Outcome Paper:

Sustainability Criteria and Indicators for Solid Bioenergy from Forests

based on the

Joint Workshops on Extending the RED Sustainability Requirements to Solid Bioenergy

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Foreword

This outcome paper is based on the results of a series of Joint Workshops[1] organized by a team of institutions. Representatives from various agencies, research institutes, NGOs, utilities and public administration within European countries have participated and contributed to them.

The 1st Joint Workshop was held in Brussels on October 15, 2011, indicating the willingness of developing sustainability criteria for solid bioenergy. It was acknowledged that criteria must be balanced with forestry policy but consensus was not reached that the criteria must be defined under an extended RED.

The 2nd Joint Workshop was held in Den Haag on March 12, 2012, highlighting the need to apply the same criteria to feedstock produced within European Member States and elsewhere. It was also remarked the various regulations on forests with different requirements, definitions and indicators, and the need to address the "carbon debt".

The 3rd Joint Workshop was held in Uppsala during June 28-29, 2012. Sustainability scheme including criteria and indicators were discussed in depth, with a specific session on GHG emissions calculation methodology and payback time.

This outcome paper aims to bring together and summarize ideas expressed by the participants in the Joint Workshops in order to propose a set of criteria and indicators for solid bioenergy from forests. Both the most relevant scientific literature and the state-of-the-art at different levels (forestry perspective, various certification schemes and countries initiatives) were considered in order to develop this proposal.

The authors present this paper hoping to substantiate the ongoing discussion, and help implementing adequate safeguards for the future sustainable bioenergy development in Europe, and beyond

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All views expressed here are those of the authors.

[1] See http://www.iinas.org/redex.html for documentation of all workshops, and further information.

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Abbreviations

a	annum (year)
ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (France)
BEFSCI	Bioenergy and Food Security Criteria and Indicators (FAO project)
BMP	Best Management Practices
C&I	Criteria and indicators
CA	Canada
CEN	European Committee for Standardisation
CBD	UN Convention on Biological Diversity
CIFOR	Center for International Forestry Research
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COP	Conference of the Parties
CPF	Collaborative Partnership on Forests
CWD	Coarse Woody Debris
dbh	diameter at breast height
EEA	European Environmental Agency
EFI	European Forest Institute
EC	European Commission
EPA	Environmental Protection Agency (USA)
ETS	(CO_2) Emission Trading System (of the EU)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCCC	UN Framework Convention on Climate Change
FLEGT	Forest Law Enforcement, Governance and Trade
FMP	Forest Management Plan
FSC	Forest Stewardship Council
FRA	Forest Resources Assessment
GAP	Good Agricultural Practices
GBEP	Global Bioenergy Partnership
GEF	Global Environment Facility
GHG	greenhouse gas(es)
ha	hectar(es)
IC	Imperial College, London
IIASA	International Institute for Applied Systems Analysis
IINAS	International Institute for Sustainability Analysis and Strategy
ILO	International Labour Organisation
ILUC	indirect land use change(s)
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardization Organization
ISRIC	International Soil Reference and Information Centre
ISS-CAS	Institute of Soil Science - Chinese Academy of Sciences
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organization
IWPB	Initiative Wood Pellet Buyers
JRC	Joint Research Centre

KP	Kyoto Protocol
LCA	Life Cycle Analysis
LUC	land use change(s)
M	million
MtOE	million tonnes of oil equivalent
MCFPE	Ministerial Conference on the Protection of Forest in Europe
NREAP	National Renewable Energy Action Plans
NTFP	Non-timber forest products
OECD	Organization for Economic Development and Cooperation
OEKO	Oeko-Institut - Institute for Applied Ecology
PA	Protected area(s)
PEFC	Program for the Endorsement of Forest Certification
RED	Renewable Energies Directive 2009/28/EC
REDD	Reducing Emissions from Deforestation and Forest Degradation
SE	Sweden
SFM	sustainable forest management
SOC	soil organic carbon
SRC	short-rotation coppices
t	tonne(s)
tOE	tonnes of oil equivalent
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFF	United Nations Forum on Forests
USA	United States of America
USDA	US Department of Agriculture
WCMC	World Conservation Monitoring Center
WTO	World Trade Organization

Glossary

Above-stump woody biomass: All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage (FAO 2010c)

Below-Ground Biomass: all biomass of live roots. Fine roots of less than 2mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter (FAO 2010c)

Biological legacies: organisms, organically derived structures, and organically produced patterns that survive from the pre-disturbance system. In forests, biological legacies include intact thickets of understory vegetation, large living and dead overstory trees, logs, and patches of undisturbed or partially disturbed forest (Lindenmayer et al. 2006)

Coarse woody debris (CWD): both down wood and standing snags (e.g. Loeb 1999; Riffell et al. 2011)

Criterion: A principle or standard that a thing is judged by. A criterion can, therefore, be seen as a ‘second order’ principle, one that adds meaning and operationality to a principle without itself being a direct measure of performance (CIFOR 1999)

Dead wood: All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country (FAO 2010c)

Deforestation: direct human-induced conversion of forested land to non-forested land (UNFCCC 2001). In FRA (FAO 2000), deforestation is "the conversion of forest to another land-use class or the long-term reduction of the tree cover below the minimum 10 percent threshold"

Down coarse woody debris (DCWD): downed dead wood such as logs, stumps, piles of limbs and other woody material of a minimum size found on the forest floor. Although no universally recognized size criteria exist, most studies defined CWD as >10cm in dbh and >60cm in length (Riffell et al. 2011)

Fine woody debris (FWD): down, dead woody material <10cm in dbh or <60cm in length (Riffell et al. 2011).

Forest: is a minimum area of land of 0.05-1.0 ha with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 m at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest. (UNFCCC 2001)

Forest degradation: The reduction of the capacity of a forest to provide goods and services (FAO 2010c).

Forest harvest residues: growing stock volume cut or knocked down during harvest, low-quality commercial trees, dead wood and non-commercial tree species typically left at the harvest site (Riffell et al. 2011)

Forest management: a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner (UNFCCC 2001)

Forest management plans: Information (in the form of text, maps, tables and graphs) collected during (periodic) forest inventories at operational forest units level (stands, compartments) and operations planned for individual stands or compartments to reach the management goals and equivalents as "Information collected on forest area, at forest management or aggregated forest management unit level (forest blocks, farms, enterprises, watersheds, municipalities, or wider units), and strategies/management activities planned to reach the management or development goals" (Forest Europe 2011)

Fuelwood: see Woodfuels

High Conservation Value Forests (HCVF): forests of outstanding and critical importance due to their high environmental, socio economic, biodiversity or landscape values (Proforest 2003)

Indicator: An indicator is any variable or component of the forest ecosystem or management system used to infer the status of a particular criterion. Indicators should convey a 'single meaningful message' (CIFOR 1999)

Payback time: the time in which the cumulative emissions from the bioenergy system are equal to the counterfactual emissions of the fossil energy system replaced

Planted Forest: Forest predominantly composed of trees established through planting and/or deliberate seeding (FAO 2010c)

Primary Forest: Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed (FAO 2010c)

Principle: A fundamental truth or law as the basis of reasoning or action. Principles in the context of sustainable forest management are seen as providing the primary framework for managing forests in a sustainable fashion. They provide the justification for criteria, indicators and verifiers (CIFOR 1999)

Protected Areas: Areas especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (FAO 2010c).

Reforestation: is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989 (UNFCCC 2001)

Roundwood: all wood obtained from removals, including wood recovered from natural, felling and logging losses. It can be sub-divided into industrial roundwood (wood in the rough), and wood fuel (Forest Europe 2011a)

Snags: standing dead, dying, or live defective trees with cavities or the potential to develop cavities, taller than 1.8 m in height and larger than 10 cm dbh, although others may use slightly different girth and height criteria (Riffell et al. 2011)

Stumps and roots: Parts of the whole tree volume, which exclude the volume of the above-stump woody biomass. The height of the stump is taken to be that at which the tree would be cut under normal felling practices in that country or region. Excludes: Small roots (FAO 2000)

Woodfuels: all types of bioenergy derived directly and indirectly from trees and shrubs grown on forest and non-forest lands. Also biomass derived from silvicultural activities (thinning, pruning etc.) and harvesting and logging (tops, roots, branches, etc.) is included (FAO 2001)

Woody biomass: the mass of the woody parts (wood, bark, branches, twigs, stumps and roots) of trees, alive and dead, shrubs and bushes, includes: above-stump woody biomass, and stumps and roots; excludes: foliage (FAO 2000)

1 Introduction

1.1 The Role of Solid Biomass for Energy

Biomass is the largest contributor of renewable energy to the global energy system (IPCC 2011) and will continue to grow in importance over the next decades according to several forecasts (IEA bio 2011). It not only supplies energy for electricity, heat, and transportation fuels, but also chemical feedstocks, food, feed, and fiber. Furthermore, biomass growth – both through natural processes and human cultivation – provides and interacts with important ecosystem services.

In Europe, a major share of bioenergy comes from woody biomass, and this lignocellulosic feedstock is expected to play an important role in meeting the EU renewable energy target of 20% by 2020 (IC et al. 2012), and is considered to contribute to the reduction of greenhouse gas (GHG) emission under the European Emission Trading Scheme through co-firing in coal-fired power plants.

According to the National Renewable Energy Action Plans (NREAP), biomass is expected to provide 57 % of the renewable energy consumption at the European level in 2020, compared to 62 % in 2005 (IC et al. 2012). The EU's gross final energy consumption **from biomass** is expected to increase from 85 MtOE in 2010 (9 MtOE electricity, 62 MtOE heat and 14 MtOE biofuels) to 140 MtOE in 2020 (20 MtOE electricity, 90 MtOE heat and 30 MtOE biofuels).

Primary biomass consumption is expected to reach 178 MtOE in 2020 (119 MtOE solid biomass, 21 MtOE biogas, 8 MtOE bioliquids, and 30 MtOE biofuels).

Thus, sustainable biomass production and reliable supply of large feedstock quantities are crucial for meeting the EU 2020 RED targets.

Biomass import is likely to play a significant role in meeting the bioenergy 2020 targets, which might lead to higher sustainability risks outside of Europe[2]. It has been estimated that biomass imports into Europe will be more than 20 MtOE of primary energy equivalent for heat, cooling and electricity[3]. Currently main pellets exporting countries are Canada, USA and Russia and potential supply routes from South America (Brazil and Argentina) and South Africa area have been identified[4].

Furthermore, competition between alternative use of biomass resources for food, feed, fibre and fuel is a major issue for bioenergy deployment, and advanced technologies for producing biofuels from lignocellulosic feedstock could also lead to competition between transport fuel and heat and power applications (IC et al. 2012).

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[2] See presentations at the 1st and 2nd Joint Workshops available at http://www.iinas.org/Work/Projects/REDEX/redex.html

[3] See EC (2012a-c), VITO et al. (2011) and the presentation of F. Langue "The EC report on sustainable solid biomass: status and key issues" at the 2nd Joint Workshop, March 2012 http://www.oeko.de/service/bio/dateien/en/wshag_langue_wscriteria_bioenergy2012.pdf

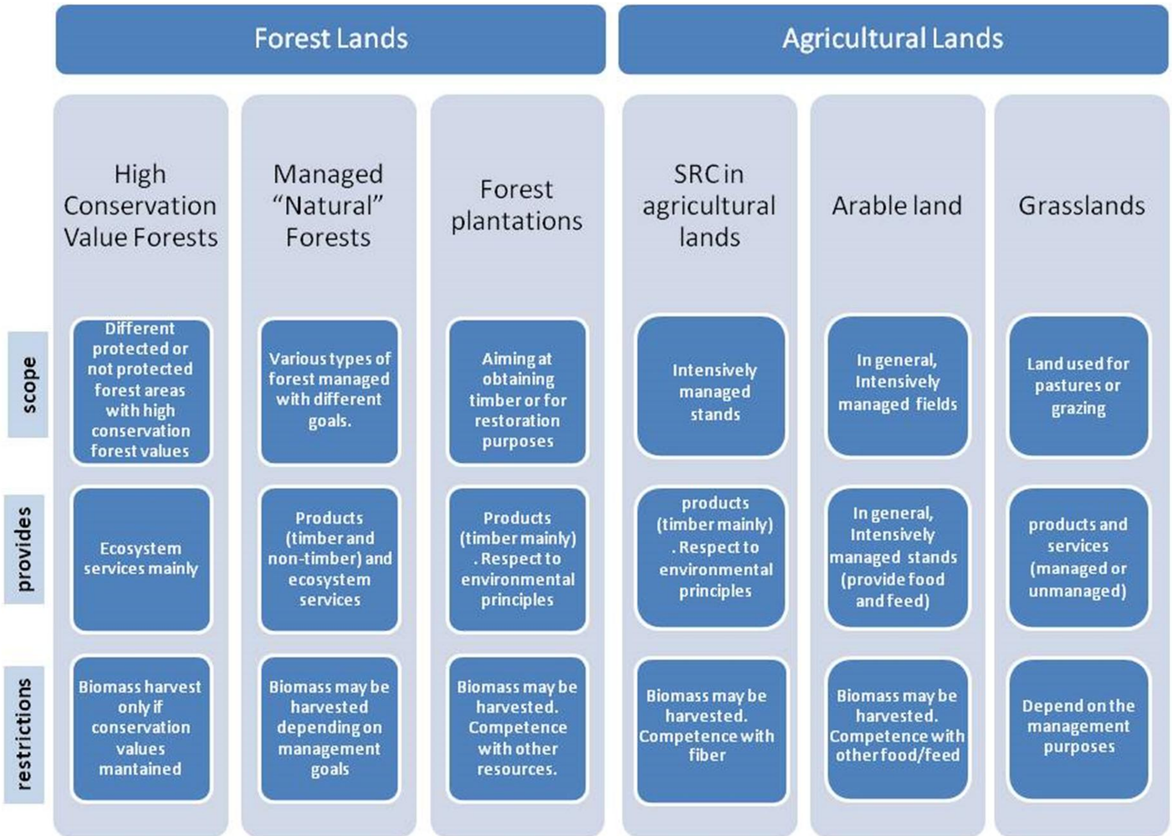
[4] See Heinimö (2011), Junginger et al (2011) and the presentation of G. Volpi "Commission's views on biomass sustainability" at the 1st Joint Workshop, Oct. 15, 2011 http://www.oeko.de/service/bio/dateien/en/volpi_dgener_sustainable_bio.pdf

1.2 Forests, Forest Sustainability and Forest Bioenergy

If not sustainably produced, bioenergy from forest can place extra pressure on biodiversity, soil, and water resources, and could lead to increased deforestation, loss of wetlands and peatlands and land degradation, which means severe negative impacts on climate change.

The expected increase of solid biomass supply for bioenergy could imply sustainability risks which might be comparable in magnitude to those of biofuels and bioliquids (IC et al. 2012). However, risks from biomass utilization, to a great extent, depend on the land use and land cover of the area they are obtained from. Figure 1 roughly summarizes the main differences on issues related to biomass production from different types of areas.

Figure 1: Land uses and their connection with biomass production



Source: own compilation; SRC: Short rotation coppices; note that in this paper, the concepts of High Conservation Value Forests (HCVF) and High Biodiverse Forest (HBF) are used interchangeably

As shown in the figure above, the key risks that potentially threaten sustainable woody bioenergy production **from forest are different** from those that (agricultural) biofuels feedstock production implies. Forest management intensification is one of the central concerns of woodfuel supply.

Compared to annual and perennial (short-rotation) crops, managed forests have far longer rotation times and the limits of their sustainable use depend on many factors, such as protected areas and species, biodiversity, water and soils.

The environmental impacts of bioenergy harvesting from forest vary in nature and extent according to scale, intensity and type of production and harvesting system used, and can be either positive or negative (FAO 2010a). Potential positive benefits include reduced fire risk and lower nutrient leakage on eutrophicated sites (EEA 2006).

There are various major potential sources of bioenergy from forests, including the groups listed below:

- Residues from logging operations that are normally left in the forest after stem wood is harvested, such as un-merchantable wood, slash, stem tops, branches, foliage and stumps.
- Wood material from pre-harvest thinning and cleanings. It is constituted by the same woody material as residues from logging. Sometimes they are not performed due to a lack of market demand and low prices but they provide an opportunity to obtain woody biomass and to improve the habitat value for many species.
- Complementary fellings which comprises the difference between the maximum sustainable harvest level and the actual harvest amount. This means that majority of harvested biomass is timber.

This paper focuses on the impacts of the first two types of woody forest biomass collection due to the **additional** risks of negative impacts these practices imply as compared to conventional forest operations for timber and pulp & paper production. It is assumed that complementary fellings which could provide additional timber will be performed as conventional ones so they entail the same impacts as conventional logging. But it should be taken into account that a rising of extraction rate driven by an additional demand for energy applications could result in negative effects on ecosystem services, which would not occur otherwise.

1.3 EU Sustainability Requirements for Bioenergy

In 2009, the EU laid down the Directive 2009/28/EC on the promotion of the use of energy from renewable sources (Renewable Energies Directive = RED, see EC 2009). Under the RED, biofuels and bioliquids have to meet the following mandatory sustainability requirements in order to be accounted for the EU renewable energy for transport target, especially:

- Minimum GHG gas emission reduction (Art. 17.2), set at least 35 % (50 % in 2017) and 60 % in new installations from 2017.
- Protection of land with high biodiversity value (Art. 17.3). Primary forests, areas designated by laws, other highly biodiverse areas (recognized by international agreements or IUCN) and natural and non-natural highly biodiverse grasslands should be excluded.
- Protection of land with high carbon stocks (Art. 17.4). Wetlands, continuosly forested areas and lightly forested areas with this status in January 2008 and no longer has it should be avoided. Not applicable if the status in January 2008 is maintained.
- Protection of peatlands (Art. 17.5).

In addition, agricultural raw materials cultivated in the EU shall be obtained in accordance with cross compliance[5], and the EC has several report obligations[6].

In order to comply with these criteria, many certification schemes, mostly focused on the sustainability of liquid biofuels come up in recent years (van Dam, Junginger, Faaij 2010). This study accounted for a total of 67 certification initiatives. As of August 2012, the EC had recognized 11 voluntary schemes for biofuels production.[7]

In 2010, the EC released a report on sustainability requirements for the use of biomass other than biofuels or bioliquids, providing recommendations for developing national schemes for solid and gaseous biomass used in electricity, heating and cooling (EC 2010a). In the absence of an EU-wide sustainability scheme, the EC recommends that national sustainability schemes for bioenergy comply with the RED requirements for biofuels and bioliquids.

The EC acknowledged sustainability concerns on biomass production in terms of protecting the biodiversity of ecosystems and carbon stocks (EC 2010a), but argued that Member States should not impose sustainability criteria to waste, as this is covered by environmental rules laid down in a separate waste legislation at national and EU levels.

Still, as the use of various residues and wastes as a bioenergy feedstock is expected to increase significantly (IC et al. 2012) there is a need to have a clear and verifiable definition or list of by-products, residues and waste. Furthermore, unsustainable use of forest residues could cause biodiversity, soil and water impacts (see Chapter 4), and the net GHG implications of using forestry residues are under discussion (see Chapter 6). In a recent communication, the EC announced to broaden sustainability requirements for bioenergy (EC 2012a-c), but the respective report is yet to be published.

1.4 Scope and Structure of this Paper

Based on scientific review, experiences in EU Member States and selected other countries, as well as discussions during the Joint Workshop series, this paper proposes a set of feasible sustainability criteria and indicators that can be used as starting points to ensure that additional forest biomass harvesting for bioenergy is sustainable.

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[5] Requirements and standards under the provisions referred to under the heading 'Environment' in part A and in point 9 of Annex II to Council Regulation (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers and in accordance with minimum requirements for good agricultural and environmental condition defined pursuant to Article 6(1) of that Regulation

[6] The EC shall, every two years, report in respect of both third countries and Member States that are a significant source of biofuels or of raw material for biofuels consumed within the Community, on national measures taken to respect the sustainability criteria set out in relation to no-go areas and for soil, water and air protection. Also, the EC shall report on the impact on social sustainability in the Community and in third countries of increased demand for biofuel, on the impact of Community biofuel policy on the availability of foodstuffs at affordable prices, in particular for people living in developing countries, and wider development issues, every two years.

[7] See the European Commission section of biofuels at:
http://ec.europa.eu/energy/renewables/biofuels/sustainability_schemes_en.htm

This set aims to provide basic criteria and indicators to be used at EU or country level as well as for certification schemes. More refined definitions of indicators are subject to regional and landscape considerations by Member States, or respective sub-national levels.

The set has been proposed specially to avoid negative effects of increasing forest biomass for bioenergy procurement in regions with high risk profile (developing countries with weak forest governance). It also proposes general indications that biomass harvesting should comply with independently of the biome.

Some specific thresholds at landscape and stand level are proposed subjected to the availability of more specific thresholds at a more local level. Whatever more specific and detailed indicators and thresholds had been developed at local level, these recommendations should be taken into account.

Chapter 2 gives a brief compilation of the current status of sustainability forest management frameworks and sustainability certification with regard to solid bioenergy from forests, and summarizes and concludes that additional work is needed.

In Chapter 3, key country activities regarding sustainable solid bioenergy are presented for selected (mainly European) countries.

Chapter 4 introduces and discusses the major ecological risks associated with solid bioenergy harvesting from forests, which establishes the base for Chapter 5 which presents the key sustainability C&I suggested here.

Chapter 6 gives a discussion of the GHG balances of bioenergy from forests which is an additional fundamental issue of sustainable bioenergy. This section broadens the scope beyond the current “zero GHG” view on forest residues.

In Chapter 7, the suggested criteria and indicators are summarized, and Chapter 8 briefly presents open questions and further work.

In the Annexes, additional information is provided.

2 Sustainable Bioenergy from Forests: Current Status in Certification Systems

2.1 Sustainable Forestry

Forests are wooded areas (see definition for details) governed by multifaceted ecological processes and – if managed – influenced by human activities. Many features characterize forests, such species, age, structure, soil properties, climate conditions, human intervention, etc. and make their dynamics complex. The Forest Resource Assessment (FAO 2010b) points out:

- **Primary forests**. They account for 36 percent of forest area, but the area of primary forest has decreased 0.4 percent annually from 2000 to 2010 largely due to reclassification to other categories.
- **Planted forests**. The area of planted forest is 7 percent of total forest area (264 million ha = Mha) and it is increasing by around 5 Mha on average. Most of this was established through afforestation particularly in China. Three-quarters of all planted forests consist of native species while one-quarter comprises introduced species mainly in South America.
- **Forest for conservation of biological diversity**. The area designated for the conservation of biological diversity accounts for 12 percent of the world´s forests. It has increased by more than 95 million hectares since 1990. Most but not all of them are located inside protected areas, which cover an estimated 13 percent of the world's forests.
- **Productive Forests**. 30 percent of the world's forests are primarily used for production of wood and non-wood forest products.
- **Protective Forest**. 8 percent of the world's forests have protection of soil and water resources as their primary objective.

It is widely accepted that in Europe a considerable amount of wood fuel is utilized for own consumption and enters neither markets nor statistical records (Forest Europe 2011a). Currently, in EU 27 the fellings are less than the net annual increment. Thus, 64 percent of the net annual increment in EU27 (609 million cubic meter, Mm^3) is removed from the growing stock by fellings (388 Mm^3) showing a decreasing harvesting volume. This current level of fellings has advantages for biodiversity as forests of all sorts in Europe are growing older, thus restoring underrepresented late succession stages (EEA 2006).

At the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, forests became a priority in the international policy agenda. Since that time, several processes were initiated to assure and enhance sustainable forest management (SFM) aimed at preserving the ecosystem services that forests provide. For this, SFM processes developed sustainability criteria and indicators (C&I) which also act as cross-sectoral[8] linkages (see Table 1). Currently, about 150 countries are participating in one or more of the on-going C&I processes for SFM (FAO 2008).

[8] FAO. Forestry Department http://www.fao.org/forestry/ci/16622/en/

Table 1: International processes on criteria and indicators for sustainable forest management

Process	SFM set of C&I	Geographical Scope
African Timber Organization (ATO)	5 principles, 2 sub-principles, 28 criteria and 60 indicators for application at the regional, national and forest management unit levels	13 Central and West African countries
Dry-zone Africa	7 national level criteria and 47 indicators	28 Sub-Saharan countries
Dry forest in Asia	8 national level criteria and 49 indicators	9 Asian countries
Lepaterique	4 criteria and 40 indicators, at the regional level, and 8 criteria and 53 indicators, at the national level	7 Central American countries
Tarapoto Proposal	7 national level criteria and 47 indicators. 4 criteria and 22 indicators for the forest management unit level and 1 criterion and 7 indicators for the regional level.	8 Amazonian countries
International Tropical Timber Organization (ITTO)	7 criteria and 66 indicators applicable both at the national and forest management unit levels	33 producing countries (with humid tropical forests) and 27 consuming countries
Pan-European Forest	6 national level criteria and 27 indicators	46 countries, 14 world-wide observer countries, 31 observer organizations
The Montreal Process	7 national level criteria and 67 indicators	12 countries with temperate and boreal forests worldwide
Near East	7 national level criteria and 65 indicators	30 countries Near East

Source: FAO (2008) and own compilation

These systems are often used to guide policy development, monitor and exchange information on their national implementation of SFM and the design of C&I at more local levels through governmental activities or (private sector) certification schemes (Stupak et al. 2011).

The existing and suggested certification systems do **not have specific standards nor C&I for bioenergy-related woody biomass** harvest, which limits their ability to address the bioenergy-related “additional” risks (and show a need for further advancement of the current criteria and indicators)

The overall logic of C&I initiatives is to build on the “three pillar” concept of sustainable development, i.e. to reflect economic, environmental and social aspects.

