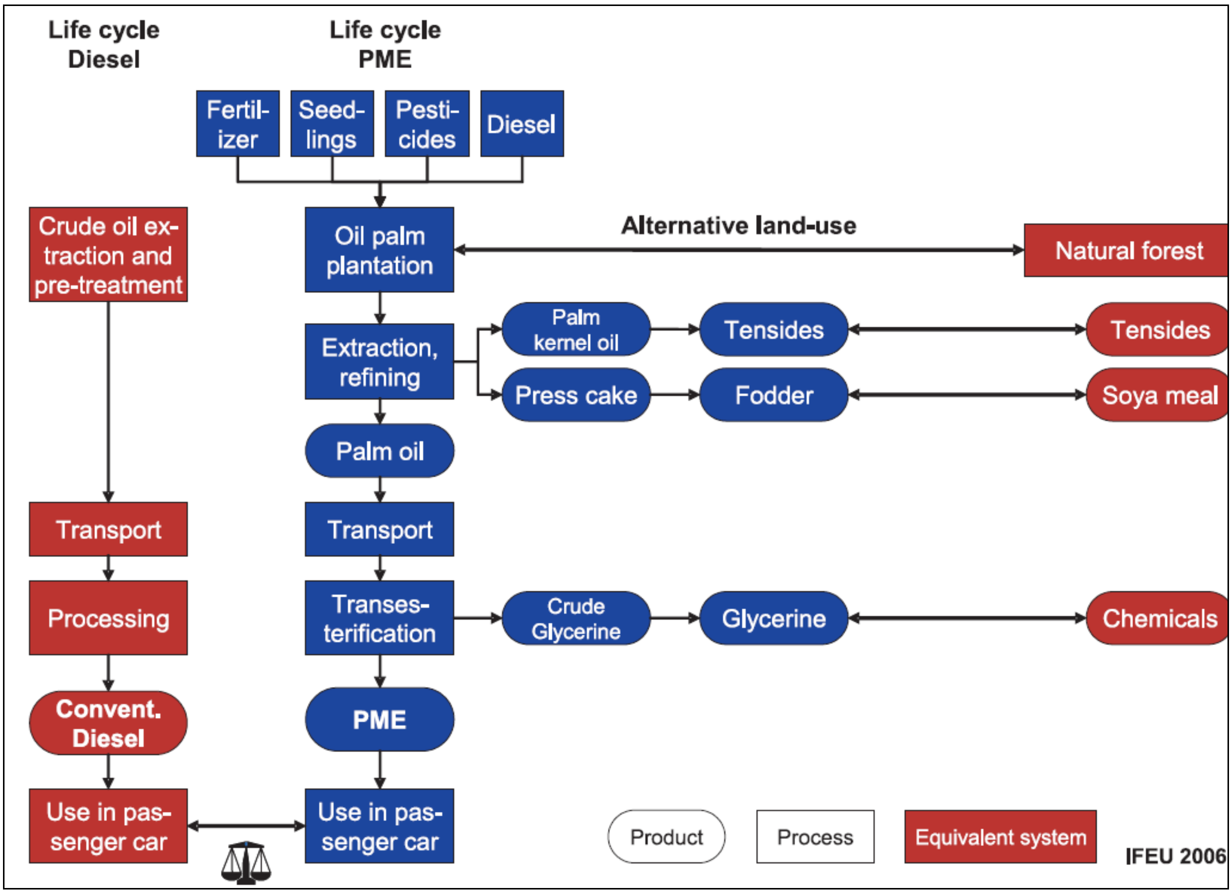
Bioenergy systems encompass the production of the biomass, all conversion processes, waste treatment, any transportation of goods and the use of the biomass. The production of ancillary material is also included as well as all downstream processes like effluent and waste treatment. The use phase is included with the assumption that all carbon is released as carbon dioxide. The CO_2 emitted during biomass combustion was absorbed when the biomass crop was grown. This is the short carbon cycle that makes biomass use renewable and this should be accounted for.

Fossil Fuel Reference Systems

The fossil fuel reference systems encompass the extraction of crude oil, the transportation to the refinery, all refinery processes to produce gasoline and diesel and the use of the fuels. The production of ancillary material is included. Also all downstream processes like effluent and waste treatment are included. The use phase is included with the assumption that all carbon is released as carbon dioxide. However, different substituted products may have differing GHG performances. For example, for electricity substitution a specific power plant, a national mix or marginal electricity production can be regarded. The preferred method is to use the national mix for the country in which the fossil fuel reference process takes place.

100 For a more detailed discussion, see Fargione et al. (2008); Fehrenbach/Fritsche/Giegrich (2008); RFA (2008); Searchinger et al. (2008)

Figure 5-1 System boundaries for palm oil methyl ester and fossil fuel reference



Source: IFEU

Exclusion of Processes

In general, the following processes are **not** considered, as they are of minor importance for the end result:

- production of capital goods and infrastructure;
- inputs of less than 1% by weight into a specific process

If there is uncertainty whether the ignored processes may be relevant for the end result, e.g. in case of GHG intensive inputs below the 1% cut-off criterion, a sensitivity analysis should be performed.

5.2 Consideration of By-products

Table 5-2 compares the pros and cons for various options to consider co-products.

Substitution Method

For a comprehensive GHG balance, the "substitution" method attempts to model reality by tracking the likely fate of by-products.

In the example of the PME life cycle (see Figure 5-1), substitutes are tensides, soy meal and chemicals. The analysis has to determine the energy and emission credit that is equal to the energy and emissions saved by not producing the material that the co-product is most likely to displace.

There is, however, uncertainty with respect to the exact use of the co-product, because any of the functions performed by co-products are capable of being performed by more than one substituted product. For example, co-products used as animal feed can replace many different animal feed products. These different substituted products may have differing GHG performances. Also, the impacts may change when the system is scaled up, e.g. the market for protein cake as animal feed tends to get saturated quite quickly. The system tends to get very complex.

Allocation Method

Many studies have used "allocation" methods whereby energy and emissions from a process are allocated to the various products e.g. by mass, energy content, or monetary value. Among these, the allocation by energy content is most widely used, such as in the European Directive for sustainable biofuels. Emissions that take place up to and including the process step at which a co-product is produced shall be divided between the biofuel or its intermediate product and the co-products in proportion to their energy content.

The allocation of co-products by energy content has the following advantages:

- The substitution approach has substantial weaknesses when used for regulatory purposes (variability in assumptions, large amount of data required).
- As regards the options for allocation, allocation by energy is more robust compared to allocation by mass or market price.
- Energy allocation avoids the problem of creating undesirable incentives for the energy use of co-products rather than for example their use as animal feed, because GHG credits from actually burning co-products (e.g. palm press cake) are often higher than the credits calculated from substitution.

Among allocation methods, inputs and outputs shall be allocated to the co-products by their share of the lower heating value (= net calorific value). This is appropriate because energy crops substitute fossil energy. A consistent table of lower heating values shall be used (see Annex A).

Selection of Methods

While using the energy allocation approach is reasonable with respect to the certification process from the standpoint of a regulatory agency, the substitution methods allows to look at the entire system and is especially important for decision-makers in countries in which increased production of energy crops is evaluated. Land use changes caused by the conversion of land for the production of animal feed that would otherwise need to be produced if co-products were not available and used for this purpose would be neglected if the energy allocation method would be used.

This land use change and related feed production is not only important in terms of GHG balances, but also links directly to the land available for bioenergy production, see the chapter on biodiversity and the links to the Bioenergy and Food Security (BIAS) project.

Within the BIAS framework, it is proposed to use the substitution and energy allocation methods in parallel. This ensures that the results can be used for certification purposes (e.g. the EU Directive requires allocation by energy), and also allows to adequately address the complex issues that can only be properly addressed by using substitution method. A sensitivity analysis using allocation by market value is an option, especially if full substitution analysis is not feasible.

Table 5-2 Comparison of Co-Product Consideration

	Feature	PRO	CON
Substitution (system expansion to cover all products)	Widening the scope, taking interrelated sectors into consideration	• Possibility to consider mechanisms that are actually happening • Specific developments (progress) can be considered	• System expansion tends to raise complexity untraceable for "non-experts" • The multiple pathways open a range of +/- unbound choices • Needs evidence of what is really substituted
Allocation	Focus remains on main output	• By-products of the biofuel chain are seen as by-products of the biofuel chain	• No consideration of any correlations with other production sectors
Allocation by energy content (lower heat value)		• Robust and widely unambiguous approach • Coefficients are empirical, provable and available • Energy is the major issue concerning biofuel	• Energy content is not always the most appropriate indicator • In some cases the LHV is unclear (varying water content)
Allocation by market value		• Market coefficients are representing the real driving forces for producing a (co-) product. • Coefficients are in most cases available and published	• Market values are very variable and fluctuant; their "validity" has to be determined by convention over a certain time span • Market values are not scientifically based

Source: own compilation

5.3 GHG Accounting of Land Use and Land Use Change

The expansion of energy crop production is almost always connected with land use change since the production area was most likely dedicated to some purpose (i.e. production of food or other crops, settlement, forest, natural protection area, set-aside land). Three types of impacts can be distinguished:

- If energy crop production has been an ongoing practice for many years (at least since the reference year 2005), only changes in the carbon storage in the soil that are attributable to the crop itself as well as emissions of methane and nitrous oxides from fertilizer application have to be accounted for. A change in direct land use does not happen.
- Direct land use change occurs whenever a new plantation is established, disregarding if cultivation of crops has taken place on that land before, or if the area might have been under forest or other natural and near-to-nature ecosystems.
- Indirect land use can be described as the shift of the land use prior to biofuel production to another area where a land use change occurs (also referred to as leakage, displacement).

Accounting for direct and indirect land use changes requires a specific consideration and in the BIAS framework (as well as in the BEFS framework) land use changes for bioenergy production are specifically taken into account. Also, the intensification of agricultural crop and livestock production that might develop in parallel with bioenergy production has a direct influence on the greenhouse gas emissions of bioenergy crops.

Direct Land Use Change

Bioenergy systems interact directly with the land they are cultivated on. The type of land use impacts the storage of carbon in the soil and above ground and may also result in constant emissions of greenhouse gases such as methane and nitrous oxides (N_2O).

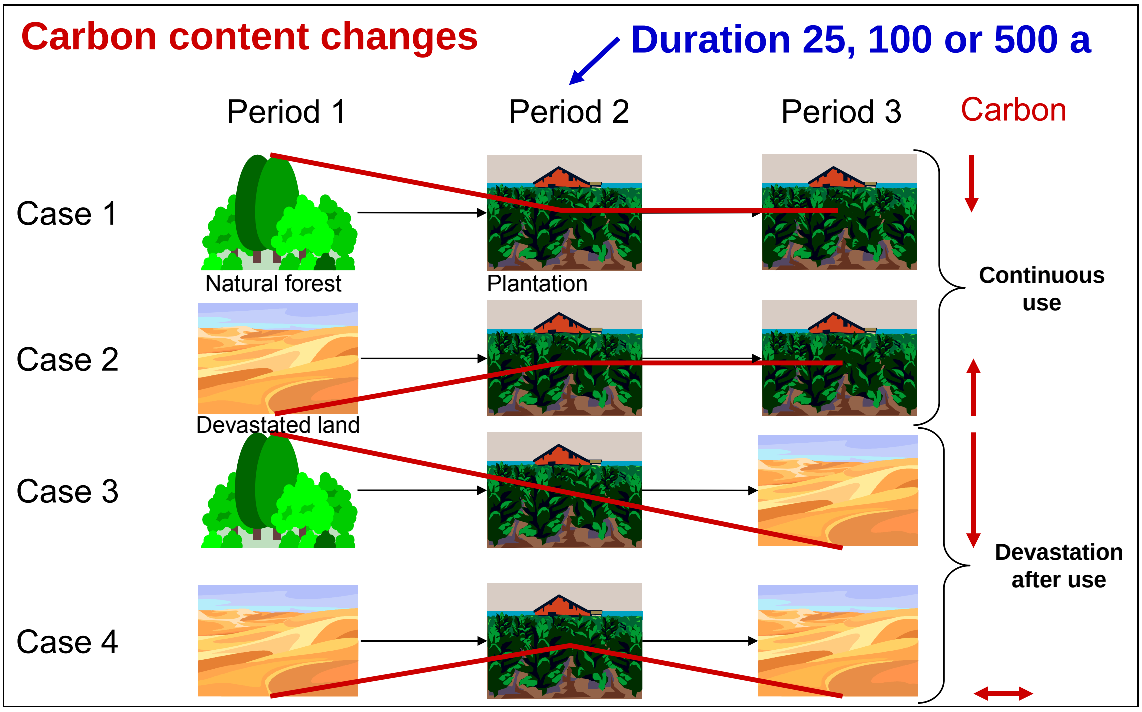
Land use changes may influence dramatically the GHG balances depending on the nature of the changes and the period of time over which their impact occurs. In Figure 5-2, several idealized direct land use changes are compared. For the carbon storage aspect all carbon above and below ground has to be taken into consideration. The difference of the system before and after the change to the energy crop system has to be calculated. The difference whether it is positive or negative has to be attributed to the biomass and to the product derived from it (e.g. biofuel).

The task to obtain reliable information on above and below ground carbon storage is complex and data intensive. Therefore IPCC values (GHG Reporting Guidelines (Vol. 4) 2006) are preferred as long as no specific information is available, but it should be noticed that the IPCC values are average values that can differ considerably for specific bioenergy settings. These factors take into account changes in the carbon stocks of biomass, dead organic matter and soils. They cover the changes between forestland, cropland, grassland, wetland, settlements and other land uses. Permanent emissions of methane and nitrous oxides have to be taken into account as well. Data are provided in Annex A.

While the GHG benefits of using land to produce energy crops recur each year, carbon stock effects of land use change can be thought of as one-off changes.

It is therefore necessary to decide over how many years the impact of the carbon stock change should be spread. In line with the proposed GHG balance method of the EU, the carbon storage effect of land use should be accounted for over a 20 year period, with no discounting. All land use changes that took place after January 1, 2005 should be accounted for. The year 2005 was selected as reference year because it represents the start of expanded worldwide production of energy crops.

Figure 5-2 Examples for Carbon Stock Changes

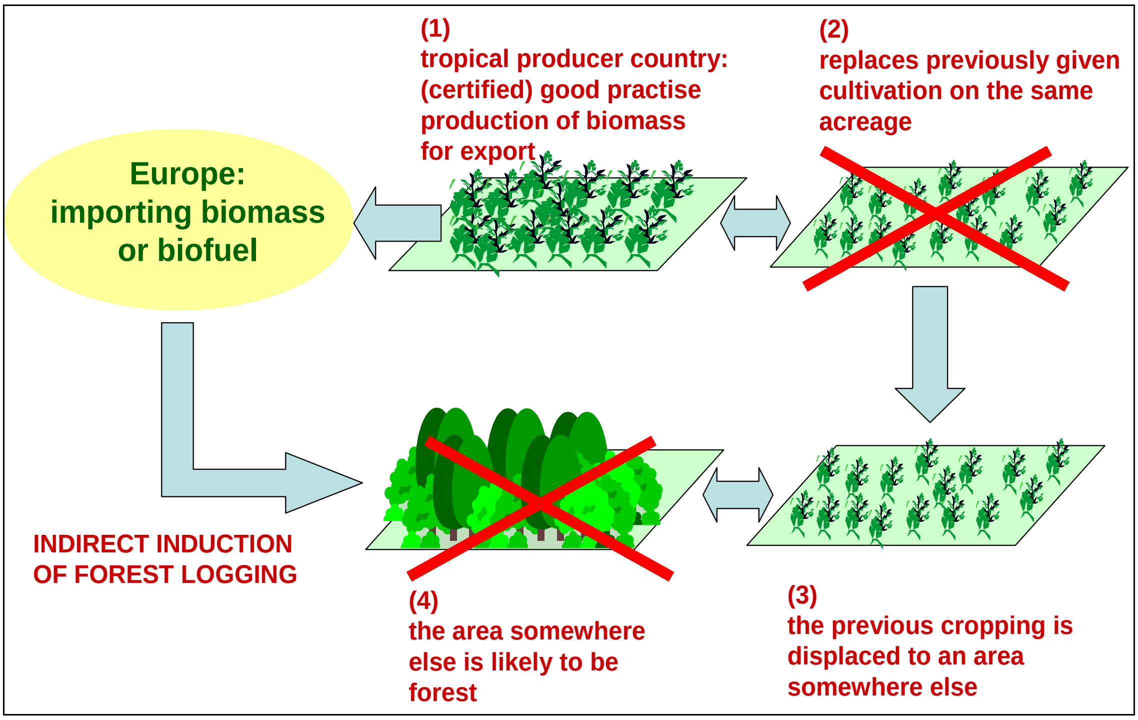


Source: IFEU

Indirect Land Use Change

Indirect land use can be described as the shift of the land use prior to energy crop production to another area where a land use change occurs (also referred to as leakage or displacement). Figure 5-3 demonstrates an example of indirect land use change, the displacement by increased use of bioenergy in Europe.

Figure 5-3 Example of the Mechanism of Indirect Land Use Change



Source: IFEU

The scheme refers to an increase of biomass imported from a country in the Southern hemisphere where good practice and absence of direct land use change may be certified. However, the area now being used by the new crop is no longer available for the previous crop which is still needed. The previous cropping will be displaced to other areas, most likely to areas that are not yet in use (e.g. natural forests).

Agrarian markets are global and the arable area on our globe is limited. For purpose of GHG balancing with regard to indirect land use changes, it is not relevant at which location the biomass is actually produced and used. The indirect land use changes have to be taken into account for the biofuel GHG balance. The estimate of indirectly caused GHG emissions should take all countries into account that trade agrarian products. To date, there is no definitive scientifically accepted approach to address this issue; a possible pragmatic approach is the “iLUC factor” proposed by Fritsche (2007).

It is defined by the global average share of area in use for producing agrarian products for export purpose and the land use change is given in the corresponding regions. In line with the settings for direct land use change a conservative carbon release due to conversion of high carbon content natural systems to arable land is determined to 400 t CO_2 per ha. For a 20-year period, this results in 20 t CO_2 per hectare per year.

The estimate of indirectly caused GHG emissions should take all countries into account that trade agrarian products. These countries are potentially urged to increase biomass production for the global market of biofuels and thus in these countries displacements effects are likely to occur. The share of area utilized for producing biomass for export reflects the origin and country specific yields. The data can be acquired from FAO data banks.

The iLUC approach could also be based on a global partial equilibrium model, accounting for changes in cropland within the agricultural sector based on interactive forces of supply and demand which the model allows to reach equilibrium.

It should be stressed that to date, no generally accepted method exists. By contrast, computable general equilibrium (CGE) modeling accounts for broader effects on the economy, such as rates of economic growth, changes in energy consumption, etc., and has the advantage of greater completeness – still, it introduces a broader range of uncertainties (Searchinger 2008). For example, effects on the broader economy will depend on the price of producing biofuels. Higher liquid fuel prices likely increase greenhouse gas emissions in the developing world by encouraging greater reliance on coal instead of oil or natural gas for electricity. CGE models also have to build on a broad range of expectations about the economy as a whole and about government policies (Searchinger 2008).

5.4 The BIAS Module for GHG Emission Balances

Modeling of Agricultural Systems

Modeling agricultural systems for GHG accounting is not always straightforward because of widely varying parameters and complex system interactions. Therefore some conventions are needed. Agricultural systems are often composed of various cultivations and shifts of cultivations. For simplicity reasons the cultivation of energy crops shall be averaged over the total period of the agricultural system (with varying crops), and interactions with the change in cultivations (e.g. fertilizer interactions) shall be taken into account in the average data.

Biomass left on the agricultural land or brought back to the land has to be taken into account for balancing the fertilizer demand or carbon storage calculations (direct biomass loop). Secondary biomass (e.g. straw, leaves, etc.) being used for non-energy purposes and brought back to the agricultural land has to be taken into account for balancing the fertilizer demand or carbon storage calculations. This shall be done even if it is not returned to the original land (indirect biomass loop).

Nitrogen fixation for subsequent cultivations (e.g. legumes like soy plants) and nitrogen release from previous cultivations have to be taken into account. Therefore a nitrogen balance has to be calculated which serves as the basis for the mineral fertilizer demand. This interaction with cultivation changes shall be considered.

Manure is not considered as a co-product of another system (e.g. meat production, milk production). It is modeled from the moment of its generation until its end use on the land. All agricultural activities shall be modeled as they occur in reality. This includes machine work, pesticide application, fertilizer application, biomass burning, etc.

Modeling of Conversion and Transport Systems

GHG calculation for conversion steps within the biofuel chain is state of the art. Direct emissions, as well as emissions due to energy use (e.g. electricity, process heat, steam) and auxiliary material (e.g. methanol, process agents etc.) have to be accounted including the upstream processes (e.g. production of fertilizer and pesticides).

The specific process is defined with reference to realistic examples in practice. Country-specific emission factors are given in Annex A.

Modeling transport needs is first defined as means of transport and distances. With regard to default values both data types are defined taking conservativeness into account. For instance truck transport is generally assumed for overland transport even if rail would be possible and practiced in special cases. Distances are estimated on a realistic base but also preferring longer (not the potentially longest) routes in case of doubt.

Modeling of Auxiliary Energy Inputs

Auxiliary energy inputs such as electricity can use process-specific data (e.g. a specific power plant), a national mix or marginal processes. With respect to electricity input, the preferred method is to use the national mix for the country in which the process takes place.

Bioenergy from Residues and Wastes

Biomass residues and waste enters the GHG balancing system without upstream emissions and inputs. Only the point of handing over wastes to the bioenergy system must be defined.

Biomass wastes must be declared explicitly as waste, i.e., the material is defined as waste according to national and international legislation and being reported under waste reporting requirements. If biomass-based material does not fulfill these requirements, it has to be considered as co-product of another system and will be charged with GHG emissions from the other system according to given allocation rules (e.g. oil seed extraction cake). In addition, guidelines for extraction rates have to be formulated for residues to avoid humus depletion or loss of habitats (e.g. through removal of dead wood), see Chapters 2 and 4.

The production of bioenergy from wastes might compete with other recycling or recovery options so that possible impacts need to be analyzed.

5.5 Data Issues

In order to simplify the calculation process, default values are provided in Annex A for the following parameters:

- GHG emissions from fossil reference systems
- Carbon stocks in natural areas and land use types
- Field emissions of N_2O and CH_4
- Lower heating values of materials
- Default values for land use change
- GHG emission factors for electricity use by country or region (grid mix)
- GHG emission factors for transportation by country or region (truck, train, ship)
- GHG emission factors for fertilizer and pesticide production

Data Collection and Reporting of Results

For data collection, a country-specific questionnaire should be used. Data should be tested for internal consistency. If specific country, sector or site data are used, they need documentation, and the resulting differences to the default data should be indicated.

The results of the GHG balance should be reported depending on the scope of the work:

- For certification schemes, emissions should be reported as g CO_2 equivalent per MJ.
- For other purposes, a suitable functional unit should be selected, e.g. g CO_2 eq./ha.

6 Perspectives for Applying and Refining BIAS

The overall methodological approaches presented in the previous sections are compiled with the perspective to apply the framework in the real world, i.e. to make use of the framework in the context of (national and regional) bioenergy-related policy development, and decision-making.

With the exception of a preliminary case study for the biodiversity framework (see Appendix I), and a small case study for the GHG approach[101], the overall BIAS framework has not been “tested” yet.

Further refinement of the suggested tools and methods as well as applicability of the databases will be possible only through a comprehensive desktop study, or through selected further case studies which apply the BIAS concept to a given country, or region.

For that, it is suggested to seek close collaboration and exchange with FAO’s ongoing activities on bioenergy and food security.

In addition to “full-scale” testing of the BIAS approach, it might be useful to consider a **compacted version** which would translate the rather complex data collection and processing of the BIAS modules into a simplified **set of rules**.

Drawing from the basic approaches of the analytical framework and the respective flow-charts presented here, a condensed version could develop a procedural matrix with qualitative “checks” to focus more data-intense, quantitative work on key areas of interest, or conflict.

Furthermore, the BIAS framework modules can be tested in “stand-alone” mode so that e.g. isolated case applications can be carried out for the analytical frameworks for soil or water.

Before doing so, it is recommended to consider results from and potential interaction with other sustainable bioenergy projects by FAO and other organizations.

