Forest bioenergy and biodiversity in the EU

The threats, the possibilities and the challenges

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Introduction

Bioenergy is in the spotlight. Long overlooked because of cheap coal and oil, biomass is promoted as a way to reduce greenhouse gas (GHG) emissions. It also cuts across many different technological and policy areas: for example electricity and heat production, climate, energy, agriculture, waste policy and nature conservation.[1] This focus on biomass for energy brings both potential benefits and threats in areas beyond energy production.

Forests are one of the European Union (EU)'s most important ecosystems, covering 36.4 per cent of the total land area.[2] Originally, the cover was much larger, but human processes like urbanisation and agriculture have reduced it to approximately half of the original cover.[3] Within that 36.4 per cent, most of the forests are used for economic gain and in these areas the biodiversity has diminished because of overly-intensive forest use.

In 2009, in Europe (excluding the Russian Federation) around eight percent of the forest area is protected[4] and less than one per cent is strictly protected, meaning it falls within the International Union for Conservation of Nature (IUCN) Category I for protected areas.[5,6] Unless additional areas are protected, there will be further extinctions of forest-dependent species in forests across Europe and probably at global levels. In addition to the relatively small percentage of protected forests in Europe, the existing protected areas are not well connected by ecological corridors — a prerequisite to

1 Faaij, A. (2006): 'Bio-energy in Europe: changing technology choices.' *Energy Policy* 34:322-342

2 Eurostat (2007): *Forest statistics*. 95 pp., Office for the Official publications of the European communities, Luxembourg

3 Williams, Michael (2003): *Deforesting the Earth: from prehistory to global crisis*. 689 pp. University of Chicago Press

4 MCPFE (2007): *State of Europe's Forests 2007*. MCPFE, Warsaw, Poland

5 IUCN (1994): *Guidelines for Protected Areas Management Categories*. IUCN, 261pp., Cambridge, UK and Gland, Switzerland

6 Scherzinger, W. (1996): *Naturschutz im Wald - Qualitätsziele einer dynamischen Waldentwicklung*, Verlag Eugen Ulmer, Stuttgart, Germany

ensuring the dispersal between metapopulations.

Forests in the EU are in dire need of protection. Biodiversity is still being lost, despite the Member States' agreement at the 2001 Gothenburg summit to halt biodiversity loss by 2010 and the Biodiversity Action Plan adopted in 2006. At present this target seems unreachable.[7,8] Assessment of the conservation status of forest habitats of European interest (protected under the Habitats Directive) reveals a sad picture: only 20 per cent of those are deemed to have a *favourable* (as defined in the EU's Habitat Directive) conservation status.[9] The most significant threat to biodiversity in the EU is habitat loss and fragmentation, although the EU has no indicator for assessing this.[10]

In addition, many forest ecosystems have so-called *extinction debt* (meaning that even if forest degradation were stopped, species would still creep closer to extinction, due to the historic decrease or degradation of their habitat area) the extent of which is unknown.

While there are possible benefits from substituting fossil fuels with biomass, there are also considerable risks to biodiversity and forest ecosystem functioning and resilience. These risks need to be considered in determining the level of biomass that forests in Europe can provide without long-term decline in resilience and biodiversity. This report looks at the possible benefits of biomass use and considers the levels of biomass that may be available. It also discusses in detail the meaning of *sustainable biomass* and the practices that have a high risk of long-term damage to forest biodiversity and resilience, or increase of GHG emissions. As with all discussions about energy, it is crucial that any biomass policy must be created in addition to, rather than instead of, large cuts in Europe's energy use.

Summary:

- Less than one per cent of European forests are strictly protected
- Only one fifth of the forest habitats in EU, protected under the Habitats Directive, has a favourable conservation status.
- This situation will lead to further extinctions but the scope is unknown.