This is also reflected in the definition of SFM of the Ministerial Conference on the Protection of Forests in Europe: *“the stewardship and use of forests and forest land in* *a way, and at a rate, that maintains their biodiversity, productivity, generation capacity, vitality, and their potential to fulfill now and in the future, relevant ecological, economic, and social functions at local, national, and global levels [...].''* (MCPFE 1993)

This definition has been adopted by FAO, and there is growing international consensus on key elements of SFM, as can be seen by the comparison of respective international processes: All definitions include economic, environmental and social issues.

The United Nations Forum on Forests (UNFF) identified the same issues in its reference framework for SFM.

Table 2: Common Principles of Environmental Issues in SFM Definitions

Environmental aspect	UNFF "Theme" of SFM	Addressed in international processes
Maintenance & productivity	Productive functions & forest resources	90%
Forest health & vitality	Forest health and vitality	100%
Ecosystem functions	Protective functions of forest resources	90%
Carbon cycles		40%
Soil and water		70%
Biodiversity	Biological diversity	80%

Source: own compilation

In 2007, the UN General Assembly adopted the Non-Legally Binding Instrument on all types of forests with the scope that SFM, as a dynamic and evolving concept, aims to maintain and enhance the economic, social and environmental values, for the benefit of present and future generations (UN 2008).

At European level in 2011, ministers responsible for forest in Europe made a decision to elaborate a legally binding agreement on forests in Europe. The intergovernmental committee is open to the 46 European states, including the Russian Federation, and the Forest Europe's members from the European Union. This body aims to address, inter alia, SFM in Europe and the long-term provision of a broad range of goods and forest ecosystem services[9].

On the other hand, the MCPFE Working Group on "sustainability criteria" for forest biomass production, including bioenergy (2009) examined the tools of the MCPFE with regard to SFM related to sustainable production of woody biomass and proposed some refinements. During the Policy Debate on Wood Energy held in Geneva in May 2012 (UNECE 2012), a wide group of stakeholders agreed that the production and consumption of woody biomass for energy purposes must be accompanied by the development of certification schemes and criteria to meet sustainability requirements while achieving renewable energy and biological diversity targets.

[9] Intergovernmental Negotiating Committee for a Legally Binding on Forest in Europe: http://www.forestnegotiations.org

Best Management Practices for biomass harvesting

Several tools and regulations exist to assure SFM at forest unit level. However, these guidelines don´t address specifically issues of concern for biomass harvesting. This is the main reason that has motivated various countries and states to develop specific biomass harvesting guidelines in order to give advice on concrete issues regarding this practice, i.e.:

- Europe (Forest Energy Portal undated)[10]: some regions of Germany, Finland, France, Hungary, Latvia, Sweden, UK
- USA (Forest Guild, Pinchot Institute for Conservation 2012 and Indiana Department of Natural Resources undated): Kentucky, Indiana, Maine, Maryland, Michigan, Minnesota, Missouri, Pennsylvania and Wisconsin.
- Canada: New Brunswick (WWF CA 2010), Nova Scotia (Nova Scotia Natural Resources 2010) Ontario (WWF CA 2010) and Manitoba and Quebec are developing them (WWF 2010)
- New Zealand (Forest Energy Portal undated)

These guidelines address specific issues regarding: amount of residues that should be left on the ground, avoidance of nutrient depletion and fertilization, biodiversity concerns, areas of protection, etc… Relevant information about these guidelines is available in sections 3 and 4. Annex 2, Overview of sustainability topics, synthesizes the the main issues covered by various publications related to the utilization of forest biomass for energy and wood ash recycling (Stupak et al. 2007).

Forest Management Plans

A very extended tool to assure SFM is the development of a Forest Management Plan (FMP). A FMP is a tool for guiding and achieving SFM, defined as "All the information, in the form of text, maps, tables and graphs, collected during forest inventories and condensed into a written scheme of management aiming at continuity of policy and action and controlling the treatment of a forest" (FAO 2005)[11]. It comprises long-term goals as well as annual plan of operations (operations in the short term) but shows great variability among and within countries (Forest Europe 2011). FMP, written for a period of 10-15 years typically include (EDF, Pinchot Institute for Conservation 2012):

1. an articulation of the objectives of the woodland owner,
2. forest inventory data,
3. maps denoting relevant property-specific information (e.g., location, boundaries, individual stands, soil types, tree retention areas, key conservation features, and future harvest areas), and
4. detailed descriptions and chronology of silvicultural treatments for each forest stand

The development of a FMP could help to assure that biomass harvesting is ecologically sound and aligned with the long-term productivity and ecosystem services of the stand but its existence *per se* does not assure that it would be the guide when activities on

[10] http://forestenergy.org/pages/databases/harvesting+guidelines/

[11] FAO 2005: Language Resources Project http://termportal.fao.org/faoterm/search/pages/termUrl.do?id=63580

the stand are performed. However, through this tool a deep reflection of the goals of the stand as well as the techniques proposed to achieve them can be defined.

In this regard, MCFPE (2002), FSC (2012) and PEFC (2010) standards include the existence of a FMP among their sustainability C&I. The Swedish Forest Agency (2008) requires the extraction of harvesting residues to be documented through a FMP or equivalent.

On the other hand, the EU Biodiversity Strategy (EP 2012) calls on the Member States to adopt FMP or equivalent instruments including effective measures for conservation and recovery of protected species and habitats and related ecosystem services. The respective EC communication (EC 2011b) argues that FMP or equivalent instruments should include as many of the following measures as possible:

- maintain optimal levels of deadwood, taking into account regional variations such as fire risk or potential insect outbreaks;
- preserve wilderness areas;
- ecosystem-based measures to increase the resilience of forests against fires as part of forest fire prevention schemes, in line with activities carried out in the European Forest Fire Information System;
- specific measures developed for Natura 2000 forest sites;
- ensuring that afforestation is carried out in accordance with the Pan-European Operational Level Guidelines for SFM33, in particular as regards the diversity of species, and climate change adaptation needs.

At international level, more than 40 % of the total world-wide forest area has a management plan FAO (2010b), and 77 % of European forests (Forest Europe 2011). This number is steadily increasing.

2.2 Existing Forest Certification System

Forest certification emerged in the early 1990s as a voluntary, market-driven way to limit deforestation especially in tropical forests, giving consumers, retailers, and manufacturers the opportunity to purchase products derived from environmentally and socially responsible forest operations.

In NGO meetings parallel to the 1992 UNCED, the idea of developing an international system for certifying and labelling forests and forest products was launched. As a result, in 1993 a voluntary non-profit organisation called Forest Stewardship Council (FSC) was launched supported by WWF and other NGO. FSC developed into the first forest certification scheme. Several other schemes followed focusing on specific regional conditions, and other factors.

Today, the second-most prevalent system is the Program for the Endorsement of Forest Certification (PEFC) which was founded in 1999 as an international umbrella organisation with a primary background in the forestry sector, providing endorsement and recognition of existing national forest certification systems.

The PEFC and the FSC both covers a large area of certified forest and 16 national systems, striving to achieve the same ultimate objective of SFM. Other forest certification schemes at forest management unit level are (van Dam 2010; PEFC 2012):

- ITTO and ATO/ITTO Tropical Forest
- SFI - Sustainable Forestry Initiative (recognized by PEFC)
- ATFS - American Tree Farm System (recognized by PEFC)
- CSA - Canadian Standards Association
- CERFLOR Scheme - Brazil (recognized by PEFC)
- LEI - Lembaga Ekolabel Indonesia
- PAFC - Pan African Forest Certification Scheme (PAFC Gabon is recognized by PEFC)
- CERTFOR Chile (recognized by PEFC)
- MTCC - Malaysian Timber Certification Council
- AFCS - Australian Forestry Certification Standard (recognized by PEFC)
- FFCS - Finnish Forest Certification System (recognized by PEFC)

It seems that some convergence between FSC and PEFC is taking place over time - standards and thresholds set for various indicators with regard to woodfuel issues differ more between countries than between the general FSC and PEFC systems (Stupak et al. 2011).

As of May 2012, 394 Mha were certified which equals to almost 10 % of the world forest area, of which 147.7 Mha corresponded to FSC and most of the other certified areas to PEFC (UNECE, FAO 2012). Western Europe and North America (USA and Canada) account for the vast majority of the certified forest area, whereas certified tropical forest area represent roughly 2 % of the total forest area (UNECE, FAO 2012). If only larger-scale forest operations are considered, the certified share in 2010 was approx. 50 % (Liedeker 2012).

2.3 Other Certification Initiatives

2.3.1 Normative Work of CEN

The CEN/TC 383 Committee for ‘‘Sustainably produced biomass for energy applications’’ is elaborating a European standard (prEN 16214) for sustainable biomass for energy applications. This standard is strictly bound to the EU RED, which means that e.g. social issues, indirect effects and requirements specifically related to solid biomass are going to be handled as soon as there are the according RED amendments adopted.

2.3.2 Normative Work of ISO

On the international level, the International Standardization Organization (ISO) is developing an international standard to address sustainability issues related to bioenergy production (ISO 13065). The ISO/PC 248 has four working groups on: cross-cutting issues; GHG; environmental, economic and social aspects; and indirect effects.

Its objectives are the following: comply with national and/or regional legislation; respect the Universal Declaration of Human Rights; use natural resources in a rational and sustainable way; bioenergy from production and up to use should be sustainable in relation to biological diversity; reduce GHG emissions in relation to the fossil energy source; promote economic and social development; bioenergy production should be economically and financially viable in the long term.

2.3.3 Wood Pellet Buyers: An Industrial Initiative

From the industry sector, the **Initiative Wood Pellet Buyers** (IWPB) has to be highlighted. This sustainability scheme, developed by major utilities in Europe, aims to harmonize common quality specifications and sustainability principles for woody biomass, mainly pellets (IWPB 2012). The set, still a draft, focuses on voluntary verification (not certification[12]) and consists of 9 sustainability principles (IWPB 2012):

The first three (GHG balance, carbon stock, and biodiversity) are based on the RED, the other five (protection of soil and air quality, protection of water resources, competition with local resources, and local socio-economic performance) have to be assessed and improved in time. The last one concerns the ethics of the companies. These proposed principles are not yet endorsed by IWPB members and will be further developed through pilot applications and (IWPB 2012).

2.3.4 Scientific and NGO Proposals

Various researching groups have attempted to create the basics for sustainability certification schemes at various geographical levels and with a variety of scopes, e.g. Abbas et al. (2011), Lattimore et al. (2009), and Lal et al. (2011). Furthermore, NGO such as WWF have prepared documents on sustainable bioenergy (WWF 2012). The substance of these proposals has been taken into account in the discussion of sustainability issues in Chapter 4 and the definition of proposed C&I in Chapter 5.

2.4 Raw Material Legitimacy: FLEGT

Beside certification of forest products, there has been discussion on other means to reduce deforestation - one option is to mandatorily require forest operators to “prove” the legality of their harvested timber products. In that regard, The EU introduced in 2003 the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan (EC 2003)[13].

It specifies a number of measures to exclude illegal timber and timber products from markets, to improve the supply of legal timber and to increase the demand for responsible wood products. Trade accords with timber exporting countries, known as Voluntary Partnership Agreements (VPA), and a ban on illegally-produced wood, known as the EU Timber Regulation, are a central element of the strategy.

FLEGT VPAs are bilateral legally binding agreements between the EU and timber exporting countries, which aim to guarantee that the wood exported to the EU is from legal sources, and to support partner countries in improving their own regulation and governance of the sector (EFI 2012).

Accordingly with the information provided by EFI (2012), there are currently six countries developing the systems agreed under a VPA (Cameroon, Central African Republic, Ghana, Indonesia, Liberia, Republic of Congo-Brazzaville) and six countries that are negotiating with the EU (Democratic Republic of Congo, Gabon, Guyana,

[12] See the presentation of Yves Ryckmans at the 1st Joint Workshop: http://www.oeko.de/service/bio/dateien/en/ryckmans_sus_bio.pdf

[13] Already in 2008, the USA introduced an equivalent regulation through the amended Lacey Act which concerns the import and trade of illegally sourced wood - see http://www.aphis.usda.gov/plant_health/lacey_act/

Honduras, Malaysia, Vietnam). Furthermore, there are around 15 countries from Africa, Asia and Central and South America that have expressed interest in VPAs.

The EU Timber Regulation (EC 2010b) means that all wood products, whether harvested within the EU or imported, are supplied legally. It implies that all 'operators' will have to be able to show due diligence. Moreover, it includes specifically to fuel wood and wood in chips or particles whether or not agglomerated. It will go into effect from 3 March 2013.

In this regulation, it is stated (Art. 3) that the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) places a requirement on parties to CITES only to grant a CITES permit for export when a CITES-listed species has been harvested, inter alia, in compliance with national legislation in the exporting country.

Timber embedded in timber products listed in Annexes II and III to Regulation (EC) No 2173/2005 which originate in partner countries listed in Annex I to that Regulation and which comply with that Regulation and its implementing provisions shall be considered to have been legally harvested.

In addition, timber of species listed in Annex A, B or C to Regulation (EC) No 338/97 and which complies with that Regulation and its implementing provisions shall be considered to have been legally harvested. It is assumed here that respective bio-energy co-products of such timber harvest and bioenergy products derived from downstream processing of such timber (e.g. pellets) is be subject to FLEGT regulation.

2.5 GBEP Criteria and Indicators

Furthermore, the Global Bioenergy Partnership (GBEP) which promotes the sustainable development of biomass and biofuels on the national level and develops a respective voluntary international sustainability framework for bioenergy. GBEP has worked in a Task Force on Sustainability on developing criteria, or themes, and indicators regarding the sustainability of bioenergy, based on which GBEP agreed on a 24 indicators for sustainable bioenergy on the national level (GBEP 2011):

- Environmental (GHG emissions, productive capacity of the land and ecosystems, air quality, water availability, use efficiency and quality, biological diversity, land-use change, including indirect effects)
- Social (price and supply of a national food basket, access to land, water and other natural resources, labour conditions, rural and social development, access to energy, human health and safety)
- Economic (resource availability and use efficiencies, economic development, economic viability and competitiveness, access to technology and technological capabilities, energy security/diversification of sources and supply, energy security/Infrastructure and logistics).

These indicators are currently tested in several countries, and based on the outcome, the set of indicators might be improved in the future.

2.6 Summary of Initiatives

The previous sections examined key certification schemes developed from various sectors, as well as other relevant activities to ensure the sustainability of bioenergy from forests. A more detailed revision of various certification initiatives can be obtained in reports of van Dam (2010) and Martikainen et al. (2010). As expected, different goals at various levels are pursued by the stakeholders. Hence, to perform an exhaustive benchmark of these initiatives could be challenging and, to some extent, with uncertain outputs. The following table assesses the compliance with various indicators by different certification schemes.

It could be concluded that none of the sets currently in place comply with all the ecological indicators laid down by the RED and beyond. For example, forest certification schemes such FSC and PEFC encompass a wide array of environmental issues but lack of GHG balances considerations. Hence, work aiming at unifying various approaches such as forest certification schemes, criteria developed for biofuels and bioliquids, standardization schemes, and global efforts such as developed by GBEP are needed.

Table 3: Environmental Criteria considered in various certification schemes

Environmental Criteria	Legislative requeriments	Forest certification schemes		Utility companies Schemes
	RED (Biofuels)	**FSC**	**PEFC**	**IWPB**
greenhouse gas balance	=	-	-	+
carbon storage in soil	+	=	-	=
soil protection	=	+	+	+
water management	=	+	+	+
ecosystem protection	-	+	+	+
waste management	-	+	+	=
biodiversity protection	+	+	+	+
use of chemicals, pest control, fertilizer	-	+	+	=
land use change	-	+	+	-
use of GMOs	-	+	+	-
emissions other than GHGs (air quality)	-	-	-	+
conservation of primary forest	+	+	=	+
minimization of deforestation	-	+	+	=
sustaining yield of land	-	+	+	-
restoration of forests and ecosystems	-	+	+	-

Source: Sluka 2012; (+) extensively covered; (=) partially covered; (-) not covered;

FSC: Forest Stewardship Council; PEFC: Program for the Endorsement of Forest Certification; IWPB: Initiative Wood Pellet Buyers

3 Selected Country Activities and Experiences

3.1 Germany

State of forests in Germany

An area of 11 Mha, or 31%, of Germany, is covered with forest. Forested areas in Germany increased over the past decades. As a result of agricultural reorganization, more and more cultivated grassland has either been afforested or abandoned to the course of natural succession. About 40% of this forested area is now stocked with broadleaf trees. 60% are predominantly pure or mixed conifer forests.

Consumption of wood for energy also significantly increased over the past years. Currently, around 1/3 of the annual cut from German forests is consumed in the energy sector for heat and power generation.

Table 4: Data on Forests in Germany

Forest area[a]	Total land area	35.8 Mha
	Forest area	11.1 Mha (31 %)
	Of which are confers Average standing volume	60 % 348 m³/ha
	Of which are broadleaves Average standing volume	40 % 273 m³/ha
	State forest area	30 %
	Municipalities and public owners forest area	20 %
	Private forest owners area	44 %
	Federal forest area	6 %
Forest use[b]	Annual cut (m³)	ca. 70 Mio. m³/year (adjusted)
	conifers in %	80 %
	broadleaves in %	20 %
	Wood consumption (in % of annual cut) total: Energy uses Solid uses	 27 % 73%
	Consumption of conifers in % of annual cut	80 % solid, 20 % energy
	Consumption broadleaves in % of annual cut	30 % solid, 70 % energy

Source: own compilation;
[a] Geman Forest Inventory (Bundeswaldinventur 2002) available at:
http://www.bundeswaldinventur.de/enid/a3e98d89c6aefb9226bbfad5a4307011,0/75.html;
[b] Seintsch, vTI, 2006

Political promotion of biomass use

The Renewable Energy Sources Act (Erneuerbare Energien Gesetz – EEG) promotes renewable energy mainly by stipulating feed-in tariffs that grid operators must pay for renewable energy fed into the power grid[14]. The latest EEG amendment (EEG 2012) was established in 2012.

The purpose of the law is to facilitate the sustainable development of energy supply, particularly for the sake of protecting the climate and the environment, to reduce the costs of energy supply to the national economy (also by incorporating external long-term effects), to conserve fossil fuels and to promote the further development of technologies for the generation of electricity from renewable energy sources. To this end, the Act aims to increase the share of renewable energy sources in the German electricity supply. Accordingly renewable energy shall account for 35% of the electricity production by 2020, for 50% by 2030, for 65% by 2040 and for 80% by 2050. In 2010 solid biomass (primarily wood based fuels) contributed 11.4% to renewable electricity production (which equals 1.9 % of total electricity production).

The EEG only regulates the renewable electricity sector. The Renewable Energies Heat Act (Gesetz zur Förderung Erneuerbarer Energien im Wärmebereich – EEWärmeG) promotes the increase of heat generated from renewable energy to 14% by 2020. By 2010 solid biomass constituted 73.7 % of renewable heat production (which equals 7% of total German heat production), mainly in form of forest wood. Most important users of biomass based heating energy are private households.

Biomass use – volumes and sources

Origin of woody biomass in Germany are forests (roughly 50 to 80 million m³ total annual cut) and the German wood recycling system (around 30 to 50 million m³ annually). Wood of both origins can either be used in the energy sector or the solid wood processing sector. Annual harvesting in German forests is dynamic and harvested volumes range from 50 to 80 million m³. According to long term model projections (WEHAM Forest development and timber resource modeling) [15], 80 million m³ is the maximum sustainable annual harvesting volume in German forests.

Of the annually harvested wood in German forests roughly 1/3 is declared being for energy production. However, these official figures are not definite, since statistically recorded wood for non-energy purposes may finally end in energy uses when the buyer of the wood decides to re-define the consumption purpose. This has become increasingly common since the prices for energy wood and low quality industrial wood (for pulp, boards, etc.) have narrowed. The wood will be finally used in the sector (energy or solid use) where it generates the higher margin. In general, the official statistics underestimate total annual harvest in German forests and especially the proportion of wood harvested for energy generation.

A total of approximately 55 million m³ of wood (equals roughly 27.5 million dry tons) is yearly consumed by the energy sector in Germany. A detailed consumption analysis undertaken by the Federal Ministry of Food, Agriculture and Consumer Protection

[14] See the Overview Renewable Energy Sources Act at the German Energy Blog: http://www.germanenergyblog.de/?page_id=283

[15] See for more details the German Reference Level for Forest Management, available at: http://www.holzundklima.de/aktivitaeten/lulucf/docs/2011-02%20German-RL-2011.pdf

(Germany) is shown in the table below. Roughly 50% of these 50 million m³ origins directly from German forests, while the other 50% origin from recycling sources.

Table 5: Wood biomass consumption for energy production in 2008

Consumer	**M. m³**
Combined heat power plants / and heat plant with > 1 MW total capacity	19.8
Combined heat power plants / and heat plant with < 1 MW total capacity	5.0
Private households	25.2
Other energy users (wood pellets, biofuels, etc.)	4.7

Source: Federal Ministry of Food, Agriculture and Consumer Protection (Germany) 2012

Most of the biomass consumed by the German energy sector comes from domestic sources (forests and recycling system). However, imports have become increasingly important, though at very low level.

The total wood pellet production volume in Germany was 1.75 Mt in 2011 and it is estimated that about 75 % are intended for the heating market (certified wood pellets) and the remaining for power plants for electricity generation. Pellets used for power generation (about 10 %) are entirely exported. The total export volume for 2010 is estimated at 715,000 t and the import volume at 270,000 t In relation to wood waste, the total export volume for 2010 is estimated at 715,000 t and the import volume at 270,000 t (Thrän et al. 2012).

German forest management practice – sustainability, good forest practice and certification

German forest management is based upon a multifunctional management approach. This approach aims at pursuing three functions: utilization function categories: direct utilization functions (supply of timber, game, non-timber forest products),ecosystem functions (watershed services, climate regulation and carbon sequestration, air quality, soil stabilization and erosion control, biological diversity), and cultural function (physical and psychological benefits for recreation seekers, cultural heritage, spiritual values when indicated). In theory all three categories of functions can be maintained on the same forest area, if sustainably and adequately managed.

In common terms, Germany's forest management system is SFM. However, the concept of SFM does not constitute a concrete, original management concept, but rather provides as wider concept, incorporating a set of technical management models. Thus, in day to day forest management "good forest practice" is applied, which considers situational best practice options to maintain the multifunctional optimum.

Over the past years forest certification systems have been increasingly applied in Germany. I.e. state owned forests have undergone PEFC certification. About 7.3 million ha are currently PEFC certified (roughly 2/3 of total German forest area).

Covering around 5% of German forest area, FSC is the second largest certification system in Germany. In the near future important areas will be added, such as a full forest area of the federals state of Baden-Württemberg (around 1.4 million ha).

Many forest areas have undergone double certification from PEFC/FSC.

German forest management practice – legal biodiversity aspects

The German National Forest Act (Bundeswaldgesetz) states that Forest Law is to enhance forestry, conserve forests based on their economic, environmental and recreation benefits, and to ensure balance between the public and the private forest owners. The Act not only contains immediately effective provisions, but also the regulative framework that is then laid down in detail and put into effect by way of federal state laws. A number of additional provisions such as ordinances and administrative regulations apply to the state-owned forests.

According to the National Forest Act, all forest owners are under the obligation of "sustainable, proper management". Besides the economic utility of the forest (supply of wood), the other functions of the forests, which in the public debate are increasingly gaining importance, for example "the continuous capacity of the natural resources", need to be taken into account.

Besides the forest laws there is a number of other laws directly or indirectly affecting forest management, in particular federal laws such as the National Act on Nature Conservation (BNatSchG), the Act on Compensation of Damage to the Forest, the Act on Forest Seeds and Seedling Plants, the Water Act, the National Hunting Act, the Act on Regional Development, the Act on Waste Disposal, and a large number of state laws and other legal provisions on a federal state level.

The German forest management system provides different levels of biodiversity protection. According to the 2002 Ministerial conference on the Protection of Forests in Europe there are three main classes and three subdivisions with many overlaps:

1. Conserving Forest Biodiversity, including three divisions: i) No active intervention; ii) Minimum intervention; and iii) Conservation through active management. All three in total comprise 19.9% of forest area in Germany
2. Protection of Landscapes and Special Natural Elements, covering about 43.6% of Germany. This is specifically for protecting special areas and important regions of forests that have significant ecological significance.
3. Forests with Protective Functions which covers 27.8% of German forests.

3.2 Finland

The Finnish Forestry Centre Tapio has recommended the following issues for Finnish private forests (Siitonenen, Berglund 2009):

- 30 % of logging residues should be left unharvested
- No stump harvesting from key habitats or the near surroundings of key habitats, moist or rocky sites, slopes, waters and retention tree groups.
- Coarse fresh stumps, higher than 25/ha

Additional recommendations are (Fernholz et al. 2009)

- Large dead wood (standing or on the ground) is not to be collected and should not be damaged (exceptions are made for harvests being conducted in response to storm events and for insect or disease concerns)
- Stumps must not be removed from riparian areas
- Stumps should not be removed on steep slopes or must be planned

- A filtering zone of 2 to 10 meters must be left along riparian zones, with width dependent upon the slope and other watershed characteristics.
- Equipment may not operate, and no stumps may be pulled in this area.
- Rocky, dry, poor soils, open swamps and other types of sites are not recommended for stump or residue harvest.
- Stumps are not to be lifted if they are decayed, less than 15cm in diameter, on steep slopes, on a site with bedrock near the surface, in riparian zones or nature areas, or near saved trees and snags.
- All stumps larger than 15 cm in diameter should be left (20 such stumps per hectare). Fifty stumps per hectare must be left in clay and silt soils.
- Stumps from diverse tree species should be left.