101 This is carried out by IFEU. Results will be available later this year, and published by FAO.

7 References

Abell et al. 2008: Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation; in: BioScience vol. 58 No. 5, pp 403-414

Alcamo, J. et al. 2003: Developing and Testing the WaterGap 2 Model of Water Use and Availability; in: Hydrological Sciences vol. 48 (2003), p. 317-337

Andrews, S.S., Karlen, D., Cambardella, C. 2004: The soil management assessment framework: A quantitative soil quality evaluation method; in: Soil Science Society of America Journal 68: 1945-1962

Badgley, C. et al. 2007: Organic agriculture and the global food supply; in: Renewable Agriculture and Food Systems 22:86-108

Bai, Z.G. et al. 2008: Global assessment of land degradation and improvement 1: identification by remote sensing. Report 2008/01, ISRIC - World Soil Information Centre; Wageningen

Baker, W.L., Dillon, G.K. 2000: Plant and vegetation responses to edges in the southern Rocky Mountains. Pp 221-245 in: Knight, R.L. et al. (eds.) Forest fragmentation in the southern Rocky Mountains; Colorado (University Press of Colorado)

Bartholomé, E., Belward, A.S. 2005: GLC2000: A new approach to global land cover mapping from Earth observation data; in: International Journal of Remote Sensing 26:1959-1977

Bastida, F. et al. 2008: Past, present and future of soil quality indices: A biological perspective; in: GEODERMA 147: 159-171

Bauen, A., Watson, H. 2006: Methodology for Carbon Reporting under the Renewable Transport Fuel Obligation (RTFO) – worked out by E4tech, commissioned by LowCVP, draft from Dec 2006

Benedict, M.A., McMahon, E.T. 2006: Green Infrastructure: Linking landscape and communities; Washington DC (Island Press)

Bergsma, E. et al. 1996: Terminology for Soil Erosion and Conservation; International Society of Soil Science; Vienna

Bergsma, G., Vroonhof, Dornburg 2007: The greenhouse gas calculation methodology for biomass – based electricity, heat and fuels; CE and Utrecht University commissioned by SenterNovem, draft from Jan. 2007

Berndes, Göran 2002: Bioenergy and water – the implications of lager-scale bioenergy production for water use and supply; in: Global Environmental Change vol. 12 (2002), p. 253-271

Berndes, Göran 2008: Water demand for global bioenergy production: trends, risks and opportunities; prepared for WBGU; Berlin http://www.wbgu.de/wbgu_jg2008_ex02.pdf

Butterfield, J., Bingham S., Savory A. 2006: Holistic Management Handbook: Healthy lands, healthy profits. Island Press, USA.

Bouwman, AF et al. 2006: Integrated modelling of global environmental change. An overview of IMAGE 2.4. Netherlands Environmental Assessment Agency (MNP); Bilthoven

Brookfield, H., Stocking, M. 1999: Agrodiversity: definition, description and design; in: Global Environmental Change-Human and Policy Dimensions 9:77-80

Bryant et al. 1997: The Last Frontier Forest: Ecosystems and Economies on the Edge; World Resources Institute; Washington DC

Bubb, P. et al. 2005: Biodiversity Indicators for National Use: Experience and Guidance; UNEP-WCMC; Cambridge

Burgess, N. et al. 2004: Terrestrial ecoregions of Africa and Madagascar: A conservation assessment; Washington DC (Island Press)

CBD (Secretariat of the Convention on Biological Diversity) 2006: Global Biodiversity Outlook 2; Montreal

CBD (Secretariat of the Convention on Biological Diversity) 2007: New and emerging issues relating to the conservation of sustainable use of biodiversity: Biodiversity and liquid biofuel production. UNESCO, UNEP/CBD/SBSTTA/12/9, 25 April 2007

CBD (Secretariat of the Convention on Biological Diversity) 2008: The potential impacts of biofuels on biodiversity - matters arising from SBSTTA recommendation XII/7; Note by the Executive Secretary; UNEP/CBD/COP/9/26

Cochrane, M.A., Laurance, W.F. 2002: Fire as a large-scale edge effect in Amazonian forests; in: Journal of Tropical Ecology 18:311-325

COM (Commission of the European Communities) 2006a: Thematic Strategy for Soil Protection, COM(2006) 231 final; Brussels http://ec.europa.eu/environment/soil/pdf/com_2006_0231_en.pdf

COM (Commission of the European Communities) 2006b: Proposal for a Directive oft the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC, COM (2006) 232 final; Brussels http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf

de Almeida, E.F. et al. 2007: The performance of Brazilian biofuels; an economic, environmental and social analysis; CEMT/OCDE/JTRC/TR(2007)

de Bie, C.A. 2000: Comparative performance analysis of agro-ecosystems; PhD-thesis, University of Wageningen

de Graaf J. et al. 2007: Monitoring and evaluation of soil conservation and watershed development projects; Science Publishers, USA

de Heer, M. et al. 2005: Biodiversity trends & threats in Europe, development and test of a species trend indicator. Report nr. 717101001, National Institute for Public Health and the Environment (RIVM) and World Conservation Monitoring Centre (UNEP/WCMC); Bilthoven

Dinerstein, E. et al. 1995: A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean; World Bank, Washington DC

Dudley, N., Phillips, A. 2006: Forests and Protected Areas: Guidance on the use of the IUCN protected area management categories; IUCN; Gland/Cambridge

Eckelmann, W. et al. 2006. Common criteria for risk area identification according to soil threats; European Soil Bureau Research Report No.20, EUR 22185 EN; Luxembourg

Ecologic 2004: Assessing the Economic Impacts of Soil Degradation (Volume I: Literature Review). Final Report to the DG TREN http://www.ecologic.de/modules.php?name=News&file=article&sid=1006

Edwards R., Larivé J.-F., Mahieu V., Rouveirolles P. 2007: Well-to-wheels analysis of future automotive fuels and powertrains in the European Context. JRC/ EUCAR/ CONCAWE: version 2c, March http://ies.jrc.ec.europa.eu/WTW

EEA (European Environment Agency) 2003: Europe's water: An indicator-based assessment; Environmental issue report No 34; Copenhagen

EEA (European Environmental Agency) 2004: High nature value farmland Characteristics, trends and policy challenges. EEA Report No 1/2004; Copenhagen

EEA (European Environment Agency) 2005: Agriculture and environment in EU-15 – the IRENA indicator report; Copenhagen http://www.eea.europa.eu/publications/eea_report_2005_6

EEA (European Environmental Agency) 2006: How much bioenergy can Europe produce without harming the environment? EEA Report No 7/2006; Copenhagen http://reports.eea.europa.eu/eea_report_2006_7/en/eea_report_7_2006.pdf

EEA (European Environmental Agency) 2007: Estimating the environmentally compatible bioenergy potential from agriculture; EEA Technical Report, Copenhagen http://reports.eea.europa.eu/technical_report_2007_12/en/Estimating_the_environmentally_compatible_bioenergy _potential_from_agriculture.pdf

EEA (European Environment Agency) 2009: Water Resources across Europe – confronting water scarcity and drought; Copenhagen

EJF (Environmental Justice Foundation) 2003: What's your poison? Health threats posed by pesticides in developing countries; London www.ejfoundation.org/pdf/whats_your_poison.pdf

EMPA (Swiss Federal Institute for Materials Science and Technology) 2007: Life cycle Assessment of Energy Products: Environmental Impact Assessment of Biofuels - Executive Summary; Zah, Rainer et al.; St. Gallen http://www.bfe.admin.ch/php/modules/enet/streamfile.php?file=000000009552.pdf&name=000000280006

Environment Agency 1999: Pesticides in the Aquatic Environment; Wallingford

FAO (Food and Agriculture Organization of the United Nations) 2001: Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World (FAO, 2001); Dixon, J./Gulliver, A./Gibbon, D./Hall, M., Rome http://www.fao.org/DOCREP/003/Y1860E/y1860e00.htm

FAO (Food and Agriculture Organization of the United Nations) 2002: The International Code of Conduct on the Distribution and Use of Pesticides; Rome www.fao.org/ag/agp/agpp/pesticid/Code/PM_Code.htm

FAO (Food and Agriculture Organization of the United Nations) 2004: Guiding Principles for the Quantitative Assessment of Soil Degradation; Rome ftp://ftp.fao.org/agl/agll/docs/misc36e.pdf

FAO (Food and Agriculture Organization of the United Nations) 2005a: Agro-ecological zoning and GIS applications in Asia with special emphasis on land degradation assessment in drylands (LADA); Proceedings of a Regional Workshop Bangkok, Thailand 10–14 November 2003; AGL/MISC/38/2005; Rome

FAO (Food and Agriculture Organization of the United Nations) 2005b: Land Cover Classification System (LCCS): Classification Concepts and User Manual; Rome http://www.fao.org/DOCREP/003/X0596E/X0596E00.htm

FAO (Food and Agriculture Organization of the United Nations) 2006a: Prevention and disposal of obsolete pesticides; Rome www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/Pesticid/Disposal/en/index.html

FAO (Food and Agriculture Organization of the United Nations) 2006b: Global Forest Resources Assessment 2005 – Progress towards sustainable forest management; FAO Forestry Paper 147; Rome

FAO (Food and Agriculture Organization of the United Nations) 2006c: Guidelines for soil description; Rome

FAO (Food and Agriculture Organization of the United Nations) 2007a: First FAO Technical Consultation on Bioenergy and Food Security - SUMMARY PROCEEDINGS; 16-18 April 2007; Rome

FAO (Food and Agriculture Organization of the United Nations) 2007b: Global Assessment of Land Degradation and Improvement; Bai, Z.G./Dent, D.L./Olsson, L./Schaepman, M.E.; FAO LADA working paper; Rome

FAO (Food and Agriculture Organization of the United Nations) 2008: Manual on integrated soil management and conservation practices; FAO Land and Water Bulletin 8; Rome

FAO (Food and Agriculture Organization of the United Nations)/IIASA (International Institute for Applied Systems Analysis)/ISRIC (World Soil Information Centre), ISS-CAS (Institute of Soil Science – Chinese Academy of Sciences), JRC (European Commission Joint Research Centre) 2008: Harmonized World Soil Database (version 1.0); Rome etc. http://www.iiasa.ac.at/Research/LUC/luc07/External-World-soil-database/HTML/index.html

Fargione, J. et al. 2008: Land Clearing and the Biofuel Carbon Debt; in: Science vol. 319 (5867), p. 1235 – 1238 http://www.sciencemag.org/cgi/content/abstract/1152747

Fehrenbach, H., Fritsche, U., Giegrich, J. 2008: Greenhouse gas Balances for Biomass: Issues for further discussion; issue paper for the informal workshop, January 25, 2008 in Brussels http://www.oeko.de/service/bio/dateien/en/ghg_balance_bioenergy.pdf

Fischer, Günter et al. 2000: Global agro-ecological zones assessment: Methodology and results; Interim Report IR-00-064; IIASA/FAO; Laxenburg

Fishpool, L. 2004: From endemic bird areas to important bird areas and conservation action sites across Africa; in: Burgess, N.D. et al. (Eds.): Terrestrial ecoregions of Africa and Madagascar: A conservation assessment; Washington DC (Island Press); p. 158-161

Forastieri, V. 1999: The ILO programme on occupational safety and health in agriculture; International Labour Office (ILO); Geneva www.ilo.org/public/english/protection/safework/agriculture/agrivf01.htm#ae

Fritsche, Uwe R. 2007: GHG Accounting for Biofuels: Considering CO_2 from Leakage; Oeko-Institut; Darmstadt, May 2007

FSC (Forest Stewardship Council) 2000: FSC Principles and Criteria for Forest Stewardship; FSC reference code: FSC-STD-01-001 (April 2004)

Gawler, M. 2007: Strengthening the capacity of governments to implement priority activities of the CBD PoWPA. Eastern Europe Regional Workshop, Isle of Vilm, 17-21 June 2007; Workshop Report

GEF (Global Environment Facility) 2007: FOCAL AREA STRATEGIES AND STRATEGIC PROGRAMMING FOR GEF-4; Washington DC http://www.thegef.org/uploadedFiles/Documents/Council_Documents__(PDF_DOC)/GEF_31/C.31.10%20Focal%20Area%20Strategies.pdf

GEMIS (Global Emission Model for integrated Systems) Version 4.1; Fritsche, U. et al., Darmstadt/Freiburg/Berlin www.gemis.de

Gemmill, B. 2004: Guide to Best Practices for Sectoral Integration: Managing agricultural resources for biodiversity conservation; UNDP/UNEP/GEF Biodiversity Planning Support Programme (BPSP)

Green, R.E. et al. 2005: Farming and the fate of wild nature; in: Science 307:550-555

GREET (Greenhouse gas, regulated emissions, and energy use in transportation) GHG Tool developed by Argonne National Laboratory (Wang et al.); Chicago

Groom, M.J. et al. 2006: Principles of Conservation Biology; 3rd ed.; Sunderland (Sinauer Associates)

Groves, CR. 2003: Drafting a conservation blueprint: A practitioner's guide to planning for biodiversity; Washington DC (Island Press)

Guerreiro, A. 2006: The technological dimension of biofuels; EPE/Ministry of Mines and Energy presentation at the Seminar Expert Meeting on Participation of Developing Countries in New Dynamic Sectors of World Trade: Review of the Energy Sector Adjusting to the New Energy Economy; UNCTAD, Geneva

Gyasi, E.A. et al. (eds.) 2004: Managing agrodiversity the traditional way: Lessons from West Africa in sustainable use of biodiversity and related natural resources; United Nations University Press, Tokyo

Haffmans, S. 2005: Kosten-, Markt- und Gesundheitsaspekte des Pestizideinsatzes in Afrika [Cost, market and health aspects of the pesticide use in Africa]. Pestizid Aktions-Netzwerk e.V. (PAN Germany), Hamburg http://www.pan-germany.org/deu/~news-236.html

Hammer, K., Teklu, Y. 2008: Plant genetic resources: Selected issues from genetic erosion to genetic engineering; in: Journal of Agriculture and Rural Development in the Tropics and Subtropics 109:15-50

Hartje, V., Klaphake, A. 2006: Implementing the Ecosystem Approach for freshwater ecosystems – A case study on the Water Framework Directive of the European Union; BfN-Skripten 183; Bonn

Hennenberg K. et al. 2008: Core area analysis at semi-deciduous forest islands in the Comoe´ National Park, NE Ivory Coast; in: Biodiversity and Conservation 17:2787–2797

Heuvelmans, G et al 2005: Extending the Life Cycle Methodology to Cover Impacts of Land Use Systems on the Water Balance; in: Int J LCA vol. 10 (2005), p. 113-119

Hooijer, A., Silvius, M., Wösten, H., Page, S. 2006: PEAT-CO_2, Assessment of CO_2 emissions from drained peat lands in SE Asia; Delft Hydraulics report Q3943

Huddleston et al. 2006: A geospatial framework for the analysis of the poverty and environment links; FAO Environmental Natural Resources Working Paper No. 25; Rome

Hueber, S., Neumeister, L. 2005: Deutsche Pestizidexporte – Die globalisierte Gefährdung [Germen pesticide exports – a globalised threat]. Pestizid Aktions-Netzwerk e. V. Germany (PAN), Hamburg www.pan-germany.org/download/globale_gefaehrdung.pdf

IAASTD (International Assessment of Agricultural Knowledge, Science and Technology for Development) 2008: Executive Summary of the Synthesis Report of the IAASTD; Johannesburg

IE (Institut für Energetik und Umwelt) 2007: Monitoring for the effect of the amended Erneuerbare Energien Gesetz (EEG = Sustainable Energy Law) on the development of power generation from biomass, a study commissioned by BMU; Leipzig

IEA Bioenergy Task 38: Greenhouse Gas Balances of Biomass and Bioenergy Systems http://www.ieabioenergy-task38.org

IEA Bioenergy Task 40: Sustainable International Bioenergy Trade http://www.bioenergytrade.org

IFEU (Institute for Energy and Environmental Research) 2004: CO_2 Mitigation through Biofuels in the Transport Sector. Status and Perspectives; Quirin M. et al.; prepared for the Research Association Combustion Engines (FVV); Frankfurt

IFEU (Institute for Energy and Environmental Research) 2006: An Assessment of Energy and Greenhouse Gases of NExBTL; commissioned by Neste Oil Corporation; Porvoo, Finland

IFEU (Institute for Energy and Environmental Research) 2006: LCA for Biomass-to-Liquid fuels - An overall environmental assessment; Reinhardt, G. et al., prepared for the Agency of Renewable Resources (FNR); Heidelberg

IFEU (Institute for Energy and Environmental Research)/Wuppertal-Institut 2007: Rain Forest for Biodiesel? Ecological effects of using palm oil as a source of energy; on behalf of WWF

IFEU/FSC/Germanwatch 2008: Criteria for a Sustainable Use of Bioenergy on a Global Scale; R+D Project No. 206 41 112 commissioned by the German Federal Environment Agency (UBA); Heidelberg/Freiburg/Bonn

IIASA (International Institute of Applied System Analysis)/FAO (Food and Agricultural Organization of the United Nations) 2008: Compilation of selected global indicators of land degradation; Progress report November 2008; Land Degradation Assessment in Dry Lands Project (LADA); Rome

Ingham, E. 1998. The Soil Foodweb: It's Importance in Ecosystem Health at http://www.rain.org/~sals/ingham.html

IPCC (Intergovernmental Panel on Climate Change) 2006: IPCC Guidelines for National Greenhouse Gas Inventories; prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds); published: IGES, Japan http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm

IPCC (Intergovernmental Panel on Climate Change) 2007: Climate Change 2007: Impact, Adaptation and Vulnerability, Contribution of Working Group II to the 4th Assessment Report of the IPCC; Cambridge University Press, New York

IUCN 2004: Comparing the Ecosystem Approach with sustainable use; information paper, 7th meeting of the Conference of the Parties to the Convention on Biological Diversity (COP7), Kuala Lumpur

Junge, B. et al. 2008: Soil conservation in Nigeria: Past and present on-station and on-farm initiatives; Soil and Water Conservation Society, Ankeny, Iowa http://www.swcs.org/documents/filelibrary/SoilConservationInNigeria.pdf

Karlen D.L., Ditzler, C., Andrews, S.S. 2003: Soil quality: why and how?; in: GEODERMA vol. 114: 145-156

Karlen, D.L. 1997: Soil quality: A concept, definition, and framework for evaluation; in: Soil Sci. Soc. Am. J. 61:4-10

Karlen, D.L. et al. 2008: Soil quality assessment: Past, present and future; in: J. Integr. Biosci. 6:3-14

Kniivila, M. 2004: Land degradation and land use/cover data sources; working paper, Department of economic and social affairs

Langhammer, PF et al. 2007: Identification and gap analysis of key biodiversity areas: Targets for comprehensive protected area systems; IUCN; Gland

Larson, Eric D. 2005: A review of LCA Studies on Liquid Biofuel Systems for the Transport Sector; Background Paper for the GEF-STAP Liquid Biofuels Workshop; Princeton Environmental Institute http://stapgef.unep.org/activities/technicalworkshops/biofuels

Lasco, R.D. et al 2002. Carbon Dioxide (CO_2) storage and sequestration of land cover in the Leyte Geothermal reservation; in: Renewable Energy (25)

Laurance, WF et al. 2002: Ecosystem decay of Amazonian forest fragments: a 22-year investigation; in: Conservation Biology 16:605-618

Lehner, B., Döll, P. 2004: Development and validation of a global database of lakes, reservoirs and wetlands; in: Journal of Hydrology 296:1–22

Liang L.H. et al. 2001: Biodiversity conservation through agrodiversity; in: Global Environmental Change-Human and Policy Dimensions 11:97-101

Lindenmayer, D., Fischer, J. 2006: Habitat fragmentation and landscape change: An ecological and conservation synthesis; Washington DC (Island Press)

Liniger, H. et al. 2008: A Questionnaire for Mapping Land Degradation and Sustainable Land Management: CDE/WOCAT, FAO/LADA, ISRIC; Rome

Loh, J., Wackernagel, M. 2004: The living planet report; WWF; Gland

Louwagie, G., Gay. S., Burrell A. (eds.) 2009: Addressing soil degradation in EU agriculture: relevant processes, practices and policies; report EUR 23767 EN

Loveland et al. 1999: Development of a global land cover characteristics database and IGBP Discover from 1-km AVHRR data; in: International Journal of Remote Sensing

Mace, G. et al. 2005: Biodiversity. Pp. 77-122 in: Hassan, R. et al. (eds). Ecosystems and human well-being: Current state and trends, Volume 1, The Millennium Ecosystem Assessment Series; Washington DC (Island Press)

Macedo, Isaias et al. 2004: Greenhouse Gas Emissions in the production and use of ethanol in Brazil: present situation (2002); Secretaria de Meio-Ambiente do Estado de São Paulo

Margules, C.R., Pressey, R.L. 2000: Systematic conservation planning; in: Nature 405:243-253

McNeely J.A., Scherr S.J. 2003: Ecoagriculture: Strategies To Feed The World And Save Wild Biodiversity; Washington DC (Island Press)

Mittermeier, R.A. 2005: Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions; University of Virginia, Sierra Madre

Mittermeier, R.A. et al. 1998: Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities; in: Conservation Biology 12: 516-520

Mittermeier, R.A. et al. 2003: Wilderness and biodiversity conservation; in: Proceedings of the National Academy of Sciences of the United States of America 100: 10309-10313

MNP (Milieu en Natuur Planbureau) 2007a: Biomass Assessment: Global biomass potentials and their links to food, water, biodiversity, energy demand and economy (main report)

MNP (Milieu en Natuur Planbureau) 2007b: Biomass Assessment: Assessment of the applicability of biomass for energy and materials (supporting documents)

Morton, D. et al. 2007: Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon; in: PNAS Early Edition, available at www.amazonia.org.br

Mueller L. et al. 2007: The Muencheberg Soil Quality Rating (SQR). Field manual for detecting and assessing properties and limitations of soils for cropping and grazing; Leibniz-Centre for Agricultural Landscape Research (ZALF) e. V., Muencheberg
http://www.zalf.de/home_zalf/institute/blf/blf_e/mitarbeiter/mueller/pdf/field_mu

eller.pdf

Nachtergaele, Freddy 2005: Introduction to the Land Degradation Assessment in Drylands (LADA) project; presentation held on the Regional Workshop to Present PAP/RAC - FAO Experiences in Combating Land Degradation in Mediterranean Coastal Areas, 10-12 Oct. 2005, Rome ftp://ftp.fao.org/agl/agll/faopaprac/topic1/LADAIntroduction.pdf

Nachtergaele, Freddy 2008: Mapping Land Use Systems at global and regional scales for Land Degradation Assessment Analysis; LADA Project Publication; Rome

National Research Council 2002: Down to Earth: Geographic Information for Sustainable Development in Africa; Washington DC

Neumeister, L. 2001: Beyond POPs – Evaluation of the UNEP chemical substitutes of the POPs pesticides regarding their human and environment toxicity. Pestizid Aktions-Netzwerk e.V. (PAN Germany), Hamburg http://www.pan-germany.org/download/beyond-pops.pdf

Neumeister, L./Reuter, W. 2008: Die schwarze Liste der Pestizide [The black list of pesticides]. Greenpeace; Hamburg www.greenpeace.de/fileadmin/gpd/user_upload/themen/umweltgifte/Schwarze_Liste_Pestizide_final.pdf

OECD (Organization for economic co-operation and development) 2008: Environmental Outlook to 2030; Paris

OEKO (Öko-Institut – Institute for applied Ecology) 2004: Stoffstromanalyse zur nachhaltigen energetischen Nutzung von Biomasse; Darmstadt/Berlin www.oeko.de/service/bio

OEKO (Öko-Institut – Institute for applied Ecology) 2007: Bioenergy and Nature Protection: Are Synergies Possible from Energy Use of Land Management Residues? K. Wiegmann et al., Final Report for the Federal Ministry for Environment; Darmstadt (in German) www.oeko.de/service/naturschutz

Oldeman, L et al. 1991: World map of the status of human-induced soil degradation: an explanatory note; International Soil Reference and Information Centre/UNEP; Wageningen/Nairobi http://www.isric.org/isric/webdocs/Docs/ISRIC_Report_1991_07.pdf

Oldeman, L. et al. 1991: World map of the status of human-induced soil degradation: an explanatory note; International Soil Reference and Information Centre (ISRIC)/UNEP Global Assessment of Soil Degradation GLASOD. 2nd. edition; Wageningen/Nairobi

Oldeman, L., van Lynden, G. 2001: Linking methodologies for assessing land resources, their problems and possible solutions at small scales; in: Bridges, M. et al. (eds.) Responses to Land Degradation. Proc. 2nd. Int. Conf. on Land Degradation and Desertification; New Delhi (Oxford Press)

Olson, D.M. et al. 2001: Terrestrial ecoregions of the world: A new map of life on Earth; in: BioScience 51: 933–938

Olson, D.M., Dinerstein, E. 2002. The global 200: priority ecoregions for global conservation; in: Ann. Missouri Bot. Gard. 89: 199–224

Oppermann, R. et al. 2007: Interim Report for the R&D project „Development of the High Nature Value Farmland Indicator", FKZ 350780800 of the Federal Agency for Nature Protection (BfN) – in German

Redford, K.H. et al. 2003: Mapping the Conservation Landscape; in: Conservation Biology 17: 116-131

Renard, K.G. et al. 1997: Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture; Agriculture Handbook 703

RFA (Renewable Fuels Agency) 2008: The Gallagher Review of the indirect effects of biofuels production; St Leonards-on-Sea www.dft.gov.uk/rfa/_db/_documents/Report_of_the_Gallagher_review.pdf

Rhoades JD, Chanduvi F, Lesch S. 1999: Soil salinity assessment - Methods and interpretation of electrical conductivity measurements. FAO irrigation and drainage paper 48, Rome ftp://ftp.fao.org/agl/aglw/docs/idp57.pdf

Rhoades JD., Kandiah A., Mashali AM 1992: The use of saline waters for crop production. FAO irrigation and drainage paper 48, Rome http://www.fao.org/docrep/T0667E/T0667E00.htm

Ricketts, T.H. 2005: Pinpointing and preventing imminent extinctions; in: Proceedings of the National Academy of Sciences of the United States of America 102: 18497-18501

Ricketts, T.H. et al. 1999: Terrestrial Ecoregions of North America: A conservation assessment; Washington DC (Island Press)

Ries, L. et al. 2004: Ecological responses to habitat edges: Mechanisms, models, and variability explained; in: Annual Rev. Ecol. Evol. Syst. 35:491-522

Riitter, K. et al. 2000: Global-scale patterns of forest fragmentation; in: Conservation Ecology 4(2):3 http://www.consecol.org/vol4/iss2/art3/

Riksen, M., Arrue, J.L., Lopez, M.V. 2002: What to do about wind erosion. In: Wind erosion on agricultural land in Europe; A. Warren (ed.); EUR 20370 EN, p. 39-52; Luxembourg

Rounsevell, MDA., Jones, RJA. 1993: A soil and agro-climatic model for estimating machinery workdays: the basic model and climatic sensitivity. Soil and Tillage Research 26: 179-191

Royal Society 2008: Sustainable Biofuels: Prospects and Challenges. RS Policy document 01/08; The Royal Society; London

Sagar, A.D., Kartha, S. 2007: Bioenergy and sustainable development? In: Annual Review of Environment and Resources 32:131-167

Salvatore et al. 2005: Mapping global urban and rural population distributions; FAO Environmental Natural Resources Working Paper No. 24; Rome.