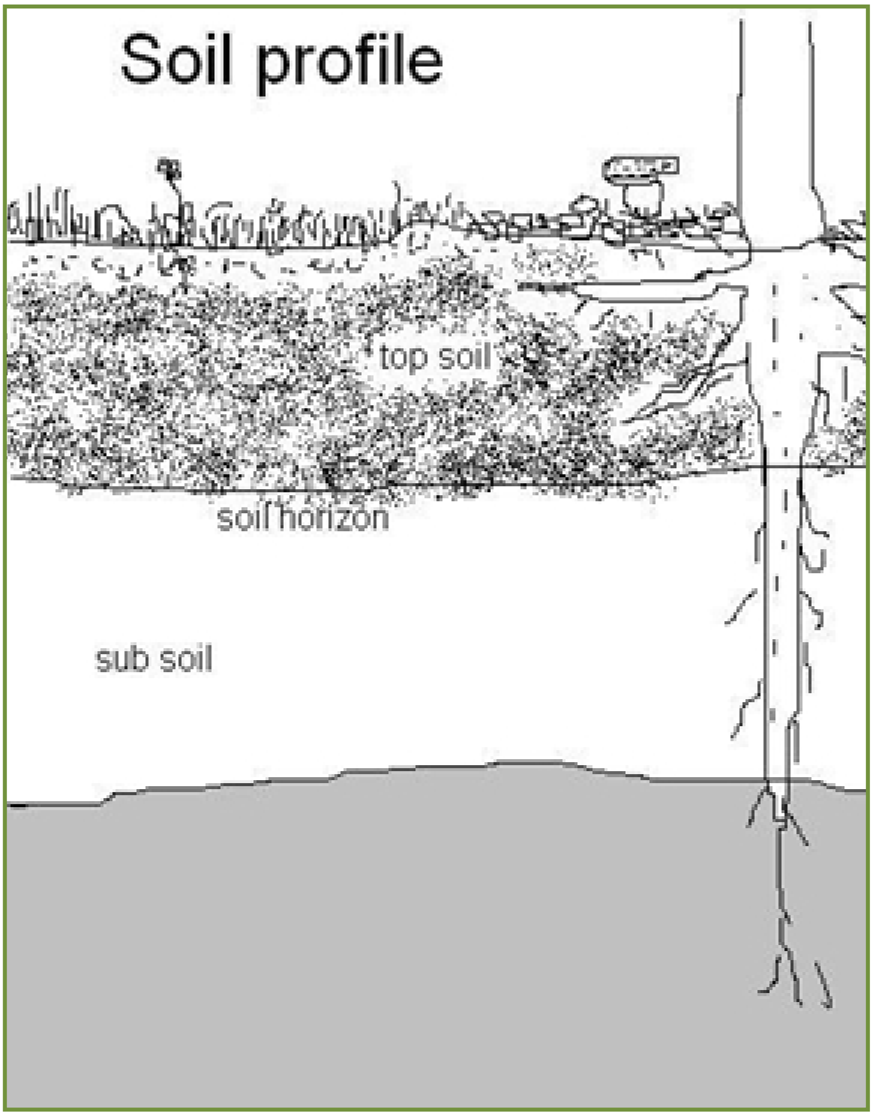
7 European Commission (2008): *A Mid-term Assessment of Implementing the EC Biodiversity Action Plan*. COM(2008)864

8 EEA (2008): *Streamlining European 2010 Biodiversity Indicators – Annex to a mid-term assessment of implementing the EC Biodiversity Action Plan*. European Commission, 82 pp., Luxembourg, Luxembourg

9 European Commission (2009): *Composite Report on the Conservation Status of Habitat Types and Species as required under Article 17 of the Habitats Directive*. COM(2009)358

10 EEA (2009): *Progress towards the European 2010 biodiversity target. European Environmental Agency, Report 4/2009*, 56 pp., Office for Official Publications of the European Communities, Luxemburg

FIGURE 1 : SOIL PROFILE



The potential benefits of increased biomass use

Bioenergy can mean many things to many people. It is claimed that it will:

- Lower the EU's GHG emissions
- Reduce the amount of fossil fuels used for heating, electricity production and transport
- Lead to a more secure energy supply as biomass can be produced locally
- Have remarkable rural development effects as producing and collecting biomass, and biomass processing, could create new jobs
- Reduce costs for agricultural overproduction in EU[11]
- Compensate for the intermittency problems of, for example, wind or solar energy, because of the possibility of long-term storage of biomass
- Deliver high energy-conversion efficiencies, through combined heat and electricity production from biomass burning.[12]

11 Lunnan, A., Stupak, I., Asikainen, A. & Raulund-Rasmussen, K. (2008): 'Introduction to sustainable utilisation of forest energy.' In Röser et al. (eds.) (2008): *Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region*. 258 pp. Springer, Dordrecht, The Netherlands

12 RCEP (2004): *Biomass as a renewable energy source. Royal Commission on Environmental Pollution Reports 25,* 96 pp., Westminster, England

What is meant by sustainable production?