3.3 Netherlands

The Dutch Commission for Sustainability Issues on Biomass (Commission Corbey) advised the Dutch government in January 2012 to establish in the EU legally binding, harmonized sustainability criteria for biomass for energy applications. The government indicated that it will, based on the experience gained with biofuels, work on the widening of European sustainability requirements into other biomass (woody) applications and the existing sustainability criteria, preferably in an European context. This is due to the fact that biomass for energy will be used more and more, both from within the EU as well as outside, in the coming years to reach the desired goal of 20% renewable energy in 2020 in the EU. The Dutch government will work together with the energy sector and other relevant stakeholders to achieve this. Building upon the existing criteria for liquid biomass in the RED and translating them in a logical way to solid and gaseous biomass is needed, as well as using existing sustainability schemes in forests and biofuels. The deployment through European legislation has the preference of the government as it will be a positive for sustainability as well as trade.

In April 2011, a “Dutch assessment protocol for voluntary sustainability schemes for solid biomass” (the Biomass Protocol) was developed as a draft national framework for sustainability criteria and for performing pilot assessments of voluntary certification systems against the requirements in the protocol. This Biomass Protocol is based on the criteria set in the EU-RED for biofuels and bioliquids, including criteria on sustainability, the mass balance system and audit quality, with some additions on soil quality.

The Commission for Sustainability Issues on Biomass also advised the government to work in the meantime (till a legislation is in place) out with the energy sector a voluntary agreement on Sustainability Reporting of solid and gaseous biomass. The government started the negotiations with the energy sector. This voluntary agreement would aim at making the information on the biomass used for energy, as well as the used sustainability schemes, more transparent.

3.4 Poland

In Poland there are currently no sustainability criteria for biomass used to produce electricity, heat and cooling. However, Poland has introduced some solutions to reduce the use of wood for energy purposes by promoting the use of agricultural biomass and biodegradable wastes.

According to the Ministry of Economy decree of 18 October 2012, the use in the combustion process of wood as well as wastes and residues of forest production and processing industry is possible, but with certain restrictions. These restrictions apply to both wastes and residues of forest production, as well as fuel wood. This refers not only to the co-firing units but also to hybrid units and units dedicated for biomass.

It should be also noted that in above mentioned decree, new regulations dedicated to wood generated energy was introduced. According to these regulations, no financial support will be granted to energy produced from good quality wood (roundwood). Good quality wood (roundwood) has been defined on the basis of existing in Poland standards.

It is worth to be mentioned that decree defines the required weight percentage of so called agricultural biomass in the weight of biomass directed to combustion process. Percentage of biomass was defined separately for the co-firing units, hybrid units and units dedicated for biomass.

It is noteworthy that the provisions of regulation was based on the fundamental assumption that biomass for energy purposes should be used primarily in the local distributed generation and in the CHP units.

Regulation distinguishes three types of units in which forest biomass can be used:

1. **Co-firing units**: In this case, it is possible to use in the combustion process (without restrictions) of wood as well as wastes and residues of forest production and processing industry, for units with an electrical capacity of not more than 5 MW. In larger units also exists the possibility of the use of that kind of biomass, but with the restrictions specified in the Regulation, which are associated with simultaneous use of agricultural biomass. In 2013, the share of agricultural biomass in the amount of biomass burned in units with a capacity above 5 MW is established at the level of 60%.
2. **Hybrid units**: In this case, it is possible to use in the combustion process (without restrictions) of wood as well as wastes and residues of forest production and processing industry, for units with an electrical capacity of not more than 20 MW. In larger units also exists the possibility of the use of that kind of biomass, but with the restrictions specified in the Regulation, which are associated with simultaneous use of agricultural biomass. In 2013, the share of agricultural biomass in the amount of biomass burned in units with a capacity above 20 MW is established at the level of 20%.
3. **Units dedicated for biomass**: In this case, it is possible to use in the combustion process (without restrictions) of wood as well as wastes and residues of forest production and processing industry, for units with an electrical capacity of not more than 20 MW. In larger units also exists the possibility of the use of that kind of biomass, but with the restrictions specified in the Regulation, which are associated with simultaneous use of agricultural biomass. In 2013, the share of agricultural biomass in the amount of biomass burned in units with a capacity above 20 MW is established at the level of 20%.

Furthermore, it should be mentioned that the restrictions which refers to using wood for energy purposes were introduced because of the forests and industry protection.

It is essential to strengthen the forest management because of the potential use of forest functions as an instrument of climate protection. In addition, currently observed situation shows that timber is a scarce resource, so its use as a fuel on a large scale is not justified.

3.5 Sweden

In Sweden[16], biomass from forests, e.g. logging residues, has become an increasingly more important energy resource over the last decades and there is a strong ambition to increase it. Bioenergy is since 2009 the largest energy source in Sweden, bigger than oil and bigger the hydro and nuclear power combined[17]. The major bioenergy producers are the forest industries and the carbon stocks are growing in spite of the increased bioenergy use, indicating that large-scale sustainable bioenergy use can be achieved. To be able to evaluate the consequences of increased biomass extraction, Sweden related result of decade-long analysis to environmental objectives and goals for forest production, set up by the Swedish parliament, and adopted 16 environmental objectives[18]. The forest production goal is described in the forestry policy[19]. The environmental objectives and the production goal are reflecting the ambition of the society concerning the environment. From this, Sweden concludes that all forestry activities that make it easier to reach the goal, or activities that do not affect the possibility to reach the goal, are acceptable[20]. On the other hand, activities that make it more difficult to reach the goal are not acceptable, unless it is possible to compensate.

The result shows that it is possible to extract more biomass from forests by using logging residues (branches, tops and stumps) without any negative impact on environmental services. Probably, it is possible to increase the energy output from 14 TWh of today to 24 TWh[21]. However, to make this possible there are a number of requirements that must be obtained. This includes:

- Biomass substitutes fossil fuels, i.e. when a new energy plant is needed, and the choice is between bioenergy and fossil energy
- General conservation considerations are used according to the forestry policy (this includes leaving trees and wood of conservation value, and avoid forestry in habitats with high conservation value)
- The extraction is mainly limited to branches, tops and stumps[22] of conifers[23]
- Nutrient compensation is applied in some cases after extraction of biofuel in thinning operations

[16] This section is a summarized version of the previous Swedish contribution, and based on a Swedish literature review (de Jong et al. 2012). This review mainly covers consequences of extracting logging residues, such as branches and tops, and stumps. But the importance and consequences of ash recycling, and intensive forestry including plantations with short rotation and nutrient optimisation is also covered. The review focuses mainly on Swedish conditions, consequently studies from northern Europe is dominating, but it also refer to a large number of studies from other parts of the world.

[17] Note that the comparison is between used biomass and delivered electricity, respectively.

[18] See http://www.miljomal.nu/Environmental-Objectives-Portal

[19] Regeringens proposition 1992/92: 226 (in Swedish)

[20] Some argue that, concerning environmental services, current forestry practice is not sustainable and, therefore, it will not be possible to use the forests more intensive and extract more wood (SSNC 2011; WWF SE 2011). However, the review shows that it might be possible both to extract more wood, and to strengthen environmental services. For example, leaving high-stumps, other dead wood and groups of deciduous trees is more valuable for biodiversity than branches, tops and stumps of coniferous trees.

[21] see Annex 1(based on the de Jong et al. 2012) on Swedish bioenergy production in different scenarios of biomass harvesting and potential consequences

[22] Stump removal must initially be carried out in a relatively small scale due to environmental constrains. A larger scale of stump harvesting might have negative impact on biodiversity, GHG emissions etc. The suggested level is uncertain, and more research is needed to find sustainable thresholds for stump extraction.

[23] This is because conifers are the dominating trees in Swedish forests. In other regions, the recommendation may be different.

- Extraction is restricted to soils with strong bearing capacity to avoid soil damage, and is not carried out in, or near areas of high conservation values, if this is negative for conservation
- Ash recycling with ash of good quality is applied in some cases.

In order to obtain this, it will not be necessary to change the forestry policy, the forestry act or the guidelines to the forestry. However, it might be necessary to set up new policy measures.

At this regard, the Swedish Forest Agency (2008) released the “Recommendations for extraction of harvesting residues and ash recycling”, with the purpose of stating under which circumstances extraction of harvesting residues and ash recycling can be done without reducing the possibilities to meet other environmental quality and production goals.

The requirements listed above are not new, and some of them have been recommended for a long time, but are obviously difficult to implement. Development of policy measures for strategies on the landscape level is one possible way to make it easier to combine forestry including increasing biomass harvesting and conservation of environmental services.

3.6 UK

The renewables obligation: Sustainability Criteria for Solid and Gaseous Biomass for Generators (greater than 50 kilowatts) specifies the reporting requirements to customers on sustainability criteria regarding GHG and previous land use (Ofgem 2011), which are based on the RED criteria. From April 2013, biomass will need to meet the sustainability criteria to be eligible to receive renewables obligation certificates (Ofgem 2011).

3.7 Canada

Woody biomass policy and guidelines in Canada are not designed and implemented by the central government, they are released at provincial level and they would apply solely to public land, not to private land (Manomet 2010).

They report that in Quebec prescriptive indicators of site sensitivity to biomass harvesting apply. New Brunswick’s guidelines take advantage of a decision support tool for sustainable biomass allocation that evolved from a model used to predict impacts of atmospheric deposition and exclude harvests on high-risk (low-nutrient) areas.

In British Columbia, biomass removals during traditional forest practices (e.g., full-tree with processing at roadside) are already covered and the retention of at least 1.6 logs per acre are required.

Comprehensive information was compiled by WWF (2010).

3.8 USA

In the United States, forestry on private and state forests is regulated primarily at the state level. Federal law requires states to address non-point source pollution of waterways. All 50 states have Best Management Practices (BMPs) programs that are intended to protect water quality and other values.

Programs in states vary from laws that prescribe mandatory practices to states that use voluntary BMPs and education and outreach programs (Manomet 2010). Skog and Stanturf (2011) point out that states vary in their emphasis on what to protect in BMP guidelines, partially a reflection of diverse forest ecosystems, land ownership, and levels of timber harvesting.

U.S. federal policy on the use of woody biomass from forests has focused on how to define biomass and how or if sustainable should be legislated. The US "Woody biomass utilization strategy" (Patton-Mallory 2008) states that the primary objective is sustaining healthy and resilient forests.

Among the long-term actions included to reach the goals of the strategy the development of guidelines for BMPs is included. The development of sustainability criteria for forest biomass provision is also considered in the Forest service research and development bioenergy and biobased products strategic direction (USDA FS 2010).

Key areas of legislative focus are the type of wood that qualifies as renewable biomass, what kinds of ownerships can provide woody biomass, and the types of forest from which woody biomass can be procured.

At least nine states have developed additional guidelines for biomass harvesting in existing forest stands (5 in the Midwestern Region; 3 in the Northeastern Region and 1 in the Southern Region). The primary concern addressed by these guidelines is the potential effect of removing greater amounts of biomass than would be removed in conventional harvest, and the common remedy is to specify what and how much material should be left on-site (Skog, Stanturf 2011).

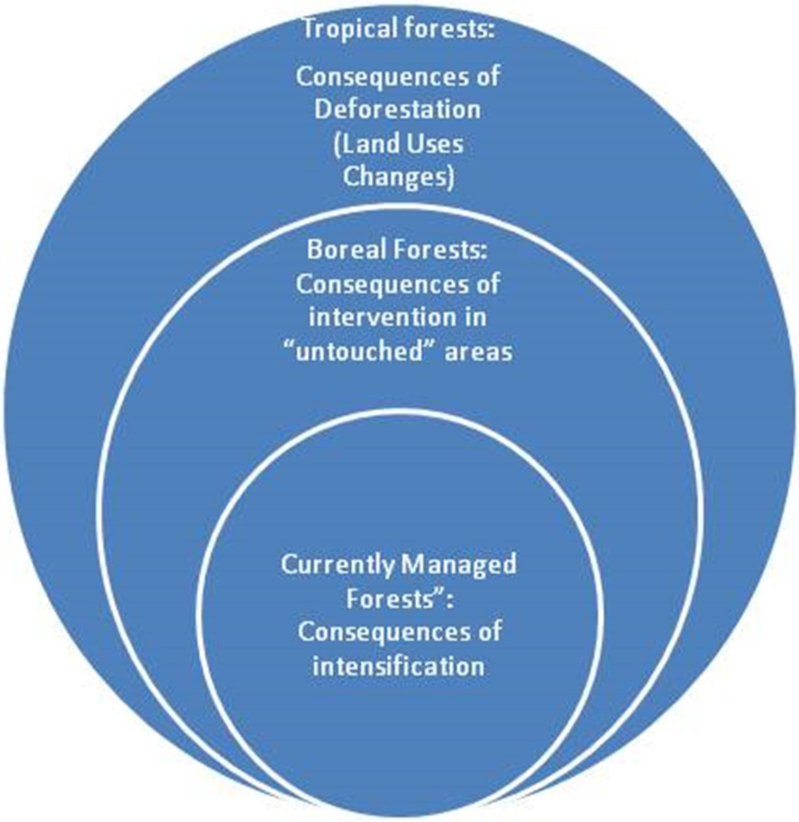
The existing guidelines for different states and (FSC) certification scheme cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and disturbance. Additionally, some states place restrictions on re-entry to the site for biomass removal following conventional harvest.

4 Ecological Risks of Harvesting Solid Bioenergy from Forests

Increased solid biomass extraction from forests implies potential impacts on biodiversity and water availability and quality. Furthermore, unsustainable forestry practices combined with increased removal of residues and other formerly not extracted parts of the tree could lead to negative impact on soil, including reduction of soil carbon stocks, soil erosion, soil loss (especially of fertile top-soil), loss of soil organic matter, nutrient depletion, and reduced water retention. Another potentially major negative effect is simplification and homogenization of managed forests (Siitonenen, Berglund 2009).

Forest biomes reflect the ecological and physiognomic characteristics of the vegetation broadly corresponding to climatic regions of the Earth and they may be classified as boreal, temperate and tropical forest (CBD undated). A first approach to forest risks from additional bioenergy extraction is to consider different geographical areas, as risks to e.g. central European forests are different to those that unmanaged boreal or tropical forest may face. Figure 2 offers a schematic summary of this concept.

Figure 2: Conceptual map of generic risk depending on the forest area



Source: own compilation

Depending on the international and national drivers pushing for woody biomass supply, more pressure could be exerted on tropical forests. This risk could be examined from two perspectives:

- First from the wood resource that tropical forest might provide.

- Second from the point of view of the additional pressure put in place for land use change in order to create short rotation plantations or other cultivations for biomass provision.

This section will identify areas that should be protected from extraction (no-go areas) as well as the potential risks faced in managed forests.

4.1 Impacts on Biodiversity

Forest harbour two thirds of the world´s terrestrial biota but not all of them are equally biodiverse (FAO 2010b), and differ in their conservation value, respectively. Thus, depending on the objectives of the stand go or no go areas may be defined. From a biodiversity point of view two risk-mitigation strategies have been identified (Franke et al. 2012):

- Conservation of areas of significant biodiversity value. It has to be remarked that habitat losses represent the major threat to biodiversity.
- Promotion of forestry practices with low negative impacts on biodiversity.

4.1.1 Definition of “no-go“ areas

The conversion of areas of high biodiversity value to bioenergy feedstock production can have significant negative impacts on biodiversity and ecosystems, through landscape change, fragmentation and loss of ecological corridors, etc. Areas inhabited by threatened or endangered species and sensitive sites for wildlife including areas such wetlands, caves and breeding areas should receive special consideration. Hence, the establishment and protection of highly biodiversity or conservation values is needed.

The Strategic Plan for Biodiversity 2011 – 2020, adopted by the 10th Conference of the Parties (COP) to the Covention on Biological Diversity in Nagoya in 2010 proposed 20 targets to be met by 2020, some of them directly related to forests and to the synergies agenda (CBD, UNCCD, UNFCCC 2012):

- Target 5. The rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced
- Target 7. All areas under forestry are managed sustainably, ensuring conservation of biodiversity
- Target 11. At least 17 per cent of terrestrial and inland water areas are conserved
- Target 14. Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded.
- Target 15. Enhance the resilience and the contribution of biodiversity to carbon stocks through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems. The scope is to restore 150 Mha of degraded forest landscapes by 2020.

This section will examine the interactions between forest bioenergy and areas of special concern such as:

- Areas designated for biodiversity protection (recognized by laws or identified by international agreements, IUCN or other organizations)
- Primary forests (including old-growth forest)
- Areas with risks of hazards, disturbed areas and salvage logging
- Wetlands
- Riparian areas and buffer zones

Areas designated for biodiversity protection

Areas designated by laws

Significant biodiversity value areas have been protected through different national and international processes. Thus, CBD has recognized protected areas (PA) as cornerstones of biodiversity conservation. PAs play a critical role in conservation of biodiversity, maintaining genetic resources, protecting important ecosystem functions and helping to protect many fragile human communities and cultural landscapes (Dudley, Phillips 2006).

To the end of conserving forest, the protection of at least 10 % of each of the world´s forest types was adopted in the 9th COP of the CBD (CBD 2008). However, concerns about the representativeness of this protection target have been raised and it has been suggested that this percentage of the remaining forest protection will not be enough to maintain forest biodiversity (Schmitt et al. 2009). In this regard, it has also been acknowledged that PAs often represent the minimum threshold for areas of significant biodiversity value, and existing PAs throughout the world are still far from fulfilling either global biodiversity commitments or the needs of species and ecosystems (Franke et al. 2012).

In the world the total percentage of the terrestrial protected area represents 12.7 %; it covers 11.6 % in developed regions and 13.3 % in developing countries (IUCN, UNEP-WCMC 2011). The area designated for the conservation of biological diversity accounts for 12 percent of the world´s forests and it has increased by more than 95 million hectares since 1990 (FAO 2010b). Most but not all of them are located inside protected areas, which cover an estimated 460 Mha (FAO 2010b)[24].

In Europe (EU27) about 11 percent of the forest area are protected, in different degree, with the main objective of conserving biodiversity, and additional 10 percent with the main objective of protecting landscape (Forest Europe 2011a).

According to Forest Europe (2011a), protected forests are classified in (i) non active intervention (1 percent), (ii) minimum intervention (3 percent) and (iii) conservation through active management (7 percent). In North Europe and in some Eastern European countries, restrictive protection with no or minimal intervention dominates, whereas in Central and Southern European countries, active management in protected areas is emphasized (Forest Europe 2011a).

Other highly biodiverse areas (recognized by international agreements or IUCN)

International Union of Conservation of Nature (IUCN), has developed global set of standard categories that classify protected areas based on management objectives allowing comparison between countries due to the lack of international standardization of the national designations. Six categories have been proposed, corresponding to the following main management targets (Dudley 2008):

- Category I: Wilderness protection
- Category II: Ecosystem protection and recreation
- Category III: Conservation of specific natural features
- Category IV: Conservation through management intervention

[24] Protected areas may be designated for other reasons than the conservation of biological diversity then areas of these categories not necessarily have to be equivalent

- Category V: Landscape/seascape conservation and recreation
- Category VI: Sustainable use of natural ecosystems

Categories I-IV are generally more restrictive in extraction of natural resources and land use change and categories V-VI considers protected areas that are designated for multiple-use management of forest resources (Schmitt et al. 2009)

Of the global forest cover, 7.7% fell within protected areas under IUCN management categories I–IV and with the inclusion of IUCN categories V and VI, the level of global forest protection increased to 13.5% (Schmitt et al. 2009). Considering their biodiversity importance, forest protection within global priority areas was insufficient, e.g., median protection of 8.4% in biodiversity hotspots (IUCN I–IV).

WWF has ranked the most biologically outstanding ecosystems through the establishment of **Global Ecoregions**. An ecoregion is defined as a "large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions". The analysis of Global Ecoregions is to assure that the full range of ecosystems is represented within regional conservation and development strategies, so that conservation efforts around the world contribute to a global biodiversity strategy. Currently, 238 ecoregions have been selected[25].

In relation to the protection of significant biodiversity value areas a broader concept namely **High Conservation Value Forest (HCVF)** was first defined by the FSC and increasingly being used for other purposes (Proforest 2003).

HCVF are the forests that contain environmental and social values of outstanding significance or critical importance as shown in the table below (Proforest 2003).

FSC specifically recognizes the maintenance of HCFV among their principles and remarks that management activities in HCVF shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach (FSC 2012).

On the other hand, PEFC acknowledges among its criteria the “Maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems”. It is stated that forest management planning, inventory and mapping of resources shall identify, protect and/or conserve ecologically important forest areas containing significant concentrations of protected, rare, sensitive or representative forest ecosystems, among others.

Table 6: High Conservation Values and their key elements

HCV1 Globally, regionally or nationally significant concentrations of biodiversity values
HCV1.1 Protected Areas
HCV1.2 Threatened and endangered species
HCV1.3 Endemic species
HCV1.4 Critical temporal use

[25] WWF: http://wwf.panda.org/about_our_earth/ecoregions/about/

HCV2 Globally, regionally or nationally significant large landscape level forests
HCV3 Forest areas that are in or contain rare, threatened or endangered ecosystems
HCV4 Forest areas that provide basic services of nature in critical situations HCV4.1 Forests critical to water catchments HCV4.2 Forests critical to erosion control HCV4.3 Forests providing barriers to destructive fire
HCV5 Forest areas fundamental to meeting basic needs of local communities
HCV6 Forest areas critical to local communities' traditional cultural identity

Source: Proforest (2003)

Primary forests

FAO (2010a) defined Primary Forest as "naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed". FAO also acknowledges virgin forest and frontier forest as related terms[26].

Some key characteristics of primary forests are (FAO 2010c):

- They show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes,
- The area is large enough to maintain its natural characteristics, and
- There has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become re-established.

In addition to preservation of biological diversity, primary forests also fulfill many other essential functions from the protection of soils and water to the preservation of cultural and religious values. The value of "primary forest" may vary according to the context (Paré 2012):

- It is identified as primary forest in that landscape
- Sites with exceptional biodiversity value
- Abundance of specific ecosystem type in the landscape
- Area already fully protected in that landscape (area km^2 as well as proportion of the original areas)
- Connectivity - are protected areas connected by forests with a continuous cover that can serve as corridors or are they surrounded by an urban landscape.

Primary forest sums 35.7 percent of the total forest area at global level[27] FAO (2010a) and 2.8 percent in Europe excluding Russia Federation (FAO 2011). Boreal primary forests are abundant in the Russia Federation (256 Mha) and Canada (165 Mha) and tropical primary forests in Brazil (477 Mha), Peru (60 Mha) or Indonesia (47 Mha).

[26] Consultation of the FAOTerm database on July 23 2012: http://termportal.fao.org/faoterm/main/start.do?lang=en

[27] It has to be noted that information is missing for some large tropical countries.

It should be kept in mind, that the worldwide definitions of natural forest and related terms are used only in the reviews of global and regional forest resources in order to make different counties data comparable (Rouvinen, Kouki 2008).

Moreover, the definition provided by FAO is quite controversial and difficult to apply at operational level especially for some ecosystems (Thiffault 2012). Applied terminology at more local scale is used to be based on specific ecological factors and considerations and it is likely that a generally applicable and precise definition of natural forest cannot be achieved because the definition is context-, scale-, and value-dependent (Rouvinen, Kouki 2008).

The Canada Country Report (FAO 2010d) states that primary forest is reported as "reserved" plus "not accessed" areas. The Russian Federation Country Report (FAO 2010e) also points out for primary forest that all mature and overmature coniferous stands of trees are included as they are a climatic climax as well as all reserve forests. These facts express the great difficulty of providing a universal definition applicable to a great variety of environmental and socio-economic contexts.

From the biodiversity perspective, not all forests are biodiverse equal and some of them may not be rich in terms of biodiversity (FAO 2010b). Thus, tropical forests are the richest ecosystems on the world and they are impaired by a list of risk. A long-term analysis over the "health" of tropical reserves around the world has revealed that half of them are experiencing an erosion of biodiversity (Laurence et al. 2012). The main drivers of this are habitat disruption, hunting and forest-product exploitation and both changes outside and inside reserves are of great importance (Laurence et al. 2012). The importance of establishment ecological buffers around the reserves has also been remarked.

When the reason is to protect biodiversity and from intense management the definition of old-growth forests could be more appropriate (Thiffault 2012). It is recognized by IUFRO (2012) as "a forest dominated by mature organisms that have originated naturally from those endemic to the forest or its surrounds, in which the genetic, species and structural diversities have not been significantly changed by human activity".

The EC (2007) acknowledges that natural old forests represent climax or late succession stages with slight human impact or without any human impact. Old natural forests are habitats of many threatened species. Some of the present old natural forests have human impact, but in spite of that they maintain many characteristics of the natural forests.

Various approaches in North America indicate that old-growth forests may include any or all of the following issues (Uhlig 2001):

- Large old trees for species and site
- Complex stand structure characterized by wide variation in tree size and spacing, with multiple canopy layers and canopy gaps
- Large dead standing trees and accumulations of downed woody materials, tip-ups and mounds
- Specific composition of the forest community described through the occurrence or changing abundance of certain associated species (e.g., herbaceous plants, lichens and other bryophytes or wildlife species)
- Few or no signs of human disturbance
- Net growth equal to or less than zero
- Age of dominant species exceeding average natural disturbance interval for ecosystem, and/or, forest system near or in late succession or "climax" stage.

The terms primary forest and old-growth forest are sometimes used interchangeably (CPF 2012) although most scientists recognize that an old-growth forest have not to be a primary forest (Hilbert, Wiensczyk 2007). Thus, secondary forest can become old-growth forests over time. In fact, CBD (undated) recognized that old growth forest stands are stands that have developed the structures and species normally associated with old primary forest of that type have sufficiently accumulated to act as a forest ecosystem distinct from any younger age class.