Sanderson, E.W. et al. 2002: The human footprint and the last of the wild; in: Bioscience 52:891–904.

Scales, B.R., Marsden, S.J. 2008: Biodiversity in small-scale tropical agroforests: a review of species richness and abundance shifts and the factors influencing them; in: Environmental Conservation 35:160-172

Schmitt, C.B. et al. (eds.) 2007: A global network of forest protected areas under the CBD: Opportunities and challenges; in: Proceedings of an international expert workshop held in Freiburg, Germany, May 9-11, 2007; Remagen

Scholes, R.J., Biggs, R. 2005: A biodiversity intactness index; in: Nature 434:45-49

Schroers, J. 2006: Zur Entwicklung der Landnutzung auf Grenzstandorten in Abhängigkeit agrarmarktpolitischer, agrarstrukturpolitischer und produktionstechnologischer Rahmenbedingungen – eine Analyse mit dem Simulationsmodell ProLand. Dissertation. Fachbereichs Agrarwissenschaften, Ökotrophologie und Umweltmanagement. Justus-Liebig-Universität Gießen

Scott, M.J. et al. 2001: Nature reserves: do they capture the full range of America's biological diversity?; in: Ecological Applications 11: 999-1007

Searchinger, Timothy et al. 2008: Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change; in: Science, 319, 1238-1240

Shi, X.Z. et al. 2004. Soil Database of 1:1,000,000 Digital Soil Survey and Reference System of the Chinese Genetic Soil Classification System; in: Soil Survey Horizons 45:129-136

Smith, R., Gross, K., Robertson, G. 2008: Effects of crop diversity on agroecosystem function: Crop yield response; in: Ecosystems vol. 11, p. 355-366

Smith, R.D., Maltby E. 2003: Using the Ecosystem Approach to Implement the Convention on Biological Diversity: Key Issues and Case Studies. IUCN, Gland/Cambridge

SRU (Sachverständigenrat für Umweltfragen) 2007: Klimaschutz durch Biomasse – Sondergutachten; Berlin

SSSA (Soil Science Society of America) 1997: Glossary of soil science terms 1996. Soil Science Society of America Inc., Madison WI

Stattersfield 1998: Endemic bird areas of the world. Priorities for biodiversity conservation; Bird Life International; Cambridge

Strand, H. et al. (eds.) 2007: Sourcebook on Remote Sensing and Biodiversity Indicators; Secretariat of the Convention on Biological Diversity; Technical Series no. 32; Montreal

Strittholt, J. et al. 2007: Coverage of protected areas; in: Strand, H et al. (eds.) 2007, p. 131-141

Sudfeld, C. 2002: Important Bird Areas in Deutschland; in: Ber. Vogelschutz 38: 17-109

TUM (Technical University of Munich)/TUB (Technical University of Berlin) 2008: Übertragbare Strategie zur naturverträglichen Biomassebereitstellung auf Landkreisebene - Am Beispiel des Landkreises Ostprignitz-Ruppin in Brandenburg und des Chiemgaus in Bayern [Transferrable strategy for compatible biomass provision on district scale]. Final Report to the Deutsche Bundesstiftung Umwelt (DBU) (to be published)

UN-Energy 2007: Sustainable Bioenergy: A Framework for Decision Makers; United Nations; New York ftp://ftp.fao.org/docrep/fao/010/a1094e/a1094e00.pdf

UNEP (United Nations Environment Programme) 2004: Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach; Abaza, Hussein/Bisset, Ron/Sadler, Barry; UNEP-DTIE, Paris http://www.unep.ch/etb/publications/EnvImpAss/textONUBr.pdf

UNEP (United Nations Environment Programme) 2006: Global Deserts Outlook; Nairobi http://www.unep.org/geo/gdoutlook/

UNEP (United Nations Environment Programme) 2007: Global Environment Outlook 4. Environment for Development; Nairobi http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf

UNEP (United Nations Environment Programme) 2008: Existing knowledge and limits of scientific assessment of the sustainability impacts due to biofuels by LCA methodology; Menichetti, Emanuela/Otto, Martina; Paris

UNEP (United Nations Environment Programme)/UNCTAD (United Nations Conference on Trade and Development) 2008: Best Practices for Organic Policy - What developing country Governments can do to promote the organic agriculture sector; New York http://www.unep.ch/etb/publications/UNCTAD_DITC_TED_2007_3.pdf

UNEP (United Nations Environment Programme)/UNCTAD (United Nations Conference on Trade and Development) 2008: Organic Agriculture and Food Security in Africa; New York http://www.unctad.org/en/docs/ditcted200715_en.pdf

van Cauwenbergh, N. et al. 2007: SAFE - A hierarchical framework for assessing the sustainability of agricultural systems; in: Agricultural Ecosystems and Environment 120:229-242

van Lynden 2000: Soil degradation in Central and Eastern Europe: The assessment of the status of human-induced degradation (ver. 1.0); ISRIC Report 2000/05; Wageningen

van Velthuizen, H. et al. 2007: Mapping biophysical factors that influence agricultural production and rural vulnerability; ENVIRONMENT AND NATURAL RESOURCES SERIES 11; FAO/IIASA; Rome ftp://ftp.fao.org/docrep/fao/010/a1075e/a1075e00.pdf

WAB (Wetenschappelijke Assessment en Beleidsanalyse) 2007: Biomass assessment: Assessment of the applicability of biomass for energy and materials; Netherlands Environmental Assessment Agency; Bilthoven

Wassenaar, T. et al. 2007: Projecting land use changes in the Neotropics: The geography of pasture expansion into forest; in: Global Env. Change 17:86-104

Weber, C. 2001: FAO und WHO warnen vor Pestiziden mit geringer Qualität. [FAO and WHO warn of low quality pesticides]. From: Pesticide-Letter, January/February 2001 www.pan-germany.org/deu/~news-311.html

Weber, C. 2008: Pestizid Aktions-Netzwerk e.V. (PAN): Personal communication, March

WHO (World Health Organization) (2006): Guidelines for the safe use of wastewater, excreta and grey water – Volume 2: Wastewater use in agriculture. WHO, France http://whqlibdoc.who.int/publications/2006/9241546832_eng.pdf

Wikramanayake, E.D. et al. 2002: Terrestrial Ecoregions of the Indo-Pacific: A conservation assessment; Washington DC (Island Press)

Wischmeier W.H., Smith D.D. 1978: Predicting rainfall erosion losses – a guide for conservation planning. USDA Agriculture Handbook 537

WOCAT (World Overview of Conservation Approaches and Technologies) (2007): Where the land is greener – case studies and analysis of soil and water conservation initiatives worldwide. Editors: Liniger, H. and Critchley, W. Centre for Development and Environment (CDE), Bern

WOCAT (World Overview on Conservation Approaches and Technologies) 2007: Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide; Stämpfli AG, Bern

World Bank (International Bank for Reconstruction and Development) 2008a: Strategic Environmental Assessment for Policies: An Instrument for Good Governance, Ahmed, K., Sanchez-Triana, E. (eds.); Washington DC http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/0,,contentMDK:21819527~isCURL:Y~menuPK:2453820~pagePK:148956~piPK:216618~theSitePK:244381,00.html

World Bank (International Bank for Reconstruction and Development) 2008b: Toxic pollution from agriculture – An emerging story; Washington DC http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:21139876~pagePK:64165401~piPK:64165026~theSitePK:469382,00.html

WRB (World Reference Base for Soil Resources) 2006: A framework for international classification, correlation and communication. World Soil Resources Report No.103; FAO; Rome

WRI (World Resources Institute) 2008: http://earthtrends.wri.org/updates/node/264

Wuppertal-Institut/IFEU/FUER 2007: Sozial-ökologische Bewertung der stationären energetischen Nutzung von importierten Biokraftstoffen am Beispiel von Palmöl; prepared for BMU; Berlin

WWAP (World Water Assessment Programme) 2006: United Nations Water Development Report. Water: A Shared Responsibility; Paris/London www.unesco.org/water/wwap/wwdr/wwdr2

WWAP (World Water Assessment Programme) 2009: United Nations Water Development Report 3: Water in a Changing World; Paris/London www.unesco.org/water/wwap/wwdr/wwdr3

WWF (World-Wide Fund for Nature) 2006: Sustainability Standards for Bioenergy; Fritsche, U., Hünecke, K., Wiegmann, K. (Öko-Institut), prepared for WWF Germany; Darmstadt/Berlin http://www.oeko.de/service/bio/dateien/wwf.pdf

WWI (Worldwatch Institute) 2007: Biofuels for Transportation - Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century; Hunt, Suzanne et al.; London (Earthscan)

Young, C. P. 1986: Nitrate in groundwater and the effects of ploughing on release of nitrate; in: Effects of Land Use on Fresh Waters, p. 221–237; Chichester

8 Glossary

Abandoned farmland refers to unused areas within a cultural landscape where former agricultural activities have been given up (Schäfer 1992).

Agriculture comprises every systematic cultivation form of soil by crop crowing or creating of grassland for animal production (Schäfer 1992).

Agricultural biodiversity, sometimes called '**agrobiodiversity**', encompasses the variety and variability of animals, plants and micro-organisms which are necessary to sustain key functions of the agro-ecosystem, its structure and processes for, and in support of, food production and food security (FAO/CBD, Workshop 1998)[102]. The term agro-biodiversity encompasses within-species, species and ecosystem diversity.[103]

Biological diversity (=biodiversity) means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, article 2).[104]

Cultivated and Managed Terrestrial Areas refers to areas where the natural vegetation has been removed or modified and replaced by other types of vegetative cover of anthropogenic origin. This vegetation is artificial and requires human activities to maintain it in the long term. All vegetation that is planted or cultivated with the intention to harvest is included (e.g., wheat fields, orchards, rubber and teak plantations).[105]

Degraded land is characterized by a long-term decline in ecosystem function and productivity and measured in terms of net primary productivity (Bai et al. 2008; GLADA project). Land degradation has also be defined as a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided (UNEP 2007), or as the decline of natural land resources, commonly caused by improper use of the land (Bergsma et al. 1996).

Ecoregions are relative large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change.

Ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.[106]

Fallow within the agricultural sector describe the interruption cultivation for one or several vegetation periods to achieve a refreshment/improvement of soil fertility (Schäfer 1992, see also → abandoned farmland and → shifting cultivation).

---

102 see http://iufro-archive.boku.ac.at/silvavoc/glossary/2_1en.html and further definitions on this website

103 EEA Glossary: http://glossary.eea.europa.eu/EEAGlossary/A/agrobiodiversity

104 http://www.cbd.int/convention/articles.shtml?a=cbd-02

105 http://www.fao.org/DOCREP/003/X0596E/x0596e01f.htm#p381_40252

106 Article 2 of the Convention on Biological Diversity , see http://www.cbd.int/ecosystem/description.shtml

Forestry is the art, science, and practice of studying and managing forests and plantations, and related natural resources. Modern forestry generally concerns itself with: assisting forests to provide timber as raw material for wood products; wildlife habitat; natural water quality regulation; recreation; landscape and community protection; employment; aesthetically appealing landscapes; biodiversity management; watershed management; and a 'sink' for CO_2.

Grassland refers to vegetation types characterized by a dominant and continuous grass layer and no or a low cover of trees and shrubs. Grassland comprises steppes, some savanna types, arid grassland as well as meadow and pasture (Schäfer 1992).

High Conservation Value areas (HCV) are critical areas in a landscape which need to be appropriately managed in order to maintain or enhance HCV. There are six main types of HCV, based on the definition originally developed by the FSC to certify forests, but increasingly applied to assessments of other ecosystems[107]:

HCV1. Areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia).

HCV2. Globally, regionally or nationally significant large landscape-level areas where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.

HCV3. Areas that are in or contain rare, threatened or endangered ecosystems.

HCV4. Areas that provide basic ecosystem services in critical situations (e.g. watershed protection, erosion control).

HCV5. Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).

HCV6. Areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

High nature value (HNV) farmland comprises the core areas of biological diversity in agricultural landscapes. They are often characterized by extensive farming practices, associated with a high species and habitat diversity or the presence of species of conservation concern (EEA 2004, 2005).

High Conservation Value Forests (HCVF) are those that possess one or more of the following attributes: (1) Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia). (2) Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance. (3) Forest areas that are in or contain rare, threatened or endangered ecosystems. (4) Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control). (5) Forest areas fundamental to meeting basic needs

---

107 http://www.bioenergywiki.net/images/b/b3/Env_paper_6_-_HCV_Areas.pdf as well as http://hcvnetwork.org/about-hcvf/The%20high-conservation-values-folder

of local communities (e.g. subsistence, health). (6) Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities) (FSC 2000).

Land use is series operation on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources (de Bie 2002).

Marginal land is defined as an area where a cost-effective production is not possible, under given side conditions (e.g. soil productivity), cultivation techniques, agriculture policies as well as macro economic and legal conditions (Schroers 2006).

Natural vegetation is defined as areas where the vegetative cover is in balance with the abiotic and biotic forces of its biotope.[108]

Protected areas are defined by the IUCN as "an area of land and/or sea especially dedicated to the protection and maintenance of biodiversity, and of natural and associated cultural resources, and managed through legal or other effective means". This definition is similar to the one adopted by the Convention on Biological Diversity (CBD), which defines a protected area as "a geographically defined area that is designated or regulated and managed to achieve specific conservation objectives" (Dudley/Phillips 2006).

Shifting cultivation is an agricultural system in which plots of land are cultivated temporarily, and then abandoned. This system often involves clearing of a piece of land followed by several years of wood harvesting or farming until the soil loses fertility. Once the land becomes inadequate for crop production, it is left to be reclaimed by natural vegetation, or sometimes converted to a different long term cyclical farming practice.[109]

Semi-natural vegetation is defined as vegetation not planted by humans but influenced by human actions. It includes vegetation due to human influences but which has recovered to such an extent that species composition and environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. These may result from grazing; possibly overgrazing the natural phytocenoses, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed. Other examples are previously cultivated areas which have been abandoned and where vegetation is regenerating as well as secondary vegetation developing during the fallow period of shifting cultivation.[110]

Sustainable use means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations (CBD, article 2).[111]

Used land and unused land refer more to a gradual change from intensely used land towards land that is not influenced by any land-use form. Agriculture and forestry (see definition above) as well as infrastructure can clearly be considered as **used land** to meet

108 http://www.fao.org/DOCREP/003/X0596E/x0596e01f.htm#p381_40252

109 http://en.wikipedia.org/wiki/Shifting_cultivation

110 http://www.fao.org/DOCREP/003/X0596E/x0596e01f.htm#p381_40252

111 http://www.cbd.int/convention/articles.shtml?a=cbd-02

humans needs (food, fodder, fiber, and infrastructure), whereas for extensive land-use forms (e.g. collection of medicinal plants or sporadic hunting) it is difficult to decide up to which use-intensity land is still considered as unused land. The terms unused land and **idle land** can be used synonymously.

Unused land comprises abandoned farmland, degraded, devastated and waste land as well as areas of undisturbed wildlife.

9 Abbreviations

AKST	Agricultural Knowledge, Science and Technology
AZE	Alliance for Zero Extinction
BSO	Biofuels Sustainability Ordinance (Germany)
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CI	Conservation International
EEG	Renewable Energy Sources Act (Germany)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRA	Global Forest Resources Assessment
FSC	Forest Stewardship Council
GIS	Geographical information system (with digital spatial database)
GLC 2000	Global Land Cover 2000
HNVC	Area of High Nature Conservation Value
IUCN	International Union for the Conservation of Nature and Natural Resources
NGO	Non-governmental organization
OEKO	Öko-Institut (Institute for applied Ecology)
PA	Protected Area
PoWPA	Programme of Work on Protected Areas
TNC	The Nature Conservancy
UBA	German Federal Environment Agency (Umweltbundesamt)
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
WCMC	UN World Conservation Monitoring Centre
WWF	World-Wide Fund for Nature

Annex A: Examples for Settings on the Country Level

Table A- 1 Example for Setting: La Pampa province, Argentina - Soybean production for biodiesel

Key Data for Setting	Type of data	Unit	Value	Remarks
Location	GIS	Deg	Latitude: -36.34 (South) Longitude: -64.16 (West)	Based on capital Santa Rosa – La Pampa province – AR
Climate	*temperature (mean, min/max), humidity, precipitation; frost (if any):* Average annual temperature: Average temperature July Average temperature January Precipitation Frost days	 °C °C °C mm/year Descriptive	 14 (NW) -16 (W) 7-8 22-24 500 (centre of La Pampa) 604.35 (Anguil) Limited number of days/year	
Cultivation system	text: crop and intensity of management; rotation (if any)	Crop: System:	Soybean Intermediate production Direct seeding + reduced tillage	
Previous land use	pre-project land use systems (if any)	Description	Various: a) Abandoned cropland b) Degraded grassland	

Key Data for Setting	Type of data	Unit	Value	Remarks
Soil	AEZ soil quality characteristics	Description	HAC soils (including Molisols)	Molisols dominate in the province
Water	volume of (seasonal) rainfall	mm/year	604.35	Based on Anguil (average year 2006-2007)
	Water Stress Index	- mm/month	January: 63.8 April: 22.0 July: 1.5 September: 79.9	Negative number: shortage Based on monthly rainfall data Anguil (average year 2006-2007)
Yield	Annual net primary production (biomass growth) for cultivation scheme	tdm/ha*a GJ/ha*a	S: 2.1 tdm/ha*a mS: 1.3 tdm/ha*a 18% oil content S: 0.01 GJ/ha*a mS: 0.007 GJ/ha*a *+ additional by-products*	By-product from soybean is meal.
Land	Costs of rent	€/ha*a	S land: 102 mS land: 88	
Equipment	Capital costs	€/ha	O&M: 11.7	
	fixed annual costs	€/ha*a	Marketing costs: 29.97 Monitoring costs: 3.0	

Key Data for Setting	Type of data	Unit	Value	Remarks
Agrochemicals	Amount of fertilizers used	t/ha*a	- (in this scenario)	
	Prices of fertilizer used	€/t	Urea: 327 Phosphate monomaniac: 388	
	Amount of pesticides used Herbicides: Insecticides:	 l/ha*a kg/ha*a kg/ha*a l/ha*a l/ha*a l/ha*a	S land: Roundup Full II: 3.5 Metsulfuron: 0.008 Roundup Max: 2.7 Cipermetrina: 0.15 Lorsban: 1.4 Opera: 0.5	mS land: Roundup Full II: 2.13 Metsulfuron: 0.005 Roundup Max: 1.64 Cipermetrina: 0.09 Lorsban: 0.85 Opera: 0.3
	Prices of pesticides used: Herbicides: Insecticides:	 €/l €/kg €/kg €/l €/l €/l	 Roundup Full II: 8.8 Metsulfuron: 22.5 Roundup Max: 12.1 Cipermetrina: 3.8 Lorsban: 4.0 Opera: 20.5	
Labor	Wages	€/person*hour	2.0	
	Persons employed or	Work	1.07	

Key Data for Setting	Type of data	Unit	Value	Remarks
	work load	hours/ha*a		
Energy	Amount on inputs (fuel, electricity)	GJ/ha*a or MWh/ha*a	0.98 GJ/ha (fuel input) Electricity: -	27.7 l/ha
	Prices of inputs (fuel, electricity)	€/GJ €/MWh	Fuel: 9.3 Electricity: 2.0	0.33 €/liter (diesel price) 0.02 €/kWh

Notes:

Prices are based on prices from 2007 to early 2008. The conversion of prices from US$ to € is based on February 2008 (1€=1.47 US$)

Source:

- J. van Dam, A.P.C. Faaij, J. Hilbert, H. Petruzzi, W.C. Turkenburg (2009) Large-scale bioenergy production from soybeans and switchgrass in Argentina, Part A: Potential and economic feasibility for national and international markets. In: Renewable and Sustainable Energy Reviews, in press.
- J. van Dam, A.P.C. Faaij, J. Hilbert, H. Petruzzi, W.C. Turkenburg (2009) Large-scale bioenergy production from soybeans and switchgrass in Argentina, Part B: Environmental and socio-economic impacts on a regional level. In: Renewable and Sustainable Energy Reviews, in press.

Table A- 2 Example for Setting: Ethanol from Sugar Cane in Brazil

Key Data for Setting	Type of data	Unit	Value	Remarks
Location	GIS	DEG	Latitude:23°33' Longitude:46°38'	Climate data are for the city of São Paulo
Climate	Lowest temperature Maximum temperature Rainfall	°C °C mm/a	12 27 1350	Most rainfall occurs during the summer months.
Cultivation system	Sugar cane, conventional intensive management (ploughing, application of agro-chemicals, lime and fertilizers, mechanical harvesting; no irrigation; 5 harvests per 5 year growing cycle.			Mechanical harvesting can only be applied on slopes below 12%.
Previous land use	Depends on the site. Anecdotic information indicates that sugar cane replaces conventional agricultural land, namely pasture land, cropland and fruit orchards. .			Only anecdotic information is available.
Soil	AEZ soil quality characteristics			
Water	volume of (seasonal) rainfall	l/ha*a	1350	
	Water Stress Index		unknown	
Yield	Annual net primary production (biomass growth) for cultivation scheme	t/ha*a	67	Cane stalks only
Land	Costs of rent	€/ha*a		
Equipment	Capital costs	€/ha		Varies widely, depending

Key Data for Setting	Type of data	Unit	Value	Remarks
	Fixed annual costs	€/ha*a		on the harvesting system (manual or mechanical)
Agrochemicals	Amount of N in fertilizers used Amount of P2O5 in fertilizers used Amount of K2O in fertilizers used Amount of lime	kg/ha*a kg/ha*a kg/ha*a kg/ha*a	30/80 120/25 120/120 367	Data are for plant cane / ratoon. The application of vinasse and filter mud cake can reduce the need for fertilizers
	Prices of fertilizer used	US $/t	NPK compound 2-20-201 96 4-14-82 96 4-20-203 95 5-25-154 99 12-6-125 96 20-5-206 90 Amm. sulph. 94 Urea 83 Average 94	
	Fungicides Insecticides Araricides Other defensives	kg/ha*a kg/ha*a kg/ha*a kg/ha*a	0.00 0.12 0.00 0.04	Data refer to kg active ingredient

Key Data for Setting	Type of data	Unit	Value	Remarks
	Herbicides	kg/ha*a	2.20	
	Prices of pesticides used	€/t	N/A	
Labor	Wages	€/pers.*month	247	Average sugar cane sector
	Persons employed or work load	pers/ha*a	2	Estimated
Energy	Amount on inputs (fuel, electricity)	GJ/ha*a	~2108	
	Prices of inputs (fuel, electricity)	€/ha*a	138	

Sources:

- Smeets E, Junginger M, Faaij A, Walter A, Dolzan P, Turkenburg W. The sustainability of Brazilian ethanol--An assessment of the possibilities of certified production. Biomass and Bioenergy 2008;32:781-813.
- Macedo IC. Sugar cane's energy. Twelve studies on Brazilian sugar cane agribusiness and its sustainability. UNICA; 2005, p. 237.
- Macedo IC, Leal MRLV, Da Silva JEAR. Assessment of greenhouse gas emissions in the production and use of fuel ethanol in Brazil. Brazil: Secretariat of the Environment of the State of São Paulo; 2004, p. 32.