The sustainability of renewable energy sources should not be taken for granted. Bioenergy production could, for instance, cause more greenhouse gas emissions than fossil fuels, if the whole life cycle requires a lot of energy, or if growing biomass leads to undesirable land use changes. One has to keep in mind that sustainability means more than cutting down greenhouse gas emissions. Sustainability also means that biomass production does not directly or indirectly compromise soil or water quality, or biodiversity, or cause negative social impacts.

Biodiversity considerations as a whole must be prioritised when judging the ecological aspects of sustainability. As Bala et al.[13] said in their paper "… preservation of ecosystems is a primary goal of preventing global warming, and the destruction of ecosystems to prevent global warming would be a counterproductive and perverse strategy."

The solutions often put forward for how to ensure sustainability are: to issue legislation and guidelines, or certify production. Unfortunately however, this could lead to problems because the scientific basis is always somewhat ambivalent and there will be gaps in knowledge, imperfect results and contradictions between studies. Regulation is always therefore made from a compromise point of view, with lobbyists having a strong effect on the outcome.[14] A negative outcome (e.g. certification of an unsustainable process) has a very strong undermining effect on sustainability.

13 Bala, G., Caldeira, K., Wickett, M., Phillips, T., Lobell, D., Delire, C & Mirin, A. (2007): 'Combined climate and carbon-cycle effects of large-scale deforestation'. *Proceedings of National Academy of Sciences of the United States of America* 104:6550-6555

14 Stupak, I., Asikainen, A., Jonsell, M., Karltun, E., Lunnan, A., Mizaraite, D., Pasanen, K., Pärn, H., Raulund-Rasmussen, K., Roser, D., Schroeder, M., Varnagiryte, I., Vilkriste, L., Callesen, I., Clarke, N., Gaitnieks, T., Ingerslev, M., Mandre, M., Ozolincius, R., Saarsalmi, A., Armolaitis, K., Helmisaari, H.-S., Indrikson, A., Kairiukstis, L., Katzensteiner, K., Kukkola, M., Ots, K., Ravn, H.P. & Tamminen, P. (2007): 'Sustainable utilisation of forest biomass for energy – Possibilites and problems: Policy, legislation, certification and recommendations and guidelines in the Nordic, Baltic and other European Countries'. *Biomass and Bioenergy* 31:666-684

Sustainability is also constrained by social, cultural or economic factors. In this report though, we limit our scope to the ecological aspects of sustainability, by investigating how the production of bioenergy affects biodiversity.

Current biomass use

In 2006, biomass made up 4.9 per cent of the EU's total energy production and 2.7 per cent of its electricity production.[15] The proportion of biomass used in total energy production varies greatly between countries: in Malta, biomass is not used at all, but in Finland, it makes up 19.8 per cent of primary energy production. Biomass is the EU's most important 'renewable' energy source, making up 69 per cent of its total 'renewable' energy production.

What are biomass and bioenergy?

Biomass mainly comes from agricultural and logging residues and industrial waste, and can be roughly categorised into primary, secondary and tertiary residues. In his 2008 paper, Smeets[16] defines *primary* residues as those collected directly from the forest or field; *secondary* as the by-products of processing, such as black liquor or sawdust; and *tertiary* as residues such as waste paper.

Definitions are important because other studies refer to all secondary and tertiary residues as waste. In Smeets' differentiation, by-product means any material that is produced during the processing but is not intended to be the main product. However, it might be used for other purposes, such as energy production. Waste means the material discharged after the product is used. This can be municipal or industrial waste, depending on where it is produced. Biomass residues are not waste as they also have other uses: they might be used as fodder, fertilizer or raw material for wood or paper products.

In this report, the term 'forest bioenergy' is used when talking about all of the different

15 Directorate-General for Transport and Energy (2009): *EU energy and transport in figures 2009.* 228 pp., Office for the Official publications of the European communities, Luxembourg

16 Smeets, E.M.W. (2008): *Possibilities and limitations for sustainable bioenergy production systems.* Ph.D. thesis, 308 pp., Faculty of Science, University of Utrecht, The Netherlands

types of energy sources originating from forest biomass: wood, forest residues, stumps and also forest industry residues such as black liquor, but not woody energy crops or short rotation coppice.