Due to the lack of clear ecological thresholds to distinguish between old-growth and other forest development phases, it has been suggested the development of indices or scoring schemes of "old-growthness" to be established (Hilbert, Wiensczyk 2007).

Thus, the establishment of indices is often deemed as more effective than the assignment of arbitrary thresholds, even they present some limitations.

To accomplish the protection on old-growth forests, three basic approaches may be considered at a landscape level (Shorohova et al. 2011):

a) Permanent protection areas set aside,

b) Shift mosaics in the matrix and

c) The combinations of the two approaches (protected areas and managed "old-growth").

Approaches that consider the full functional landscape like the TRIAD approach[28] may make more sense for protecting landscapes that contain a high proportion of natural semi-natural forests (Paré 2012). Buffer areas, i.e. land of gradual transition between heavily harvested and lightly harvested areas, have been suggested to avoid hard-edge effect which could imply wildlife impacts (Lal et al. 2011).

In North America and Fennoscandia[29] suggested approaches to SFM are based on mimicking natural processes as well as the conservation of old-growth. In Russia, however, socio-economic difficulties have led to the maintenance of old-growth in remote regions while in more accessible areas, remaining old-growth forests are threatened (Shorohova et al. 2011).

Wetlands

Wetlands are among the world's most productive valuable ecosystems, especially because of their ability to withdraw and store enormous amounts of carbon dioxide from the atmosphere. They also support a vast amount of biological diversity, providing the water and primary resources as well as protection against natural disturbances. With the aim of conserving and wise using of all wetlands the Convention on Wetlands was launched in Ramsar (Iran) in 1971 (Ramsar Convention Secretariat 2011).

As defined by the Convention, wetlands include a wide variety of habitats, both non-forested and forested wetlands. In the Ramsar classification of wetland types, developed to support the designation of Wetlands of International Importance (Ramsar sites), three types of forested wetland are recognized (Blumenfeld et al. 2009):

- Intertidal forested wetlands: including mangrove swamps, *nipah* swamps and tidal freshwater swamp forests

[28] i.e. part conservation, part ecosystem management with corridors and forest cover, part intensive forestry

[29] Finland, Norway, Sweden, Karelia and the Kola Peninsula.

- Freshwater, tree-dominated wetlands: including freshwater swamp forests, seasonally flooded forests, and wooded swamps on inorganic soils, and
- Forested peatlands: including peatswamp forests

In February 2010, 12 % of the global area of Ramsar sites worldwide (185 Mha) were predominantly one or other of these three types of forested wetlands. Intertidal forested wetlands (largely mangrove systems) covered 8.9 Mha; freshwater, tree-dominated wetlands summed 12.9 Mha and peatlands (most of them boreal systems) included 1 Mha. FAO (2010b) reports that the total area of mangroves is estimated at 15.6 Mha as of 2010, with a reduction of 0.5 Mha since 1990, but the rate of net loss appears to have slowed down (FAO 2007).

Riparian Areas

Riparian areas can be defined as transitional areas occurring along land and freshwater ecosystems characterized by distinctive soil, hydrology and biotic conditions strongly influenced by the stream water (Clerici et al. 2011). They are distinguished by gradients in biophysical conditions and environmental processes and are fragile ecosystems and they play a key ecological role (Clerici et al. 2011). Riparian zones include both floodplain and wetland indicators and upland areas away from the shore that have a direct water-land interaction and they can be associated with perennial, intermittent or ephemeral streams (Clerici et al. 2011).

Despite some variations in details in concepts and definitions on riparian areas, there is a wide agreement regarding the notably value of its environmental services. Key services and functions comprise their relevance as highly valuable habitat and refuges site, e.g. for regional flora during dry periods and as a connection and corridor system in highly fragmented landscapes; their ability to reduce nonpoint nutrient and pollution sources towards the streams by plant uptake, physical filtering and chemical transformation (e.g. denitrification), together with trapping sediment-bound pollutants and waters coming from streams; and their contribution to stabilize river banks via vegetation roots, provide friction and resistance to runoff during floods

Fixed width buffers along watercourses have been widely applied to preserve riparian areas ecological features and functionality. Buffer ranges between 30 and 41 m from stream have been proposed to allow maintenance of the ecological functions (Clerici et al. 2011).

More precise methods use spatial tools incorporating various layers of information to delimitate riparian areas.

Areas with risks of hazards, disturbed areas and salvage logging[30]

Most forests are affect by natural disturbances both biotic and abiotic that play a key role in the maintenance of ecosystem processes and biodiversity through the creatation of structural complexity and landscape heterogeneity. FAO (2010b) reports close to 40 Mha of forest per year affected adversely by insect pests and diseases (of special concern is the Mountain Pine Beetle in West North America). Regarding fires the total mean area affected annually amounts 20 Mha of forests and an additional 18 Mha of other wooded land.

[30] For further information about this issue see Annex 3: Salvage logging for bioenergy?

To prevent more severe disturbance effects, in SFM it is stated that mobilisation measures should be considered in forest with high **risk of hazards** such fires, insect infestation etc… in order to improve forest ecosystem health.

Once the disturbance occurred, the removal of the timber and wood products may be an option. **Salvage logging** comprise the removal of dead trees or trees damaged or dying because of injurious agents… to recover economic value that would otherwise be lost (Lindenmayer, Burton, Franklin 2008). This operation can put in market great amount of timber and wood products (Lindenmayer, Burton, Franklin 2008), with much variation between years and a rising trend of damage from at least from storms and fires (Schelhaas 2008).

The impacts of salvage logging vary in response to a wide range of factors can be negative, neutral or positive. Impacts on the physical structure of forest stands, ecosystem processes and other cumulative effects can be observed.

Various studies (Lindenmayer, Noss 2006; Bunnell, Squires, Houde 2004 and Bunnell, Kremsater, Houde 2011) proposed recommendations for rational salvage harvesting at stand and landscape level, with especial focus on biological legacies maintenance. They are summarized as follows:

- Protect some areas and sensitive sites from salvage logging.
- Conserve patches, even of affected species by a insects pest as the lodgepine in the case of mountain pine beetle, or harvest in a low-intensity within the perimeter of a disturbed area.
- Retain certain biological legacies and leave slash.
- Control minor vegetation sparingly.
- Schedule salvage logging so that effects on natural recovery of vegetation are limited.
- Ensure the future maintenance or creation of particular habitat elements for species of conservation concern
- Ensure adequate riparian buffers
- Plan both areas to be reserved from harvest and areas to be harvested as large blocks.
- Plan harvest over larger areas quickly and deactivate roads when finished.

Albeit in many occasions the debate of salvage logging is between intervention against no intervention many alternatives exists (Castro et al. 2011).

The issue of making use of biomass from primary forests – either in form of salvage harvest or any other means of extracting biomass for bioenergy from such forests – is still discussed with regard to its sustainability.

A Canadian-European workshop on this issue was held in Quebec in October 2012 which helped furthering considerations regarding potential use of residues from primary forests.

4.1.2 Proper management of harvestable stands

SFM seeks to maintain or enhance ecosystem functions and biodiversity. After clear-cuts, slash left on the ground provide shelter, regulate wind velocity, water infiltration, regeneration, light and fluctuations in surface temperature. When residues, snags and stand trees are removed the lack of habitat may have detrimental effects on some species. This alters forest structure and can lead to a loss of biodiversity that may impact on forest productivity and other ecosystem services.

Table 7 reports main risks on biodiversity from additional forest biomass harvesting on managed areas.

The reaction against forest simplification and the recognition of the necessity for a better integrated wood production and biodiversity protection gave birth to the concept of retention forestry which has been used as an approach to forest management based on the long-term retention of structures and organisms, such as live and dead trees and small areas of intact forest, at the time of harvest for more than 2 decades (Gustafsson et al. 2012). As a more specific part of this wide approach is the concept of deadwood retention.

Deadwood is a measure of habitat quality (EEA 2011). Due to shorter periods of cutting, managed forests contain less deadwood than unmanaged forests. Thus, in natural forest the amount of deadwood may reach more than 200 m^3 per ha while in managed forests deadwood volumes can range from 2 m^3 per ha to 10 m^3 per ha (EEA 2011).

Deadwood, in the form of both standing dead trees and down wood and debris, is an essential structural component for biodiversity in forest systems (Janowiak, Webster 2010). In fact, in current forestry practices thresholds ranging from 20 to 50 m^3 per ha for Central European forests have been proposed (Müller, Bütler, 2010). For example, in Hessian State Forest (Germany) deadwood thresholds proposed depend on the types of species groups that the forest harbors. This amount varies from 33 m^3 per ha to 144 m^3 per ha (Hessen-Forst 2011).

Although retention levels can range more than fortyfold, a minimum amount of 5-10 % in terms of the area or wood volume retained has been suggested (Gustafsson et al. 2012). At this regard, WWF (2004) suggested between 20-30 m^3 per ha of deadwood or 3-8 % of total volume for European boreal and temperate forests.

However, Forest Europe (2011) reports that the average volume of deadwood, both standing and lying, in European Forests is about 10 m^3 per ha, ranging from 8 m^3 per ha in North Europe to 15 m^3 per ha in South-East Europe.

Structurally diverse large-diameter coarse woody debris provides a wide range of substrates and microhabitats for diverse array of wildlife species. Some studies report that the extraction of residues may reduce the survival of some ground-dwelling forest organisms (i.e. Dynesius, Åström, Nilsson 2008) or change species composition and reduce species richness of liverworts and mosses (Åström et al. 2005).

On the other hand, it has been reported that the extraction of residues has a negligible long-term impact on abundant saprotrophic fungi (Allmér, Stenlid, Dahlberg 2009). It has been also stated that the current situation of residues extraction in Sweden doesn´t imply of regional extinction of wood- and bark-inhabiting basidiomycetes, beetles, and lichens (Dahlberg et al. 2011).

Table 7: Potential impacts of forest biomass harvesting on biodiversity in managed areas

Risk	Issues	Causes
Landscapes, ecosystems and habitats	Decrease in area and diversity of forest cover Decrease in overall forest resilience/ increased susceptibility to insects and disease Decrease in habitat connectivity at both the landscape and stand levels (e.g., forest patches, migration corridors, connected networks of DWD) Reduction in ecosystem functions and services Loss of DWD and dead wood needed for the survival of some species of mosses, fungi, insects, small mammals and cavity nesting birds Overall reduction in quantity and quality of adjacent aquatic habitats	Road building to access previously non-merchantable biomass Excessive removal of dead and downed wood Increased thinning Excessive gathering from the forest floor Mechanical damage to residual trees from intensive harvesting, lack of care, and multiple interventions over the rotation Unsustainable production processes and absence of appropriate guidelines Uncontrolled intensification of forest management Decrease in overall forest health Decrease in habitat connectivity at both the landscape and stand levels
Species	Changes in forest composition Species loss due to habitat degradation Proliferation of invasive species and species that prefer disturbance landscapes Inadequate maintenance of trophic levels	Encouragement of naturally occurring species (e.g., aspen, willow, poplar, eucalyptus), depending on regional situation Extensive clearing Open corridors and increasing traffic into forests
Impacts on regeneration	Lack of suitable micro-sites for seedling establishment because of extreme soil microclimatic conditions Reduction in nurse logs and organic woody substrates for seedling establishment Reduction in habitat for seed-dispersing birds and mammals Proliferation of invasive species and species that prefer disturbance landscapes	Open corridors and increasing traffic into forests Excessive clearing of deadwood, downed wood and slash

Source: adapted from Lattimore et al. (2009)

Retention of biological legacies (e.g. hen trees) during harvesting operation also deemed of importance because they can enhance structural heterogeneity of the stand. The preservation of some patches of these legacies has also been proposed to mitigate the reduced shelter (i.e. Dynesius, Åström, Nilsson 2008)

Riffell et al. (2011) revised effects of coarse woody debris manipulations from 26 studies and recognized the impact of lower CWD in birds and invertebrates but not in other taxa. The lack of information about biodiversity response to remove of fine woody debris was remarked.

Riffell et al. (2011) also acknowledged that operational biomass harvests may not change CWD levels enough to appreciably influence forest biodiversity, especially when following biomass harvest guidelines that require leaving a portion of harvest residues[31]. Bouget, Lassauce, Jonsell (2012) suggested the development of operational guidelines, pointing out various cautionary measures.

The variety of ecosystems and dynamics make difficult to fix a threshold for the amount of harvest residues that should be left after harvesting. Thus, there are no universal effects of forest biomass harvesting on site productivity and they are site dependent (Manomet 2010). In fact, the literature generally suggests that minimum retention levels will differ based both on underlying site productivity as well as with the volume of material harvested and the anticipated amount of time the stand will have to recover before the next harvest. Figure 3 graphically explains how as low and less infrequent harvest, the less downed wood material need to be left on the ground (Forest Guild Biomass Working Group, 2012).

Certification schemes such as PEFC and FSC address in various ways the residues issue (harvesting vs. retention, see Stupak et al. 2011). In fact, various approaches, even opposite, have been put into place and rarely a threshold of residue retention is provided.

Even though the heterogeneity of residues amounts and thresholds (see Tables 8 and 9) various reports and guidelines suggest to maintain within the stand between 1/5 (Swedish Forest Agency 2008) and 1/3 of the harvest residues (Siitonenen, Berglund 2009 for Finland). The Swedish recommendations (Swedish Forest Agency 2008) suggest to leave coarse dead wood (diameter >10 cm) to maintain biodiversity.

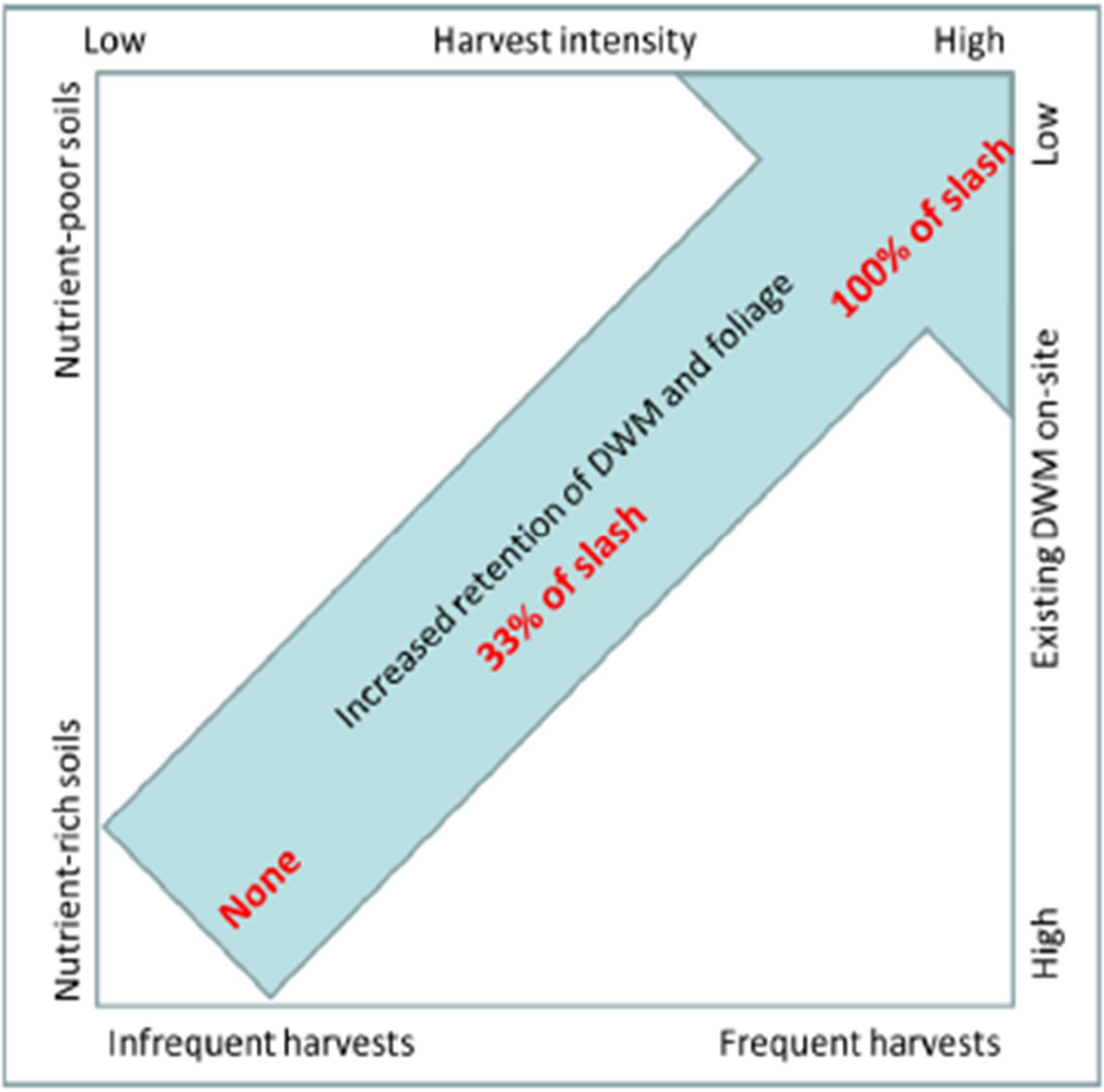
Retention of biological legacies during harvesting operation is also deemed of importance because they can enhance structural heterogeneity of the stand. The preservation of some patches of these legacies has also been proposed to mitigate the reduced shelter (i.e. Dynesius, Åström, Nilsson 2008). The scientific studies do not provide a definitive answer to the question of how much harvest residues should be left after a harvest. Some recommendations made for some USA states are given in the table above for the US, though.

Other assessments for the USA forest, have recommended to maintain between 2.5 and 7.4 t/ha of DWM (Forest Guild Biomass Working Group 2012) and from 5 to 11 snags between 4 and 10 cm dbh, depending on the site. The General Guidelines for retaining forest structures for the Northeast of US (Forest Guild Biomass Working Group 2010) point out to keep on site a minimum of:

- 10 live decaying trees 30-45 cm dbh
- 2.5 live decaying trees larger than 45 cm dbh
- 12.5 snags larger than 25 cm dbh

[31] It should be noted that coarse woody debris (CWD) is different from slash, especially as the latter excludes standing snags.

Figure 3: US Recommendations for residues



Source: Forest Guild Biomass Working Group 2012

The Swedish recommendations of logging residues and ash recycling advise the retention of rarer tree species (Swedish Forest Agency 2008).

This guideline states that it is of especial importance not to damage trees and shrubs, standing as well as fallen, that have been left behind from previous forestry operations.

The retention of snags should be adapted to the forest type and the needs of the wildlife species (Watt, Caceres 1999). Ranges between 5 and 30 snags per ha have been suggested (Watt, Caceres 1999).

Table 8: Recommendations for deadwood retention in selected countries

Country	Recommendations for retention of deadwood	Source
Canada	Considerations for the maintenance of long-term site productivity (e.g. retention of tops, limbs and slash, slash redistribution, etc.) is addressed in several provinces of Canada, e.g. Quebec requires a minimum of 30 % of woody material to be left on the ground	WWF 2010
Finland	It is recommended to leave 30 % of logging residues. Large dead wood (standing or on the ground) is not to be collected and should not be damaged (exceptions are made for harvests being conducted in response to storm events and for insect or disease concerns)	Siitonenen, Berglund 2009; Fernholz et al. 2009
France	It is specifically stated that part of the slash should be on the ground, and the difficulty of recollecting more than 70% is pointed out.	ADEME 2006
Sweden	At least 20 % of the harvesting residues should be left in the clearcut area, and importance of leaving tops, coarse branches and dead wood from deciduous trees as well as tops of pines is highlighted.	Swedish Forest Agency 2008
USA	Different approaches, values for Coarse Woody Material and Fine Woody Material (see Table 9 for further details)	Skog, Stanturf 2011

Source: own compilation from various authors

Table 9: Recommendations for coarse, fine material and snags retention in some US States

	MN	MO	PA	WI
CMW	Leave all existing	Leave 33 % of harvestable biomass	Leave 15 % to 30 % of harvestable biomass	Leave all pre-harvest
FWM	Retain and scatter tops and limbs from 20 % of the trees harvested			Retain minimum of 12,35 tons per ha
Snags	Leave all snags if possible	Leave 15 to 30 snags per ha	Leave all snags if possible	Leave all snags if possible

Source: Skog, Stanturf 2011; CMW (Coarse Woody Material); FWM (Fine Woody Material). MN (Minnesota); MO (Missouri); PA (Pennsylvania); WI (Wisconsin)

Another cause of concern is pioneering species which are invasive or exotic and “new” species (GMO) that can take advantage of intensive harvested stands if removal is not performance carefully leading native species displacement. Invasive species can pose a significant threat to food security, human health and local economy. Invasive species may endanger biodiversity, decreasing native species abundance and diversity via direct competition and other indirect effects, especially in certain sensitive ecosystems.

Thereby, residues removal and harvest operations should be performed in a way that doesn´t allow pioneering species to colonize the stand.

Finally, other indirect impacts on biodiversity can be derived from the regeneration. They can be grouped in (Evans, Perschel, Kittler 2010):

- Removal of tree tops and branches may also remove seeds or cones, which may reduce the amount of natural regeneration
- Re-entering a site. Several States in the USA avoid re-entering a stand to remove biomass

These impacts could be prevented putting in place some operational measures such as scheduling the harvesting.

4.2 Impacts on Soils

Soils are of utmost importance in forest ecology and in the definition of site productivity. Soils serve as the substrate for plant growth, supply nutrients, regulate hydrology and provide water to trees and harbor microorganisms essential to decomposition and nutrient cycling. In addition, soils can be positively or negatively impacted by management. The most relevant potential impacts of soils from forest biomass harvesting are summarized below.

Table 10: Potential impacts of forest biomass harvesting on soils

Risk	Issues	Causes
Effects on physical properties (moisture, structure, temperature, erodability)	Exposure of soil surface/drying of surface layers, soil temperature extremes, wind and water erosion Compaction/decreased soil oxygen and soil porosity/decreased water infiltration/waterlogged ruts Rise of water table and saturation of soil due to loss of evapotranspiration after clearcutting Instability and erosion, especially on sloping terrain resulted of stump removal	Exposure of soils through removal of protective litter layer, deadwood, downed wood or slash; loss of protective roadbed for machinery due to removal of slash; soil conditions during operations (e.g. harvesting when soil is wet) Whole tree harvesting, especially clearcutting; stump harvesting More frequent and/or intensive entries than needed for conventional harvesting (e.g., slash left to dry until foliage abscises, multiple-pass harvesting). Building of additional roads/leaving roads open longer for biomass harvesting
Changes in chemical properties (SOM and soil carbon, nutrients, toxic substances, pH and salinity)	Reductions in soil organic matter and soil carbon storage Reduction in total capital and availability of nutrients (especially N, Ca, P and K); icreased nutrient leaching from the soil Base cation depletion leading to changes in pH and buffering capacity; salinity changes due to water table modifyca-tions; accumulation of toxic substances	Removal of biomass during and/or at the end of rotation (e.g. WTH, deadwood, thinning); rotation length and species chosen (e.g., lack of time for root turnover, litterfall, natural mortality) Improper use of herbicides, pesticides and fertilizers and recycled wood ash Use of harvesting machinery (e.g., leaking of lubricants and hydraulic fluids)
Biological properties (soil biota, soil regenerative capacity)	Decreased soil biota through compact-ion; drying; accumulation of toxic elements; decreases regenerative capa-city of site due to moisture imbalance and nutrient loss	Exposure of mineral soil resulted of removal of dead wood, downed wood or slash Improper use of machinery when harvesting Improper use of herbicides, pesticides, fertilizers (including recycled wood ash)

Source: adapted from Lattimore et al. (2009)

Soil Organic Carbon is commonly used both to measure **Soil Organic Matter (SOM)** content and as an indicator to assess soil quality and its productive capacity. SOM plays a crucial role in regulating soil physical, chemical, and biological properties and processes as well as in soil carbon stocks. SOM is presented in soils as both labile and stable forms, the last one representing the long-term carbon sequestration pools. Decomposition of the labile pool by soil microbes is a major carbon flux in ecosystems. Disturbance can enhance the turnover of both labile and stabile organic matter leading to increase decomposition of the labile pool and loss of carbon from the SOM pool (Walmsley, Godbold 2010).

Forest management can contribute to increase C accumulation in soils, likely because it maintains a lower average stand age (Laudon et al. 2011). As a result of forest harvesting, no overall effect on soil C has been determined except when there was intense burning, removal of coarse woody debris, or soil tillage (Johnson, Curtis 2001).

4.2.1 Nutrient cycles

Soil nutrients, such as nitrogen, phosphorus, calcium, magnesium, and potassium, are also essential for plant growth and development. This is the reason why more intensive removals of wood biomass for bioenergy frequently raises concerns about whether adequate levels of nutrients can be maintained to protect site productivity. In addition, biomass extraction is generally composed by material with high nutrient concentrations such as bark and branches. The more biological active part of the plant (roots, leaves, fine branches and bark) the more nutrient concentrations contain. It is also acknowledged that the nutrient concentrations seem to be species dependent[32].

The intensification of biomass removals through **whole tree harvesting** (WTH) instead of stem only harvesting removes a higher quantity of nutrients potentially causing long-term productivity decline. Due to technical constraints, this harvesting method doesn´t remove all the above ground biomass present in the stand. It implies to leave on site about 25 % of pre-harvest total above ground biomass which represents half of that left biomass with stem-harvest only method (Hesselink 2010). Berch, Morris, Malcolm (2011) acknowledge that efficient biomass harvesting operations in Sweden are now removing as much as 90% of total logging residue.