Annex B Databases and Products

The following collection of databases and products related to the biodiversity (Section 2), soil (Section 3) and water (Section 4) comprises the topics listed below. The focus is on globally available data. In some cases, also regional data sources are given.

1. Protected Areas, areas of high biodiversity and areas of undisturbed wildlife
2. Land Classification Systems and Land-Cover Mapping
3. Forests
4. Wetlands
5. Degraded Land
6. Agricultural Production and Land Use
7. Soil, Slope and Elevation
8. Water, Hydrology and Climate

The overall structure of the database and product tables is as follows

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Name or Acronym	What is the aim, who is the user? What is the content? **Guidance on using the source**	web link to data or literature Information on spatial cover (global, regional, national), GIS data (in brackets if yes) resolution (site-specific or not, or resolution), link to or inclusion of other products?, data quality (data base, year of acquisition and update)

Table A- 3 Databases on Protected Areas, areas of high biodiversity and of undisturbed wildlife

Database / Product	Scope / Content	Reference / Availability / Quality
Integrated Biodiversity Assessment Tool (IBAT)	IBAT provides information on high-priority areas for conservation, whether formally protected or not. The site-scale information including Key Biodiversity Areas (KBAs), Important Bird Areas (IBAs), and Alliance for Zero Extinction (AZE) sites in at least 173 countries, and data from the World Database on Protected Areas (WDPA). IBAT is a response to the need identified by companies to have available fine-scale biodiversity data to incorporate into decision-making processes and management strategies. This information is directly relevant to a number of other stakeholders as well, for example in the creation of national development and conservation strategies. **<u>Evaluation:</u> IBAT provides information including GIS maps on above mentioned areas and brings together different databases of biodiversity relevant areas, legally protected or not, which need to be considered at the beginning of decision making processes. A map viewer at the web site depicts GIS information at country level according to different categories (definition of conditions and uses). IBAT can be used as a starting point to locate sites that are unsuitable for bioenergy feedstock production and those that may be suitable after further ground truth.**	www.ibatforbusiness.org Globally available (GIS), site-specific information. IBAT is a global meta-database for other datasets; its quality depends on quality of the original data. IBAT was published in October 2008 and will be up-dated regularly. Required registration for accessing and downloading the data. Scale of data application: national, provincial and local.
World	The WDPA plays a critical role in measuring progress	Strittholt et al. 2007; http://www.unep-wcmc.org/wdpa/index.htm ;

Database / Product	Scope / Content	Reference / Availability / Quality
Database on Protected Areas (WDPA)	toward global goals and targets for biodiversity protection and will function as a key support mechanism in the assessment and monitoring of protected area status and trends. The WDPA is compiled from multiple sources and is the most comprehensive global dataset on marine and terrestrial protected areas available. The WDPA stores key information about protected areas such as name, designation or convention, total area (including marine area), date of establishment, legal status and IUCN Protected Areas Management Category. It also stores the spatial boundary and/or location (where available) for each protected area in a Geographical Information System (GIS). **Evaluation: WDPA gives site specific information including GIS maps on national (catalogued or not by IUCN categories) and international protected areas (World Heritage Sites, Ramsar Sites, etc). Information on protected area categories (IUCN category/ international agreement definition) allows identifying restrictions and opportunities in decision making processes. National protected areas not catalogued should be reviewed according to the guidelines for applying protected areas management categories (IUCN)**	www.wdpa.org Integrated in IBAT. Globally available (GIS), site-specific information. GIS data are not available for all protected are as (publishing restriction). Current version was published in October 2008. Scale of application: national, provincial and local
Key	Key Biodiversity Areas (KBAs) are places of international	Center for Applied Biodiversity Science (CBS), Conservation

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Biodiversity Areas (KBA)	importance for the conservation of biodiversity through protected areas and other governance mechanisms. They are identified nationally using simple, standard criteria, based on their importance in maintaining populations of species (see criteria in Langhammer et al. 2007). As the building blocks for designing the ecosystem approach and maintaining effective ecological networks, key biodiversity areas are the starting point for landscape-level conservation planning. Governments, intergovernmental organizations, NGOs, the private sector, and other stakeholders can use key biodiversity areas as a tool to identify national networks of internationally important sites for conservation. The Mapping of High Nature Value Farmland (EEA 2004; http://reports.eea.europa.eu/report_2004_1/en) is of relevance for the detection of KBA in the cultural landscape of Europe. **o** **Evaluation:** **KBA give site-specific information including GIS maps on areas covering high biodiversity values. KBA need t be considered in decision making processes. Where KBA assessment is not yet completed, decision makers should make use of the KBA-tool to identify further biodiversity relevant areas**	International (CI); Langhammer et al. 2007; Integrated in IBAT (www.ibatforbusiness.org) or data available on request (www.conservation.org). Mapping was carried out, completely or partially, in 183 countries. Process still on going internationally. In some countries KBA do only refer to IBA or AZE. Globally available (GIS), site-specific information; national availability depends on progress in further mapping. Scale of data application: national and provincial.
Alliance for Zero Extinction	Prevent extinctions of species by identifying and safeguarding key sites, each one of which is the last remaining refuge of one or more Endangered or Critically	Ricketts et al. 2005; http://www.zeroextinction.org/search.cfm; Integrated in IBAT (data available on request, but with strong

Database / Product	Scope / Content	Reference / Availability / Quality
(AZE)	Endangered species. Location of 595 areas that worldwide harbor remaining populations of nearly 800 highly endangered species. See detailed mapping criteria under http://www.zeroextinction.org/overview.htm **<u>Evaluation:</u> AZE sites are included in the KBA database. Decision makers should use the AZE approach to identify local and provincial threatened species, and therefore key sites for them (example: Red Natura 2000).**	restrictions) Globally available (GIS), site-specific information. Scale of data application: national, provincial and local
Important Bird Areas (IBAs)	The IBA Program seeks to identify, document, and promote the conservation and sustainable management of a network of sites that are important for the long-term viability of naturally occurring bird populations across the geographic range of bird species for which a site-based approach is appropriate (see details on criteria for IBA in Fishpool 2004). The basis for this work is the World Bird Database (WBDB) containing 250,000 records. Endemic Bird Areas (EBA, http://www.birdlife.org/datazone/ebas/index.html) are the basis for the identification of IBA, but EBA are less site-specific. **<u>Evaluation:</u> IBA are included in the KBA database. They significantly contribute to identifying priority areas for global biodiversity conservation using birds as**	Stattersfield et al. 1998; Fishpool 2004; http://www.birdlife.org/datazone/index.html; Integrated in IBAT (data available on request) Globally available (GIS), site-specific information. Data are already available for 176 countries (www.birdlife.org/datazone), and data assessment is still ongoing. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	indicators, and their protection should be incorporated in decision-making processes. Additional local and regional identification of relevant areas for bird protection should be also taken into account by decision makers.	
Important Plant Areas (IPAs)	Knowledge on the location of IPAs shall contribute to "The Global Strategy for Plant Conservation" sets the overall target of protecting 50% of the world's most important areas for plant diversity by 2010, and should be used during decision making. Mapping of IPAs that are natural or seminatural sites exhibiting exceptional botanical richness and/or supporting an outstanding assemblage of rare, threatened and/or endemic plant species and/or vegetation of high botanic value. Additional information is provided by the Centers of Plant Diversity (North, Middle and South America, see http://botany.si.edu/projects/cpd/table_of_contents.htm) **Evaluation: IPA should be used during decision making processes to identify important areas of plan diversity. Where IPA assessment is not yet completed, decision makers should make use of the IPA-tool to identify further high botanic value areas**	http://www.plantlife.org.uk/international/plantlife-data-zone.html Globally available, site-specific information. Data collection had a strong focus on Europe, but is now expanded world wide. GIS information is not available. Scale of data application: national, provincial and local
Biodiversity	Mapping of Biodiversity Hotspots that contain at least 1,500	Mittermeier et al. 2005;

Database / Product	Scope / Content	Reference / Availability / Quality
Hotspots	species of vascular plants (> 0.5 percent of the world's total) as endemics, and the area has to have lost at least 70 percent of its original habitat. Available are the location of Biodiversity Hotspots (maps and GIS-data) and a species database. In some region, Biodiversity Hotspots are site specific; in other regions they cover rather large areas with fuzzy boundaries. As a global prioritization system, hotspots are extremely important in informing the flow of conservation resources, and also as an informative basis for public and private decision makers. Related to the Biodiversity Hotspots is the concept of High-Biodiversity Wilderness Areas (Mittermeier et al. 2003, http://www.conservation.org/explore/priority_ areas/wilderness/Pages/default.aspx), that represent areas of low human impact harbor a high amount of biodiversity. These sites, however, are characterized by a large-area extension. **Evaluation: Biodiversity Hotspots provide basic information for decision makers on global pattern of biodiversity. A provincial or local selection of suitable areas is not possible on basis of these data, but information can be used to select priority areas when starting more detailed biodiversity assessments.**	http://www.biodiversityhotspots.org/xp/Hotspots/resources/pages/maps.aspx Globally available data (GIS), in some cases site specific, in most cases not, depends on country/ region Scale of data application: national.
Global 200 – priority	Global 200 is an attempt to identify a set of ecoregions (Olson et al. 2001;	Olson & Dinerstein 2002;

Database / Product	Scope / Content	Reference / Availability / Quality
ecoregions for global conservatio n	http://www.worldwildlife.org/science/ecoregions/biomes.cfm) whose conservation would achieve the goal of saving a broad diversity of the Earth's ecosystems. These ecoregions include those with exceptional levels of biodiversity, such as high species richness or endemism, or those with unusual ecological or evolutionary phenomena. Data resolution of Global 200 has a global character and is not site-specific. Associated are detailed descriptions of ecoregions including biodiversity features and threads of species (see also WWF Wildfinder http://www.wwfus.org/wildfinder/searchByPlace.cfm#). The data set forms a fundamental background for decision making. **<u>Evaluation:</u> Global 200 ecoregions provide basis information for decision makers about exceptional global biodiversity regions. A provincial or local selection of suitable areas is not possible on basis of these data, but information can be used to select priority areas when starting more detailed biodiversity assessments.**	http://www.worldwildlife.org/science/ecoregions/global200.html Globally available data (GIS), not site-specific. Scale of data application: national
Millennium Ecosystem Assessment (MA); World Data Center for	The objective of the MA – called for by the United Nations Secretary-General Kofi Annan in 2000 – was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MA has involved	MA reports: http://www.maweb.org WDCBE: http://wdc.nbii.gov/ma/ (meta-database) Globally available data (GIS only partially). Different dates of publication and resolution, depends on data and provider.

Database / Product	Scope / Content	Reference / Availability / Quality
Biodiversity and Ecology (WDCBE)	the work of more than 1,360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems. The WDCBE is the collaborative web site project with the MA. WVCBE is developed as an interactive system that will allow easy access to reports, maps and the data collected during the MA global evaluation of ecosystems. Ultimately, the MA information stored in WDCBE will form the baseline for future assessments of the earth's ecosystems by scientists, managers, policy-makers, educators, and the public. **Evaluation: MA publications and data provide ground information for decision makers to guide and guaranty a multivariable ecological approach in the decision making processes. The WDCBE constitutes a tool for this purpose. Specific local questions such as selection or assessment of areas on basis of given biological or social data should be assisted by site specific data.**	Scale of data application: national, provincial and local

Table A- 4 Databases on Land Cover Classification Systems and Land-Cover Mapping

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Land Cover Classificatio n System (LCCS)	LCCS is a harmonized land cover classification system developed by FAO and UNEP. LCCS enables comparison of land cover classes regardless of mapping scale, land cover type, data collection method or geographic location. It is applicable in all climatic zones and under different environmental conditions. LCCS enables an assessment of land cover and the ability a monitoring of changes. Software has been developed to guide the user to select the appropriate class facilitating the complex classification process and ensure standardization. GLC2000 project and the recently published GlobCover are examples of LCCS application. **<u>Evaluation:</u> LCCS represents a standard legend and guide of classification without geographical limitations, which allows comparing different land cover classification data outputs and methods. This land cover classification system should be considered in the decision making processes to guaranty consistent within and comparability among assessments.**	FAO (2005) Version 1.0 (published in 1998) http://www.fao.org/DOCREP/003/X0596E/X0596E00.htm Version 2.0 (published in 2005) http://www.fao.org/docrep/008/y7220e/y7220e05.htm#TopOfPage Software version 2.0 can be ordered Globally applicable classification system. Scale of data application: national, provincial and local
Glob Cover Land Cover Map (GlobCover)	The GlobCover project has developed a service capable of delivering global composite and land cover maps. With a resolution of 300 m, GlobCover represent the newest globally available dataset on land cover with highest resolution. The Global Land Cover Map is compatible with the UN Land Cover	General information and contact: http://dup.esrin.esa.it/projects/summaryp68.asp Data download: http://ionia1.esrin.esa.int/index.asp Globally available (GIS), site specific (300 m) GlobCover LC version 2 was published in September 2008.

Database / Product	Scope / Content	Reference / Availability / Quality
	Classification System (LCCS) and its land cover categories were in accordance established. The Global Land Cover Map together with a set of MERIS Full Resolution composites provides the results of GlobCover project, an ESA initiative in partnership with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. As input were used observations from the 300m MERIS sensor on board the ENVISAT satellite mission over a period of 19 months (December 2004 – June 2006). **<u>Evaluation:</u> Land Cover Map GlobCover based on the UN Land Cover Classification System is an essential tool in decision making processes. GlobCover provides high resolution information to identify land cover patterns, which will help private and public decision makers to minimize subsequent disputes between land-use planning and existing uses. Further more, a broad vision of current human activities and therefore possible located ecological pressures can be detected.**	Scale of data application: national, provincial and local
The Global Land Cover 2000 (GLC2000)	GLC2000 presents a consistent picture of the land-cover situation in 2000. Similar to GlobCover, GLC2000 was produced in compliance with the UN Land Cover Classification System (LCCS). The main data set used for this project was the "VEGA 2000" data set, composed of 14 months of daily 1-km resolution satellite data acquired over the whole globe by the VEGETATION instrument on-board the SPOT 4 satellite for the period Nov. 1999 – Dec. 2000. The project was coordinated by the Joint Research Centre (JRC), Institute for Environment and Sustainability.	http://www-tem.jrc.it/glc2000 Bartholomé / Belward 2005. Reports under http://www-tem.jrc.it/glc2000/publications.htm Globally available (GIS), site specific (1km). Published in November 2002. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	GLC2000 predicts cropland much better than MODIS land cover product, but the reverse is true for pastures (Ramankutty 2008). Ramankutty merges the two satellite-derived land cover classification data sets to present a 5 arc minute dataset (http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html). **<u>Evaluation:</u> GLC2000 allows private and public decision makers to recognize land cover patterns in 1999/2000. Tough GlobCover resolution is more suitable on a local scale; data from GLC2000 are still useful for e.g. trend analysis.**	
MODIS/Terra Land Cover Type Yearly	Also Terra Land Cover Maps comprises layers on different land-cover categories. The data are obtained yearly from MODIS with a resolution of 1 km. Instead of LCCS as classification system (GLC2000, GlobCover), the land classification system of this mapping approach follows the global vegetation classification scheme of the University of Maryland and the International Geosphere-Biosphere Programme (IGBP). There is free direct on-line access to most of the data, and it will be complete in the near future. A new combined Land Cover product has been produced at higher spatial resolution (500m), using Aqua and Terra inputs, that is still under evaluation. **<u>Evaluation:</u> The MODIS/Terra land cover products provide the same as GlobCover and GLC2000 land cover patterns information. Results comparison is limited because of use of different classification systems, in this case IGBP. Failing**	Land Cover Yearly L3 Global 1km https://lpdaac.usgs.gov/lpdaac/products/modis_product_table/land_cover/yearly_l3_global_1km/v5/terra Land Cover Yearly L3 Global 500m https://lpdaac.usgs.gov/lpdaac/products/modis_product_table/land_cover/yearly_l3_global_500m/v5/combined Data Download https://lpdaac.usgs.gov/lpdaac/get_data/data_pool Globally available (GIS), site specific (1 km and 500 m) Data are available since 2001 to present. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	previous local field checking, source and type of collected data should be considered by decision makers to select land cover data.	
Global Land Cover Characteristics (GLCC)	The land-cover data set is derived form 1 km Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12 month period (April 1992 – March 1993) and is based on a flexible data base structure and seasonal land cover regions concepts. It was developed on a continent-by-continent basis with the same map projection (Interrupted Goode Homolosine). As classification scheme the International Geosphere-Biosphere Programme (IGBP) land cover legend was used. Funding for the project was provided by the USGS, NASA, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the UNEP. Others important initiatives in relation with land cover and land use change and interrelated data are the Land Cover /Land Use Chage (LCLUC, http://lcluc.umd.edu/index.asp) Program (NASA) and the Global Earth Observation System of Systems (GEOSS, http://www.epa.gov/geoss/). **Evaluation: GLCC is based on IGBP classifications. Comparisons of results and analysis of time series with the MODIS /Terra land cover products are possible on basis of the same land cover classification system. Especially decision makers in areas affected by population and production activities booms should consider these analyses in decision making process.**	Olson (1994a, 1994b, cited in Kniivila 2004); http://edc2.usgs.gov/glcc/ Globally available (GIS), site specific (1km) Version 1.2 was published in 1997, and the revised Version 2.0 in 1999 Scale of data application: national provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
Satellite Imagery	Different satellites have been launched, among others: ASTER, IKONOS, Landsat, MODIS or CBERS. The application potential of a given satellite, respectively a given sensor is established as a function of its spatial resolution, temporal resolution, and spectral and radiometric characteristics. According to project objectives, study area and experiences of users, different images will be used. Regarding land cover, medium resolution imagery such as TM and ETM+ 30 m resolution Landsat imagery or CDD 20 m resolution CBERS imagery are suitable for global analysis. Interesting to be mentioned is the TerraLook project, which provides access to satellite images for users that lack prior experience with remote sensing or GIS technology. **Evaluation: Satellite imagery requires experience and knowledge of spatial analysis to extract information for decision makers. Once determine precise parameters and goals not covered by elaborated tools or data, respective analysis of satellite data can be helpful in decision making processes.**	Global Land Cover Facility: http://glcf.umiacs.umd.edu/data/ Terralook (USGS): http://terralook.cr.usgs.gov/ and http://terralook.sourceforge.net/ CBERS Program: http://www.cbers.inpe.br/?hl=en Constant production and publication of satellite imagery. Scale of data application: national, provincial and local

Table A- 5 Databases on Forests

Database / Product	Scope / Content	Reference / Availability / Quality
Forest and woodlands from land-cover mapping[112]	Global land cover maps like GlobCover, GLC2000 and MODIS/Terra Land Cover consider forest and woodland categories that can be used to identify the location of forests on a site scale (see more details under Point 2). **<u>Evaluation:</u> The identification of areas covered by forests and woodlands (important environmental services sites) through the extraction of forest layers must take into account the used land cover classification system and related considerations. Its application on local scale should be checked in decision making processes.**	See details under Point 2. Scale of data application: national, provincial and local.
MODIS Vegetation Continuous Fields (MOD44B)	MOD44B represents a global dataset on the proportion of tree cover based on MODIS data with a resolution of 500 m. The inputs date from October 31, 2000 to December 9, 2001. The training data are derived by aggregating high-resolution Landsat images to the MODIS data. This map contains proportional estimates for vegetative cover: woody vegetation, herbaceous vegetation and bare ground. This technical method will be used for the generation of a new validated global three cover map. The project Global	http://glcf.umiacs.umd.edu/data/vcf/ Globally available (GIS), site specific (500 m) Published in 2003 Scale of data application: national, provincial and local

112 Especially for forest assessments, additional regional data are available (see overview in Strand et al. 2007).

Database / Product	Scope / Content	Reference / Availability / Quality
	Remote Sensing Survey is managed by Global Forest Resources Assessment Program (see http://www.fao.org/forestry/fra2010-remotesensing/en/ and http://www.fao.org/forestry/48035/en/). **Evaluation: Before using discrete classification schemes, this continuous classification scheme regarding tree cover may represent an advantage for classification in areas of heterogeneous land cover. Decision makers should evaluate their needs to decide on their preferences (e.g. data on land cover classes from GlobCover or proportion of tree cover).**	
Global Forest Resources Assessment. Forestry Databases (FRA 2000 / FRA 2005)	Forestry Department of FAO maintains an array of global databases where information covering various aspects of forestry is stored for analysis and further dissemination. FRA 2005 is a global assessment of forest and forestry. It examines the current status and recent trends for about 40 variables covering the extent, condition, uses and values of forest and other wooded land, with the aim of assessing all benefits from forest resources. The next report FRA 2010 is currently ongoing and will include innovative geo-referenced forest information based on a developed MODIS Vegetation Continuous Field. In relation to FRA The World's Mangroves 1980-2005 can be mentioned. It has no GIS associated data but, as FRA, shows global statistic data. **Evaluation: The evaluated variables in FRA report**	http://www.fao.org/forestry/databases/en/ http://www.fao.org/forestry/site/fra/en/ Globally available (no GIS), national level information. No site specific Ongoing purpose: FRA 2010 Remote Sensing Survey. Final report in 2011 (See: http://www.fao.org/forestry/48035/en/) The World's Mangroves: http://www.fao.org/docrep/010/a1427e/a1427e00.htm Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	provide on national scale important background information for planning processes. The database inform about extent of forest and other wooded land and its changes, composition of growing stock and ownership of forest, among others. Related GIS data are not till now available. Stakeholders should consider this information in the decision making processes.	
Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)	The GOFC-GOLD is an international platform to provide ongoing space-based and in-situ observations of forest and vegetation cover, to facilitate the sharing of results and observations and to promote cooperative activities. Its aim is to develop and demonstrate operational forest monitoring at regional and global scales through projects and prototype products within three primary themes: Forest Cover Characteristics and Change, Forest Fire Monitoring and Mapping and Forest Biophysical Processes. The GOFC-GOLD is a panel of the Global Terrestrial Observing System (GTOS), which is in turn integrated in the Global Observing Systems Information Center (GOSIC). GOSIC provides access to data, meta-data and additional information, and overviews of the structure and programs, for GTOS, the Global Ocean Observing System (GCOS) and the Global Ocean Observing System (GOOS). These platforms make available also a list of	http://www.fao.org/gtos/gofc-gold/catalogs.html and http://www.fao.org/gtos/tems www.gosic.org Globally available (GIS and no GIS), different levels information (regional and global). Data Portal. Publication and update depend on every data and organizations. Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	institutions and organizations which process or supply related data. **<u>Evaluation:</u> The portal is designed to promote cooperative activities and it is recommended for specialist and experts. Decision makers could look up this database in a second stage of decisions making processes to get in depth answers to specific or problematic questions.**	
Tropical Rain Forest Information Center	The Tropical Rain Forest Information Center of the Michigan State University is a NASA Earth Science Information Partner. It provides Landsat high resolution remote sensing data as well as digital deforestation maps and databases to a range of users through web-based Geographic Information Systems. The current state of the world's tropical forests is also supplied through maps. To access of data registration is mandatory. Most of satellite imagery has to be paid. **<u>Evaluation:</u> Products available without charge focus principally in tropical forest region (Brazilian Amazon and Southeast Asia). Forest cover date should be used to compare previous status/ progressive to assess positive or negative developments. Satellite imaginary should be requested by GIS specialists.**	http://www.trfic.msu.edu/products.html http://www.trfic.msu.edu/data_portal.html Globally available (GIS). Site specific (Landsat Data, 30 m) Map Products of Brazilian Amazon and Southeast Asia show forest cover for the years 1973, 1985, 1992 and 1996 Scale of data application: national, provincial and local.
Global Forest Watch and	The Global Forest Watch is an initiative of the World Resources Institute (www.wri.org) with the goal to map	http://www.globalforestwatch.org/english/index.htm Interactive Maps:

Database / Product	Scope / Content	Reference / Availability / Quality
World Intact Forests	intact forests and forest of high biodiversity. Through a data explorer spatial datasets (GIS) can be downloaded or interactive maps can be queried. This web portal provides specific country GIS data of Alaska, Brazilian Amazon, Cameroon, Canada, Central Africa, Congo, Indonesia, Russia and Venezuela. Several regional and global data are also available. As a follow-up of this assessment the World Intact Forest Landscape map was published in 2007. The forest zone was identified using existing data based on medium resolution data. Only unfragmented areas larger 500 sq km were analyzed using GLCF images of Landsat 7 (1999-2002). **Evaluation: Products focus on forests with wide extensions in the countries mentioned above. The supplied maps include different themes, not only forest related maps. The intact forest maps should be considered by decision makers to identify unsuitable areas for biomass production or any other productive activity. Countries not included in this project should integrate this approach to avoid "invasion" into intact forest.**	http://www.globalforestwatch.org/english/interactive.maps/index.htm Data explorer: http://ims.missouri.edu/gfwmetadataexplorer/ Bryant et al.(1997) The Last Frontier Forest Globally available (GIS). Site specific for specific countries/ areas World Intact Forest: http://www.intactforests.org/download/download.htm Scale of data application: national and provincial.
Global Forest Fragmentation Data	Global Forest Fragmentation Data was provided by the United States Department of Agriculture (Forest Service). The Global Land Cover Characteristics database (GLCC; Loveland et al. 1999) derived from satellite (AVHRR)	Documentation and data download: http://www.ecologyandsociety.org/vol4/iss2/art3/ Riitters et al. 2000 Globally available (GIS). Site specific (1 km)

Database / Product	Scope / Content	Reference / Availability / Quality
	imagery taken form April 1992 to March 1993 was used to characterize the fragmentation around each forest pixel. Six categories of fragmentation were determined: interior, perforated, edge, transitional, patch, und undetermined). **<u>Evaluation:</u> The forest fragmentation depicted in this map refers 1992-1993 situations. The data can be analyzed together with new data on forest patterns to identify changes and evolutions in forest areas, and especially positive or negative developments of the fragmentation status. Conclusions should be applied by decision makers to define action lines.**	Published in 2000, based on 1992 – 1993 data. Scale of data application: national, provincial and local

Table A- 6 Databases on Wetlands

Database / Product	Scope / Content	Reference / Availability / Quality
Global Lakes and Wetlands Database (GLWD)	GLWD was generated through the combination of best available sources for lakes and wetlands on a global scale (resolution 1:1 to 1:3 million). GLWD presents three levels: large lakes and reservoir (1), smaller water bodies (2) and wetlands (3). Also products from land-cover assessments (GlobCover, GLC2000, MODIS Land Cover) cover information on wetlands and can be used for data verification (see links under Land Cover Classification). **Evaluation: Presence of and proximity to water bodies should be considered in decision processes. GLWD identify where they are and classify them in categories. Subsequent analyses to evaluate quantity and quality for lakes and wetlands should be carried out to assess their current and future suitability for human activities. Such suitability status is essential to guaranty the protection of environmental services related to the lakes and wetlands.**	Lehner/Döll (2004), http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_publikationen/2004/lehner_doell_JHydrol2004_GLWD.pdf Data download: http://www.worldwildlife.org/science/data/item1872.html Globally available (GIS). Site specific (30 Second resolution – 1 km x 1km at the equator) Published in 2004 Scale of data application: national, provincial and local
Wetlands of International Importance (Ramsar Sites Database)	This database provides the list of Wetlands of International Importance selected by the Ramsar Convention Contracting Parties according to established criteria. Together with a Ramsar information sheet, GIS data will be supplied once the user is registered. Georeferenced Ramsar Sites can be found also under WDPA and IBAT. Currently there are 1822 designated Ramsar sites selected by their significance in terms of ecology, botany, zoology, limnology or hydrology. They are important sites for the conservation of global biological diversity and for sustaining human life through ecological and	Description: http://ramsar.wetlands.org/Database/AbouttheRamsarSitesDatabase/tabid/812/Default.aspx Datadownload : http://ramsar.wetlands.org/Database/Searchforsites/tabid/765/Default.aspx Globally available (GIS). Site specific. Last Update of the Ramsar Sites List was in October

Database / Product	Scope / Content	Reference / Availability / Quality
	hydrological functions (Ramsar Strategic Framework). **<u>Evaluation:</u> The importance of Ramsar is internationally recognized and their protection must be considered in any decision making process also including surrounding areas, where implementation of projects or activities could affect them indirectly.**	2008 Scale of data application: national, provincial and local
Freshwater Ecoregions of the World (FEOW)	FEOW provides a global biogeographic regionalization of the Earth's freshwater biodiversity. It is a useful tool for global and regional conservation planning projects, especially to identify threatened freshwater systems. A description of the freshwater ecoregion and references are enclosed. FEOW is a project of WWF and The Nature Conservancy. A related database is HydroSHEDS (see Point 8: water, hydrology and climate). **<u>Evaluation:</u> Particularly national spatial planning could benefit from this information to initiate appropriate-located low impact projects. A provincial or local selection of suitable areas is not possible on the basis of this dataset and its related information.**	Abell et al. 2008 article and data download under : http://www.feow.org/downloads.php Search and description ecoregions: http://www.feow.org/search/index.php Globally available (GIS). Not site specific. Published in 2008 Scale of data application: national

Table A- 7 Databases on Degraded Land

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Global Assessment of Land Degradation and Improvement (GLADA)	Within the GEF-UNEP-FAO program Land Degradation Assessment in Drylands (LADA), GLADA identifies status and trends of land degradation and hotspots suffering extreme constraints or areas at severe risk and, also, areas where degradation has been arrested or reversed. The identification of land degradation hotspots is carried out using remotely sensed data and existing datasets. NDVI indicators and the trend of biomass production are applied to identify land cover and its changes. The classification will be carried out manually, through 30 m resolution Landsat data, to recognize the probable kinds of land degradation. Following-up, field examination will be done by national teams, also within the LADA program. **Evaluation: The results of GLAD provide internationally essential information, especially as the assessment of degraded lands still poses problems from the definition of degraded land to its mapping with a suitable resolution. In case when degraded lands are not interesting for food production, they should be considered by decision makers as priority in**	http://www.isric.org/UK/About+ISRIC/Projects/Current+Projects/GLADA.htm Globally available (GIS). Site specific On going LADA: http://www.fao.org/nr/lada/ Scale of data application: national, provincial and local.

Database / Product	Scope / Content	Reference / Availability / Quality
	biomass production planning reducing possible land and resources competition.	
Global Assessment of Soil Degradation (GLASOD**)**	The GLASOD project produced a world map of human induced soil degradation. Soil scientists throughout the world collected the data using uniform guidelines and international correlation. The type, extent, degree, rate and main causes of degradation were identified and listed within a database. GLASOD shows some limitations. These are, among others, its low resolution not being appropriate for national breakdowns and its complex legend. Despite a missing updated GLADOD is the most comprehensive database covering land degradation that occurred before 1990. Due to the fact that land degradation is cumulative, results from GLADA will only partly be able to replace information from GLASOD. __Evaluation:__ **Data were collected subjectively by scientists. Until the GLADA project provides better information, the GLASOD database the only one containing global information on degraded lands. Though its national or regional application is limited, decision makers should consult it together with national or sub national database especially regarding degradation that**	Oldeman et al. 1991, http://www.isric.org/isric/webdocs/Docs/ExplanNote.pdf Oldeman and Van Lynden 2001 Data Download: http://www.isric.org/NR/exeres/545B0669-6743-402B-B79A-DBF57E9FA67F.htm http://www.grid.unep.ch/data/data.php Viewer Maps: http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp CD available: http://www.fao.org/ag/agl/lwdms.stm Data: http://www.fao.org/ag/agl/agll/terrastat/index.asp, www.fao.org/geonetwork Globally available (GIS), not site specific (1:10 Million) Published in 1990. Second revised edition in October 1991. Scale of data application: transnational

Database / Product	Scope / Content	Reference / Availability / Quality
	occurred before 1990.	
South and Southeast Asian Soil Degradation Status Assessment (ASSOD)	This project provided revised sub-regional Guidelines for General Assessment of Status of Human Induced Soil Degradation. As outputs, a South and Southeast Asia Sub-regional Map on the Status of Human-Induced Soil Degradation at a scale of 1:5 Million was generated and a digitized version of the map as well as a digital geographical database is available. Whereas in GLASOD the number of degradation (sub-)types per map unit was restricted to two, ASSOD allows for a potentially unlimited number of degradation types per unit. In ASSOD the degradation is defined in the context of “impacts on agricultural productivity”, others than soil functions have not been considered. This impact on productivity is taken as a standard for the intensity of degradation rather than the intensity of the process (“degree” in GLASOD). **<u>Evaluation:</u> Regional application of GLASOD project. Data were also collected subjectively by scientists. The intensity of degradation only refers to the impact on agricultural productivity, whereas others soil functions are not considered. Decision makers should consult this database as reference to locate degraded**	Van Lynden and Oldeman, 1997 Final report and data download: http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/ASSOD.htm Regionally available (GIS), not site specific (1:5 Million) Published in 1997 Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	lands in the absence of more precise information.	
Soil Degradation Assessment in Central and Eastern Europe (SOVEUR)	The SOVEUR project for Central and Eastern Europe developed a harmonized soil and terrain database at 1:2.5 million scales. Using regional soil information and auxiliary information on climate, land use and the type of soil pollution, the status of human induced soil degradation and the areas considered vulnerable to defined pollution scenarios were identified and mapped. For the SOVEUR project, the status of degradation was evaluated both in terms of the type and intensity of the process (degree) as well as the impact of degradation on various soil functions (not only impact on productivity like in ASSOD).This FAO project is also available as CD Rom. **Evaluation: The SOVEUR project broadens the degradation concept by considering and evaluating various soil functions. Decision makers within the project area should consult this database as reference to identify degraded lands.**	Van Lynden, 2000 http://www.isric.org/ISRIC/WebDocs/Docs/SOVEUR_Rep2000_05.PDF Explanatory note and data download: http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/SOVEUR.htm Regionally available (GIS), not site specific (1:2.5 Million) Published in 2000 Scale of data application: transnational and national

Table A- 8 Agricultural Production and Land Use

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Food Insecurity, Poverty and Environment Global GIS Database (FGGD)	As a part of the Poverty Mapping Project, FAO prepared this database for global analysis of food insecurity and poverty in relation to environment. FGGD provides a GIS database regarding monitoring, assessing and analyzing environmental and other geospatial dimensions of drivers of poverty and food insecurity, particularly in relation to agro-ecological zones, accessibility, farming system zones and crop and livestock production systems. Besides information on, e.g., topography, human population and socioeconomic indicators (Huddleston et. al. 2006, Salvatore et. al. 2005), land productivity potential for different cropping systems are depicted (van Velthuizen et al. 2007). Suitability maps for rainfed production of each case have been elaborated according to three levels of inputs (low, intermediate or high. This database and methods rely on the FAO/IIASA global agro-ecological zoning (GAEZ) method for evaluating productivity potential of the world's land area for rainfed agriculture, updated and published in 2002 (Fischer et al. 2002) **Evaluation: Comprehensive international cropping system database according to GAEZ methodology. Decision makers should consider these suitability maps to locate production areas, especially in case of the absent of national assessments.**	http://tecproda01.fao.org/~lorenzo/ and also as DVD together with Ataman et al. (2007) publication Suitability maps for crops: http://www.fao.org/docrep/010/a1075e/a1075e00.htm, http://www.fao.org/ag/agl/agll/cropsuit.asp Globally available (GIS). Site specific (30 arc seconds) or not (5 arc minutes) Published in 2007 Global Agro-ecological zoning (GAEZ): http://www.fao.org/ag/agl/agll/prtaez.stm Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
Agro-MAPS: Global Spatial Database of Agricultural Land Use Statistics	This database contains data on crop production; area harvested and crop yields, for one or more years, for each country. It has been separately prepared by FAO (for Africa and the Middle East), the International Food Policy Research Institute (IFPRI, Latin America, Asia, Australia and New Zealand) and the Center for Sustainability and the Global Environment (SAGE, (the rest of the world). This information is provided regionally according to administrative division and subdivision of the countries. Export and download all available data is possible. A combination of Agro-MAPS and national agricultural statistics with the new gridded map of global croplands for the year 2000 (Ramankutty et al. 2008 – see Section Land Cover) has been developed to present a database of global land use practices describing the areas and yields of 175 individual crops around the year 2000 at a 5 min by 5 min spatial resolution (Monfreda et al. 2008) **Evaluation: Agro-MAPS provide provincial statistic information for every crop. Decision makers could use this database to evaluate agricultural importance of specific crop in a region.**	Concept and document http://www.ifpri.org/data/gs_agromaps.htm Database http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx Globally available. Not site specific. Available data from 1975 Scale of data application: national
Land Use Systems of the World (LUS)	LUS aims to provide worldwide land-use data and to give guidance for its creation. The available LUS beta version has been developed in the framework of the LADA project by the Land Tenure and Management Unit of FAO. The produced maps provided as raster format provide information on land use systems, ecosystems, crops, crop groups, irrigated areas, thermal climate, length of growing period (LGP), soils, slope, population density and infant mortality	Documents: http://www.fao.org/nr/lada/index.php?option=com_docman&task=cat_view&gid=37&Itemid=157 Data download: http://www.fao.org/nr/lada/index.php?option=com_content&task=blogsection&id=4&Itemid=158

Database / Product	Scope / Content	Reference / Availability / Quality
	rate. The overall quality of the map, however, depends heavily on the individual quality of the data for the different countries that varies significantly between mapping regions. **<u>Evaluation:</u> see more details under GLADA – Point 5.**	Globally available. Not site specific (5 arc minutes – 0,0833 decimal degrees) Beta version published, on going. Scale of data application: national
Problem Soil Database (ProSoil**)**	ProSoil provides a literature database on agricultural problem soils. Within the ProSoil database different types of agricultural problem soils have been selected for their consideration: acid soils, calcareous soils, histosols, salt affected soils, sandy soils, steep lands and vertisols. Database queries considering soil types, location, crop types and agricultural technologies relevant literature sources can be identified. Furthermore, according to the World Reference Base for Soil Resources (WRB) a glossary of diagnostic horizons for agricultural problem soils is given. **<u>Evaluation:</u> Decision makers could use this literature database as information source for specific problems. In-depth knowledge is necessary to carry out suitable planning processes and to anticipate later indirect impact.**	http://www.fao.org/AG/AGL/agll/prosoil/default.htm Database: http://www.fao.org/AG/AGL/agll/prosoil/prosoil.asp Literature sources available.

Table A- 9 Databases on Soil, Slope and Elevation

Database / Product	Scope / Content	Reference / Availability / Quality
Harmonized World Soil Database (HWSD)	HWSD combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) including the information from the FAO-UNESCO Soil Map of the World. Based on raster data with a resolution of about 1 km (30 arc seconds by 30 arc seconds) over 15,000 different soil mapping units are recognized in the HWSD. For these mapping units occurring soil types and their properties are listed. The use of a standardized structure allows database queries to identify the location of soils units regarding selected soil parameters (organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry). Previous Databases such as the World Soil and Terrain Database (SOTER), the Digital Soil Map of the World, the World Inventory of Soil Emission Potentials (WISE) and the European Soil Database (ESD) can be consulted separately. The Soil Map of China integrates in HSWD is not available independently. **Evaluation: Most comprehensive soil database. Suitable at every scale. Decision makers should consider in principle this database, where others have been integrated, to get information on soil distribution and properties.**	FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) http://www.iiasa.ac.at/Research/LUC/luc07/External-World-soil-database/HTML/index.html ; Globally available (GIS – own software), site specific (30 arc second). Ground Data Information: - SOTER http://www.fao.org/ag/agl/agll/soter.stm - Digital Soil Map of the World: http://www.fao.org/ag/agl/agll/dsmw.htm - WISE: http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/WISE.htm - ESD: http://eusoils.jrc.it/ESDB_Archive/ESDB/index.htm - The Soil Map of China: http://www.issas.ac.cn/english/index.htm Scale of data application: national, provincial and local
World Reference Base for Soil	WRB is an initiative of FAO and UNESCO supported by UNEP and ISRIC-World Soil Information which dates back to 1980. The	http://www.fao.org/ag/agl/agll/wrb/default.stm Global Soil classification system.

Database / Product	Scope / Content	Reference / Availability / Quality
Resources (WRB)	intention of the project was to establish a worldwide soil classification. The WRB is a comprehensive classification system that enables people to accommodate their national classification system, supplying a set of prefix and suffix qualifiers for specials categories. ISRIC (www.isric.org) as an international institute aims to inform and educate through public information, teaching and advocacy; to serve the scientific community as a custodian of soil information and applied research. **Evaluation: International standard for soil classification. Tool for soil specialist and scientists. Decision makers should consider the database as reference to ensure comparability of assessed data with other projects.**	Published in 1998, second edition in 2006 http://www.fao.org/ag/agl/agll/wrb/doc/wrb2007_corr.pdf
U.S. General Soil Map (STATSGO2)	STATSGO2 was developed by the U.S. National Cooperative Soil Survey. It consists of a broad based inventory of soils and non-soils areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The data are available for the conterminous United States, Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. Individual state extents are also available. The dataset was created by generalizing more detailed soil survey maps. Where more detailed soil survey maps were not available, data on geology, topography, vegetation, and climate were assembled, together with Land Remote Sensing Satellite (Landsat) images. Map unit composition was determined by transecting or sampling	http://www.soils.usda.gov/survey/geography/statsgo/ National available (GIS), site specific Published in 1994 by Natural Resources Conservation Service, United States Department of Agriculture. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	areas on the more detailed maps and expanding the data statistically to characterize the whole map unit. **Evaluation: Once HWSD was published, it is advisable to make use of it preferably. STATSGO2 is not updated.**	
The National Soil Database (NSDB), Canada	The NSDB is the set of computer readable files which contain soil, landscape, and climatic data for all of Canada. It serves as the national archive for land resources information that was collected by federal and provincial field surveys, or created by land data analysis projects. Included data: National Ecological Framework (scale of 1:30 M to 1:1 M), Soil Map of Canada (1:5 M), Agroecological Resource Areas (1:2 M), Soil Landscapes of Canada (1:1 M), Canada Land Inventory (1:250.000) and Detailed Soil Surveys (1:20.000 to 1:250.000) **Evaluation: Decision makers in Canada should consider these databases as reference to get information on soil distribution and properties. A comparison with global database (HWSD) is advisable.**	http://sis.agr.gc.ca/cansis/nsdb/ Metadata for the NSDB: http://sis.agr.gc.ca/cansis/nsdb/meta/query.html National available (GIS), site specific or not (depending on data) Scale of data application: national, provincial and local
Australian Soil Resource Information System (ASRIS)	ASRIS provides online access to the best publicly available information on soil and land resources in a consistent format across Australia. It covers information at seven different scales. The upper three levels provide broad descriptions across the complete continent. Lower levels provide more detailed information for regions where mapping is complete. This information relates to soil depth, water storage, permeability, fertility, carbon, salinity and erodibility. ASRIS includes a soil profile database with fully	http://www.asris.csiro.au/index_other.html Data view and download: http://www.asris.csiro.au/mapping/viewer.htm National available (GIS - online) Site specific or not depending on data. Scale of data application: national, provincial and

Database / Product	Scope / Content	Reference / Availability / Quality
	characterized and representative sites. Information is displayed using maps, satellite images, tables, photographs and graphics. **Evaluation: Decision makers in Australia should consider this database as reference to get information on soil distribution and properties. A comparison with global database (HWSD) is advisable.**	local
NASA's Shuttle Radar Topography Mission (SRTM)	The Shuttle Radar Topography Mission (SRTM) is a joint project between NASA and NGA (National Geospatial-Intelligence Agency) to map the world in three dimensions. Flown aboard the NASA Space Shuttle Endeavour February 11-22, 2000, SRTM successfully collected data over 80% of the Earth's land surface, for all area between 60 degrees North and 56 degrees South. SRTM data is being used to generate a digital topographic map of the Earth's land surface with data points spaced every 1 arc second for the United States of latitude and longitude (approximately 30 meters). SRTM achieved horizontal and vertical accuracies of 20 meters and 16 meters, respectively. Data view and download through interactive maps is also possible. Further it is notable that based on SRTM GTOPO 30 and the Consortium for Spatial Information of the Consultative Group on International Agricultural Research (CGIAR-CSI) data sets provide data sets on slope and aspect. Both databases are included as supplementary data in the Harmonized World Soil Database. **<u>Evaluate:</u> Most recent projects requiring information on topography refer to this source. Decision makers which need information on slope and aspect should take into account this global database.**	http://www2.jpl.nasa.gov/srtm/index.html Data download: - Seamless SRTM 3 Arc Second (90 m): http://seamless.usgs.gov/products/srtm3arc.php - Seamless SRTM 1 Arc Second (30 m): http://seamless.usgs.gov/products/srtm1arc.php Globally available (GIS), site specific Global Terrain Slope and Aspect Data Documentation - References http://www.iiasa.ac.at/Research/LUC/luc07/External-World-soil-database/HTML/global-terrain-doc.html GTOPO 30: http://edcdaac.usgs.gov/gtopo30/gtopo30.html CGIAR-CSI: http://srtm.csi.cgiar.org/ Scale of data application: national, provincial and local

Table A- 10 Databases on Water, Hydrology and Climate

Database / Product	Scope / Content	Reference / Availability / Quality
AQUASTAT	A FAO's global information system on water and agriculture developed by the Land and Water Division. It contains general and country specific data and information about water resources, water consumption (per Sector) und agricultural water management, with emphasis on countries in Africa, Asia, Latin America and the Caribbean. There are different kinds of data: concrete data (number), country profile (text) and maps (downloadable, geo-referenced or not). For example: main country database (http://www.fao.org/nr/water/aquastat/dbase/index.stm), climate information tool (http://www.fao.org/nr/water/aquastat/gis/index3.stm) or global or spatial maps (http://www.fao.org/nr/water/aquastat/maps/index.stm) The Digital Global Map of Irrigation Areas is a good example of spatial map, which shows the percentage of each 5 arc minutes by 5 arc minutes cell that was equipped for irrigation around the year 2000 (Siebert et al. 2005, http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/1_irrigation_map/index.html, http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm The internet side http://www.fao.org/nr/water/aquastat/infosystems/index.stm links to other information systems, databases and spatial datasets related to the field of water resources and agriculture are presented. Most of them are mentioned within this section **<u>Evaluation:</u> Decision makers should consider this database, which**	http://www.fao.org/nr/water/aquastat/main/index.stm Globally and regional available (GIS), partially site specific. Data related to main country profile are updated every 5 years. Others, unknown updated. Others graphics and maps: http://www.fao.org/nr/water/infores_maps.html Scale of data application: national and provincial

Database / Product	Scope / Content	Reference / Availability / Quality
	compiles good structured and useful data formats, as starting point. Depending on the planning or decision processes complementary database will be needed. Most of them are mentioned below.	
Water Systems Analysis Group (WSAG) – University of New Hampshire	The WSAG is a global hydrology research group within the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. Its mission is to serve as a research and advanced training facility for analyzing the global water system, the critical global change issue of its alteration through anthropogenic activities, and the impacts of a changing water system on society. Research themes are: arctic hydrology, humans and the global water cycle, monitoring of inland and coastal waters and land-river-coastal systems. Various databases and tools can be accessed from this web site, for example, the Data Synthesis System for World Water Resources (DSS) - http://www.wwap-dss.sr.unh.edu/download.html , supported by the United Nations Educational, Scientific, and Cultural Organization's International Hydrological Programme (UNESCO/IHP), or the World Water Development Report II - http://wwdrii.sr.unh.edu/download.html -within the World Water Assessment Program. **Evaluation: Heterogeneous database of great use for scientists and specialists. Both data and tools for water resources planning and management processes are provided. Due to wide range of data targeted search without in-depth knowledge is complex. This database supplies further databases (GIS and not GIS information) or related links mentioned and evaluated below.**	http://www.wsag.unh.edu/ Data download http://www.wsag.unh.edu/data.html Globally or regional available (GIS), depends on the database. Not site specific Scale of data application: transnational and national
UNESCO International	IHP is UNESCO's international scientific cooperative program in water research, water resources management, education and capacity-building. Among its	http://typo38.unesco.org/en/themes/global-changes-and-water-resources.html

Database / Product	Scope / Content	Reference / Availability / Quality
Hydrological Program (IHP)	primary objectives are to develop techniques, methodologies and approaches to better define hydrological phenomena and to assess the sustainable development of vulnerable water resources. Associated programs are linked to this website, as for example, Ecohydrology and GRAPHIC Program. **Evaluation: Decision makers should use this source to find reports and research studies which deal with similar problematic or provide possible solutions or successfully/ unsuccessfully water management experiences. Specific data are not supplied.**	Global contacts available. No possible to download data.
World Water Assessment Program (WWAP)	The World Water Assessment Program (WWAP), founded in 2000, is the flagship program of UN-Water. Housed in UNESCO, WWAP monitors freshwater issues in order to provide recommendations, develop case studies, enhance assessment capacity at a national level and inform the decision-making process. Its primary product, the World Water Development Report (WWDR), is a periodic, comprehensive review providing an authoritative picture of the state of the world's freshwater resources. UN-Water (www.unwater.org) is a mechanism to strengthen co-ordination and coherence among all UN bodies dealing with water-related issues, from health to farming, environment to energy, food to climate, and sanitation to disasters. It was set up in 2003, through a decision by the High Level Committee on Programmes (HLCP) of the United Nations. **Evaluation: The World Water Development Reports (WWDR) provide a global vision on water status and associated problematic. Indicators, graphics, consulting processes and case study constitute important updated information for water resources planning processes which should be considered by decision makers.**	http://www.unesco.org/water/wwap/ Documents available. No GIS data available.