Different types of biomass

Natural or semi-natural forests. Most forests used for biomass are in semi-natural condition, which means they have been logged or used in some other way before. Natural forests are usually protected although there is still logging in old-growth forests.

Tree plantations are a frequently-used source of forest products.[17] In Western Europe, this has been a trend for the last 200 years.[18] Some of the plantations, especially in the Mediterranean region, consist of non-native species, such as *Eucalyptus*. There is also a growing interest in using genetically modified (GM) tree species, as they are seen as being more productive. Although there are at present no commercial GM trees in Europe, they are already used in China. As with natural or semi-natural forests, most wood from plantations will be used as industrial roundwood or pulpwood because it is economically more lucrative. From May 2009[19] however, there was a remarkable change as European pulpwood began to cost as much as energy wood, caused by a drop in demand for pulpwood in the traditional forest industry.

Short rotation coppice (SRC) is a type of biomass harvested every three–to–seven years. Compared to tree plantations it grows faster and is harvested much more frequently. Willow is the most popular short rotation species, followed by poplar. There are more studies focused on willow than other energy crops (for example aspen or ash) so there is a much more solid base of knowledge about the environmental aspects of willow short rotation coppice.[16]

Grass energy crops such as miscanthus and switchgrass are also of growing interest. They are both perennial grasses. Worldwide future production of biomass is largely expected to rely on these energy crops.[20] There can also be annual energy crops such as fibre sorghum when the fields are tilled every year.

17 Madsen, L. (2002): 'The Danish afforestation programme and spatial planning: new challenges.' *Landscape and Urban Planning* 58:241-254

18 Watkins, (1993): 'Ecological Effects of Afforestation'. *Studies in the History and Ecology of Afforestation in Western Europe*, C.A.B. International, Wallingford, UK

19 Hawkins Wright (2009): 'Biomass & Pellet Market Analysis'. *Forest Energy Monitor*, Volume 1, Issue 1

Traditional coppice is normally harvested every seven–to–45 years and coppice with standards is harvested every 10–50 years with an upper level of 110–130 years.[20]

Coppice with standards means that scattered individual stems are allowed to grow on through several coppice cycles. There are also what are known as agroforestry systems, which provide simultaneous agricultural and forestry production.[21]

Biomass in Member States

Use and production of biomass varies a lot country-by-country; it is also claimed that many energy statistics underestimate the domestic use of wood.[22] Northern forest-industry countries, such as Finland and Sweden, produce a lot of forest bioenergy as a by-product of the paper and wood industry. Consequently, the industry is also the biggest producer and user of electricity from bioenergy (about 25 per cent of total EU bioenergy production.[23]) On the other hand, there are countries like France, where bioenergy is predominantly used for the heating and cooling of houses.

Uses of biomass

Bioenergy can be created from biomass via different routes. Generally, the most efficient way of converting biomass to bioenergy is through using combined heat and power (CHP) plants. To make CHP most efficient, the source of biomass, the processing plant and the recipient of heating should be close to each other. Despite biomass's flexibility, there are infrastructure issues that have to been taken into account such as transportation, infrastructure and pollution from small-scale burning plants. The increase of efficient bioenergy use would require infrastructure development and consideration of all the environmental problems that come with it.

20 Van Calster, H., Baeten, L., De Schrijver, A., De Keersmaeker, L., Rogister, J., Verheyen, K. & Hermy, M. (2007): 'Management driven changes (1967-2005) in soil acidity and the understorey plant community following conversion of a coppice-with-standars forest.' *Forest Ecology and Management* 241:258-271

21 Current, D., Brooks, K., Ffolliot, P. & Keefe, M. (2009): 'Moving agroforestry into the mainstream.' *Agroforestry Systems* 75:1-3

22 Mantau, U., Steierer F., Hetsch S., Prins Ch. (2008): *Wood resources availability and demands – Part I National and regional wood resource balances 2005;* Background paper to the UNECE/ FAO Workshop on Wood Balances, Geneva, 2008

23 CEPI (2009): *Key statistics 2008: Paper and Pulp Industry*. CEPI, 12 pp., Brussels, Belgium

Biofuels, or agrofuels are liquid or gaseous transport fuels produced from biomass.[24] There has been a huge emphasis on biofuels in EU energy policy because there are very few substitutes to replace fossil fuels in the transport sector.[25] Agrofuels have come under heavy criticism however, because of the multitude of problems related to their production. They can directly lead to negative land-use change but also have indirect impacts such as reducing the land available for food production, which can lead to deforestation. If not managed carefully, the same criticisms could be levelled at biomass for electricity and heating. Many organisations also question how plausible it is to use food crops as fuel, both for social reasons and because they can lead to increased GHG emission.