Results from Sweden indicate that WTH can cause a reduction in site fertility and a decrease in long-term site productivity (Levin, Eriksson 2010). However, other research concluded that the effects of WTH on stand productivity are not well known and results suggest that these impacts are site-dependent (Hesselink 2010; Thiffault et al. 2011).

Several authors have recognized that sites with low soil fertility are more likely to experience nutritional deficiencies. The performance of stem-only harvest has been recommended in certain soils and for demanding tree species in order to limit nutrient depletion (Paré, Rochon, Brais 2002). Therefore, sensitive soil types should be determined and appropriate guidelines developed and applied.

A more recent source of biomass for bioenergy is the use of the **stumps**. In traditional forestry, stump removal is performed in order to control pests and diseases or to prepare the field for restocking purposes. Stump harvesting for bioenergy may lead to undesirable environmental impacts if not developed carefully, including (Walmsley, Godbold 2010):

[32] See the presentation of S. Hellsten at the 3rd Workshop available at: http://www.iinas.org/Work/Projects/REDEX/redex.html

- Removal of soil organic matter inputs
- Adverse impacts on forest soil carbon stores and greenhouse gas emissions
- Increased soil erosion
- Increased soil compaction
- Depletion of soil nutrient stocks and changes in nutrient cycling
- Unknown impacts on future productivity
- Loss of valuable habitat for fungi, mosses, bryophytes and insects
- Increase of non-forest vegetation, favoring invasive pioneering species and therefore additional herbicide requirements.

The stump biomass may constitute and important amount of the extracted stem volume (about 35 %, depending on the species). From a nutrient perspective some recommendations for stump removal are[33]: (i) avoid small roots, (ii) control the tree species to be removed, some should be avoided, (iii) avoid small young tree species (birch) and (iv) consider the location.

Stumps harvesting is a trending practice in Fennoscandia. However, many biomass harvesting guidelines developed in the USA advice to leave stumps and root systems on the ground (Evans, Perschel, Kittler 2010). The long term effects of stump removal are mainly unknowns. More research on the effects of stump harvesting as well as best practice guidelines should be developed and communicated in order to minimize environmental impacts (Walmsley, Godbold 2010). Hence, environmental effects of stump removal should carefully examined before harvesting.

When full tree is removed (WTH + stumps) losses of base cations may be observed and reducing buffer capacity against acidification[34]. It should be mentioned that some studies[35] have concluded that difference in nutrient losses between stem and WTH is higher than between WTH and WTH plus stumps. However, losses at stump removal are still important (particularly in combination with WTH).

4.2.2 Fertilization

The use of agrochemicals can increase productivity but also imply potentially effects on soils, biodiversity and water quality. Ash treatments at low levels have been successfully used in both Europe and the USA for nutrient replacement into poor forest soils (Pitman 2006). Wood ashes provide base cations but they don´t content N so additional application should be performed in case it is needed. Also wood ash amendment has been proposed to correct specific soil deficiencies in some places (Pitman 2006). When these practices are put in place, the preservation of organic matter and other soil properties should be assured.

The key determinants of wood ash chemistry are the tree and part (wood or bark) species combusted, the nature of the burn process and the conditions at the application site (Pitman 2006). Wood ash from hardwood species produces higher levels of macronutrients in their ash than conifers, and the silica content is frequently lower. Fly ash should not be used as fertilizer due to the high concentrations of cadmium, copper, chromium, lead and arsenic. Heavy metal, radionuclide and dioxin contamination of wood ash-based fertilizers is minimal and unlikely to affect ecosystem function. The form of the ash at application is also

[33] Ibid

[34] Ibid

[35] Ibid

important, with loose ash releasing Ca, K and Na more rapidly than granulated or otherwise stabilized ash.

The effects of wood ash are primarily determined by application rate, ash form (stabilized or not) and soil type. The benefits are maximized at low dose rates, with possible toxicity from applications in excess of 10 t ha^{-1}(Pitman 2006). Swedish recommendations (Swedish Forest Agency 2011) points out that a maximum of two applications of 3 t per ha each should by recycled with a maximum of 6 t per ha per rotation. The ash shall be stabilized. For most forest sites, a single wood ash application per rotation could replace all the nutrients lost after WTH (Pitman 2006). Long-term increases in stand growth after wood ash application together with N have been reported (Saarsalmi et al. 2012).

If loose ash is spread, the most pronounced environmental effect is an increase in soil pH and an increased mineralisation rate of soil organic matter (Stupak et al. 2007). Furthermore, some negative impacts on changes in soil flora and fauna, and increased concentrations of heavy metals in soil have also been reported. However, the risk of negative impacts on forest ecosystems can be considerably diminished if recycled ash is stabilised and hardened before spreading.

Data from Swedish forests typically show that N fertilization can increase C sequestration until a certain quantity of application. When the soil is saturated N leaching can be observed, whit the negative consequences that can come up such as eutrophication.

Nitrate leakage with increased fertilization intensity could contribute to the eutrophication and reduction of species diversity in surface waters.

In order to avoid acidification and nutrient depletion of forest land the Swedish Forest Agency (2008) has proposed ash recycling to be done on sites where extensive amounts of harvesting residues are extracted at some point during the rotation period. Extraction of harvesting residues should be compensated with hardened wood ash if:

- The total extraction of tree parts other than the stem over the rotation represents more than 0.5 t of ash per ha, and
- Most of the conifer needles are not left fairly evenly dispersed.

Swedish studies conducted with various tree species have shown that the energy input is low in comparison with the energy obtained in the harvested materials (Thelin 2009). Moreover, the relationship between the increments of energy harvested in comparison to the control and energy input for production and spreading of fertilizers ranged from 22:1 to 156:1 (Thelin 2009).

Another study carried out in Sweden (Sathre, Gustavsson, Bergh 2010) with the purpose of analyzing the GHG implications of increasing biomass production through forest fertilization concluded that emissions derived from forest operations (including fertilization) are minor compared to the available bioenergy and the avoided emissions due to material and fuel substitution. It was also stated that the increased soil carbon stock due to fertilization was balanced by a decreased carbon stock of about the same amount due to residue harvesting.

Several standards accept fertilisation or liming to correct specific problems such as maintenance of water quality, reaching overall goals of ecosystem restoration or environmental quality, correcting nutrient deficiencies or imbalances, afforestation of degraded land, or stand establishment in general or in plantations if the rationale for their use is given (Stupak et al. 2011). PEFC pays attention to the influence that such substances could have on water quality. In PEFC, fertilisation is usually restricted to different degrees among member standards (from prohibited to minimised). Some national standards of both FSC and PEFC allow for wood ash recycling to compensate for intensified removal of residues (Stupak et al. 2011).

4.2.3 Physical properties

On the other hand, harvesting can also cause soil displacement, rutting and erosion, as well as compaction and other structural changes (Janowiak, Webster 2010) which effect on regeneration, tree growth and other ecosystem impacts. The response of soils to disturbance associated with harvesting is not homogenous.

Reeves et al. (2012) report that soil reactions to harvest activities depend primarily on soil moisture during harvest operations, soil organic matter content, and soil textural class. They recognize the importance of other features such inherent soil bulk density, forest type, soil parent material, and slope. Other studies acknowledge the importance of forest floor depth (all organic horizons), soil quantity of coarse fragments and soil depth (Kimsey, Page-Dumroese, Coleman 2011). Other factors to consider are type of machinery, season and weather conditions during harvesting (Page-Dumroese, Jurgensen, Terry 2010).

Soil compaction in the surface layer can increase surface runoff, decrease runoff water quality, thereby further increasing soil and water losses, and reduce soil water retention. Soil erosion removes especially of fertile top-soil, the soil fraction in which most organic matter is found. Stump removal implies high risks for soil erosion and removal of fertile soil.

The degree to which soil compaction occurs is related to initial soil characteristics. The risk of these impacts on soil productivity may be exacerbated by both greater removal of residues and increases in machinery use (Janowiak, Webster 2010). Soil compaction is often caused by the first few passes of machinery so if biomass harvesting is resembled traditional forestry substantial effects are not expected but if a two-pass system is used, additional trafficking can result in more compaction. Schedule activities when soils are dry or frozen will prevent many potential negative impacts on soil physical structure and surface water quality.

Another cause of concern is mechanical site preparation techniques such as tillage, raking, windrowing, disking and piling which can lead to reductions in soil organic matter (Lattimore et al. 2009).

In case new areas are accepted as go-areas (unmanaged primary forest or areas where harvesting is not undertaken because trees are unmarketable) roads and infrastructure may be developed.

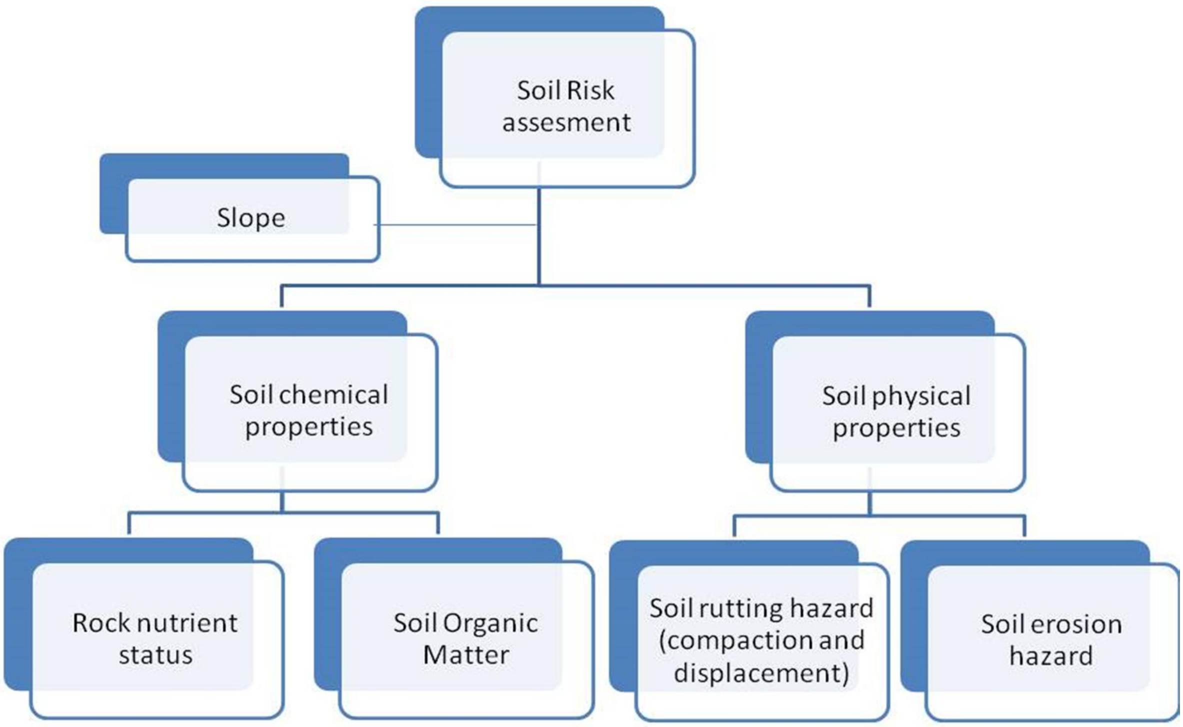
4.2.4 Soil Sensitivity Maps

Soil sensitivity rating maps applying geographic information system (GIS) may be developed in order to assess the biomass harvesting risk. The definition of soil risks maps considering chemical and physical properties and the establishment of thresholds for a “traffic light system” may be applicable. The assessment of relevant parameters could be based in considering a number of aspects as shown in Figure 4. Thus, this methodology has been used in other studies to screen biofuel projects (Franke et al. 2012). Once the factors to consider have been chosen and elaborated, soils could be grouped in three main categories:

- “Green”: Soils where biomass extraction could be performed without restrictions.
- “Yellow”: In this group soils with some concerns will be grouped. Some precautionary measures should be considered.
- “Red”: This category will be comprised by soils that should be avoided.

These maps should be developed an appropriate scale that allows to apply them at stand unit level.
The identification of areas where biomass harvesting is most appropriate has been developped, for example in UK (UK Research Agency of the Forestry 2009), combining soil types by ground damage, soil fertility and soil acidity. French recommendations suggest to define soil sensitivity based on the texture and trophic level (ADEME 2006). Wisconsin (US), Main (USA) and New Brunswich (Canada) have identified more sensitive sites for biomass procurement according to soil features (Evans, Perschel, Kittler 2010). In Quebec (Canada) soil physical and geochemical features were selected as prescriptive indicators of site sensitivity (Thiffault et al. 2010).

Figure 4: Concept map of the factors included for the assessment of a soil risk map



Source: own compilation based on Kimsey, Page-Dumroese, Coleman (2011)

Soil nutrient depletion risks

The nutrient balance in soils depends on the inflows (atmospheric deposition and weathering and N-fixation) and the outflows (harvest and leaching). In addition, fertilization can be introduced in the model to estimate the potential sustainable harvesting (Figure 5).

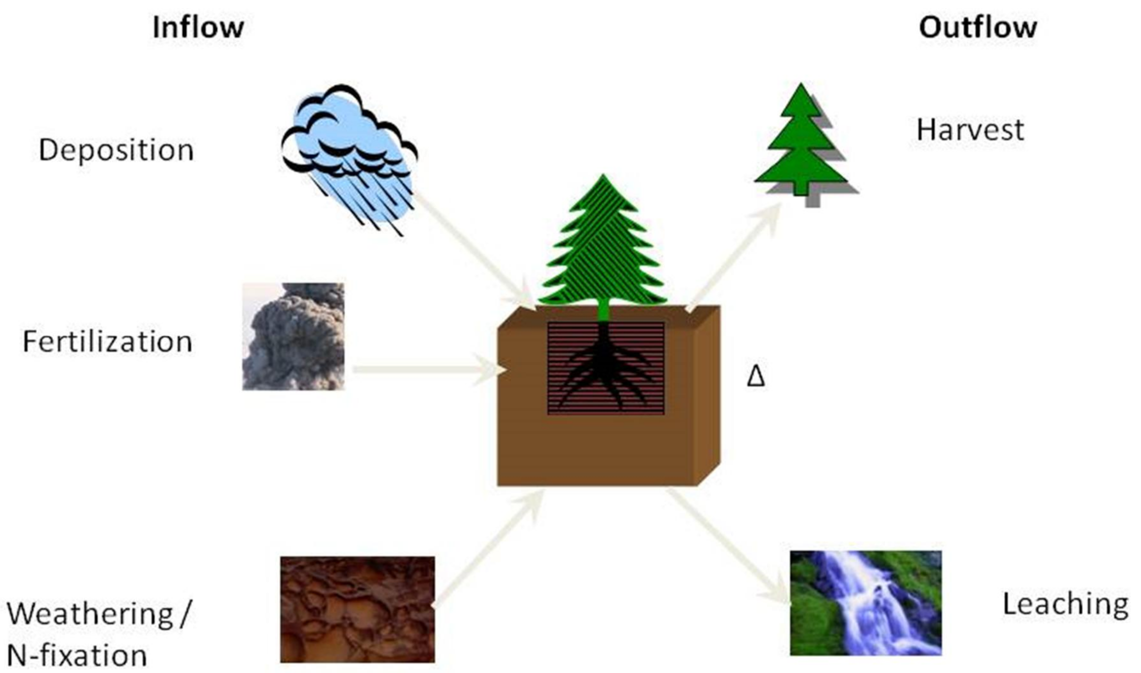
The development of soil nutrients depletion risks may consider (Kimsey, Page-Dumroese, Coleman 2011): rock nutrient status and soil organic matter. In addition, fertilization could be introduced in the model to estimate the potential sustainable harvesting. These types of models have been used i.e. by Ettmayer, Katzensteiner, Eckmüllner (2012) in the Alps; by Akselsson, Westling (2005) and by Hellsten, Akselsson (2012) for Sweden.

Soil nutrient classification in the above mentioned groups can be obtained through the development and effectiveness of such model. The areas with high sensitivity from a nutrient perspective (red areas) could be avoided from harvesting. In that areas that some nutrient risk could be observed the measures to mitigate potential impacts should be put in place. How fertilization and ash recycling is considered need further exploration.

Soil Disturbance Susceptibility

To assess soil disturbance susceptibility depth to water table, rock fragments and slope for rutting hazards evaluation and slope and soil erosion factor for erosion hazards may be considered (Kimsey, Page-Dumroese, Coleman 2011).

Figure 5: Nutrient mass balance calculation



Source: adapted from Hellsten (2012)

4.3 Impacts on Water and Hydrology

Forests have an important role in maintaining and improving water retention capacity, protecting watersheds and maintaining clean water for streams and wetlands. Residues harvesting can affect hydrologic flows and physical, chemical, and biological properties of waterways (Lattimore et al. 2009). It is recognized that road construction is usually the greatest contributor to erosion of the nutrient-rich soil surface layers. Main impacts of residues harvesting on water and hydrology are shown in the following table.

Logging often results in higher soil moisture levels and runoff, which can alter soil nutrient flows, increase streamflow levels, and impact fish and other aquatic organisms (Janowiak, Webster 2010). Harvesting significant amounts of vegetation adjacent to waterways raises the likelihood of increased water temperature, altered chemistry, and reduced clarity that can impair biological communities and ecological processes.

Overall, the effects of harvesting on forest hydrology are highly variable among sites and from year to year; however, harvest impacts are generally greatest immediately after harvest and recover to pre-harvest conditions within 2–5 years (Janowiak, Webster 2010).

When streamside vegetation is removed, incident light and stream temperatures can be increased. Also sediment delivery and inputs of woody debris can be impacted.

Table 11: Potential impacts of forest biomass harvesting on water and hydrology

Risk	**Issues**	**Causes**
Ecosystem hydrologic flux (infiltration, groundwater recharge, interception and transpiration)	Compaction creating impermeable soils and waterlogged depressions Decreased interception and transpiration Changes to water tables	Removal of slash and resultant loss of protective roadbed for extraction machinery Removal of vegetation and alteration of soil properties Whole-tree harvesting, especially clearcutting
Physical (turbidity, temperature, light infiltration), chemical (nutrients, toxic compounds, pH) and biological properties	Soil exposure/increased overland flow/erosion and sedimentation/ increased turbidity, decreased light availability Loss of streamside canopy cover/ increased light infiltration/temporary temperature changes in water bodies adjacent to heavily harvested areas Management of streamside zones (SMZs) (e.g., water temperature) Transport of topsoil into watercourses Subsurface and lateral flow of herbicides and fertilizers to adjacent water bodies Changes in the buffering capacity of the soil and mobilization of toxic elements (e.g., Al) contributing to alterations in water properties Eutrophication of aquatic ecosystems Disruption of aquatic habitats	Harvesting intensity and exposure of soils Soil condition during operations (e.g., harvesting when soil is wet or frozen) Selection and use of machinery Design and construction of roads and stream crossings Harvesting in riparian areas Excessive nutrient leaching, especially N and P through management activities Improper use of herbicides, pesticides, fertilizers (including recycled wood ash)

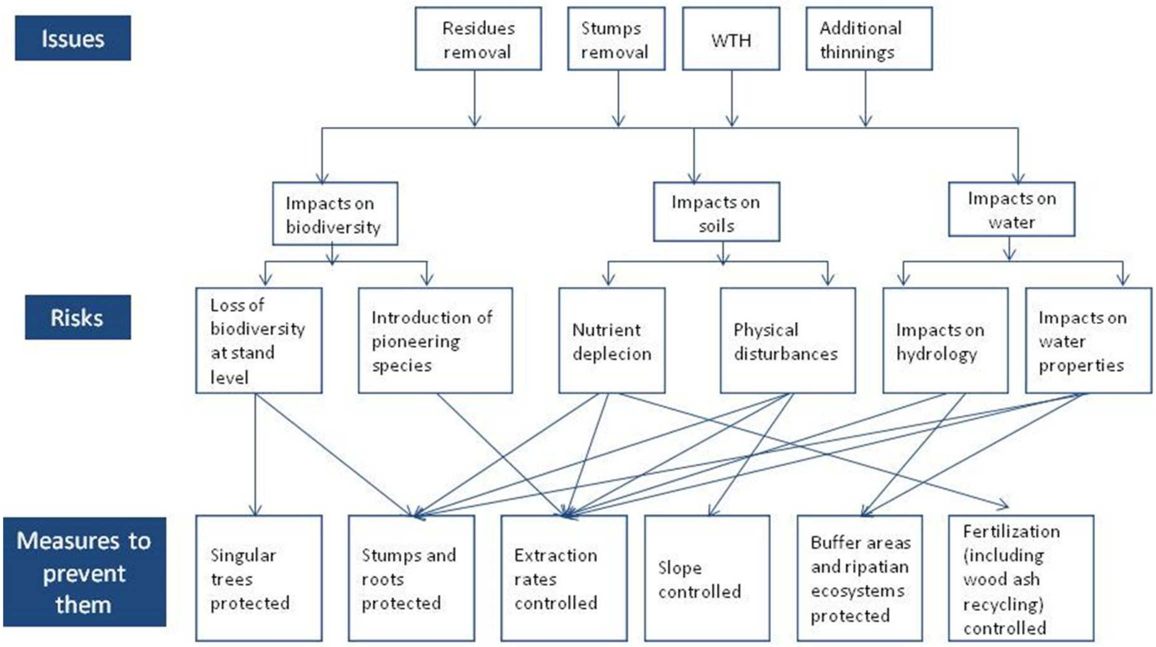
Source: adapted from Lattimore et al. (2009)

4.4 Summary of Ecological Risks associated with Solid Bioenergy from Forests

In previous sections we revised the major impacts to biodiversity, soils as well as water and hydrology associated with forest residues removals. Also, the main drivers that lead with these risks were examined. First approach would be to split between go and no-go areas. It is wide acknowledged that protected areas should be encompassed in a no-go category. Concerns about different types of forest (primary forests, tropical and boreal forests and old-growth forests) have been raised and should be explored into more detail.

Once the no-go areas are excluded of the analysis, the measures that may be considered to prevent mentioned risks in managed areas are summarized in Figure 6:

Figure 6: Risks associated with solid bioenergy from Forests



Source: own compilation; WTH: Whole Tree Harvesting

It can be stated that many of the measures that could be considered to prevent risk are based on the control of the amount of residues harvesting. Thus, the amount of residues left on the ground can affect biodiversity, nutrient cycles, soil disturbances and water quality, quantity and hydrology. Other considerations are also of relevance to protect different ecological dynamics (i.e. maintain biodiversity at forest unit level through the preservation of snags and other biological legacies when harvesting) have to be taken into place.

5 Key Sustainability Criteria and Indicators for Solid Bioenergy from Forests

The main objective of the C&I proposed here is to reduce the risk of future forest degradation due to increased bioenergy provision from existing forests, and to secure net GHG reductions, so this set is result oriented. The conservation of biodiversity and the avoidance of negative productivity impacts in managed forest landscapes are the first basic principles for which C&I need to be developed.

To accomplish these goals various spheres of action have been introduced: the respect for international relevant legislation; the exclusion of areas of ecological relevance (defined by different concepts) and the assurance of SFM at forest unit level.

As some of the impacts of forestry practices to provide more for bioenergy products are not well-known, the approach of the proposed C&I follows the **precautionary principle**, i.e. when the potential negative effects are not well studied, conservative indicators have been proposed. Adaptive forest management[36] is suggested in order to incorporate all the scientific knowledge that is developed and contrasted.

Forests share a number of important elements but the variability of ecosystem dynamics and forestry performance traditions lead to many different ways of achieving compliance with this set instead of a single approach to forestry. It also makes it difficult to establish general thresholds for some indicators. Therefore, the maintenance of ecological processes has to be assured independently that for the same purpose values of certain issues could be in completely different order or magnitude in other areas. This report suggests certain values for some issues that may be universally agreed and proposes that certain values are defined at a more local level.

Hence, the factors that need to be regulated have been built on three criteria, as follows:

- Protecting Biodiversity: This criterion encompass both the definition of no-go areas as well as the protection of biodiversity on managed areas. In this regard, it should be highlighted that indicators proposed in harvestable areas are indirect measures of some aspects of the biodiversity. It means that measures directly correlated with biodiversity won´t be taken (i.e. occurrence of distribution of targeted species); instead the amount of residual removals needed to maintain the biodiversity would be considered.
- Sustainable Forest Management: This criterion is of special concern for harvestable areas for which . indicators are proposed to assure legality and enhance SFM .
- Net GHG emission reduction: Chapter 6 reviews the current state-of-the-art GHG emissions cycles from forest biomass. In line with the criteria laid down by the RED indicators of net GHG emission reduction are proposed. Other considerations of concern such as payback time are discussed in the mentioned chapter.

[36] The Forest Encyclopedia defines Adaptive Forest Management (http://www.forestencyclopedia.net/p/p1286) as: a dynamic approach to forest management in which the effects of treatments and decisions are continually monitored and used, along with research results, to modify management on a continuing basis to ensure that objectives are being met

5.1 Protecting Biodiversity

As discussed in Chapter 4.1, there are two main concerns about biodiversity protection: First, to avoid areas of high biodiversity value preventing deforestation and forest degradation, especially by defining “no-go” areas. Secondly, to assure biodiversity protection also within “go areas”, especially by maintaining adequate habitats for many species. To establish respective safeguards, three key topics are suggested here:

- Definition of highly biodiverse forests as “no-go” areas for forestry products such as timber and bioenergy, including Protected Areas and other areas suggested by International Agreements or NGOs as well as riparian areas and buffer zones;
- Exclusion of primary and old-growth forests from bioenergy harvest unless the extraction is compatible with biodiversity conservation, and
- Sustainable extraction rates for residues and biological legacies retention for **all** forests.