Database / Product	Scope / Content	Reference / Availability / Quality
WHO/ UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation	The goals of the JMP are to report on the status of water-supply and sanitation, and to support countries in their efforts to monitor this sector. The data collected for JMP come from two main sources: assessment questionnaires and household surveys. The web page presents water supply data and sanitation coverage data at different scales (from global to regional), providing both total access and house connections data. **Evaluation: Specific useful information to be considered by decision makers for water resources planning processes that involve water supply and sanitation. If a national database exists, a comparison is possible.**	http://www.wssinfo.org/en/welcome.html Globally available. Not site specific Data available between 1990 and 2004 Scale of data application: transnational and national
World Resources Institute (WRI) – Watersheds of the World	Watersheds of the World provides maps of land cover, population density and biodiversity for 154 basins and sub-basins around the world. It lists indicators and variables for each of these basins and, where appropriate, provides links and references to relevant information. It further contains 20 global maps portraying relevant water resources issues. The information is provided by the Water Resources eAtlas, a collaborative product of WRI, IUCN, IWMI, and the Ramsar Convention on Wetlands. Furthermore, WRI supplies a database with water related data, maps and also country profiles: http://earthtrends.wri.org/searchable_db/index.php?theme=2 **Evaluation: This database provides information by river basin, depending on country size; data could be applied at regional or national scale. This information refers to global river basin, site specific data are not provided. National water resource planning and management processes should refer to these data in absence of better national monitoring systems.**	http://earthtrends.wri.org/maps_spatial/watersheds/index.php http://earthtrends.wri.org/maps_spatial/watersheds/notes.php Globally available. Not site specific. Published in 2005 Scale of data application: transnational and national (by river basin)

Database / Product	Scope / Content	Reference / Availability / Quality
International Water Management Institute (IWMI)	IWMI is one of 15 international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). Its aim is to improve the management of land and water resources for food, livelihoods and nature. Its research themes are: water availability and access, productivity water use, water quality, health and environment and water and society. Among the tools and resources available in the IWMI website, can be mentioned, for example, the Global Irrigated and Rainfed Areas Mapping (http://www.iwmigiam.org/info/main/index.asp), the Water and Climate Atlas (http://www.iwmi.cgiar.org/WAtlas/) and the Eco-Hydrological Databases (http://dw.iwmi.org/ehdb/wetland/index.asp). IWMI offers also some models or software (http://www.iwmi.cgiar.org/Tools_And_Resources/Models_and_Software): the Global Environmental Flow Calculator (GEFC) the Global Policy Dialogue Model (PODIUM), WATERSIM to understand the key linkages between water, food security and environment; and OASIS (Option Analysis in Irrigation Systems). **Evaluation: The thematic of the supplied data coincide with other databases (e.g. irrigation and water and climate atlas). Location, available technical means and planning objectives will establish the most suitable database. Models and software are provided. Specialized literature should be consulted to support the most appropriate data selection**	http://www.iwmi.cgiar.org/index.aspx Globally available (GIS). Site specific or not depending on the data Different publication date. Scale of data application: national and provincial
Project WATCLIM	The specific objectives of the project are to carry out global analyses needed to provide water managers and other stakeholders with the latest information about the impact of climate on water resources, which are performed using the WaterGAP model. The WaterGAP model has been developed at the Center for Environmental Systems Research at the University of Kassel in Germany in cooperation with the National Institute of Public Health and the Environment of	http://www.usf.uni-kassel.de/watclim/ Globally available. No site specific. Final Report published in March 2003 WaterGAP 2.1 (Water – Global Assessment

Database / Product	Scope / Content	Reference / Availability / Quality
	the Netherlands. The aim of the model is to provide a basis (1) to compare and assess current water resources and water use in different parts of the world, and (2) to provide an integrated long-term perspective of the impacts of global change on the water sector. WaterGAP belongs to the class of environmental models which can be classified as 'integrated' because they seek to couple and thus integrate different disciplines within a single integrated framework. **<u>Evaluation:</u> Since the impact of climate on water resources should be consider in water management processes, the provided information is in particular decisive for future action lines and projects. The application of this model should be carried out by water specialists.**	and Prognosis) http://www.usf.uni-kassel.de/watclim/pdf/watergap_model.pdf Scale of data application: transnational and national
Digital Global Map of Artificially Drained Agricultural Areas	The map was developed by combining national statistics provided by international organizations (e.g. FAO, ICID, CEMAGREF), the "Global Croplands Dataset" (Ramankutty et al. 1998) and the "Digital Global Map of Irrigation Areas" (Siebert et al. 2005). No data on agricultural drainage could be found for 120 countries. Most of them are very small so that their agricultural drainage area may be neglected in global assessments. However, there are also some larger countries (in particular in Africa) where it is known that artificially drained areas are existing but the extent of these areas is unknown (e.g. Mali, Niger, Chad, Mozambique). Therefore the real global extent of agricultural drainage may be underestimated in this inventory. **<u>Evaluation:</u> Because of small scale of data collection this database could be indecisive. In planning and management processes where drained agricultural areas play an important role, the data should be considered in any case.**	http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/2_agricultural_drainage_map/ind ex.html Feick et al. 2005 http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/Global_Drainage_Map/index.html Globally available (GIS) Not site specific (5 arc minutes) Scale of data application: national
Global	The global drainage direction map DDM30 is a raster map which describes the	http://www.geo.uni-

Database / Product	Scope / Content	Reference / Availability / Quality
Drainage Direction Map	drainage directions of surface water with a spatial resolution of 30' longitude by 30' latitude. DDM30 is based on (1) the digital drainage direction map with a resolution of 5' of Graham et al. (1999) for South America, Australia, Asia and Greenland, and (2) the HYDRO1k digital drainage direction map (as flow accumulation map) with a resolution of 1 km (USGS, 1999) for North America, Europe, Africa and Oceania (without Australia). The resulting drainage direction map was manually corrected using the vectorized river data sets of ESRI (1992) and ESRI (1993). A possible complementary database is the Global Runoff Data Centre (GRDC) (http://grdc.bafg.de/servlet/is/Entry.987.Display/), a digital world-wide source of discharge data and associated metadata (http://grdc.bafg.de/servlet/is/2377/). GRDC operates under the auspices of the World Meteorological Organization (WHO) and with the support of the Federal Republic of Germany within the Federal Institute of Hydrology. **<u>Evaluation:</u> This database is useful for regional water planning processes (e.g. agriculture or industry) considering production activities. A local or provincial application is restricted due to low resolution of data.**	frankfurt.de/ipg/ag/dl/datensaetze/3_drainage_direction_map/index.html Döll et al. 2002 http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/Global_Water_Modeling/DDM30/index.html Globally available (GIS) Not site specific (30 arc minutes) Scale of data application: regional
Global Lakes and Wetlands Database (GLWD)	See information under section 4 – Wetlands.	http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_publikationen/2004/lehner_doell_JHydrol2004_GLWD.pdf
Global Water System Project Digital Water Atlas	The purpose of the 'Digital Water Atlas' is to describe the basic elements of the Global Water System, the interlinkages of the elements and changes in the state of the Global Water System by creating a consistent set of annotated maps. The project will especially promote the collection, analysis and	http://atlas.gwsp.org/ Data download http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemi

Database / Product	Scope / Content	Reference / Availability / Quality
	consideration of social science data on the global basis. The content of the Digital Water Atlas is available online with free and open access. Registered users can also download and use the datasets used to produce the maps. An interactive map viewer option is accessible for all users **<u>Evaluation:</u> Digital Water Atlas provides global water related maps. Comparison or example from others country or regions should be taken into account together with concrete conditions and parameters. Decision makers should consider these maps to get an overall situation picture.**	d=63 Globally available (GIS), not site specific Different publication date Scale of data application: national
Global Land Data Assimilation System (GLDAS)	The goal of GLDAS is to generate optimal fields of land surface states and fluxes by integrating satellite- and ground-based observational data products, using advanced land surface modelling and data assimilation techniques (Rodell et al. 2004; http://disc.sci.gsfc.nasa.gov/hydrology/overview/GLDAS_summary.shtml#rodell #rodell Data assimilation techniques for incorporating satellite based hydrological products, including snow cover and water equivalent, soil moisture, surface temperature, and leaf area index, are now being tested and implemented. The output fields support several current and proposed weather and climate prediction, water resources applications, and water cycle investigations. The project is funded by NASA's Energy and Water Cycle Study (NEWS) Initiative. **<u>Evaluation:</u> GLDAS provides weather/climate prediction and water cycle investigations which should be considered by decision makers. For its application and data interpretation specialists and scientists should be consulted.**	http://disc.sci.gsfc.nasa.gov/hydrology/overview Data Download http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings Globally available (GIS), resolution of 1 - 0,25 degree Scale of data application: national and provincial

Database / Product	Scope / Content	Reference / Availability / Quality
HydroSHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales)	HydroSHEDS has been developed by the Conservation Science Program of World Wildlife Fund (WWF), in partnership with the U.S. Geological Survey (USGS), the International Centre for Tropical Agriculture (CIAT), The Nature Conservancy (TNC), and the Center for Environmental Systems Research (CESR) of the University of Kassel, Germany. HydroSHEDS is derived from elevation data of the Shuttle Radar Topography Mission (SRTM) at 3 arc-second resolution (90 m at Equator). The goal of developing HydroSHEDS was to generate key data layers to support regional and global watershed analyses, hydrological modeling, and freshwater conservation planning at a quality, resolution and extent that had previously been unachievable. As opposed to HYDRO1k for the development of HydroSHEDS not only digital elevation models were taken into account, the Global Lakes and Wetlands Database (Lehner and Döll, 2004), the ArcWorld global vectorized river network (ESRI 1992) and Digital Chart of the World (DCW) global vectorized river network (ESRI 1993) are also data source for the generation of HydroSHEDS **<u>Evaluation:</u> HydroSHEDS provides currently the best scaled hydrological data and maps for studies and analyses. Decision makers should consider this database for planning and management processes, especially in high erosion risk areas.**	http://hydrosheds.cr.usgs.gov/ Data download http://gisdata.usgs.net/website/HydroSHEDS/ Documentation: Lehner et al. 2008 http://gisdata.usgs.net/HydroSHEDS/downloads/HydroSHEDS_TechDoc_v11.pdf Globally available (GIS), partially site specific (from 3 arc-second to 5 minute) Published in October 2008 Scale of data application: national, provincial and local
CROPWAT - AQUACROP - CLIMWAT	CROPWAT is a practical tool to carry out standard calculations for evapotranspiration and crop water use studies. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. AQUACROP is a new version of CROPWAT: A tool for (1) predicting crop	AQUACROP 3.0 (published in January 2009) http://www.fao.org/nr/water/aquacrop.html CROPWAT version 5.7 published in 1992 http://www.fao.org/nr/water/infores_database

Database / Product	Scope / Content	Reference / Availability / Quality
	production under different water-management conditions (including rainfed and supplementary, deficit and full irrigation) under present and future climate change conditions, and (2) investigating different management strategies, under present and future climate change conditions. It can be applied at all locations; agricultural sector; site-specific, but can be extrapolated to larger scale by GIS applications. CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT or AQUACROP and allows the ready calculation of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide. The climatological data included are maximum and minimum temperature, mean daily relative humidity, sunshine hours, wind speed, precipitation and calculated values for reference evapotranspiration and effective rainfall. **Evaluation: Important tools to enhance the decisions in agriculture development and crop selection. Action lines and long run projects/ programs should be designed taking into account future situation and factor interactions. Specialist should be consulted for making use of these tools.**	s_cropwat.html Documentation: Irrigation and Drainage Papers No. 24 and 33 CLIMWAT http://www.fao.org/nr/water/infores_databases_climwat.html New version CLIMWAT 2.0 is compatible with AQUACROP Scale of tool application: national, provincial and local
FAOClim – LocClim – Web LocClim	Among the climate information tools presented by AQUASTAT, these are the main once. FAOClim is a CDRom, which contains worldwide agro-climatic data. It covers monthly data for 28100 stations, for up to 14 observed and computed agro-climatic parameters, their averages and also time series for rainfall and temperature. LocClim was developed to provide an estimate of climatic conditions at locations for which no observations are available, and the related web interface, the Web	FAOClim http://www.fao.org/sd/2001/EN1102_en.htm LocCLIM http://www.fao.org/sd/2002/EN1203a_en.htm Web LocClim http://www.fao.org/sd/locclim/srv/en/locclim.h

Database / Product	Scope / Content	Reference / Availability / Quality
	LocClim, offers a local monthly climate estimator. **<u>Evaluation:</u> These tools offer worldwide and local agro-climatic information/estimates that can be helpful for decision makers to decide on cropping systems. However, quality of applied extrapolations strongly depends on the density of climate stations, and in areas with low amount of data, estimations need to be handled caution.**	ome Scale of tool application: national, provincial and local
The Wastewater Database	Developed by the Water Quality and Environment Group, the Wastewater Database contains information on wastewater production, treatment, re-use, as well as economic information provided by member states. The Database information is sorted by region and country containing fields on wastewater production, treatment technologies, and financial/economical parameters by country. **<u>Evaluation:</u> This database provides worldwide information on wastewater production and management. Decision maker should consider this information in water planning processes to guaranty benefits and continuity in treatment plant and re-use tasks.**	http://www.fao.org/nr/water/infores_databases_wastewater.html Globally available. Not site specific Documentation: Wastewater treatment and use in agriculture – FAO irrigation and drainage paper 47 (Pescod, 1992) http://www.fao.org/docrep/T0551E/T0551E00.htm
Water Indicators and Indices	The use of indicators and indices is a practical approach in water management and analysis. Some of the indices mentioned in text can be consulted directly in internet: - the water scarcity index (http://www.fao.org/nr/water/art/2007/scarcity.html), - the water poverty index (http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=1299&action=select_countries) and	Documentation Water Scarcity Index: Smakthin et al., 2004. http://www.unep.org/dewa/vitalwater/ Documentation Water Poverty Index: Sullivan, C. http://www.ceh.ac.uk/sections/ph/WaterPovertyIndex.html

Database / Product	Scope / Content	Reference / Availability / Quality
	- the water exploitation index (http://themes.eea.europa.eu/Specific_media/water/indicators/WQ01c%2C2004.05) can be consulted directly in the internet or through the supplied contacts. **Evaluation: A suitable selection of indicators should be based on specific parameters, locations and targets. Literature and specialist should be consulted for using them in water resources planning and management.**	Lawrence et al. , 2003 http://ideas.repec.org/p/kee/kerpuk/2002-19.html Scale of indicators application: national, provincial and local, depending on indicator
Geo Data Portal / UNEP/DEWA -GridEurope	The GEO Data Portal is the authoritative source for data sets used by UNEP and its partners in the Global Environment Outlook (GEO) report and other integrated environment assessments. Its online database holds more than 450 different variables, as national, sub-regional, regional and global statistics or as geospatial data sets (maps), covering themes like Freshwater, Population, Forests, Emissions, Climate, Disasters, Health and Gross Domestic Product (GDP). The user can display them on-the-fly as maps, graphs, data tables or download the data in different formats (shapefile, Adobe pdf, Excel, CSV). **Evaluation: Geo Data Portal provides different data formats on diverse environmental thematic and required data within a decision making process can be queried.**	http://geodata.grid.unep.ch/# Globally available (GIS) Not site specific Different dates of publication Scale of data application: transnational and national
Global Observing Systems Information Center (GOSIC)	GOSIC provides access to data, metadata and information, and also overviews of the structure and programs form the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). GOSIC provides access to data and information of these partner programs, but not always to the same level of detail. Due to extensive number of data, a search through "data registry" is	http://www.gosic.org/default.htm http://www.gosic.org/ios/GCOS-main-page.htm http://www.gosic.org/ios/about-GTOS-observing-system.htm Scale of data application: national,

Database / Product	Scope / Content	Reference / Availability / Quality
	recommended (http://gosic.org/Datasets/ds-report.asp) **<u>Evaluation:</u> GOSIC provides general information about water and climate related parameters. A specific search is necessary to extract required data.**	occasionally provincial
Center for International Earth Science Information Network / Socioeconomic Data and Application Center	CIESIN's mission is to provide access to and enhance the use of information worldwide, advancing understanding of human interactions in the environment and serving the needs of science and public and private decision making. The Socioeconomic Data and Applications Center (SEDAC) is one of its major ongoing activities. SEDAC's aim is to develop and operate applications that support the integration of socioeconomic and earth science data and to serve as an "information gateway" between the earth sciences and social sciences. **<u>Evaluation:</u> SEDAC provide different data formats on diverse environmental and socioeconomic thematic that can be useful for decision making.**	http://www.ciesin.columbia.edu/download_data.html http://sedac.ciesin.columbia.edu/ Globally and regional / national available (GIS), depends on the data. Scale of data application: national

Annex C Indicators Addressing Biodiversity

Biodiversity indicators are communication tools that summarize data on complex environmental issues. They can be used to signal key issues to be addressed through policy or management interventions. Indicators, therefore, are important for monitoring the status and trends of biological diversity and, in turn, feeding back information on ways to continually improve the effectiveness of biodiversity policies and management programmes (CBD 2006).

An important issue for effective policy support is the development of a small number of simple biodiversity indicators that adequately express the status and trends in biodiversity. Key questions that need to be addressed are (WAB 2007):

1. What is changing (indicator)?
2. Why is it changing (drivers)?
3. Why is it important (human use)?
4. What can be done about it (policy options and measures)?

Parties to the Convention on Biological Diversity (CBD) have established a number of indicators to assess progress at the global level towards the 2010 Biodiversity Target, and to communicate effectively the trends related to the three objectives of the Convention and the seven focal areas (see Table 0-1 and more details in CBD 2006).

WAB (2007) highlight six composite indicators as especially composite indicators are found more useful for policy makers. The indicators have been regularly implemented in official assessment reports (see Table 0-2):

1. Natural Capital Index (NCI)
2. Living Planet Index (LPI)
3. Biodiversity Intactness Index (BII)
4. Mean Species Abundance (MSA)
5. Species Assemblage Trend Index (STI)
6. Red List Index (RLI)

Further often used indicators are related to (sustainable) human use of available land and biomass, e.g., Ecological Footprint (EF) and Human Appropriation of Net Primary Production (HANPP).

The above mentioned indicators cannot be translated directly into a biodiversity value, but can serve as a proxy as they are related to the main drivers. Major features of the indicators and their comparison are given in the following tables.

Table A- 11 Headline indicators for assessing progress towards the 2010 Biodiversity Target[113]

FOCAL AREA: Reducing the rate of loss of the components of biodiversity, including: (i) biomes, habitats and ecosystems; (ii) species and populations; and (iii) genetic diversity ▪ Trends in extent of selected biomes, ecosystems and habitats ▪ Trends in abundance and distribution of selected species ▪ Change in status of threatened species ▪ Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance ▪ Coverage of protected areas
FOCAL AREA: Maintaining ecosystem integrity, and the provision of goods and services provided by biodiversity in ecosystems, in support of human well-being ▪ Marine Trophic Index ▪ Connectivity/fragmentation of ecosystems ▪ Water quality in aquatic ecosystems
FOCAL AREA: Addressing the major threats to biodiversity, including those arising from invasive alien species, climate change, pollution, and habitat change ▪ Nitrogen deposition ▪ Trends in invasive alien species

113 Focal areas and associated headline indicators are from decision VII/30, with refinements as recommended in SBSTTA recommendation X/5. This table lists only those headline indicators discussed in the Global Biodiversity Outlook 2 (CBD 2006), and the sequence of focal areas differs from decision VII/30.

FOCAL AREA: Promoting sustainable use of biodiversity ▪ Area of forest, agricultural and aquaculture ecosystems under sustainable management ▪ Ecological footprint and related concepts
FOCAL AREA: Protecting traditional knowledge, innovations and practices ▪ Status and trends of linguistic diversity and numbers of speakers of indigenous languages
FOCAL AREA: Ensuring the fair and equitable sharing of benefits arising out of the use of genetic resources ▪ Indicator to be developed
FOCAL AREA: Mobilizing financial and technical resources, especially for developing countries, in particular, least developed countries and small island developing states among them, and countries with economies in transition, for implementing the Convention and the Strategic Plan ▪ Official development assistance provided in support of the Convention

Table A- 12 Composite indicators regularly implemented in official assessment reports

The Natural Capital Index (NCI) is based on the abundance of individuals of species, relative to the low-impacted or pre-industrial state. In essence NCI measures human impact. NCI has been used in UNEP's Global Environment Outlook 1 and 3 (UNEP/RIVM, 2004), and it is very easy to monitor and to model, even for poor countries, which makes it more feasible for global use. The ecosystem quantity (extent) is based on land use and land cover monitoring, the ecosystem quality component is based on literature reviews, expert judgment and modeling exercises (UNEP, 1997).
The Living Planet Index (LPI) is calculated from measured population sizes (i.e. species abundance) of a representative selection of species (for world ecosystems) relative to 1980. The LPI does not distinguish between natural and man-made ecosystems and is entirely calculated on the mean species abundance of a core set of species. In essence LPI measures human impact since 1970. The valuation principle is: the more individuals per species the better. LPI has been applied in various WWF reports (Loh/Wackernagel 2004) and the 2nd Global Biodiversity Outlook (CBD 2006).
The Biodiversity Intactness Index (BII) is based on the mean species abundance relative to the natural or low-impacted state at the ecosystem level. The valuation principle is naturalness, and no distinction is made between natural and agricultural ecosystems. The BBI is derived and calculated from land-use and land cover data. Each land use category has a fixed biodiversity value, based on field data and expert judgment. In essence BII

measures human impact by agriculture, extensive grazing and forestry. National parks are used as reference. It has been specifically designed for species-data poor regions, and has been applied in Southern Africa and in the South African assessment of the Millennium Ecosystem Assessment (Scholes/Biggs 2005).
The Mean Species Abundance (MSA) is based on the mean abundance of individual species relative to the abundance in natural or low-impacted situations at the ecosystem level. No distinction is made between the natural and man-made ecosystems, contrary to NCI. It has been designed for global and regional assessments in which models calculate the future status for different scenarios. In essence MSA measures human impact. Therefore, the valuation principle is “naturalness”. It is not intended to highlight individual species under threat. It has been linked to the dynamic global environmental change model IMAGE (Bouwman et al. 2006), and has been applied various studies (e.g., UNEP 2006, 2007).
The Species Assemblage Trend Index (STI) gives the mean abundance of a species group compared to a reference year (i.e. 1980). These could be taxonomic groups, species of cultural interest, endemic species, migratory species, threatened species, etc. In essence STI measures human impact on a species group since the reference year. The valuation principle is: the more individuals per species the better. STI has been applied in various national and European reports (e.g., de Heer et al. 2005).
The Red List Index (RLI) is based on weighting the extinction-risk of species from particular taxonomic groups. In essence RLI measures human impact – in terms of risk of extinction – per species group since a certain year. The valuation principle is: the lower the extinction-risk the better. Several varieties of RLI have been used all over the world, making comparisons difficult. Currently the RLI is redesigned to improve its communicative value.

Source: WAB (2007)

Table A- 13 Comparison between Six Composite Indicators Regarding Features and Meaning

Indicator	Level	Baseline or reference	Valuation principle	Species/area weighted	Meaning
NCI	ecosystem	preindustrial	more natural the higher	area	change in naturalness since industrialization
BII	ecosystem	natural	more natural the higher	area and species	change in naturalness
MSA	ecosystem	natural	more natural the higher	area	change in naturalness since industrialization
LPI	ecosystem	1970 -	more indiv. the higher	species	change in species abundance since 1970
STI	species	1980	more indiv. the higher	species	change in species abundance of group
RLI	species	extinction risk	less risk the higher	species	change in extinction risk of group

Source: WAB (2007)

Annex D Tanzania Case Study to Identify Biodiversity-Relevant Areas

The BIAS approach to identify biodiversity-relevant areas described in Chapter 2 is based on the use of existing data bases. To test this approach, a brief desktop case study for Tanzania was carried out in which relevant global data were collected and implemented in the Geographic Information System ArcGis. These data are also available for most countries in the world, so that this approach can hence be carried out with relative low human and technical recourses in other countries as well.

Six data layers have been used for the top-down analysis (see Figure A-1): Critical and endangered ecoregion (Olson et al. 2001) and biodiversity hotspots (Mittermeier et al. 2005) have almost the same spatial extension, whereas Key Biodiversity Areas (Conservation International) together with World Heritage and Ramsar Sites cover additional areas. Wetlands (Lehner/Döll 2004) show a relative low spatial extension in Tanzania. Protected areas (PA) in Tanzania according to IUCN-WCMC are partly – but not fully – congruent with areas of the upper data sets, stressing the need to extend the PA network in Tanzania.