What are known as *first-generation agrofuels* do not directly affect forests in the EU because they are made from sugar, starch, animal fats and vegetable oils. Indirectly their production may affect forests. For example: shrubs are cut back on marginal land to plant maize; land adjacent to forests is returned to more intensive use. *Second generation agrofuels* are expected to make use of cellulosic biomass, which is not used for food. In the future, agrofuel production could have a larger direct impact on forests in the EU because they might become a source for fuels.

Summary

- Currently, biomass is the most important source of renewable energy in EU; most of the biomass comes from forests
- Other sources are tree plantations, coppice and grass energy plants
- There are huge differences in biomass production between Member States.

24 European Union (2009): *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. Official Journal of European Union L140/16-62

25 van Dam, J., Faaij, A.P.C., Lewandowski, I. & Fischer, G. (2007): 'Biomass production potentials in Central and Eastern Europe under different scenarios.' *Biomass and Bioenergy* 31:345-366

Future biomass use

The effect that EU regulations may have on biomass use

In 1997, the EU set a target that by 2010, 12 per cent of the total energy consumption in the EU would be renewable. This does not seem viable because alternative forms of energy such as fossil fuels are more economical — because (among other factors) their cost does not include the damage they cause to the ecosystem. [26] Targets for improved energy efficiency have also not been reached, meaning that energy consumption is greater than expected. In 2005, the European Commission drafted its Biomass Action Plan,[27] in which it stated that biomass production could be significantly increased without negative environmental effects. The target for energy production from biomass is 150 Mtoe by 2010. The main instruments to strengthen the energy role of biomass are: nationally set targets; more efficient energy-conversion plants; and information for suppliers and customers. Biomass mobilisation from forests is encouraged through the Forest Action Plan.[28]

The European Parliament and European Council agreed on the climate package with what are known as the *202020 targets*. By 2020, the EU should reduce greenhouse gas emissions by 20 per cent and energy consumption should be reduced by 20 per cent. At the same time, renewable energy sources should count for 20 per cent of energy consumption. The targets for renewable energy being used in transport were raised

26 European Commission (2007): *Renewable Energy Road Map Renewable energies in the 21st century: building a more sustainable future*. COM(2006)848

27 European Commission (2005): *Biomass Action Plan*. COM(2005)628

28 European Commission (2006): *EU Forest Action Plan*. COM(2006)302

to 10 per cent by 2020 (Renewable Energy Sources (RES) directive.)[28] The 10 per cent transport target is national and the 20 per cent target of renewable energy is EU wide, because Member States each have a different potential to produce energy from renewable sources. One of the tools for Member States to demonstrate how they are going to implement the Directive and EU targets, is the National Renewable Energy Action Plans. The European Commission released the template for the action plans at the end of June 2009 and Member States should submit the plans to the European Commission by the end of June 2010. In the action plans, the Member States should explain their energy policy, expected consumption and means of reaching the targets. Member States need to assess their domestic potential for increased mobilisation of domestic and imported biomass resources. One of the problems is that it is difficult to estimate the potential for woody biomass before sustainability criteria are in place, and they are not yet elaborated in the RES directive. From the NGO perspective, it is important that National Renewable Energy Action Plans will be in line with other national plans for guiding forest use, such as the forest and rural development programmes and biodiversity action plans.

Supply: How much wood is available?

It is important to look at what these EU targets translate into — in terms of demand for biomass versus how much supply there is available. Estimates vary of how much extra wood is needed to reach the 2020 target, but those estimates which use comparable methodologies, tend to produce convergent results. A compilation of different studies is presented in Table 1.

In 2004, the use of biomass for energy production in the EU20 was 65.5 Mtoe of which 58.9 Mtoe was forest-related. The target for 2010 in the EU15 was 135 Mtoe but (despite it being roughly the same as the biomass potentially available)[29] this will not be achieved.[30] It is notable that the EU's bioenergy potential differs remarkably from the global picture, as most of the EU's biomass is expected to come from forest sources.