5.1.1 High Conservation Value Forests (HCVF)

Areas inhabited by threatened or endangered animals and plants and sensitive sites for wildlife including areas such wetlands, caves and breeding areas should receive special consideration. In HCVF, biomass harvest - for any purpose - should be avoided unless it is deemed necessary to control invasive species, enhance the biological value of the habitat, or reduce natural hazards risks (wildfire, pest attacks etc...). Special attention to the scale and intensity of forest operation should be paid in HCVF, i.e. biomass from silvicultural operations **could** be removed **if** needed for conservation purposes and not as a source of long-term biomass supply. Thus, bioenergy harvest operations in patch of rare ecosystems, areas with threatened or endangered species can be managed only if **prior** evidence is given that the conservation goals are achieved.

Proposed indicator I1.1

Biomass should not be harvested in High Conservation Value Forest, except if biomass harvest is performed in order to control invasive species, preserve or enhance the biological value of relevant habitats, or reduce natural hazards risks (wildfire, pest attacks etc...) which are not part of natural forest life-cycles.

As HCVF are yet an exception and no international agreement exists on how to define HCVF, the following definition of “highly biodiverse forests” is suggested to allow for an analog to the RED “highly biodiverse grassland”:

Definition:

Forests and other wooded land are highly biodiverse if they are species-rich or harbour rare, threatened or endangered ecosystems or species recognized by international agreements or included in national lists or lists drawn up by intergovernmental organizations or the IUCN. Various categories of areas protected by law are included among highly biodiverse forests and other woodlands.

5.1.2 Primary and old growth forests

The issue of primary forests faces an ambiguous definition and it is recognized that different biomes harbor various degrees of biodiversity richness. This is the reason that the definition of highly biodiverse areas within primary forest needs further discussions. An alternative concept to capture the essence of biodiversity importance in primary forest is the old-growth forests. A more detailed examination to address the most suitable strategy for biodiversity protection within these areas is needed.

Proposed indicator I1.2

Primary forest (old-growth forest or tropical primary forest) should be excluded unless evidence is provided that biomass harvest does not interfere with nature protection purposes.

5.1.3 Bioenergy from salvage logging or from forests with high risk of hazards

Salvage logging is a controversial activity that if not performed under certain rationales may cause environmental impacts (see Annex A-3). Therefore when biomass is harvested both from salvage operations or from forests with high risk of hazards (wildfires, insects attacks, etc..) measures to prevent impacts on environment should put in place.

Proposed indicator I1.3

Bioenergy may be sourced from forests with high risk of hazards or from salvage logging, taking into account all other indicators.

5.1.4 Riparian Areas in watercourses

Riparian Areas play a central role in protecting land and aquatic ecosystems. Hence, a buffer area should be established in the borders of watersheds in order to protect biodiversity of these areas as well as water ecosystems in the surroundings.

Proposed indicator I1.4

At least 100 m of riparian ecosystems from the watercourse is established to protect freshwater resources. A thinner buffer could be established if evidence is provided that other indicators are maintained or enhanced.

5.1.5 Sustainable Extraction Rates

In section 4.1.2 impacts of extraction rates on biodiversity were examined. Many potential negative impacts of biomass harvesting are associated to the amount of deadwood left on the stand.

Measuring all biodiversity aspects is not practical at operational level and may be not necessary when effective cost-effective indicators are available (Geburek et al. 2010). Hence structural attributes, correlated with biodiversity components, can be used as proxies to determine the biodiversity richness (Berch, Morris, Malcolm 2011). For example, one of the indicators used at European level to measure the forest biodiversity is the amount of deadwood (EEA 2011).

Qualitative recommendations about which types of habitats or wood types have been suggested to prevent species extinction of flora and fauna (Jonsell 2007). A more precise approach would be to map and quantify site-specific negative effects of intensive harvesting, as recommended for Europe (Swedish Forest Agency, 2007).

Retention of Deadwood

Residue removal can affect some species, and alter forest dynamics (see Section 4 for further details). It has been acknowledged that certain amount of residues has to be left on the ground to foster biodiversity, soil health, and water retention. An excessive residue removal can also unleash pioneering species introduction which pose potential detrimental effects on biodiversity.

Proposed indicator I 1.5- I 1.6

An adequate amount of residues is left on the ground to protect biodiversity. If more adequate thresholds are not available at biome or landscape level a general recommendation is that residue harvesting not exceeds 1/3 of total available harvest residues. More intensive harvesting could be performed if evidence is provided that other indicators are maintained or enhanced.

Residual harvesting should be performed in a way that does not allow pioneering species entry.

Retention of biological legacies and snags

Another cause of concern is the maintenance of biological legacies and snags when harvesting. Thus, silviculture mimicking natural processes has demonstrate that the maintenance of live cavity trees, den trees, other live decaying trees, and snags to be of crucial importance when clear-cutting. Moreover, these materials provide basic structure for regeneration and stand development and are of special concern when salvage logging is performed.

Proposed indicator I1.6

In case that retention forestry is performed in previous activities, live cavity trees, den trees, other live decaying trees, and snags left should be respected. When the retention of biological legacies is not considered in previous activities and in the absence of a more specific threshold at biome or landscape level, at least 30 snags/ha should be kept. Larger amount of snags, live cavity trees, den trees etc.. could be harvested if evidence is provided that biodiversity is maintained or enhanced.

5.2 Sustainable Forest Management

5.2.1 Existence of a Forest Management Plan (FMP)

The development of a FMP could help to reach the specific goals defined for a stand. Thus, its existence and effectiveness could contribute to make that biomass harvesting is ecologically sound and aligned with the long-term goals of the stand. If biomass harvesting is included among the plan´s goals, several specific issues such as intensity, ways of performance, timing, machinery, etc… may be addressed.

Proposed indicator I2.1

FMP or equivalent tool exists and is implemented (in practice).

5.2.2 Raw Material Legitimacy: Respect to FLEGT

In Chapter 2.4, the regulation at European level that has entered into force both FLEGT and EU Timber Regulation was discussed. This legislation aims to avoid the entrance into the European market illegally harvested timber and timber products. Some concern had been raised about a potential loophole for woody residues. Thus, compliance with legislation affecting woody residues should be assured.

Proposed indicator I2.2

Woody bioenergy feedstocks are supplied in accordance with EU Timber Regulation (EU No 995/2010).

5.2.3 Nutrient balance

Nutrient depletion and loss of productivity is of special concern for biomass harvesting (see Section 4). The development of soil nutrient risks maps that define locally the nutrient depletion sensitivity of the stands could be a comprehensive tool to enhance forest biomass planning. Through these maps the areas where biomass harvesting is most appropriate or inappropriate can be identified. Further work to develop the methodology to create these maps is needed but they should be based on general concepts detailed in Section 4.3.3.

In addition, compensation of nutrients extraction through fertilization can contribute to avoid nutrient depletion and thereby stand productivity. Thus, ash recycling has consolidated as a way of base cations provision that can maintain the nutrient levels in some stands. In case that wood ash recycling would be applied, heavy metal loads are not to be increased, and best available techniques should be developed and followed by foresters in order to prevent potential negative effects.

As shown before, these maps may establish three categories regarding nutrient depletion sensitivity:

- "Green areas": this category comprises areas without nutrient depletion risks. Nutrient compensation could be applied to enhance the productivity.
- "Yellow areas": this group encompasses zones that need additional measures are considered to avoid nutrient depletion. Hence, fertilization should be possible here.
- "Red areas": From a nutrient perspective, these areas should be "no go", as they already face the risk of nutrient depletion, and high rates of compensational fertilization might imply water quality risks.

Proposed indicators I2.3 - I2.5

Residues removal is restricted to areas without **nutrient depletion risks** (green areas) or with risks that could be prevented (yellow areas) according to soil nutrient risk maps developed at stand level.

Fertilization, including wood ash recycling, is allowed in order to prevent nutrient depletion. Wood ash recycling must ensure that no heavy metal loads (above current levels in forest soils) occur. Its application should be in accordance with regional guidelines or with general recommendations set up at biome or landscape level.

Stumps and roots are left in the forest, only selected extraction in exceptional cases, e.g. certain biogeographic conditions which suggest low without negative erosion and nutrient depletion impacts, may be tolerable.

5.2.4 Soil Disturbance (Compaction and Erosion)

In order to prevent the potential negative impacts that residues harvesting can pose on soil physical properties, the development of maps considering soil disturbances is proposed. To accomplish this variables such water infiltration rates, potential of erosion and compaction should be included. In addition, where risks are higher, enough felling residues must be left to protect the tracks.

Proposed indicators I2.6 - I2.7

No harvesting in area having **steep slope** (>35 degree). If harvest is performed in higher slopes areas evidence should be provided that the thresholds defined for other indicators are maintained.

Residue removal is allowed from soils with low (green areas) to medium (yellow areas) **disturbance risk** according to the soil disturbance maps developed for stand levels.

5.3 Net GHG Reduction

Forest GHG cycles are a complex issue due to the longer periods that the stand needs to reabsorb the CO_2 released when burned. Section 6 revises all the issues related to forest carbon cycles. The indicator proposed with regard to this issue is:

5.3.1 Full life-cycle GHG balance

Proposed indicator:

GHG reduction requirements take into account all C stock changes **in the forest** (live biomass, litter, soil) as well as emissions along the production chain (harvesting, processing and transport). As for the LUC emissions, the C stock changes in the forest have to be annualized in a **20 year time frame**. Indirect impacts (market mediated), if any, have to be internalised in the GHG accounting by introducing correction factors such as iLUC (indirect Land Use Change), iWUC (indirect Wood Use Change) and iFUC (indirect Fuel Use Change):

$$E = e_{ec} + e_{cs} + e_p + e_{td} + e_{ind} - e_{ccs} - e_{ccr}$$

where
E = total emissions from the use of the fuel in g CO2eq/MJ
e_{ec} = cultivation or extraction of raw materials;
e_{cs} = carbon stock changes (in soil, above and below ground in 20 years)
e_p = processing
e_{td} = transport and distribution
e_{ind} = indirect effects (ILUC or displacement)
e_{ccs} = carbon capture and geological storage
e_{ccr} = carbon capture and replacement

The GHG savings compared to fossil energy systems should be, at least, 60 %.

5.3.2 Longer-time horizon and full C accounting

Entire forest life-cycles should be considered for C analysis. A horizon of 100 years could be enough for the rotation length of most managed stands in temperate and boreal forests.

Proposed indicators I3.2

A 100 years horizon should be considered. The carbon debt should be lower than 20 years.

6 Greenhouse Gas Balances of Forest Bioenergy

The diversity of feedstock, as well as the large number of bioenergy and biofuel pathways and their complexity, lead to a very high variability of GHG performances, in terms of GHG emission reductions compared to the fossil fuels, especially if land use change is involved.

Indirect effects turned out to be in many cases a crucial factor in GHG balances due to their relevance as trigger for land use changes, though comprising many other aspects like impacts on food and feed prices and therewith supply for poor households; effects on biodiversity and environmental resources (soil, water, air) as a consequence of land use intensification; impacts on competing industries that use biomass or biogenic waste and residues as resource for products; displacement of extensive and or traditional land uses etc.

If indirect land use change (ILUC) effects are considered in GHG balances, a higher degree of uncertainty occurs. Numerous studies on biofuels found differing results, strongly depending on the assumptions made for the calculations. The uncertainties in the various life-cycle analysis (LCA) studies, specifically in regards to the boundaries of LCA and data gaps in the lifecycle inventories are important issues to consider.

The RED sustainability criterion for GHG establishes minimal threshold GHG savings and a simplified methodology to calculate GHG emissions for liquid bioenergy. In order to reduce the administrative burden for economic operators, actual and default values are provided for the most common pathways. The RED methodology used to calculate GHG savings includes all emissions from the extraction or cultivation of raw materials, emissions from processing, transport and distribution and annualised emissions from carbon stock changes caused by direct land-use changes.

The EC provided guidelines establishing the rules for the calculation of land carbon stocks, including soil organic carbon and carbon stock in the above and belowground vegetation both for the reference and the actual land use and values for different soil types and land use categories.

In the RED, though, the CO_2 emissions from the combustion are set to 0 and, in absence of land use change, (e.g. if a forest remains a forest), the carbon stock changes due to wood harvest (i.e. land use, not land use change) are not accounted for. Therefore, forest biomass appears to be one of the most promising renewables and thus likely to be subsidized and largely exploited.

But in the real world, as a matter of fact, biomass combustion causes CO_2 emissions, and, depending on the specific characteristics of the system under analysis the fossil fuel replaced and the timeframe of the analysis, the bioenergy system under certain conditions can results in GHG emissions higher than the fossil system in the short term. Hereby an adequate timeframe is necessary to consider complete forest GHG cycles which are much longer than in annual crops systems.

The principle of biomass carbon neutrality for energy sector is correct in case of accounting and reporting at country level (UNFCC reporting or Kyoto accounting) the net of imports and exports, because the changes in forest carbon stocks are accounted for in the LULUCF sector (or at least they should be).

In case of LCA for the calculation of GHG performances of a specific biofuel, this assumption is acceptable for annual and perennials crops or their residues (in case there is no iLUC), because their carbon cycle is limited to few years so that the timeframe of the analysis does not matter much. This is not the case for forest biomass that has a much longer life cycle[37].

6.1 Impact of Forest Carbon Stock Changes on Bioenergy GHG Emissions

It is only recently that the scientific community has tried to assess the GHG performances of forest bioenergy and to find a way to internalize in the LCA the carbon stock changes in the forest system. The most usual approach for the comparison of fossil systems and bioenergy from forest is to calculate the payback time of replacing fossil fuels with bioenergy.

The payback time can be defined as the time in which the cumulative emissions from the bioenergy system are equal to the counterfactual emissions of the fossil energy system replaced.

Biomass combustion releases, in most cases, more CO_2 in the atmosphere, per unit of delivered energy, than the fossil fuels they replace. This is because forest biomass normally has less energy per kg of carbon, higher extraction, processing and transport emissions and often also lower conversion efficiency. This is what is often referred to as the "carbon debt", the additional emissions over the fossil system. If the production of bioenergy increases the total productivity of the forest, the continuous replacement of fossil fuels, may, in time, pay back these additional emissions.

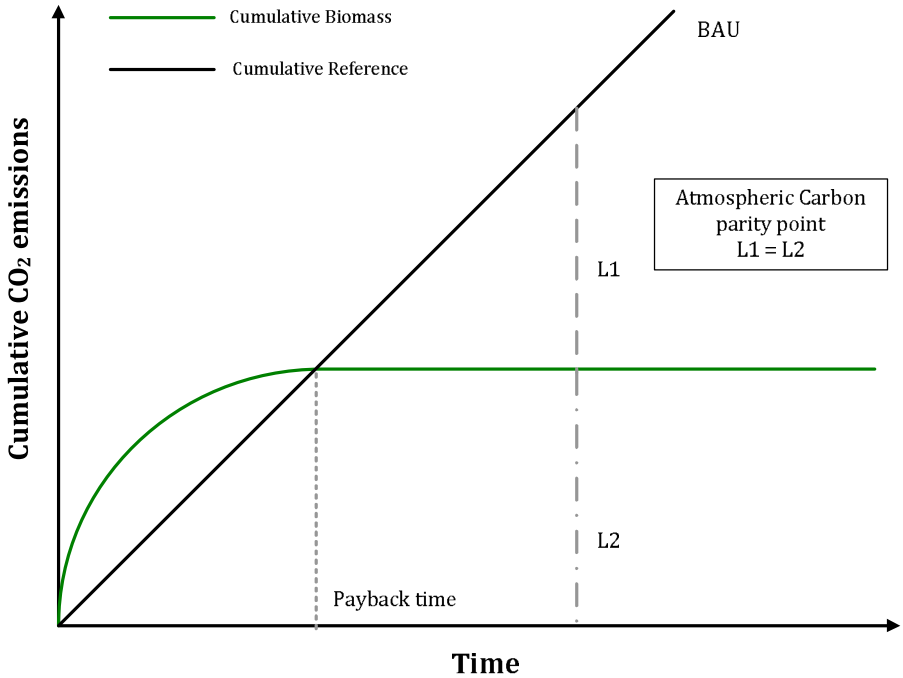
At the payback time the initial increase in CO_2 emissions above the fossil alternative is compensated in absolute terms, in that exact moment, the fossil and the bioenergy system have emitted the same amount of CO_2 in the atmosphere. The figure below illustrates the concept: the green line represents the forest carbon stock change (bioenergy CO_2 emissions), the black line the fossil system emissions, the difference between the green and the black line till the payback time (when the fossil fuel parity is reached), represents the carbon-debt.

The atmospheric carbon parity point (net zero carbon emissions to the atmosphere by balancing the amount of carbon released with an equivalent amount sequestered or offset), would not be reached until the additional emissions are saved by substituting fossil fuels combustion (when L1 equals L2).

It needs to be noted that atmospheric carbon parity point does not necessarily mean climate neutrality since GHG emissions happen at the beginning of the process while savings at the end and their effect on climate are different.

[37] For a more complete discussion of the C balance of forest bioenergy and respective climate impacts see JRC (2013).

Figure 7: Example of visual description of payback time and carbon neutrality



Source: JRC-IE (2012)

The results of most of the studies that have calculated the payback time of biomass use for bioenergy are reported in Annex 4 and summarized in the following table.

Table 12: Forest Bioenergy GHG Payback Time

Biomass source	Global warming mitigation efficiency					
	Short term (10 years)		Medium term (50 years)		Long term (centuries)	
	coal	natural gas	coal	natural gas	coal	natural gas
Temperate roundwood	---	---	+/-	-	+	+
Boreal roundwood	---	---	-	- -	+	+
Harvest residues	+/-	+/-	+	+	++	++
New short rotation plantation on marginal agricultural land	+++	+++	+++	+++	+++	+++
Forest clear cut + short rotation plantation	-	-	++	++	+++	+++

Source: compilation by JRC-IE

+/-: the GHG emissions of bioenergy and fossil are comparable; which is lower depends on specific pathways

-; --; ---: the bioenergy system emits more CO_2eq than the reference fossil system

+; ++; +++-: the bioenergy system emits less CO_2eq than the reference fossil system

Several factors contribute to positive or negative results regarding GHG emissions of the forest bioenergy system compared to the fossil reference:

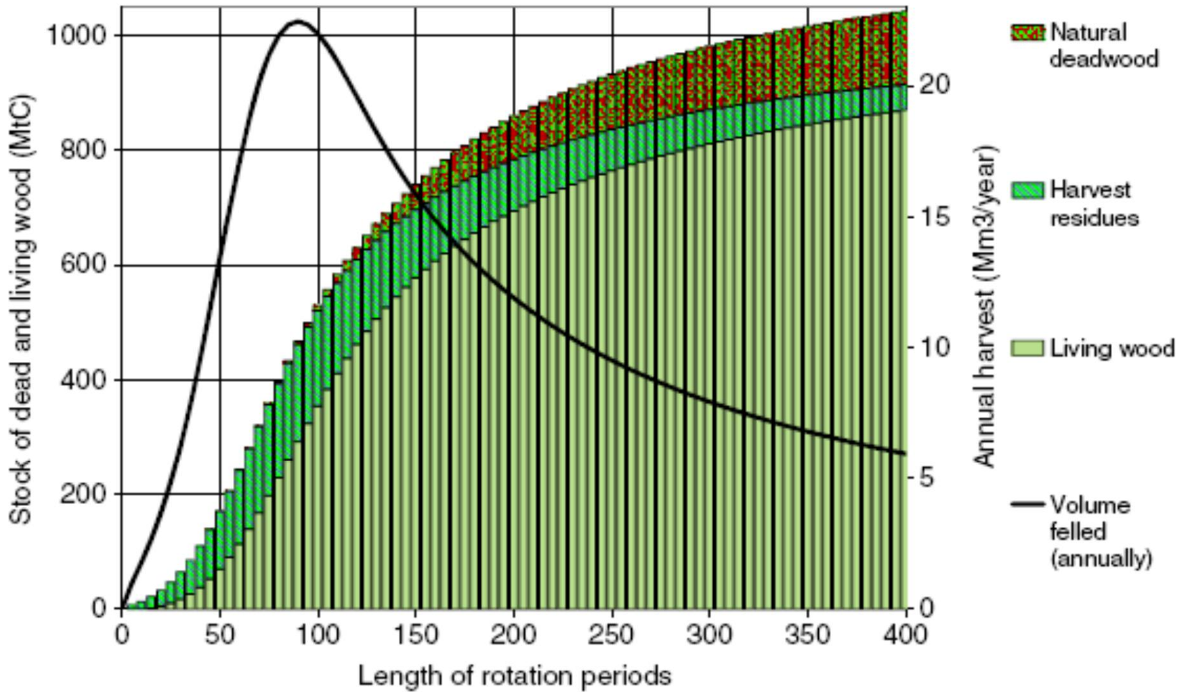
1) The **additional** harvest required to cover the supplementary demand of biomass for bioenergy will cause a decrease of carbon stock in the forest carbon pool (or a missing increase), which means a shift from a carbon stored in biomass to CO_2 in the atmosphere, as well as younger, smaller trees in the forest.
2) When burnt, biomass typically releases more direct CO_2 than fossil fuels per unit of energy due to the lower energy density. The direct emission intensity of forest bioenergy is in the range of 95-105 g CO_2/MJ, for hard coal it is 90-100 g CO_2/MJ, for lignite 100-115 g CO_2/MJ, for fuel oil 75 - 80 g CO_2/MJ, and for natural gas approx. 55-60 g CO_2/MJ[38] (note that these figures exclude life-cycle GHG emissions).
3) When additionally removed wood is combusted, the carbon is released instantaneously rather than after a long time, as for carbon stored in long living wood based products, or within the forest biomass which declines only slowly.

1) Additional harvest

Figure 8 shows the growth curve of a managed forest and the annual harvest associated. Although the data can be controversial - different input data can be used, e.g. the growth curve of a tropical or temperate forest, different ratios of residues and decay - the trend is reasonable. In managed forests, a site specific rotation length for harvesting is applied. Hence, harvesting at regular intervals guarantees an average constant carbon stock in the stand and in the forest.

[38] See the presentation of A.K. Boulamanti at the 3rd Workshop: http://www.iinas.org/Work/Projects/REDEX/redex.html

Figure 8: Total Carbon Stock for an Entire Forest Depending on the Length of Harvesting Rotation Periods



Source: Holtsmark 2012; annual volume of timber felled (black curve) and quantity of carbon stored in dead and living wood (columns) at different steady states for harvesting rotation cycles of different lengths.

Clearly there is a rotation time that maximizes the productivity, (in this case at 90 years) as well as a rotation time that maximizes the carbon stock (≥ 200 years).

Considering all the parcels in a forest, it is possible to calculate the effect of the choice of the rotation time (or harvested area) on the amount of carbon stored in the forest pools of carbon (living wood, harvest residues and dead wood) and the amount of wood to be felled annually to keep constant the rotation time. (100 hectares with a rotation time of 100 year, a hectare per year has to be harvested, with a rotation time of 50 years, two hectares per year are harvested).

Increasing or decreasing the amount of wood harvested (or changing the rotation time) results in a translation along the X axis with a change in the carbon stock in the different pools.

2) Lower efficiency

As already mentioned, different forests systems, different downstream processing and different reference systems give different carbon debt payback times.

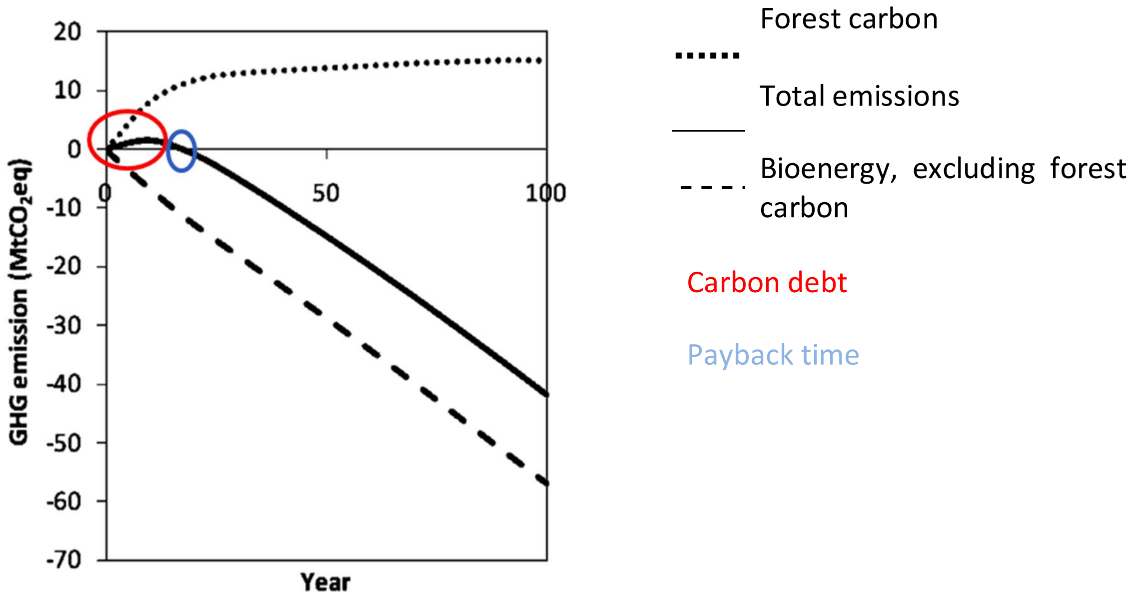
Efficient substitution replaces fossil fuels with high carbon content for heat production (e.g. coal or oil for heat) while replacing fossil fuels with high efficiencies and low carbon content (e.g. natural gas combined cycles) results in much longer payback times.