However, due to PA where restricted human land-use is allowed, additional areas are covered by the PA data set than by the other data sets. In such areas – bottom up – a careful analysis is needed to decide in for these PA which kind of bioenergy production is in line with the protection of biodiversity.

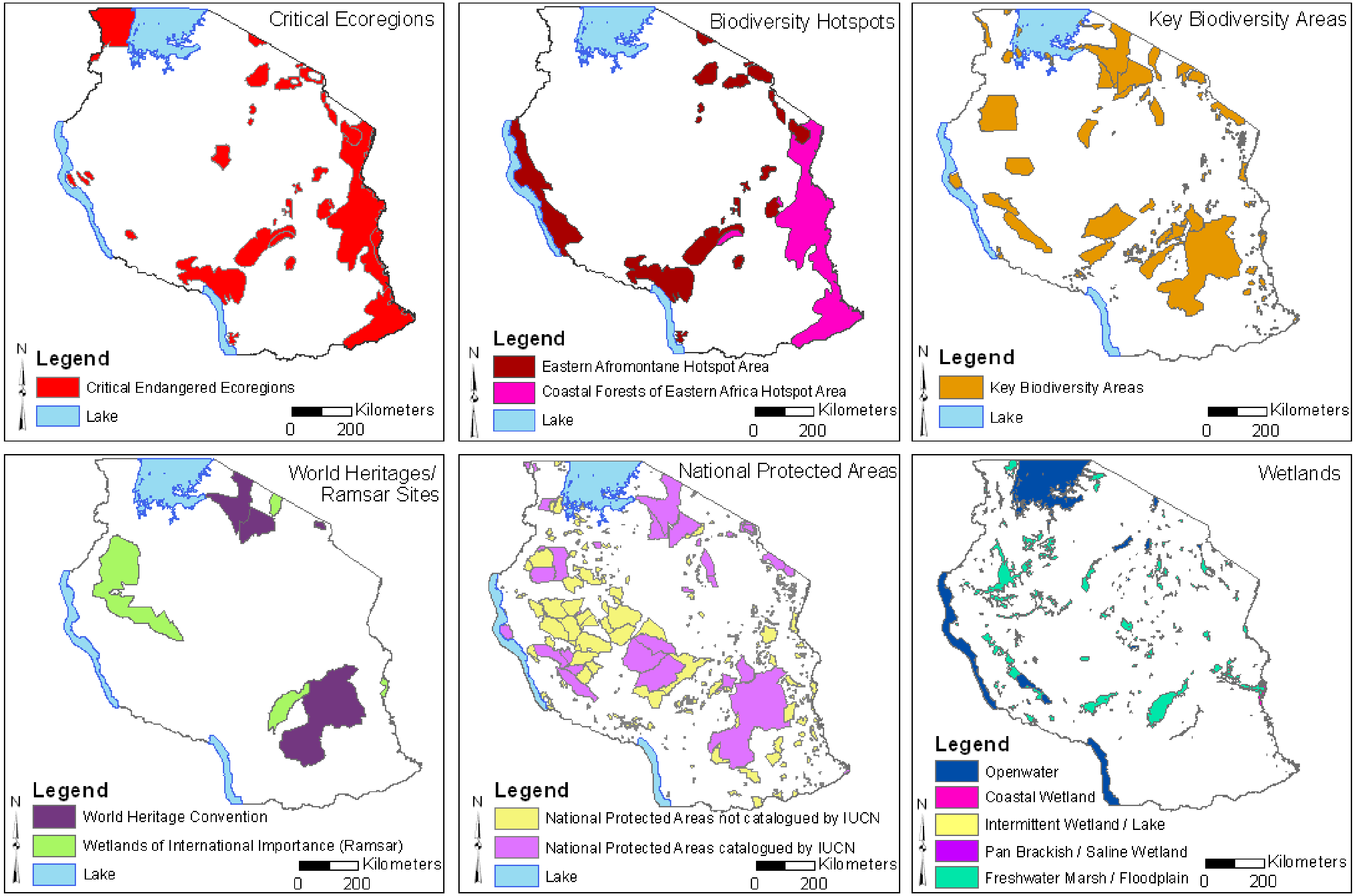
The spatial coordinates of these data layers are merged together as shown in Figure A-2 (A). Compared to other approaches to identify biodiversity relevant areas like the COMPETE-project that focused on PA data from IUCN-WCMC and specific land cover categories, the data assemblage shown here is more complete and straight forward to biodiversity-relevant areas. However, according to a quick cross-check of the data in Figure A-1 by the Tanzanian National Land Use Planning Commission revealed that these data are a good basis, but **areas are missing**. For example, the Central part of Tanzania such as Bahi Swamps is not indicated, stressing the need of careful evaluation (Gerald Mango, *pers. comm. 2008*).

Forest and woodlands can harbor high biodiversity, but not necessarily. Thus, as shown in Figure A-2, these data are plotted as overlay on the already identified biodiversity-relevant areas. Again, a bottom up analysis is needed to specify which of those forests and woodland outside of the biodiversity-relevant areas are also of importance to protect biodiversity, and which kind of sustainable bioenergy production could be possible.

The data presented here can be used as a first top-down categorization of land in Tanzania. The next top-down step would use suitability maps of specific crops, soil and water conditions as well as current land-use activities (if available).

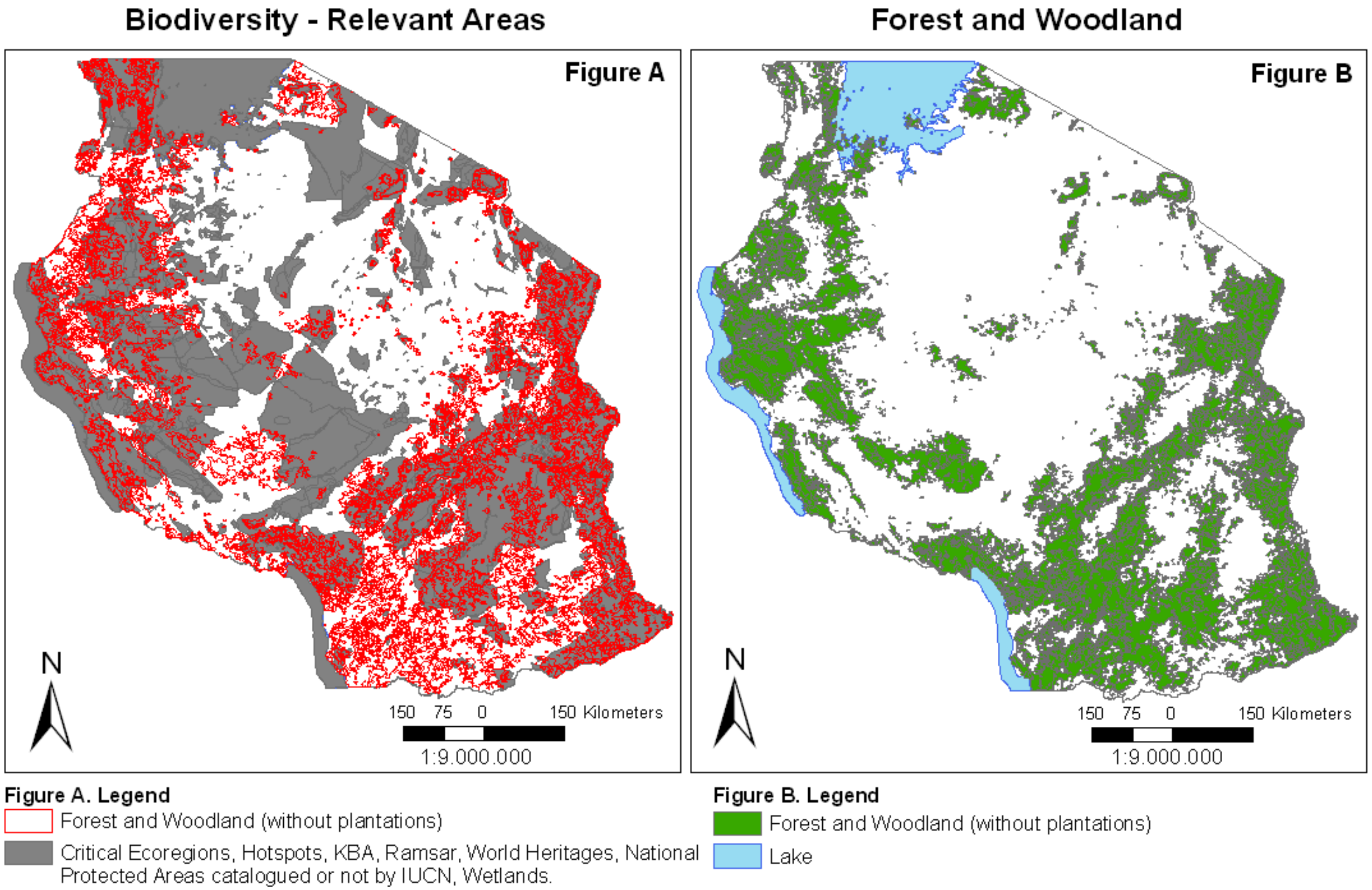
Bottom-up-wise, the white areas in Figure A-2 need more specification regarding sustainable bioenergy production systems.

Figure A-1 Data layer of biodiversity-relevant datasets for Tanzania used within the top-down analysis to identify biodiversity relevant areas



Source of data are given in the following figure

Figure A-2 *(A) Merged data layer of biodiversity-relevant datasets shown in Figure I-1 overlaid with borders of forest and woodlands. (B) Location of forests and woodlands in Tanzania.*



Sources: Forest and Woodland: GLC2000. Bartholomé and Belward 2005; http://www-gvm.jrc.it/glc2000/interactive/glc2000_vgt_1280x1024.html. Wetlands: Global Lakes and Wetlands Database. Lehner & Döll 2004; http://www.wwfus.org/science/data.cfm. UICN Catalogued and No Catalogued National Protected Areas & International Protected Areas http://www.unep-wcmc.org/protected_areas/UN_list/index.htm.Key Biodiversity Areas (KBA). Conservation International.Contact: David Knox.Terrestrial Ecoregions of Africa and Madagascar. A Conservation Assessment. By: Neil Burgess, Jennifer D'Amico Hales, Emma Underwood and Eric Dinerstein et al 2004. Biodiversity Hotspots. Mittermeier et al. 2005.http://www.biodiversityhotspots.org/xp/Hotspots/resources/pages/maps.aspx

Annex E Description of Water Indices

Water Availability Index (WAI)

The Water Availability Index (WAI) according to Meigh et al. (1999) takes the temporal variability of water availability into account. The index includes surface water and groundwater resources. WAI compares the total amount of water resources to the demands of all sectors, i.e. domestic, industrial and agricultural demands.

The index is normalised to the range –1 to +1 and is calculated as follows (Meigh et. al, 1999):

$$WAI = (R + G - D) / (R + G + D)$$

R = surface runoff, G = groundwater resources

D = sum of demands of all sectors

When the index is zero, availability and demands are equal.

This Index was applied in Sri Lanka (Dhanasekara und Maddumabandara, 2004) and Palestine (Alamarah et al., no date) amongst others in agricultural sector, in relation to water management or water demand management.

WAI is a simple Index that can be used to evaluate existing gaps between availability and withdrawal of water.

Water Stress Index (WS)

Hoekstra (2003) calculates this Index WS as follows:

$$WS = (WU / WA) * 100$$

WS = national water scarcity (%)
WU = total water consumption in country (m^3/a)
WA = national water availability (m^3/a)

This Index is not considered suitable for the objective of this project since only national water balance is taken into account.

Mekonnen/Hoekstra (no date) suggest a different determinable Water Scarcity Index (see 0).

Water Scarcity Indices (four different approaches)

Four different approaches are described under the concept *Water Scarcity Index*.

In general the *Water Scarcity Index* depicts the development of water situation in riverside states. Existing gaps between availability and consumption of water including their significance can be determined with this index.

Water Scarcity Index (according to Hoekstra)

Mekonnen und Hoekstra (no date) and Hoekstra (2003) developed a *Water Scarcity Index* based on the above mentioned *Water Stress Index*. They included the concept of *Water Footprint*[114] in this index, which was applied in a case study in Kenya and is calculated as follows:

WS = (WF / WA) * 100

WF = water footprint;

WA = national water availability (m^3/a):

Because of its national character, the Water Scarcity Index is regarded as unsuitable for the objective of this project.

Water Scarcity Index considering ecological water demand

Smakhtin et al (2002) include the concept of environmental water scarcity in the Water Scarcity Index by adding the water quantity to guaranty sustainable functions in ecosystems.

This Water Scarcity Index is calculated as follows:

WSI = (Withdrawals) / (MAR – EWR)

Beside the consideration of environmental functions is a positive aspect, it is unclear which environmental factors are incorporated and in which way.

---

[114] Definition of Water Footprint, according to Hoekstra und Chapagain (2006): The water footprint of a country is defined as the volume of water needed for the production of the goods and services consumed by the inhabitants of the country. The internal water footprint is the volume of water used from domestic water resources; the external water footprint is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country.

Water Scarcity Index (according to Asheesh)

Asheesh (no date) calculates Water Scarcity Index based on water balance as follows:

$$Wsci = (Wav / Wtad) - 1$$

Wav: available water resources in a river basin / state

Wtad: total water consumption in all river basins / states

Asheesh (no date) incorporates all significant parameters for water demand estimation, considering then the population growth as the most important parameter for this operation.

The Water Scarcity Index has been calculated and depicted in cases studies in Israel and Palestine. The idea is to create a control system within a state or among states, so that every riverside state gets the water quantity that is in need.

In this index are used the same parameter as in WSI und WS but not the connections. Insofar is classified this index as suitable, like those indices.

Water Scarcity considering desalinated water

A study of the „Research Institute for Humanity and Nature“ (Japan) refers to this index, which was deduced from Water Scarcity Index (Falkenmark) and used by UN et al. (1997), Vörösmarty et al. (2000) und Heap et al. (1998).

The water withdrawal is reduced by the desalinated water. Hence the following Water Scarcity Index (Unesco-IHE 2007):

$$R_{WS} = (W – S) / Q$$

W = annual water withdrawal, s = desalinated water resources

Q = annual available water quantity

The available water quantity has been determined with TRIP-Models (Total Runoff Integrating Pathways). Based on this model prognosis for 2050 have been developed (see chapter 3).

The question about desalinated water will play a role only in coastal areas. Otherwise this index behaves just like above mentioned indices (WSI, WS, Wsci).

Water Poverty Index (WPI)

Sullivan (2002) suggests an Index that shows the connection between water scarcity issues and socio-economic aspects[115]. This Index combines percentage of used water in a region with the population, the access to clean water and to sanitation (%) und the population with easy access to water for domestic use (%). This composite conventional Index is expressed by Sullivan (2002 cited in Alamarah (2006)) as follows:

$$WPI = Wa\ A + Ws\ S + wt\ (100 - T)$$

A: Adjusted water availability assessment (%)
S: Population with access to safe water and sanitation.
T: Time and effort taken to collect water for household.

The values for A, S und T are between 0 and 100; Wa, Ws and wt: are the weighting for each index component (wa+ ws + wt = 1). The outcome of the equation must be divided by 3 to get a value between 0 and 100.

According to another source WPI combines the following factors (Sullivan 2002, Lawrence et al. 2002):

- Resources (R)
- Access (A) to clean water, waste water treatment, irrigation (relating to % population)
- Use (U) – Efficiency of water use
- Capacity (C) to manage water
- Environment (E)

The *Environment* issue includes 16 sub-indicators to be considered. How these should be weighted and calculated is however not clear explicated.

WPI has been applied for projects amongst others in special areas such as Benin (Heidecke, 2006) or the Nile (DFID, no date).

115 weitere Informationen zu den im WPI enthaltenden Faktoren siehe: http://environ.chemeng.ntua.gr/WSM/Newsletters/Issue4/Indicators_Appendix.htm

The *Water Poverty Index* is valued as a multi-criteria tool, which could be applied for monitoring of water management measures. Due to scope and complexity of the implicated parameters WPI is considered a rather “mild” indicator, unsuitable for “strong" evaluation of water scarcity facts. Otherwise the existence of broad data availability is not guaranteed for many of the requested parameters.

Water Consumption Index

The *Water Consumption Index* (UT) developed by Mendoza et al. (1997) describes the total consumption relating to (fresh-)water resources in a country.

The water consumption is calculated from the consumption of discrete sectors (UL = local consumption (domestic use, industry, electricity)), UR= (Irrigation) divided by surface runoff (Q).

$$\text{Water Consumption } UT = (UL + UR) / Q * 100$$

The application of UT in a study by Mendoza et al. (1997) in Mexico resulted in 12 hydrological zones. Vulnerability prognoses for river watersheds were generated with the aid of diverse computer models. Calculations are based on diverse computer models.

If the index is superior to 20 %, according to Szeszatay (1970, in Mendoza et al. 1997) the zone is classified as hydrologically vulnerable.

Therefore, as result of these zones, a regional vulnerability differentiation is generated, taking into account precipitation and drought. Transfer of these zones to other regions is not possible since this study shows that there are different limiting factors.

Vulnerability of water systems

Gleick (1990) identified indicators of water resource vulnerability for the US, which allow estimating possible climatic changes (cited in Jacobs et al. no date).
This Index bases on five parameters[116], although these do not appear in each region:

- Storage volume related to renewable water resources
  (if <60 %, then vulnerable)
- Consumptive used related to available water resources
  (if >0,2, then vulnerable)
- Proportion of hydroelectricity related to total electricity
  (if hydroelectricity proportion >25 %, then vulnerable)
- Groundwater overdraft related to groundwater withdrawal
  (Value >0,25, then vulnerable)
- Stream flow variability; a system is vulnerable, if this variable is superior to 3. This variable is calculated from the 95th percentile of stream flow distribution divided by the 5th percentile (Q_{95}/Q_5).

Gleick (1990) found that the most vulnerable regions were the high irrigation areas along of the Rocky Mountains.

Compared to the previously mentioned indices, this index comprises further parameters. Since plant specific parameters are not considered, this index is unsuitable for the objective of this project, i.e. for evaluating whether an expansion of bioenergy feedstock cultivation could cause water stress or not.

---

116 http://environ.chemeng.ntua.gr/WSM/Newsletters/Issue4/Indicators_Appendix.htm

Water Resources Vulnerability Index (WRVI)

The WRVI was developed by the Stockholm Environmental Institute (SEI) in 1997 (Gleick et al. 2002) and is named also the SEI-Index (University Bochum, 2004). It consists of the following parameters:

- Reliability = Storage and Import dependence related to precipitation
- Water consumption related to resources and
- coping capacity

The use of this index requires numerous parameters, which are not easy to collect or are not globally available. Hence this index is not suitable for the objective of this project.

Water Exploitation Index (WEI)

Like the majority of mentioned indices WEI relates (fresh) water withdrawal to available resources. The WEI is calculated according to the European Environmental Agency (no date) as follows[117]:

WEI = totABS / LTAA x 100

totABS = total annual freshwater abstraction for all uses

LTAA = long term annual average of freshwater resources, where data are averaged over a period of at least 20 consecutive years. Unit = %

WEI is suitable for the presented question and the consequent division in regions with or without water stress is also applicable.

117 http://themes.eea.europa.eu/IMS/IMS/ISpecs/ISpecification20041007131848/full_spec#Methodology

Annex F Soil Quality and Risk Assessment for Soils

Table A- 14 List of Indicators used by different authors in soil quality indexes in agro-ecosystems

Authors	**Objective**	**Indicators used**
Karlen et al. (1994a)	Soil Quality Index: Evaluation of effects of crop residue management on soil quality under corn culture	Aggregate stability, porosity, worms, microbial biomass, respiration, ergosterol, total C, total N, bulk density, available water, pH, electrical conductivity
Wang and Gong (1998)	Relative Soil Quality Index: Evaluation of changes in soil quality in natural and agriculture systems	Soil depth, texture, slope, organic matter, total and bio-available N, P and K, cation exchange capacity and pH.
Hussain et al. (1999)	Adaptation of indices to evaluate effect of three cultivation systems on soil quality	Aggregate stability, organic C crop residues, porosity, exchangeable K, pH.
Glover et al. (2000)	Soil Quality Index: Evaluation of effects of different apple production systems: conventional, organic and integrated	Aggregate stability, porosity, worms, porosity, organic C, microbial biomass C and N, cationic exchange capacity, pH and N.
Liebig et al. (2001)	Land Quality Index: Agroecosystem performance: effects of conventional and alternative agricultural systems	Seed yield, N content of seed, pH, organic C, nitrates.
Andrews et al. (2002b)	Soil Quality Index: Evaluation of tomato and cotton crop quality in conventional and organic cultivation.	Organic matter, electrical conductivity, pH, water water-stable aggregates, real density and Zn
Koper and Piotrowska (2003)	Biochemical Soil Fertility Index: Comparison of long term effect of organic and mineral fertilisation in sugar beet	Organic C, total N, dehydrogenase activity, alkaline phosphatase activity, protease activity, amylase activity.
Kang et al. (2005)	Sustainability Index: Comparison of long term effect of organic amendments in systems for cultivating maize and rice.	Organic C, total N, extractable K, extractable nitrates and ammonium content, microbial biomass C and N, mineralizable N, respiration, bacterial counts, mycchorhizal infection, dehydrogenase activity.

Authors	Objective	Indicators used
Sharma et al. (2005)	Soil Quality Index: Selection of adequate managements in drylands comparing between conventional and minimal cultivation	Available N, K and S, microbial biomass C and saturated hydraulic conductivity.
Lee et al. (2006)	Soil Quality Index: Effects of swine manure compost application on soil quality under different vegetable and rice systems	Bulk density, aggregates, organic C, pH, available K and P, extractible Cu and Zn, microbial biomass, C, mineralizable N.
Puglisi et al. (2005)	Alteration index: Effects on the quality of agricultural soils contaminated with industrial and municipal wastes, organic fertilisation or irrigation with poor quality water under different crops: Ficus carica, maize, tomato, etc.	Arylsulphatase enzymatic activities, β-glucosidase, phosphatase, urease, ivertase, dehydrogenase and phenoloxidase.
Puglisi et al. (2006)	Soil Alteration Index: Effects on the quality of agricultural soils contaminated with industrial and municipal wastes, organic fertilisation or irrigation with poor quality water under different crops: F. carica, maize, tomato, etc.	PLFAs (Phospholipid fatty acid)
Mohanty et al. (2007)	Soil Quality Index: Effects of cultivation practice (conventional and without ploughing) in rice–wheat systems, and maintaining vegetal residues on soil quality.	Bulk density, aggregate stability, resistance to penetration, organic matter
Masto et al. (2007)	Soil Quality Index: Evaluation of agricultural soils fertilised with inorganic and/or farm yard manure.	Bulk density, water retention, pH, electrical conductivity, bio-available nutrients, organic matter, microbial biomass and crop yield.
Erkossa et al. (2007)	Soil Quality Index: Compare the effect of land preparation methods (broad bed and furrows, green manure, ridge and furrows, reduced tillage) on soil quality	Bulk density, aggregate stability, organic C, microbial biomass C, pH, available water capacity

Source: own compilation based on Bastida et al. (2008)

Table A- 15 Risk Area Identification for Soil Erosion

Common Criteria	Data Quality in the EU/Resolution Tier 1 Tier 2	Global data
soil typological unit (STU); soil mapping unit (SMU)	national soil databases **Tier 1**: national level **Tier 2**:regional level	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.
soil texture (at STU level)	texture class; sand, silt and clay content **Tier 1**: texture class **Tier 2**:particle size	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.
density, hydraulic properties (at STU level)	bulk density, packing density, water retention at field capacity and wilting point **Tier 1**: pedotransfer rules or functions **Tier 2**: measured data	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.
topography	gradient (slope), length, geometry, Digital Elevation Models **Tier 1**: 250 m (SRTM) **Tier 2**: 90 m	Based on NASA's Shuttle Radar Topography Mission (SRTM): GTOPO 30 included in HWSD Resolution: 90 m / 30 m.
land cover	localisation of land cover type (e.g. CORINE land cover data) **Tier 1**: 250 m **Tier 1**: 100 m	GlobCover (resolution: 300 m). An ESA initiative in partnerschip with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. Global Land Cover 2000 (resolution 1 km). Project coordinated by the Joint Research Centre (JRC), Institute for Environment and Sustainability. MODIS/Terra Land Cover Type Yearly (1 km / 500 m resolution). U.S. Geological Survey.
land use	land use, agricultural statistics (e.g. to distinguish between crop types) **Tier 1**: NUTS3[118] **Tier 2**: NUTS4	Land Use Systems of the World (LUS). FAO (LADA Project): no distinction between crop types About 8 km at equator. Agro-MAPS: Global Spatial Database of Agricultural Land Use Statistics. FAO

118 Nomenclature of Territorial Units for Statistics. There are three levels of NUTS defined, with two levels of local administrative units (see details at http://ec.europa.eu/eurostat/ramon/nuts/home_regions_en.html).