The impact assessment for the Renewable Energy Road Map estimated a maximum potential of 230 Mtoes of biomass in the EU27.[31] 63 Mtoes of this would come from

29 EUBIONET2 (2008): *Final result-oriented report. Efficient trading of biomass fuels and analysis of fuel supply chains and business models for market actors by networking.* VTT, 36 pp., Jyväskylä, Finland

30 Alakangas, A. (2007): 'Biomass trade and forest wood potential in Europe.' In *Solid biomass mobilisation for the forest-based industries and the bioenergy sectors – Proceedings from the Seminar during the European Paper Week 2007 in Brussels on 28 November 2007*. CEPI, 32 pp., Brussels, Belgium

31 European Commission (2008a): *Impact assessment – Document accompanying the package of implementation measures for the EU's objectives on climate change and renewable energy for 2020.* SEC(2008)85

agricultural crops and the rest would be covered by forest biomass.

The volume of overall removals from forests in the EU is actually over 500 million cubic metres, which is approximately 60 per cent of annual EU forest growth.[26,32] The European Forest Sector Outlook Study[33] estimated the wood supply as 724 million cubic metres in 2020. Unsurprisingly, this difference is normally considered to be the potential volume that can be used for energy production: Hetsch estimated further bioenergy capacity as 230 million cubic metres.[36]

Different methods are used to estimate how much more wood can be harvested for bioenergy.[34,35] Some of the studies count only logging and processing residues, whereas others take surplus forest growth into account. Most of the studies that are given in the table below also incorporate agricultural bioenergy production. At the moment there are estimates that 75–90 per cent of bioenergy comes from forest sources, but the current potential of agricultural production would be half of that from forest biomass.[34] There are also differences as to whether estimates are based on wood supply or demand for woody biomass. The data used for modelling is not uniform across countries and regions. When assessing the available amount of wood, many different assumptions need to be made about annual increments, mobilisation, economical plausibility and ecological constraints.

Different assessments deal with different kinds of potentials. In short: the *theoretical* potential is the overall maximum production if all of the available wood is used in the best, modern-efficiency power plants; *technical* potential refers to the output, where other demands for wood and also losses in harvest have been taken into account; *economic* potential means the amount of wood that is profitable to be used; and *environmental* potential calculates which part of the crops could be used without damaging biodiversity, or soil and water properties.[38]

General assumptions that influence such potential wood estimates can be divided into three areas: how much more wood can be felled; how much of the residues are harvested; and what is the efficiency of electricity and heat energy production.

32 Hetsch, S. (2008): *Potential sustainable wood supply in Europe*. FAO/UNECE, 42 pp., Geneva, Switzerland

33 UNECE (2005): *European forest sector outlook study. Main report*. UNECE, Geneva, Switzerland

34 McKormick, K. (2005): 'Bioenergy potentials and dynamic factors'. *Proceedings of the Beijing International Renewable Energy Conference*, Beijing, China

35 Smeets, E.M.W. & Faaij, A.P.C. (2007): 'Bioenergy potential from forestry in 2050: An assessment of the drivers that determine the potentials.' *Climatic Change* 81:353-390

The estimates are open to criticism because of the assumptions they make about the amount of wood that can be mobilised. For example, Asikainen et al.[36] estimate that 25 per cent of the annual increment could be used for fuel. Many studies, such as the European Environmental Agency (EEA) study, presume that almost 100 per cent of the wood not yet harvested can be mobilised. In fact, wood mobilisation has been a problem in the EU because the forest owners have not had enough incentive to sell wood. Some studies suggest that 35 per cent is a more accurate estimate.[36]

Another common assumption is that all new biomass will be used in CHP plants or processes with comparable efficiency, though this is not a realistic scenario. The problems in wood mobilisation include: mismatch in quality of wood needed and wood available: lack of infrastructure; and availability of workforce.[36] Fragmented forest ownership has also led to a situation where, in some areas, most of the forest is held by small-scale owners – there are 16 million forest owners in the European Union and the average size of the forest area per owner is 13 hectares. Timber harvest may not be a priority for all forest owners: they might not have sufficient incentive or knowledge to harvest timber from their forests.