Similarly, biomass used as feedstock for second generation liquid biofuels will imply longer payback times due to the low carbon intensity of the fossil alternatives (gasoline and diesel which is about 88 g $C0_2$/MJ for both fuels), and also due to the high energy requirements of the processes involved to produce lignocellulosic biofuels.

3) Instantaneous release

If the harvested wood is combusted to produce energy, then the carbon content of the wood is released in a pulse, in the year of harvest, as CO_2. If the energy content of the biomass is used to replace fossil fuel, the emissions avoided by substitution contribute to the reduction of GHG emissions, but only on the long run the amount of fossil fuel replaced by substitution becomes higher than the amount of CO_2 emitted by bioenergy. Therefore, an adequate timeframe is needed to consider forest cycles.

Table 13: GHG emission quantification example for forest Residues



Source: McKechnie et al. (2011)

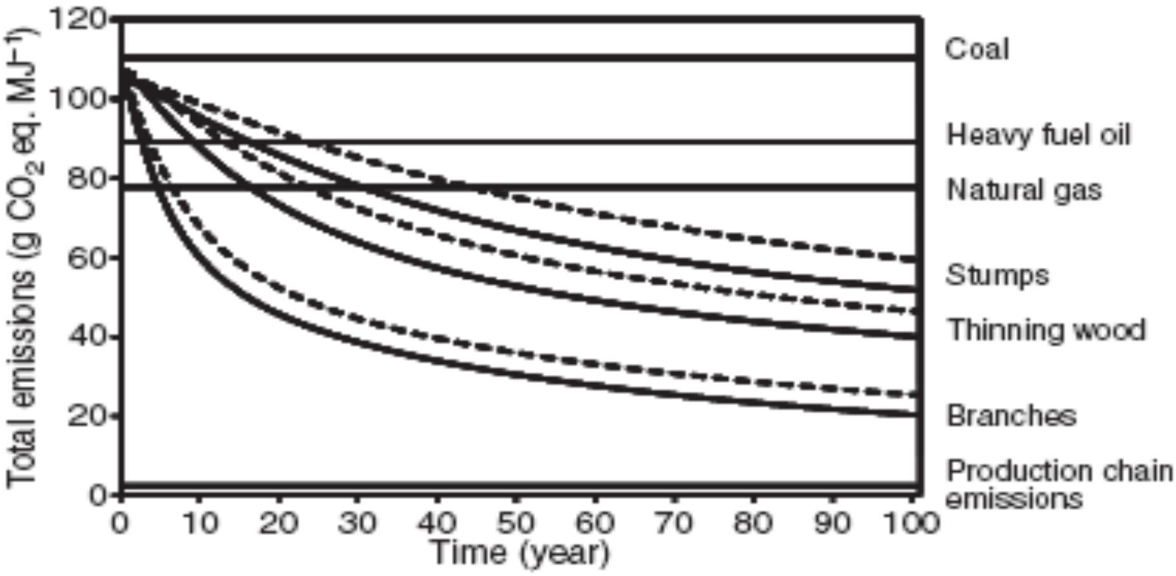
6.2 Residues

Harvest residues, when burned, will indeed release the same amount of CO_2 that had been previously stored from the atmosphere, but they will release it all and at once, in an impulse. If the residues had been left on the forest ground, the microbial decomposition, essentially fungal, and consequent CO_2 release would have still taken place but not to total conversion of the biomass to emissions and in a matter of years or decades, depending on the local climate conditions, the size of the harvested residues and the intensity of residues removal (Zanchi et al. 2010; Repo et al. 2012). Increased removal of residues could likely cause a decrease in soil carbon stocks compared to the reference case when residues are left on the site and this factor is to be accounted as well.

Trømborg et al. (2011) proposed to assume a constant decay rate so the equivalent annual rates amount 1.5-3 % for wood and 14-25 % for foliage and roots. With regard to that, the studies reviewed demonstrated that concerning only the carbon stored in the residues, after 20 years about half of the residues would still remain not decomposed, therefore burning them would actually mean reducing a carbon pool (Zanchi et al. 2010). In a policy timeframe of 100 years, the actual GHG emissions of the system should take this effect into account.

As mentioned before, one of the most important factors when comparing biomass left on ground for decomposition against its utilization as energy source is the biomass size. Figure 9 shows the results of Repo et al. (2012) in the case of energy generated from *Norway spruce* stumps (diameter 30 cm), young stand delimped thinning wood (diameter 10 cm) and branches (diameter 2 cm) over a 100 years period after the start of the practice in Northern Finland (dotted line – lower temperature and precipitation) and Southern Finland (solid line – higher temperature and precipitation).

Figure 9: Total GHG Emission per Energy Content from the Production of Energy from Harvest Residues



Source: Repo et al. 2012; Norway spruce stumps (diameter 30 cm), young stand delimped thinning wood (diameter 10 cm) and branches (diameter 2 cm). Emissions over a 100 year period after start of the practice in Northern Finland (dotted line) and Southern Finland (solid line) and the entire fuel cycle emissions of some fossil fuels. The total emission estimates of forest bioenergy include emissions resulting from the changes in carbon stocks and the emissions from production chain including collecting, transporting, chipping and combusting the forest residues.

It is well-known that most carbon in forest ecosystems is kept on soils, except for tropical forests (Trømborg et al. 2011). Figure 10 shows carbon stocks in various forest pools over time. The extraction of residues beyond a certain amount according to local conditions would result in the alteration of the soil fertility and affect the overall forest carbon balance negatively.

Recent studies suggest that harvest residue removal or forest floor disturbance could imply changes of long-term C or N storage, or both (Laiho et al. 2003; Chen, Xu 2005; Powers et al. 2005; Jones et al. 2008; Smaill, Clinton, Greenfield 2008; Jones et al. 2011; Thiffault et al. 2011; Strömgren, Egnell, Olsson 2012; Ågren, Hyvönen 2003). Still, these impacts might be offset by appropriate fertilization, taking into account respective risks, and GHG emissions.

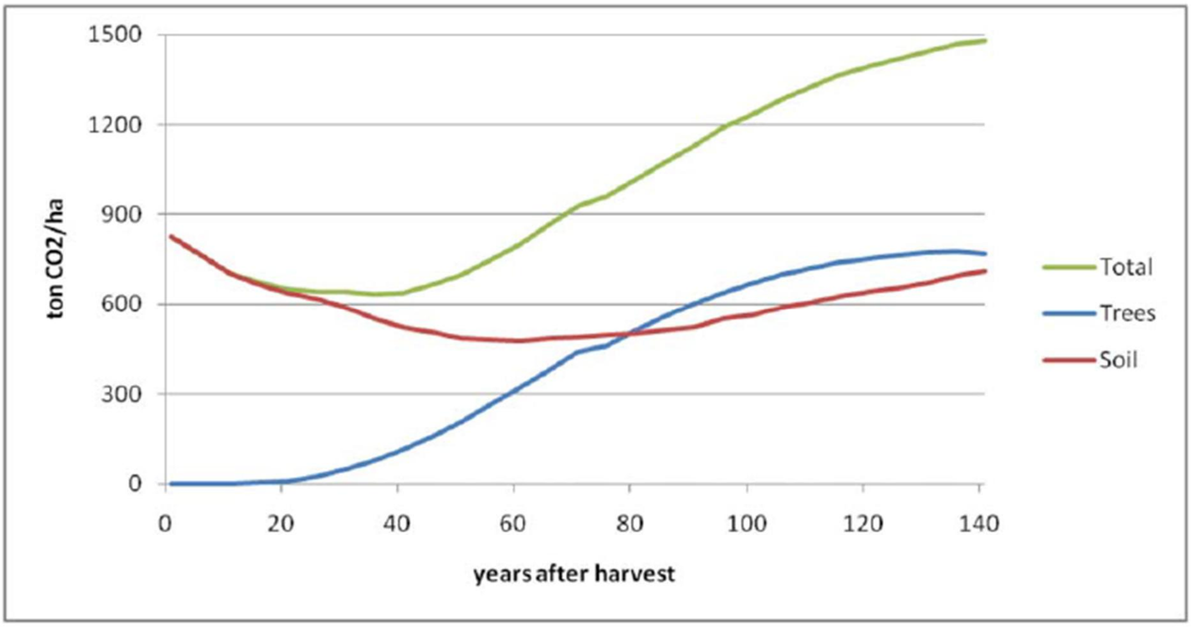
Johnson, Curtis (2001) carried out a meta-analysis of literature covering forest management effects on soil carbon and nitrogen storage, concluding that forest harvesting, on average, had no overall effect on C storage in soils, but effects of harvesting method with sawlog harvesting causing increases in soil C and N, and WTH causing decreases.

However, a meta-analysis conducted by Nave et al. (2010) found that forest harvesting (encompassing intensities and residue management practices) resulted in a significant 8% decrease in total soil C on average in temperate forest soils although numerous sources of variation were listed, including species composition and soil taxonomic order.

Jones et al. (2011) demonstrated that carbon and nitrogen storage in the forest floor would be reduced through to mid-rotation and possibly beyond, by harvest residue removal, independently of the intensity of the removal management.

Furthermore, harvest residue manipulation may have implications for the productivity of the new trees that will grow. Full recovery of the forest floor pool in C and N stocks following complete forest floor removal would have occurred in about 20 years (Jones et al. 2011). This time for total recovery can vary depending on the climate and microclimate, the mineral soil texture and the organic content in carbon, nitrogen, phosphorus and other nutrients and the auto-ecology of regenerating species.

Figure 10: Development of biomass in a typical Norwegian Norway spruce stand



Source: Trømborg et al. (2011); data for harvest after previous stand at age 90

6.3 Other Impacts on Global Warming

Effects of albedo (changes in surface reflectivity), evaporation/transpiration, and surface roughness play a relevant role in the regulation of energy fluxes and the water cycle, affecting climate across various temporal and spatial scales. (Bright, Cherubini et al. ; Betts 2000).

For instance, in tropical regions afforestation may be beneficial in reducing global warming since it can lead to cloud formations resulting in global cooling. In boreal regions, however, low surface albedo exerts a positive climatic forcing that "may exceed the negative forcing from sequestration" (Thompson et al. 2009).

Several experts suggest that current "carbon-only" approaches, which ignore the albedo effect, are “incomplete” as GHG units do not reflect the entire picture (Schaeffer, Eickhout et al. 2006; Betts, Falloon et al. 2007; Schwaiger and Bird 2010). Black carbon emissions from incomplete combustion have a relevant impact in terms of global warming as well (Ramanathan and Carmichael 2008).

Although there is evidence on the relevance of both the albedo effect and carbon black impacts, there is not yet a consensus on the methodology that might be used for the estimation of these impacts on the GHG performances for bioenergy and, in any case, the results would depend on the specific biomass, the technology used, and geographic area.

6.4 Reference System

The assumptions on the reference system are as relevant as the assumptions on the bioenergy system. The choice of the emissions per functional unit to which the bioenergy emissions are compared to is fundamental for calculating GHG savings, and also the payback time. The most important choice is between the renewable or fossil *marginal* reference system (coal, natural gas, gasoline or diesel), or the *average* per MJ (heat, electricity or fuel).

Furthermore, the timeframe of the comparison plays a relevant role. If the timeframe chosen is short, the emissions from the current reference systems can be considered adequate, but in case the timeframe is long, also the changes in the reference systems have to be accounted for. For examples, practically in all of the studies the reference system (coal or natural gas) is kept constant for the whole duration of the analysis, while, according to EU policies, the EU energy system should be decarbonized by 2050.

Obviously, what would happen to the forest has also to be accounted for in the reference system. The choice of a reference point analysis, such as in the BAF (Biogenic Accounting Factor) proposed by EPA (2011), does not fully allow to make a proper comparison of fossil and renewable systems because basically it loses all information on what would happen to the forest system without additional harvest.

6.5 Other Approaches

Particularly interesting is the approach used in the UNFCCC Clean Development Mechanism (CDM). In this case the assessment is performed at project level, therefore all the specific characteristic of the biomass used are accounted for. The UNFCCC defines a project eligible for the CDM if the biomass used is renewable (UNFCCC). For forest biomass the definition of renewable biomass implies that the biomass is originating from land areas that remain forest and sustainable management practices are undertaken to ensure, in particular, that the level of carbon stocks on these land areas does not systematically decrease over time (carbon stocks may temporarily decrease due to harvesting).

Concerning residues, for the UNFCCC, they are renewable biomass if the use of that biomass residue in the project activity does not involve a decrease of carbon pools, in particular dead wood, litter or soil organic carbon, on the land areas where the biomass residues are originating from. Specifically they mention that where a CDM project involves the collection of dead wood from a forest, which would not be collected in the absence of the CDM, the extracted biomass cannot be regarded as renewable, since it would result in a decrease of carbon stocks.

EPA (2011) included biogenic CO_2 emissions from stationary sources in the US Clean Air Act permitting requirement. In response to a petition from forest owners, the permitting requirements for biogenic CO_2 were deferred for three years in July 2011. Meanwhile, a methodological framework for accounting biogenic CO_2 emissions from stationary sources has been proposed and is under evaluation. In this methodology, EPA introduces the BAF (Biogenic Accounting Factor) which can be applied as an adjustment to stationary source emission estimates in order to reflect the connection with the land. The value for BAF typically falls between 0 and 1, with the possibility of being negative in certain circumstances. A value of 0 would mean that the biogenic CO_2 emissions are balanced by offsite factors related to the carbon cycle, such as feedstock growth (e.g. an annual crop with no land-use or land management change emissions). A value of 1 would mean that 100 percent of the biogenic CO_2 emissions are contributed to the atmosphere; in other words, the offsite factors related to the carbon cycle did not offset any of the direct biogenic CO_2 emissions from the stationary source. An intermediate value between 0 and 1, such as 0.2 or 0.5, would mean that only a portion of the biogenic CO_2 emissions could be adjusted at the stationary source; in this case, the offsite factors related to the carbon cycle offset 80 percent or 50 percent of the biogenic CO_2 emissions at the stationary source.

The method basically is a carbon balance. The biogenic CO_2 emission is accounted for and compared to the carbon removed by the atmosphere by the feedstock growth. Indirect land use change and leakage are included but there is not a specific methodology for the quantification. Leakage occurs when feedstock demand alters the amount of feedstock-related commodities entering markets for other uses, thus influencing market prices and inducing production alterations elsewhere offsite, including possible land-use change and related emissions/sequestration. The assessment is performed at regional scale and on annual or annualized basis. The reference system is the current reference point.

Another approach is to consider a forest landscape (e g 100 sites, at the ages 0-100 years. Every year one site is clear felled, and thereafter replanted. The baseline is forestry (BAU) without extraction of e.g. felling residues and stumps. Then

1. How much is the long term carbon reduction in the ecosystem at landscape level, when stumps and felling residues are harvested, compared to BAU forestry?
2. How much more biomass is harvested with stumps and felling residues, compared to BAU forestry?

The relation between 2) and 1) give an idea of the “carbon neutrality” of the harvested biomass fuel. For a proper comparison, not only C stocks, harvests and degradation rates should be considered, but also effects on forest production should be included, as well as appropriate countermeasures.

6.6 Climate Change Mitigation Policies

There is a unanimous agreement, both in the scientific community and the policy makers, that the next few decades are fundamental to keep the global average temperature increase due to GHG emissions below 2° C to prevent dangerous anthropogenic interference with the climate system. In this perspective, GHG reduction goals are set to be reached in the short term. In forestry terms, the timeframes of Kyoto and the RED are rather short. A scenario analysis of the short term effectiveness of forestry policies (UNECE, FAO 2011) analysed the effects of the implementation of two policy scenarios, one aiming at maximizing the carbon sequestration by forests and products and the other promoting bioenergy for fossil fuel substitution is reported. The first scenario results in an increase of carbon sequestration and substitution of 50 Tg C/y compared to the reference system. Promoting the use of wood for bioenergy would result in an increase of carbon uptake and substitution of 20 Tg C/y.

Table 14: Carbon Stocks and Flows in the EFSOS Scenarios (total Europe)

		Unit	Reference		Maximising biomass carbon	Promoting wood energy
			2010	2030	2030	2030
Carbon stocks	Forest biomass	Tg C	11 508	13 214	14 130	13 100
	Forest soil	Tg C	14 892	15 238	15 319	14 994
Carbon flows	Change in forest biomass	Tg C/yr		85.3	131.1	79.6
	Change in forest soil	Tg C/yr		17.3	21.4	5.1
	Net change in HWP	Tg C/yr		18.2	18.2	17.6
Substitution effects	For non-renewable products	Tg C/yr	NA	NA	NA	NA
	For energy	Tg C/yr	61.6	83.0	83.0	121.7
Totals	Stock (forest only)	Tg C	26 400	28 452	29 449	28 093
	Flow (sequestration + substitution)	Tg C/yr		203.7	253.6	224.0

Source: UNECE, FAO (2011)

In the same document it is recommended that in order to maximize the forest sector's contribution to climate change mitigation, the best strategy would be to combine forest management focused on carbon accumulation in the forest with a steady flow of wood for products and energy. The strategy suggested by UNECE-FAO, the so-called cascading use of wood, gives priority to leaving the wood in the forest, then use it for materials and finally for energy purposes. They also conclude that if wood is to play its part in reaching the targets for renewable energy consumption (promoting wood energy scenario), there would have to be a strong mobilisation of all types of wood. Supply would have to increase by nearly 50% in the next twenty years. However the mobilisation of such high volumes would have significant environmental, financial and institutional costs.

To increase European wood supply from outside the existing forest sector, it would be necessary to establish short rotation coppice on agricultural land. This could significantly reduce the pressure on the existing European forest and help to increase the share of renewables in energy supply, but at the cost of trade-offs with other land uses and, depending on site selection processes, landscape and biodiversity.

It will require a very high level of sophisticated cross-sectoral policy making, sharply focused policy instruments and strong political will to mobilise enough wood for energy, to implement the right balance between carbon sequestration and substitution and to conserve biodiversity without sacrificing wood supply. A proper accounting of carbon emissions from bioenergy would be only the first, but essential, step towards such complex policy framework.

7 Summary of the Proposed Criteria and Indicators

The proposed criteria and indicators for sustainable biomass provisions from forests are shown in the following table.

Table 15: Summary of Criteria and Indicators proposed for Bioenergy from Forest Residues

Criterion	Indicators
C1.Protecting Biodiversity	Biomass should not be harvested in **High Conservation Value Forests**, except if biomass harvest is performed in order to control invasive species, enhance the biological value of habitats, or reduce natural hazards risks (wildfire, pest attacks etc...) which are not part of natural forest life-cycles.
	Primary forest (old-growth forest or tropical primary forest) should be excluded unless evidence is provided that biomass harvest does not interfere with nature protection purposes.
	Bioenergy from forests residues may be sourced from **forests with high risk of hazards or from salvage logging**, taking into account all other indicators.
	At least 100 m of riparian ecosystems from the watercourse is established to protect freshwater resources. A thinner buffer could be established if evidence is provided that other indicators are maintained or enhanced.
	An adequate amount of residues is evenly left on the ground to protect biodiversity. If no more adequate thresholds are available at biome or landscape level a general recommendation is that residue harvesting not exceed 1/3 of total available harvest residues. More intensive harvesting could be performed if evidence is provided that other indicators are maintained or enhanced.
	Residual harvesting should be performed in a way that does not allow the occurrence of **pioneering species**.
	In case that retention forestry is performed in previous activities**, live cavity trees, den trees, other live decaying trees, and** snags left should be respected. When the retention of biological legacies is not considered in previous activities and in the absence of a more specific threshold at biome or landscape level, at least 30 snags/ha should be kept. Larger amount of snags, live cavity trees, den trees etc. could be harvested if evidence is provided that biodiversity is maintained or enhanced.
C2.Sustainable Forest Management	**FMP** or equivalent tool exists and is in practice.
	Woody bioenergy feedstocks are supplied in accordance with **EU Timber Regulation** (EU No 995/2010).
	Residues removal is allowed in areas without **nutrient depletion risks** (green areas) or with risks that could be prevented (yellow areas) according to **soil nutrient risk maps developed at stand level**.
	Fertilization, including wood ash recycling is allowed in order to prevent nutrient depletion. Wood ash recycling must ensure that no heavy metal loads (above current levels in forest soils) occur. Its application should be in accordance with regional guidelines or with general recommendations set up at biome or landscape level.

Criterion	Indicators
	Stumps and roots are left in the forest, only selected extraction without negative erosion and nutrient depletion impacts.
	No harvesting in area having **steep slope** (>35 degree). If harvest is performed in higher slopes areas evidence should be provided that the thresholds defined for other indicators are maintained.
	Residue removal is allowed from soils with low (green areas) to medium (yellow areas) **disturbance risk** according to the **soil disturbance maps developed for this purpose at stand level.**
Net GHG Reduction	GHG reduction requirements have to take into account **all carbon stock changes in the forest** (live biomass, litter, soil) as well as emissions along the production chain (harvesting, processing and transport). As for the LUC emissions, the carbon stock changes in the forest have to be annualized in a **20 year time frame**. Indirect impacts (market mediated) have to be internalised in the GHG accounting with the introduction of correction factors (such as iLUC, iWUC, iFUC). The GHG **savings** compared to fossil energy systems should be, at least, **60 %.**

Source: own compilation. iLUC: indirect Land Use Change; iWUC: indirect Wood Use Change; iFUC: indirect Fuel Use Change

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Annex 1. Swedish bioenergy production in different scenarios of biomass harvesting and the potential consequences

The following tables (de Jong et al. 2012) show the Swedish bioenergy production (TWh) in different scenarios of biomass harvesting and the potential consequences of reaching Swedish environmental targets and its reduction goal. These results are based on long-term (15-30 years) empirical research on the different environmental aspects, in nearly all kinds of representative managed forests. Some considerations are that wood-ash is recycled where needed and there is the recommended level of “nature consideration” in the forest.

Arrows indicate if the probability to reach the goal increases (↑), decreases (↓), or is unaffected (→). In some cases harvesting might have some positive (↗) or some negative (↘) impact. Grot = Branches and tops. The alternative with most energy output and least negative impact is indicated with yellow.

a) Energy output

	Extraction, proportion (%)				Total proportion of extraction from the landscape		Energy output (TWh)	
	Stand level		Landscape level					
	Grot	Stump	Grot	Stump	Grot	Stump	Final cutting	Final cutting + thinning
Stump and grot	80	80	80	40	64	32	38,7	51,5
	60	80	40	40	24	32	24,3	29,1
	80	80	80	20	64	16	30,9	43,7
	60	80	40	20	24	16	16,5	21,3
	80	40	80	40	64	16	30,9	43,7
	60	40	40	40	24	16	16,5	21,3
	80	80	80	10	64	8	27,0	39,8
	60	80	60	10	36	8	16,9	24,1
	60	80	40	10	24	8	12,6	17,4
	80	40	80	20	64	8	27,0	39,8
	60	40	40	20	24	8	12,6	17,4
	80	40	80	10	64	4	25,0	37,8
	60	40	40	10	24	4	10,6	15,4
Grot only	80	0	60	0	48	0	17,3	26,9
	80	0	40	0	32	0	11,6	18,0
	60	0	80	0	48	0	17,3	26,9
	60	0	60	0	36	0	13,0	20,2
	60	0	40	0	24	0	8,7	13,5
Present output	60	40	40	2	24	0,8	9,0	13,8

b) Environmental targets

	Extraction, proportion (%)				Sustainable forests	Acidification	Eutrophication	Non-toxic	Climate	
	Stand level		Landscape level							
	Grot	Stump	Grot	Stump					Short term	Long term
Stump and grot	80	80	80	40	↓	↘	→	↘	↗	↗
	60	80	40	40	↓	→	→	↘	↗	↗
	80	80	80	20	↘	↘	→	↘	↗	↗
	60	80	40	20	↘	→	→	↘	↗	↗
	80	40	80	40	↘	↘	→	↘	↑	↑
	60	40	40	40	↘	→	→	↘	↑	↑
	80	80	80	10	↘	↘	→	→	↑	↑
	60	80	60	10	→	→	→	→	↑	↑
	60	80	40	10	→	→	→	→	↑	↑
	80	40	80	20	↘	↘	→	→	↑	↑
	60	40	40	20	→	→	→	→	↑	↑
	80	40	80	10	↘	↘	→	→	↑	↑
	60	40	40	10	→	→	→	→	↑	↑
grot only	80	0	60	0	→	↘	→	→	↑	↑
	80	0	40	0	→	→	→	→	↑	↑
	60	0	80	0	↘	↘	→	→	↑	↑
	60	0	60	0	→	→	→	→	↑	↑
	60	0	40	0	→	→	→	→	↑	↑
Present output	60	40	40	2						

c) Production goal

	Extraction, proportion (%)				Total proportion of extraction from the landscape		Forest production	
	Stand level		Landscape level					
	Grot	Stump	Grot	Stump	Grot	Stump	Final cutting	Final cutting + thinning
Stump and grot	80	80	80	40	64	32	→	↘
	60	80	40	40	24	32	→	→
	80	80	80	20	64	16	→	↘
	60	80	40	20	24	16	→	→
	80	40	80	40	64	16	→	↘
	60	40	40	40	24	16	→	→
	80	80	80	10	64	8	→	↘
	60	80	60	10	36	8	→	→
	60	80	40	10	24	8	→	→
	80	40	80	20	64	8	→	↘
	60	40	40	20	24	8	→	→
	80	40	80	10	64	4	→	↘
	60	40	40	10	24	4	→	→
grot only	80	0	60	0	48	0	→	↘
	80	0	40	0	32	0	→	→
	60	0	80	0	48	0	→	↘
	60	0	60	0	36	0	→	→
	60	0	40	0	24	0	→	→
Present output	60	40	40	2	24	0,8	9,0	13,8

Annex 2: Overview of sustainability topics

Stupak et al (2007) synthesized the main topics covered by various publications related to the utilisation of forest biomass for energy and wood ash recycling, as follows:

Topic[a]	AT	DK			FI		LT	SE				UK		International			
	[3]	[4,5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
Policy framework, international conventions	1			1		1	1	1					1	1	1		1
Policy, institutional framework, legislation and subsidies								1						1			1
Social issues, regional development, employment, gender														1			1
Public participation													1				
Available resources, present utilisation	1			1	1	1								1	1		1
Concepts for SFM, certification, criteria and indicators														1			1
Carbon balance											1			1			
Nutrients, organic matter, soil fertility, acidification, erosion	1	1	1	1	1	1	1	1	1	1	1	1	1[b]	1	1	1	1
Effects on wood production		1			1			1		1	1			1			
Biodiversity and wildlife	1				1	1		1	1	1	1	1	1[b]	1		1	1
Insect pests		1	1		1	1		1	1	1							1
Hydrology, water quality, streams, and lakes	1					1		1		1		1		1		1	
Landscape, archaeology, culture, and leisure					1	1				1		1					
Nature conservation, sites of conservation importance													1[c]				
Silviculture[d]		1	1		1	1						1	1	1			1
Stump harvesting		1				1		1						1			1
Production costs and economy			1			1							1	1			
Harvesting methods, harvesting technology[e]			1	1	1	1	1	1	1	1	1	1		1	1	1	
Processing, handling, storage			1	1	1	1						1	1	1	1		
Logistics, transport														1	1		
Fuel quality, characteristics, standardisation			1	1										1	1		1
Working environment, health, and safety				1		1							1	1			
Markets, sales, competitiveness			1	1										1			1
Establishing of energy plant													1		1		
Wood firing, combustion, gasification, plant operation				1									1		1		
Energy distribution													1				
Plant emissions, waste production, noise, dust, smell, etc.				1									1	1	1		
Wood ash recycling					1		1	1	1	1	1			1		1	1

a. AT: Austria; DK: Denmark; FI: Finland; LT: Lithuania; SE: Sweden; UK: United Kingdom.
b. For these matters, reference is made to the UK forestry standard and associated guidelines.
c. Recommends consultancy with forest authorities and (if in or near designated nature conservation sites) statutory conservation agencies.
d. Selection of stand in relation to environmental constraints, integration into traditional forest management.
e. Sometimes including damage to the remaining stand, and soil physical damage

Overview of recommendations, guidelines, information materials, and synthesis publications related to the utilisation of forest biomass for energy and wood ash recycling

Country[a]	Reference	Publication year	Responsible and type of publication	Type of publication	Comment on contents
AT	[3]	2005	Interdisciplinary project working group—Land Innovation	Background report	Literature review with emphasis on environmental consequences for the forest and research needs
DK	[4,5]	1985	The Forest Agency	Background report and official recommendations	Official national recommendations and literature review with emphasis on environmental consequences of forest fuel extraction in clear cuts and thinnings for the forest
	[6]	1996	Main actors in Danish forestry[b]	Handbook	Brief information with emphasis on production, handling, storage, and sales
	[7]	2002	Danish Energy Agency, Centre for Biomass Technology	General information	Report with equal emphasis on forestry and energy-related issues (small boilers, district heating plants, CPH, and power plants)
FI	[8]	2001	The Finnish Forestry Research Institute	General information and recommendations	Book with information and recommendations. Special emphasis on silvicultural and environmental consequences of forest fuel harvesting
	[9]	2005	Expert group and Forestry Development Centre Tapio	Recommendations	Brief and practical guidelines including a wide range of topics related to forest fuel extraction in clear cuts and thinnings
LT	[10]	2005	Ministry of Environment, Republic of Lithuania	National recommendations	Background review and practical guidelines for wood ash recycling in Lithuanian forests, including selection of sites, recycling dosage, and environmental consequences
SE	[11]	2001	National Board of Forestry	General information and recommendations	Book with information and recommendations. Special emphasis on environmental consequences and wood ash recycling
	[12]	2002	National Board of Forestry[c]	Official national recommendations	Report with official national recommendations. Special emphasis on environmental consequences and wood ash recycling
	[13]	1998	National Board of Forestry	Scientific background report	Comprehensive review of scientific literature with emphasis on environmental consequences and wood ash recycling
	[14]	2006	Swedish Energy Agency	Scientific synthesis report	Comprehensive review of scientific literature with emphasis on environmental consequences and wood ash recycling
UK	[15]	1997	Forestry Commission	Official recommendations	Related to WTH in final fellings and especially environmentally acceptable selection of sites in relation to different harvesting technology
	[16]	1999	Main actors with interests in wood energy use in the UK[d]	Good practice guidelines	Focus especially on establishment of energy production units, but with reference to many relevant subjects related to forest fuel extraction in the forest
International	[17]	2002	IEA Bioenergy Task 31	Scientific book	Comprehensive review of economic, environmental and social aspects in the production of forest fuel and wood ash recycling
	[18]	2006	BASREC Bioenergy Working Group 2003–2005 under the Nordic Council of Ministers	Manual	Manual for developing bioenergy entrepreneurships with equal emphasis on forest fuel and energy production including emissions
	[19]	2006	The RecAsh project, EU-LIFE	Handbook	Practical information on all aspects of wood ash recycling
	[20]	2007	The WOOD-EN-MAN project, EU-FP5	Scientific book	Review of economic and environmental aspects, also including policy and recommendations

a. AT: Austria; DK: Denmark; FI: Finland; LT: Lithuania; SE: Sweden; UK: United Kingdom.
b. Danish Forest and Nature Agency, Forest & Landscape Denmark, The Danish Forest Association, Danish Forestry Extension, and DDH.
c. These recommendations in Swedish were available from 2001.
d. British Biogen (now Renewable Energy Association), The Forestry Commission, Forestry Contracting Association, Wildlife and Countryside Link, the
e. Energy Technology Support Unit (ETSU), and other stakeholders.

Annex 3. Salvage Logging for Bioenergy?

A-3.1 Large-scale Natural Disturbance of Forest Ecosystems

Natural disturbances both biotic (insect attacks and diseases) and abiotic (meteorological, climatological, hydrological, geophysical or anthropogenic disturbances such wildfires) play a key role in the maintenance of ecosystem processes and biodiversity; they create structural complexity and landscape heterogeneity. Organisms are adapted to these disturbance regimes and therefore ecosystems are able to recover from the damages. Due to climate change those disturbances are likely to increase in intensity, quantity and frequency.

Although it is common to characterize forest types by particular disturbance regimes (Bengtsson et al. 2003), most forests are affected by various disturbances acting at different temporal and spatial scales. EFI (2010) categorized storm damage in European forests into three components:

- Primary damage: Initial mechanical damage to the trees caused by the storm
- Secondary damage: Subsequent damage following the initial wind storm. This is mostly from bark beetles, but can be from other biotic factors, fire, sun, snow/ice and even additional wind damage.
- Tertiary damage: Loss of production in shortened forest rotations and other long-term constraints on forest operations

Magnitude of Natural Disturbances

There are biotic and abiotic disturbances that tipically effect different forests ecosystems around the world. For more detailed information on abiotic disturbances see FAO (2011). An assesment on fire management is provided by FAO (2006).

Insect Pests and Diseases

FAO (2010) indicates that close to 40 million ha of forest per year were adversely affected by insect pests (34 Mha) and diseases (3.8 Mha) in 2005 which means less than 2 percent of the global forest area. The mountain pine beetle deserves a special consideration because of its unprecedented magnitude. It has devastated more than 11 Mha of forest in Canada and the western US since the late 1990s and is still spreading. In British Columbia, in 2012 the epidemic had killed an estimated 710 Mm^3 of commercially valuable pine timber (MFLNRO 2012).

Forest Fires

Fire is a major disturbance factor, a strategy used for some ecosystems which has both beneficial and detrimental effects. On average, 1 percent of all forests were significantly affected each year by forest fires and 90 percent are classified as wildfires. Hence, an average of 20 Mha of forests and an additional 18 Mha of other wooded land were affected by fire annually (FAO 2010b).

Other Disturbances

Disturbance by biotic factors includes damage by biotic agents other than insects or diseases, such as storms, wildlife browsing, bark stripping, grazing or other physical damage by animals. In Europe the most common disturbance is windthrow.

A-3.2 Salvage Logging

Salvage logging (post-disturbance logging or sanitary logging) is defined by the Society of American Foresters (Lindenmayer et al., 2008) as "**the removal of dead trees or trees damaged or dying because of injurious agents… to recover economic value that would otherwise be lost**" and it is a **common response** to natural forest disturbances which has been practiced for long time. The salvaged timber substitutes green (live) wood so markets can be disrupted.

Salvaged timber now represents **a significant percentage of the wood harvested** in many regions of the world (Lindenmayer et al., 2008). Specifically, Schelhaas et al. (2008) report an annual average of 35 million m3 timber in Europe over the period 1950-2000 with much variation between years and a rising trend of damage from at least from storms and fires.

Rationales for Salvage Logging

Through salvage logging is possible to get some of economic value in dead and damaged trees back. Additional justifications such safety concerns, the fuel reduction for subsequent fires, the prevention of pests and pathogens or its contribution to ecological recovery have been offered (Lindenmayer et al. 2008). Societal perceptions have also been noted as a driver (Schmiegelow et al. 2006).

In relation to recovery, it can focus on either managing the state of the system immediately after the disturbance or managing the ongoing process of recovery (Dale et al. 1998). According to Dale et al. (1998) the common goal of recovery management is to shorten the process of succession or to maintain the process of succession at one particular state that is considered desirable for human purposes.

A-3.2 Potential Impacts of Salvage Logging

Depending on the response variables measured salvage harvesting effects can be negative, neutral or positive. It is strongly correlated to the intensity and extent of logging. In fact, there are many potential negative impacts of salvage harvesting, in terms of loss of ecosystem benefits of disturbance, removal of biological legacies, impaired ecosystem recovery, and negative impacts of natural disturbance and the one created by salvage logging (MacDonald 2007), which depend on several features of stands, including severity of the disturbance.

As in the case of conventional logging, **the impacts of salvage logging vary in response to a wide range of factors**, including the ecosystem, ecological processes, and particular elements of the biota in question; the type, intensity, frequency, and spatial pattern of logging and the preceding natural disturbance; and the potential cumulative impacts of the type and intensity of a preceding natural disturbance coupled with logging pattern, intensity, and frequency. Generalizing from the limited research to date, the impacts of salvage logging can be classified into three broad categories:

Impacts on the physical structure of forest stands and biodiversity responses

Biological legacies or residuals play a key role in ecosystem recovery, influencing the rate and pathway of post-disturbance recovery. The effectiveness of some or all of their ecological roles can be diminished if they are removed. It may alter assemblages and communities, simplifying the structure of forest stands, homogenizing landscape pattern and reducing connectivity between unburned areas.

Scientific consensus on the impacts of salvage logging on biodiversity such biota associated with structural stand features and pathways of natural regeneration and recovery has not been reached due to variable factors influencing forest ecosystems.

Impacts on key ecosystem processes

Salvage logging often impairs key ecosystem processes such as hydrological regimes (e.g., soil erosion and consequent in-stream sedimentation), **soil** profile development, and **nutrient cycling** provided by dead woody debris. **Cavity-nesting birds, small mammals, and amphibians** may be affected by harvest of standing dead and live trees. Additional road building associated with salvage logging and **ground skidding** of logs increase both soil compaction and erosion and can be particularly harmful unless disturbances are mitigated (Peterson et al. 2009).

Cumulative Effects

Organisms are typically best adapted to the disturbance regimes under which they evolved. Nevertheless, **these and other species may be susceptible to novel forms and combinations of disturbances**. Another form of cumulative effect relates to post-disturbance recovery patterns. Both in southeastern Asia and North America, salvage logging of burned rainforests led to significant forest deterioration, with major negative impacts on the regenerative potential of stands and a wide range of other undesirable effects such as facilitating the colonization of invasive grassland plants.

Seed banks for many species may be activated following a wildfire but then exhausted if extensive mechanical harvesting follows soon after and/or if a second fire occurs, as is the case when regeneration burns are used to promote germination of commercial-crop trees after salvage logging of fire-damaged stands in the wet forests of Victoria, southeastern Australia.

A-3.3 Reducing the Ecological Impacts of Salvage Logging

The effects of salvage logging may be different from or additional to the effects of traditional forms of logging varying among disturbance and forest features. Nevertheless, salvage practices can be modified to retain potential positive effects or be modified to reduce negative effects.

Current Strategies for Salvage Logging in different areas

Canada

The “Mountain Pine Beetle Action Plan 2001” was released after a stakeholders consultation aiming at combating the disturbance. Harvesting dead pine to capture economic value and reforesting the dead stands, were included among the measures considered. Subsequently, based on the 2004 Action Plan Update a number of large timber harvesting licenses were offered, designed to encourage the manufacture of new forest products. The 2005 updated Action Plan included among its objectives the recovering of the greatest value from dead timber before it burns or decays, while respecting other forest values. The forest industry is focused on salvaging the dead pine – conserving unattacked timber for the futures - until it is no longer economic.

British Columbia announced its Bioenergy Strategy in 2008 in order to explore new markets for the excess of dead wood that can be recovered for lumber. From 2008 to 2010, wood pellet production increased from 0.95 to 1.2 Mt. On the other hand, the results of Niquidet et al (2012) indicate that in the context of feedstock derived from Mountain Pine Beetle impacted stands, average delivered feedstock costs can be expected to be more than double over the life of an electrical power generating facility.

Snetsinger (2005), chief forester of the British Columbia, conscious of the problem derived from the Mountain Pine Beetle, released the "Guidance on Landscape- and Stand-level Structural Retention in Large- Scale Mountain Pine Beetle Salvage Operations" that, even not legally binding, has been implemented by forest professionals (FPB 2009). He stated that there was sufficient evidence to suggest that the risk to non timber values decreases as the amount of retention increases at either the stand or landscape level (or in some cases both) so he suggested management guidance at:

- Landscape-level Planning. To plan out many years for both the retention and harvest areas is a key issue. The central concern is the placement of increased amounts of retention across management units, considering both stand-level retention (e.g., riparian areas and wildlife trees) and landscape-level retention (e.g., old growth, ungulate winter ranges, and wildlife habitat areas).
- Stand-level Retention. The retention will be spatially well-distributed within all harvested openings to provide vertical structure, a variety of wildlife habitats, and coarse woody debris over the long term considering both the timber and non-timber values.

Europe

Most countries in Europe affected by storm damage to forests respond in a similar manner. This includes providing subsidies for harvesting, transport and forest restoration, the short-term derogation of controls, and the production of guidelines on the best methods to re-establish or regenerate the storm affected forests which differs much from one country to another. To remove as much windthrown timber from the forest as soon as possible is recommended. The common European view on the regulation of forest regeneration includes the role of forest owners in regenerating stands either by natural regeneration or artificially by planting and seeding (EFI 2010).

Possible Ways Forward

Recommendations for rational salvage harvesting at stand and landscape-level have been suggested by different studies (Lindenmayer et al 2006; Bunnell et al. 2004 and 2011). Most of those focus on biological legacies and are summarized as follows:

1) Protect some areas and sensitive sites from salvage logging.
2) Conserve patches, even of affected species by a insects pest as the lodgepine in the case of mountain pine beetle, or harvest in a low-intensity within the perimeter of a disturbed area.
3) Retain certain biological legacies and leave slash.
4) Control minor vegetation sparingly.
5) Schedule salvage logging so that effects on natural recovery of vegetation are limited.

6) Ensure the future maintenance or creation of particular habitat elements for species of conservation concern
7) Ensure adequate riparian buffers
8) Plan both areas to be reserved from harvest and areas to be harvested as large blocks.
9) Plan harvest over larger areas quickly and deactivate roads when finished.

The current debate is commonly polarized between salvage logging versus no intervention, which are the extremes of a set of multiple possibilities (Castro et al. 2011). To consider a variety of treatment options, including salvage harvesting, to help reconcile and better balance competing societal needs ranging from economic benefits to ecological restoration (Castro et al. 2011). In addition, the need of more comprehensive studies of the impact of a full range of silvicultural options for salvage harvesting over longer time periods and in a variety of forest types has been expresed (MacDonald 2007)

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Annotated Literature on GHG Emission from Forests

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	REFERENCE SYSTEM	PAYBACK TIME (yr)
(McKechnie, Colombo et al. 2011)	Ontario	Temperate	Forest management unit	REF: BAU wood for products, BIO: - BAU + residues harvest, - additional harvest without residues	Electricity coal	Residues 16 Roundwood 38
(McKechnie, Colombo et al. 2011)	Ontario	Temperate	Forest management unit	REF: BAU wood for products, BIO: - BAU + residues harvest, - additional harvest without residues	Gasoline (ethanol)	Residues 74 Roundwood >100
(Holtsmark 2012)	Norway	Boreal	Forest management unit	additional harvest	Electricity coal	190
(Holtsmark 2012)	Norway	Boreal	Forest management unit	Boreal, explicit forest model, additional harvest	Gasoline (ethanol)	340
(Colnes, Doshi et al. 2012)	US SE forests	Temperate	regional	Actual current use in a defined area for pellets production and cofiring Expanded use for pellets and cofiring	Various, Coal CHP best performance, coal co-firing worse (NG in between)	35 to 50
(Walker, Cardellichio et al. 2010)	Massachusetts	Temperate	1 stand 1 harvest	2 baseline harvest scenarios (20-32% AGB no residues) , 3 bioenergy scenarios (38, 60, 76 % + 2/3 residues)	Oil, thermal or CHP	3-15
(Walker, Cardellichio et al. 2010)	Massachusetts	Temperate	1 stand 1 harvest	2 baseline harvest scenarios (20-32% AGB no residues) , 3 bioenergy scenarios (38, 60, 76 % + 2/3 residues)	Electricity coal	12-32
(Walker, Cardellichio et al. 2010)	Massachusetts	Temperate	1 stand 1 harvest	2 baseline harvest scenarios (20-32% AGB no residues) , 3 bioenergy scenarios (38, 60, 76 % + 2/3 residues)	Gas thermal	17-37

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	REFERENCE SYSTEM	PAYBACK TIME (yr)
(Walker, Cardellichio et al. 2010)	Massachusetts	Temperate	1 stand 1 harvest	2 baseline harvest scenarios (20-32% AGB no residues) , 3 bioenergy scenarios (38, 60, 76 % + 2/3 residues)	Electricity Natural Gas	59 - >90
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only consumption emissions (same for biomass and coal),	Electricity coal	175
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (residues collection from the additional fellings only) increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only consumption emissions (same for biomass and coal),	Electricity coal	75
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only consumption emissions (N.G. 40% less emissions than biomass),	Electricity Natural Gas	300
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (residues collection from the additional fellings only) increased from 60% to 80% of Net annual increment (SFM), NO upstream emissions, only consumption emissions (N.G. 40% less emissions than biomass),	Electricity Natural Gas	200
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of Aboveground biomass (no SFM), NO	Electricity coal	230

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	REFERENCE SYSTEM	PAYBACK TIME (yr)
				upstream emissions, only consumption emissions (same for biomass and coal),		
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of aboveground biomass (no SFM), NO upstream emissions, only consumption emissions (N.G. 40% less emissions than biomass),	Electricity Natural Gas	400
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Additional Fellings (NO residues collection) increased from 60% to 80% of aboveground biomass (no SFM), NO upstream emissions, only consumption emissions (Oil 20% less emissions than biomass),	Electricity Oil	295
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Fellings Residues (from baseline felling rates and no leaves) increased from 0% to 14% of aboveground biomass left from fellings, NO upstream emissions, only consumption emissions (same for biomass and coal),	Electricity Coal	0
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Fellings Residues (from baseline felling rates and no leaves) increased from 0% to 14% of aboveground biomass left from fellings, NO upstream emissions, only consumption emissions (N.G. 40% less emissions than biomass),	Electricity N.G.	16
(Zanchi, Pena et al. 2011)	Austria	Temperate	Forest Management Unit (90 ha)	Norway Spruce, Fellings Residues (from baseline felling rates and no leaves) increased from 0% to 14% of aboveground	Electricity Oil	7

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	REFERENCE SYSTEM	PAYBACK TIME (yr)
				biomass left from fellings, NO upstream emissions, only consumption emissions (Oil 20% less emissions than biomass),		
(Zanchi, Pena et al. 2011)	Austria	Marginal Agricultural Land with low C stock	Clearing – Substitution with Short rotation plantation	Any SRF species (GHG savings higher than 100% in the short term for LUC effect, tend to 100% at equilibrium)	Electricity Coal – N.G.	<0
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	High productivity plantation (10 years rotation), wood for bioenergy.	Electricity Coal	17
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	High productivity plantation (10 years rotation), wood for bioenergy.	Electricity N.G.	25
(Zanchi, Pena et al. 2011) (Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	High productivity plantation (10 years rotation), wood for bioenergy.	Electricity Oil	20
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	High productivity plantation (10 years rotation), 50% wood for bioenergy, 50% for HWPs (additional to baseline)	Electricity Coal	0

AUTHOR	AREA	FOREST TYPE	STUDY BOUNDARIES	SCENARIOS	REFERENCE SYSTEM	PAYBACK TIME (yr)
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	High productivity plantation (10 years rotation), 50% wood for bioenergy, 50% for HWPs (additional to baseline)	Electricity N.G.	8
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	Low productivity plantation (20 years rotation), wood for bioenergy. (Additional HWPs would change the payback time)	Electricity Coal	114
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	Low productivity plantation (20 years rotation), wood for bioenergy. (Additional HWPs would change the payback time)	Electricity N.G.	197
(Zanchi, Pena et al. 2011)	Austria	Temperate forest	Forest Clearing – Substitution with short rotation plantation	Low productivity plantation (20 years rotation), wood for bioenergy. (Additional HWPs would change the payback time)	Electricity Oil	145
(Repo, Känkänen et al. 2012)	Finland	Boreal	Forest stand	Baseline scenario clear cut for materials; 3 scenarios with different residues harvest	Electricity Natural gas	Branches 8 Thinning 20 Stumps 35
(Repo, Känkänen et al. 2012)	Finland	Boreal	Forest stand	Baseline scenario clear cut for materials; 3 scenarios with different residues harvest	Electricity Heavy fuel oil	Branches 5 Thinning 12 Stumps 22

Source: own compilation by JRC-Ispra

Annex 5: SFM Tools and Methodologies

In order to assure the compliance with the indicators proposed here it will be necessary to develop and use appropriate tools and methodologies. For example, indicators 3.3 (Chapter 0) and 4.2 (Chapter 5.2.4) imply a "zoning" of woody biomass extraction rates according to mapped soil qualities based on spatially explicit (GIS) soil inventories, i.e. maps for soil organic carbon content, soil nutrients, or natural susceptibility of the soil to compaction (see Annex 5.2).

A-5.1 Overall Sustainability Tools

Some existing environmental tools may be useful for forest bioenergy sustainability assessment as well, especially the **IBAT (Integrated Biodiversity Assessment Tool)** which is an on-line database of information on high priority sites for conservation and biodiversity protection. www.ibatforbusiness.org
At stand level, the software **tool for sustainability impact assessment ToSIA** was developed for forest-wood chains (FWC). Sustainability is determined by analyzing environmental, economic, and social sustainability indicators for all the production processes along the FWC. ToSIA also offers a methodological framework to assess sustainability impacts in the forest-based sector as affected, e.g. by changes in policies, market conditions, or technology (Lindner et al. 2010).

Globally, the Bioenergy and Food Security Criteria and Indicators (BEFSCI) project (FAO 2012) has compiled a set of relevant tools and methodologies that can be used to inform the development of a sustainable bioenergy at various levels.

A-5.2 Tools for Soil Data

The Harmonized World Soil Database has been developed at 1:5,000,000 scale and contains 221 million grid cells with 16000 different soil mapping units. The database allows to display composition in terms of soil units and the characterization of selected soil parameters[39] (FAO et al. 2012).
At European level, the European Soil portal provides comprehensive information about soil at country and European levels, as well as selected information for outside of Europe[40].
The Soil Atlas of Europe (EC 2005) presents a series of soil distribution maps using the World Reference Base classification.
Eckelmann et al. (2006) presented a synopsis of common criteria and approaches to identify risk areas for the threats SOM decline, soil erosion and compaction, salinization and landslides. Currently, the JRC has developed maps for the major threats for soils such soil erosion, organic carbon, soil compaction, salinisation, contamination and acidification[41].

Other relevant tools are

- **CQESTR Model;** It is a process-based soil carbon balance model that computes biological decomposition rates of crop residues or organic amendments as they convert to soil

[39] Soil 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

[40] JRC. European Soil Portal – Soil Data and Information Systems. See: http://eusoils.jrc.ec.europa.eu/

[41] See Soil Themes at the European Soil Portal for further details: http://eusoils.jrc.ec.europa.eu/themes.html

organic matter (SOM) or soil organic carbon (SOC). It uses available input data at the field scale www.ars.usda.gov/Main/docs.htm?docid=13499

- **LADA (Manual for Local Level Assessment of Land Degradation and Sustainable Land Management):** This project developed a package of tools and methods to assess and quantify land degradation in dryland areas. The VS-Fast methodology describes and evaluates the morphological conditions of soils in the field. www.fao.org/nr/lada
- **RUSLE (Revised Universal Soil Loss Equation):** It was developed by USDA-Agricultural Research Service and can be applied to any land (including cropland) where mineral soil is exposed to the precipitation and/or where surface runoff generated by rainfall intensity is greater than the infiltration rate of water www.ars.usda.gov/Research/docs.htm?docid=6010
- **SWAT (Soil and Water Assessment Tool):** The Soil and Water Assessment Tool (SWAT) is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds, and to assess water quality issues including nonpoint source pollution problems. www.brc.tamus.edu/swat

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