Common Criteria	**Data Quality in the EU/Resolution Tier 1 Tier 2**	**Global data**
climate	precipitation: rainfall, snowfall, number of rain days, storm events PET, temperature **Tier 1**: 10 km daily average, 50 km daily average **Tier 2**: 1 km raster (modelled from national weather station network) daily – 30 years	CRU TS 2.1 Climate Database (Climatic Research Unit of University of East Anglia). About 60 km resolution at equator. FAOCLIM Database. FAO. Agroclimatic data. About 60 km resolution at equator.
hydrology	Catchment Information System Digital Elevation Model **Tier 1**: 10 km **Tier 2**: 1 km	HydroSHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales) – System Research (CESR) of University of Kassel. 90 meter resolution at equator. HYDRO1k Elevation Derivative. U.S. Geological Survey's Center for Earth Resources Observation and Science (EROS) Database. 1 km resolution at equator.
agro-ecological zone	based on soil, climate & landscape **Tier 1**: 50 km **Tier 2**: 1 km	Food Insecurity, Poverty and Environment Global GIS Database (FGGD). FAO/IIASA. About 8 km resolution at equator.

Source: EU-level following Eckelmann et al. (2006); own judgement for global data

Table A- 16 Risk Area Identification for Soil Organic Matter Decline

Data need/Level of detail:	Data in the European Union	Global data
Soil Maps: delineation of soil typological units (STU), generally through soil mapping units (SMU) for the whole country	**Tier 1**: identification of risk zones; reporting (1:1,000,000); **Tier 2**: action plans, monitoring (larger scale than 250,000)	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.
Soil Classification: World Reference Base (WRB, 1998, 2006)	The comparability between countries can be improved if national soil data (including soil mapping data) are translated into WRB	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km
Soil Map Data: typical profile descriptions and standard data for the STU	Improve digital soil data availability for fully described soil profiles; set up information system to combine plot data with map data	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km
Topography: 250 m	Digital Elevation Model exists based on SRTM 78m	Based on NASA's Shuttle Radar Topography Mission (SRTM): GTOPO 30 included in HWSD Resolution: 90 m / 30 m.
Land Cover: 250 m	Exists based on CORINE land cover for many countries. Ideally the spatially explicit distribution of crop types is known	GlobCover (resolution: 300 m). An ESA initiative in partnerschip with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. Global Land Cover 2000 (resolution 1 km). Project coordinated by the Joint Research Centre (JRC), Institute for Environment and Sustainability. MODIS/Terra Land Cover Type Yearly (1 km/500 m resolution). U.S. Geological Survey.
Climate: 250 m	does not exist at the European level where only data on a 50-km grid exist (MARS project); National data are thus required	CRU TS 2.1 Climate Database (Climatic Research Unit of University of East Anglia). About 60 km resolution at equator. FAOCLIM Database. FAO. Agroclimatic data. About 60 km resolution at equator.
Land Use	in contrast to land cover 250m, more accurate information about the abundance of land use categories (e.g. agricultural practices) is needed for soilscapes/administrative boundaries/250 m grid cells: at least, **NUTS Level III** should be considered	Land Use Systems of the World (LUS). FAO (LADA Project) About 8 km at equator. Agro-MAPS: Global Spatial Database of Agricultural Land Use Statistics. FAO (provincial data) Digital Global Map of Artificially Drained Agricultural Areas. Feick et al., 2005. About 8 km resolution at equator.

Data need/Level of detail:	Data in the European Union	Global data
Soil Management	- litter input/production coefficients per crop; - crop-specific typical agricultural practices; - expert system for crop selection and soil properties (needed to more accurately spatially disaggregate soil-related statistical land use data)	Food Insecurity, Poverty and Environment Global GIS Database (FGGD). FAO/IIASA. About 8 km resolution at equator.
Analytical Data	- soil depth: 0-30 cm, or A and B horizons with their depth; - parameters: SOC, soil inorganic carbon (SIC), pH, base saturation, N, P, bulk density, stone content, and thickness & weight of O layer horizons; - dry combustion/elementary analysis (wet oxidation does not fully detect SOC)	For the parameters organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry: Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.

Source: Eckelmann et al. (2006) and own judgement

Table A- 17 Risk Area Identification for Soil Compaction

Common criteria	Type of information	Data Quality / Resolution in EU	Global data
land use	statistical data about agriculture and forestry: crop types and forest areas, types of farming systems (annual crops, vineyards, animal breeding, etc.), type of forests	**Tier 1**: NUTS 3 **Tier 2**: NUTS 4	Land Use Systems of the World (LUS). FAO (LADA Project): no distinction between crop types About 8 km at equator. Agro-MAPS: Global Spatial Database of Agricultural Land Use Statistics. FAO (provincial data) Global Forest Resources Assessment. Forestry Databases (FRA 2000 / FRA 2005) (national data) See also land cover global data
farming and forest systems	typology of farming systems or forestry systems in relation to land use data	**Tier 1**: expert knowledge **Tier 2**: survey data	**No data available**
land cover	localisation of agricultural and forest areas, etc. using data such as CORINE land cover	**Tier 1**: 250 m **Tier 2**: 100 m	GlobCover (resolution: 300 m). An ESA initiative in partnerschip with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. Global Land Cover 2000 (resolution 1 km). Project coordinated by the Joint Research Centre (JRC), Institute for Environment and Sustainability. MODIS/Terra Land Cover Type Yearly (1 km / 500 m resolution). U.S. Geological Survey.
slope	Digital Elevation Model	**Tier 1**: 250 m **Tier 2**: 90 m	Based on NASA's Shuttle Radar Topography Mission (SRTM): GTOPO 30 included in HWSD Resolution: 90 m / 30 m.
SMU/STU delineation	National Soil Geographical Data Base	**Tier 1**: national **Tier 2**: regional	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.
STU topsoil and subsoil texture	texture class or mean silt, clay and sand content	**Tier 1**: texture class **Tier 2**: particle size	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km.

Common criteria	Type of information	Data Quality / Resolution in EU	Global data
STU description	bulk density, other parameters according to availability in soil inventories: water retention, organic matter content, structure, hydraulic conductivity, air capacity	**Tier 1**: pedotransfer functions or rules **Tier 2**: measurements and soil morphological descriptions from representative soil profiles	Harmonized World Soil Database (HWSD) FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) Resolution of about 1 km
climate	rainfall and PET	**Tier 1**: average year, data on a month or 10-day basis, NUTS 3 or 50 km **Tier 2**: 20 to 30 years one day basis, 10 km	CRU TS 2.1 Climate Database (Climatic Research Unit of University of East Anglia). About 60 km resolution at equator. FAOCLIM Database. FAO. Agroclimatic data. About 60 km resolution at equator.

Source: Eckelmann et al. (2006) and own judgement

Salinization and Sodification

Table A- 18 Required input data for the characterization and risk identification of salinization/sodification

Soil characteristics		at start t_o	yearly	3 yearly	6 yearly	Remarks
morphological description of the soil profile		+				
particle size distribution		+				
texture		+				
total water storage capacity (WC_T –pF_0)		+				on undisturbed soil cores
field capacity (FC– pF 2.5)		+				
wilting percentage (WP – pF 4.2)		+				
available moisture range (AMR = FC–WP)		+				
saturated hydraulic conductivity		+				
$CaCO_3$ content	if > 5 %	+			+	
	if 1 - 5 %	+		+		
	if < 1 %	+	+			
pH(H_2O) if $CaCO_3$	> 1 %	+		+		
	if $CaCO_3$< 1 %	+	+			
pH(KCl) if $CaCO_3$	> 1 %	+		+		

Soil characteristics	at start t_o	yearly	3 yearly	6 yearly	Remarks
if $CaCO_3$ < 1 %	+	+			
total water-soluble salts (in salt-affected soils)	+	+			
1:5 water extract analysis [pH, EC; CO_3^{2-}, HCO^{3-}, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+]	+			+	
Phenolphthalein alkalinity	+		+		
Depth of the humus horizon	+			+	profile
organic matter content	+	+			
CEC (cation exchange capacity)	+			+	
exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, K^+)	+			+	
Depth, fluctuation and chemical composition of the groundwater [pH, EC, CO_3^{2-}, HCO^{3-}, Cl^-, SO_4^{2-}, NO^{3-}, PO_4^{3-}, Ca^{2+}, Mg^{2+}, Na^+, K^+]	+	+			

Source: Eckelmann et al. (2006)

Global data:

- Most parameters are covered by: Harmonized World Soil Database (HWSD); FAO/IIASA/ISRIC/ISS-CAS/JRC (2008); Resolution of about 1 km.
- Time series are not available on a global scale.

Annex G GHG Data

GHG emissions from fossil reference systems

The GHG emissions from fossil reference system are adopted from JRC/EUCAR/Concawe (2006) as follows:

- 86.2 kg CO_2-eq. per GJ of diesel
  (adding together: crude oil extraction: 3.3; transport 0.8; refinery: 8.6; use: 73.5)
- 85 kg CO_2-eq. per GJ of gasoline
  (adding together: crude oil extraction: 3.3; transport 0.8; refinery: 6.5; use: 74.4)

Table A- 19 Basic Data on Carbon Stocks in Natural Areas and Land Use Types

Previous use		**C storage total**	**Biomass above ground**	**Biomass below ground**	**Soil organic carbon**
Grassland moderate zone	t C/ha	**70**	6.3		63
Savannah Latin America (high carbon content)	t C/ha	**134**	66	21	47
Trop. Secondary forest	t C/ha	**165** [a)]	65	45	60
Trop. rainforest SE Asia (mineral soil)	t C/ha	**265**	165	40	60
Trop. Rainforest SE Asia (wetland)	t C/ha	1,400 [a,b)]	165	40	1,200 [a,b)]
Degraded land SE Asia	t C/ha	40 [a,c)]	10		30

Source: IPCC (2006); supplementary sources:

a) Wuppertal-Inst., IFEU, FUER (2007)
b) Hoijer, A. et al. (2006)
c) Lasco, R.D. et al (2002)

Table A- 20 Lower Heating Values of Bioenergy Feedstocks and Products

		Lower heating value		Water content
Agricultural products		MJ/kg DS	MJ/kg OS	%
Wheat	Complete plant	17.1	13.5	18.4%
	Grains	17.0	13.7	16.9%
	Straw	17.2	13.3	19.8%
Maize	Complete plant	16.5	14.3	11.6%
	Grains	21.4	17.4	16.7%
	Straw	17.7	13.7	19.8%
Sugarcane	Complete plant	17.0	11.0	30.8%
	Crop harvest	17.0	11.0	30.8%
Sugar beet	Complete plant			
	beet	17.0	2.1	76.4%
	Crop harvest			
Rapeseed	Complete plant	21.8	17.0	19.6%
	Grains	26.5	21.8	16.2%
	Residue	17.0	14.7	11.8%
Soybeans	Complete plant	18.0	14.5	17.1%
	Beans/seed	20.0	17.0	13.3%

		Lower heating value		Water content
	Residue	17.0	13.0	20.5%
Palm oil	Seed head	24.6	22.3	8.5%
	Fruits	31.7	31.5	0.6%
	empty seed heads	17.5	14.0	17.5%
Semi-manufactured products				
Distiller's dried grains (DDGS)		21.8	16.0	23.9%
Molasses (45% sucrose)		19.0	7.2	55%
Bagasse (50% DS)		16.6	7.1	50%
Extracted beet slices		16.3	2.1	75.5%
Molasses, vinasse		17.0	7.2	50%
Rapeseed oil		37.2	-	0%
Soybean oil		36.6	-	0%
Palm oil		36.5	-	0%
Rapeseed extraction cakes		19.0	15.0	18.6%
Soy extraction cakes		19.0	15.0	18.6%
Oil fibers		17.5	14.0	17.5%
Palm nuts		28.0	28.0	0%
Glycerin (un-processed)		17.0	13.4	18.5%
Final product				
Ethanol		26.7	-	0%

		Lower heating value		Water content
RME		37.2	-	0%
SYME		37.0	-	0%
PME		36.6	-	0%
Hydrogenated vegetable oil		44.0	-	0%

DS: dry substance

OS: original substance with consideration to the given (default) water content

Table A- 21 Calculation of Default values for emissions from the slash-and-burn due to land use change

		Sugar cane Latin America	Soybean Latin America	Palm oil SE Asia
previous use		**savannah**	**Savannah**	**trop. rainforest**
Biomass total [a)]	**t C/ha**	**134**	**134**	**265**
biomass above ground	t C/ha	66	66	165
Emission factor für burning [b)]				
Methane (CH_4)	t/t biomass	0.0023	0.0023	0.0068
Laughing gas (N_2O)	t/t biomass	0.00021	0.00021	0.0002
emission per area [c)]				
Methane (CH_4)	t /ha	0.161	0.161	1.194
	t CO_2-eq./ha	2.9	2.9	21.8
Laughing gas (N_2O)	t /ha	0.015	0.015	0.035
	t CO_2-eq./ha	4.6	4.6	10.9
time span	Years	20	20	20
emission referring to biofuel				
not allocated	kg CO_2-eq./GJ	**4.56**	**22.8**	**12.87**
allocated [d)]	kg CO_2-eq./GJ	4.02	7.1	6.13

a) conversion factor biomasse to carbon: 0,47; according to IPCC Guidelines 2006, Volume 4, Chapter 4, Table 4.3
b) data from IPCC Guidelines 2006, Volume 4, Chapter 2, Table 2.5
c) 50% taken into account
d) allocation according to heating value along the complete production chain

Source: IPCC 2006, UNFCCC 2007

Annex H Effects of Pesticide Use in Bioenergy Crop Cultivation on Humans and the Environment

The use of pesticides is not restricted to the cultivation of food crops, but also very common in the production of energy crops. Many pesticides, however, are toxic and improper application bears high risks for human health and the environment. In industrialized as well as, and especially, in developing countries, pesticides are not always used according to the rules.

Although only about 20 % of the pesticides produced worldwide are applied in developing countries, 70 % of all statistically documented pesticide-related poisonings occur here, of which an estimated 99 % are lethal (Forastieri 1999, EJF 2003). The number of chronic and long-term damage to people's health is likely much greater.

In order to minimize the risk of an improper pesticide use and its possible negative consequences, it is reasonable to include this topic in the framework. Like for other parts of the framework, the target group is (potential) producers of energy crops aiming at exporting their products – from small-scale farmers and family businesses to large producers' cooperatives.

The impact of pesticides on humans and the environment serves as an example of environmental problems which cannot be addressed quantitatively in LCA or material flow accounting, as they occur specific to location and circumstances.

However, it is reasonable to include this topic in the framework in order to minimize the risk of an improper pesticide use and its possible negative consequences.

In order to sensitize relevant stakeholders to this issue, a questionnaire has been included in the annex. It addresses different actors such as governments, NGOs and farmers on national, regional and local level. Thereby, the focus is on energy crop producers as they are the main users of pesticides and, at the same time, are directly affected by an improper pesticide use.

The goal of this questionnaire is not to assess the specific impacts of pesticide misuse but it rather shall raise awareness among the potential users of pesticides and thus mitigate the risk of negative impacts due to an improper use.

Pesticides – a short characterization

Pesticides can be classified by means of different criteria, e.g. chemical families or the substances' use as insecticide, fungicide or herbicide. For the demonstration of the risks of the substances to humans and the environment, their division into toxicity categories is essential. Different internationally recognized criteria exist for this task. The following table offers a rough survey of the most common ones.

Table A- 22 Toxicity Classification Categories

Category	Description
Human toxicity	Carcinogenicity, mutagenicity, reproductive toxicity, hormonal effects
Environmental toxicity	Toxicity for aquatic organisms, birds, bees, earthworms
Persistency	Longevity, duration of chemical or biodegradability
Bioaccumulation	Accumulation of substances in tissues of living organisms

Source: Neumeister/Reuter (2008); Hueber/Neumeister (2005)

About 800 – 1000 active agents are currently approved worldwide which can be combined to several ten thousands of different pesticides (Weber 2008).

However, accreditation practices in single countries vary greatly: not all active agents are permitted in all countries. Furthermore, certain pesticides are produced in industrial nations exclusively for export while they may no longer be applied in the country of origin. In addition, the use of internationally condemned agents is allowed in many developing countries: nine of the so-called “dirty dozen”, extremely harmful chemicals, are still used in numerous of these countries (Neumeister 2001).

Pesticide Use: Risks for Humans and the Environment

While the majority of pesticides are applied according to the rules, a certain fraction is apparently still used wrongly, either knowingly or due to ignorance – in spite of great efforts of national and international institutions as well as special efforts of the pesticide producers to counteract this. One example is the FAO “International Code of Conduct on the Distribution and Use of Pesticides” which has been adopted in 1985 and now serves as a point of reference in relation to sound pesticide management practices (FAO 2002).

The greatest share of pesticide poisonings and environmental damages occur in developing countries where pesticides are often applied as cheap "universal remedies”; facing poverty, personal health often becomes secondary (Haffmans 2005).

Risks can occur for[119]:

I. farmers / workers themselves through
   - insufficient information on adequate protective equipment, protective clothing and tools,
   - the lack of knowledge and / or education regarding the correct use of pesticides,
   - wrong storage of the substances (e.g. in bedrooms),
   - inadequate disposal of leftovers (e.g. by incineration),
   - the use of poor quality pesticides.

II. the environment surrounding and the inhabitants of the farm through
   - the incorrect use and dosage of the substances (resulting in the contamination of soils and waterways),
   - easy access to storage rooms by unauthorized persons (e.g. children),
   - the misuse of empty containers (e.g. for food and drinking water),
   - the inadequate cleaning of contaminated materials and disposal of leftovers (e.g. in waterways).

III. others through the inadequate use and too high dosages of the substances (possible pesticide residues on crops).

The reasons for the deficiencies described above can be divided into political and economic framework conditions (liberalization of pesticide markets, corruption, minor control and consulting by state authorities, see Haffmans 2005) and into reasons which occur directly in the businesses. It is difficult to address the former, whereas the questionnaire could be applied directly at farm level and have an impact on this level.

The following reasons relating to the farm level can be named for the inadequate use of pesticides (Neumeister 2001, Haffmans 2005, FAO 2006):

- lack of awareness regarding toxicity of pesticides and respective risks,
- lack of mandatory regulations for work protection and/or their enforcement,
- ignorance regarding the substances due to:
   - partitioning of trading units into inappropriate (e.g. food) containers, often combined with mixing and dilution,
   - lack of or insufficient labeling or labels in foreign languages,
   - labels which do not match the contents
- lack of knowledge about cultivated crops, pests and adequate products and dosages (often pesticides are used without necessity).

---

119 see Weber (2001); World Bank (2008); Haffmans (2005) and FAO (2006).

Questionnaire: Deduction and Application

If pesticides are applied in an inappropriate way it is done either consciously or unconsciously. A knowingly wrong use points at institutional gaps and/or is the consequence of illegal or criminal activities. First steps for counteracting these gaps can be the creation and strengthening of control institutions and the empowerment of police authorities. In case of an unconsciously wrong application, a number of different measures such as educational activities can already lead to improvements. In accordance to this, the framework focuses on the prevention of effects resulting from ignorance. For this purpose, a set of questions was developed which was based on the deficiencies and their reasons described above. This (incomplete) set serve as a base for further discussions and addresses different stakeholders – ranging from governments and NGOs to farmers and covers all relevant levels. However, its main focus is producers of energy crops as the main pesticide users. The questionnaire can be described as follows:

Part of the questions serves the purpose of gaining direct and indirect information on the elements covered by the responsible handling of pesticides. These questions are worded in a very direct manner, such as the one about the employee training. Others, for example the question about the use and disposal of pesticide surpluses, are kept more "open" on purpose. They are meant to encourage reflection and the self-motivated search for information. Yes/No questions were avoided for precisely this reason and also in order to create the possibility and necessity of the questioned persons to familiarize with these problems. Another aspect concerns the level of details chosen in the questionnaire: Regarding 800 – 1000 active agents and their numerous combinations a detailed analysis of all pesticides and their relevance for energy crops is beyond the scope of this framework.

Where necessary, the associated effects must be considered separately for each specific case – means outside the scope of this framework. Therefore, the pesticides are regarded as one big class – independent of their toxicity.

The main prerequisite for the application of the questionnaire is the assumption that it is generally possible to create a consciousness for a responsible and environment-friendly use of pesticides and to initiate respective changes. Abuse takes place especially where control institutions are missing and where it is difficult to establish such institutions within a short period of time. In these cases, it is especially important to rely on the farmer's or biomass producer's sense of responsibility and to support it with educational activities and thought-provoking impulses.

Because a responsible use of pesticides includes their environment-friendly application, this questionnaire also serves the purpose of controlling if the cultivated energy crops might be certified and thus exported. The export of energy crops should only be permitted if pesticides were used and handled in an environment-friendly way and if this is guaranteed by respective certificates.

However, even if a change in individual awareness is possible in many cases, the power of a questionnaire such as this one is limited. It is notably neither an alternative to the creation of mandatory regulations nor to the enforcement of such regulations. Furthermore, it is not suited to completely abolish risks originating from the inappropriate use of pesticides. However, it may help minimize these risks.

List of Tables in the Main Text

Table 1-1 Typical Questions of Various Stakeholders with Regard to Environmental Impact Analyses 6

Table 1-2 Example of a Settings Matrix 8

Table 1-3 Environmental Impacts and Indicators for Bioenergy Systems 10

Table 2-1 Short-term biodiversity impact of land converted to annual and perennial bioenergy crops in both temperate and tropical regions. 12

Table 2-2 Key Issues of the Risk Mitigation Strategy to Protect Biodiversity. 14

Table 3-1 Key Issues of the Risk Mitigation Strategy for Water Resources 30

Table 4-1 Key Issues for the Risk Mitigation Strategies to Conserve the Soil 42

Table 4-2 Case Studies and Technologies by Group of Conservation Measures 43

Table 4-3 Soil, Land Cover and Climate Combinations Giving Rise to Higher Risks of Soil Organic Matter (SOM) Decline 48

Table 5-1 Greenhouse Gases and Conversion Factors 52

Table 5-2 Comparison of Co-Product Consideration 56

List of Tables in the Annex

Table A- 1 Example for Setting: La Pampa province, Argentina - Soybean production for biodiesel A-1

Table A- 2 Example for Setting: Ethanol from Sugar Cane in Brazil A-5

Table A- 3 Databases on Protected Areas, areas of high biodiversity and of undisturbed wildlife A-9

Table A- 4 Databases on Land Cover Classification Systems and Land-Cover Mapping A-17

Table A- 5 Databases on Forests A-22

Table A- 6 Databases on Wetlands A-28

Table A- 7 Databases on Degraded Land A-30

Table A- 8 Agricultural Production and Land Use A-34

Table A- 9 Databases on Soil, Slope and Elevation A-37

Table A- 10 Databases on Water, Hydrology and Climate A-41

Table A- 11 Headline indicators for assessing progress towards the 2010 Biodiversity Target A-55

Table A- 12 Composite indicators regularly implemented in official assessment reports A-56

Table A- 13 Comparison between Six Composite Indicators Regarding Features and Meaning A-58

Table A- 14 List of Indicators used by different authors in soil quality indexes in agro-ecosystems A-69
Table A- 15 Risk Area Identification for Soil Erosion A-71
Table A- 16 Risk Area Identification for Soil Organic Matter Decline A-73
Table A- 17 Risk Area Identification for Soil Compaction A-75
Table A- 18 Required input data for the characterization and risk identification of salinization/sodification A-76
Table A- 19 Basic Data on Carbon Stocks in Natural Areas and Land Use Types A-78
Table A- 20 Lower Heating Values of Bioenergy Feedstocks and Products A-79
Table A- 21 Calculation of Default values for emissions from the slash-and-burn due to land use change A-82
Table A- 22 Toxicity Classification Categories A-84

List of Figures

Figure 1-1 Principle Scheme of a Biofuel Life Cycle 3
Figure 1-2 BIAS Logic and Modules 5
Figure 1-3 Different pathways to convert biomass to energy 7
Figure 2-1 Framework to Prioritize Areas for Bioenergy Development 19
Figure 2-2 Framework to Prioritize Bioenergy Cropping Systems 25
Figure 3-1 Areas of Physical and Economic Water Scarcity 27
Figure 3-2 Options for Agricultural Management with Regard to Water 32
Figure 3-3 Watershed Management Units 35
Figure 3-4 Decision tree concerning agricultural water use for energy cropping 36
Figure 4-1 Decision Tree for Soil Conservation 45
Figure 5-1 System boundaries for palm oil methyl ester and fossil fuel reference 54
Figure 5-2 Examples for Carbon Stock Changes 58
Figure 5-3 Example of the Mechanism of Indirect Land Use Change 59