The often-cited EEA estimate is quite theoretical, in that the restricting factors taken into account are mainly the hill slope and wetness of the soil. It is calculated using assumptions about how much residue is, on average, needed and how much forest should be spared from residue harvesting. These values are used over large land areas without regional or area-based parameters to take into account special circumstances. Potential harvest levels need to be assessed on a smaller scale, taking into account soil properties, river basin management demands, community species composition, protected areas, and forestry practices. These smaller-scale assessments must also take social context into account, as it will affect the potential to mobilise the theoretically available timber. State-of-the-art biodiversity modelling programs are required to see what sort of production could actually be defined as sustainable.

The lack of extensive forest statistics means that estimates for annual increments in growing stock at EU level should also be taken with a pinch of salt. For example, if there is uneven distribution of different age classes, the increment cannot be directly used as a basis for increased fellings.[36] If there are for example lots of young forests (which is the case in some areas of the EU, due to recent mass reforestations) the potential for increasing biomass from forests will only be achieved in the future.

36 Asikainen, A., Liiri, H., Peltola, S., Karjalainen, T. & Laitila, J. (2008): *Forest energy potential in Europe (EU27). Working Papers of the Finnish Forest Research Institute 69*. Metla, 33 pp., Helsinki, Finland

Most of the estimates also lack a cost analysis. Though there might be potential for more biomass use, it could be too costly to harness.[29] Overall, the interactions of supply and demand are complex, and future policies are difficult to predict. Biomass needs vast infrastructure because power plants need to be close to forests to minimise transport costs and emissions, but close to cities or towns to maximise the potential use of all energy for heating or cooling. One of the benefits of biomass is that it can be used in small-scale decentralised power-plants. Biomass can also be converted to pellets or charcoal to enable longer transport distances without the emissions outweighing the savings, but conversion will always result in energy losses.

There are many reasons for these differences in the figures. There is no standard methodology for assessing the potential of bioenergy.[29] Even in the basic forest and agricultural statistics there are differences between classifications and data collected, so that comparisons are very difficult. Most of the studies also assume a big increase in energy crop production on agricultural land. Yet it is impossible to predict increases in the yield of bioenergy crops.[38]

Demand: How much more wood do we need?

Because of the EU targets for reducing GHG emissions and for increasing the use of renewable energy sources, demand for forest biomass is going to increase. As with the question of supply, estimates vary of how much raw material the forest industry will need, how much of the forest biomass can be used for energy production and how much biomass will need to be imported. Combined estimates of future forest industry and energy production needs in 2020 vary between 768 million cubic metres[37] and 1,210 million cubic metres.[38] These numbers are very dependent on the future prospects of the wood and paper industry. The lower range of demand figures may be compatible with potential supply figures.

The Confederation of European Paper Industries (CEPI) commissioned its own study (based on data from 16 European countries) which estimates that forest production supply for all forest-related products will equal 515–540 million cubic metres, and

37 Steierer, F. (2007): 'Wood resources availability and demands – implications of renewable energy policies.' In *Solid biomass mobilisation for the forest-based industries and the bioenergy sectors – Proceedings from the Seminar during the European Paper Week 2007 in Brussels on 28 November 2007.* CEPI, 32 pp., Brussels, Belgium

38 Mantau, U., Steierer F., Hetsch S., Prins Ch. (2008): *Wood resources availability and demands – Part II Future woodflows in forestry and energy sectors: European countries in 2010 and 2020;* Background paper to the UNECE/ FAO Workshop on Wood balances, Geneva, 2008

demand will equal 720–800 million cubic metres by 2020.[39] So it is estimated that there will be a gap between supply and demand that could be as big as half of the current forest biomass supply.

One of the deciding factors is the price that power plants are ready to pay for energy wood. Nowadays, wood is burned in coal plants or co-fired, so it is economically profitable to use wood instead of coal — if combined costs of coal and carbon-emission prices are higher than wood costs. If carbon-emission prices rise, this means there will be a further economic incentive to switch to biomass.

The general estimate is that wood production from forests could rise 50 per cent, in a suitable economic scenario. This is only plausible if forest residues and stumps are heavily harvested and forest volume increments are suitably mobilised. It must be remembered that increased mobilisation also means an increased need for external resources to harvest trees.[40] This means that, in addition to social and environmental impacts of such intensification, the building and organising of infrastructure for bioenergy production will also create extra environmental impacts.

In virtually all studies, demand for wood will by far outstrip supply, meaning that to reach the targets, there would need to be imported biomass. Nowadays, about half of imported wood products come from neighbouring Eastern European countries, such as Russia and Ukraine.[41] Within this, primarily Russian wood is used for bioenergy. Around one–fifth of the imports are tropical wood from Asia, Africa and South America. Substantial amounts of non-woody energy crops come from South America. Imports also have their own effects on biodiversity as well as significant social impacts, varying widely depending on the area of origin of the biomass.

What alternatives are there to mobilising more wood from forests?

There are two more practices that could contribute to higher wood mobilisation:

- Creating new plantations on abandoned farmland
- Using waste and by-products more efficiently, as is done in Sweden and Finland.

39 De Galembert, B. (2007): 'Bioenergy and wood mobilisation'. In *Solid biomass mobilisation for the forest-based industries and the bioenergy sectors – Proceedings from the Seminar during the European Paper Week 2007 in Brussels on 28 November 2007*. CEPI, 32 pp., Brussels, Belgium

40 METLA (2008): *Energiapuun korjuun ympäristovaikutukset - tutkimusraportti*, Metsäntutkimuslaitos, www.metsavastaa.net/energiapuu/raportti, accessed in 19.6.2009

41 WWF (2008): *Illegal wood for the European market*. 45 pp., WWF-Germany, Frankfurt-Am-Main, Germany

However, traditional wood-consuming industries will be competing with energy production for these wood resources.

Summary:

- To reach the 202020 targets, the amount of bioenergy is expected to rise two– to–three-fold by 2020
- There are lots of different estimates of the amount of forest biomass, but most of those have severe limitations and reveal a potential gap between supply and demand
- Caution should be applied to attempts to use forest bioenergy as a large part of attempts to meet 2020 targets.

Threats to forest biodiversity

We have seen then that a lot of hope rests on biomass; that EU policies are pushing for much wider use of it for their energy needs; and that as a result, demand is scheduled that will by far outstrip supply. This next section will look further into the problems that may result from using biomass in general, regardless of the current climate.

The most striking impact of modern forestry practices is the significantly lower amounts of dead wood in forests. This has led to a situation where the saproxylic species are the ones suffering most from this type of forestry.

Dead wood does not only host a large number of species but also a high number of individuals. Thus, loss of the dead wood does not lead only to the loss of species but also in a remarkable drop in the sum total of organisms.

SAPROXYLIC ORGANISMS

Saproxylic organisms are animal, plant or fungi species that use dead wood as their habitat. They use rotting wood for reproducing, foraging or shelter and cannot substitute it for other habitats. It is estimated that in Central Europe, 40 per cent of all forest fauna is dependent on this type of woodland organic system.

Loss of dead wood

As "an excellent indicator of the conservation value of the forest", the amount of dead wood is one of the biodiversity indicators for the EU's target on halting biodiversity loss.[10] The amount of dead wood is significantly smaller in intensively-used forests than in natural forests. In the EU25 area, it is approximately 10 tonnes per hectare, whereas the range in natural forests is 20–220 tonnes per hectare. In Northern Europe's managed forests, the amount of dead wood is less than one–tenth, compared to natural forests.[42]

This negligible amount of dead wood is said to be the single most important factor for the loss of biodiversity in forests.[43] The underlying reason is the number of forest species using dead wood as a habitat or using it for foraging (saproxylic organisms). This problem is particularly pronounced in boreal forests. Estimates for the number of saproxylic species in Finland is 4–5,000[47] and in Sweden 6–7,000[44] which is at least one-fifth of all the forest species in these areas. In fact, these saproxylic species have suffered most from modern forestry practices.[45]

Dead wood (or debris) is divided into two classes: *fine* and *coarse*.[50] Normally the division is based on the diameter. All twigs, branches and trunks with a diameter smaller than 10 centimetres are considered to be fine woody debris; logs and stumps larger than this are coarse. Normally, leftovers from logging are both fine (branches, twigs, etc.) and coarse (stumps).

The importance of coarse woody debris has been acknowledged for some time, but finer wood has been much less studied. Surprisingly, those studies that have been undertaken indicate that there might be more species reliant on fine rather than coarse woody debris.[46,47,48] However, most of the endangered species live on coarse woody debris, whereas organisms dwelling in, or on, fine woody debris are more abundant. Forest practices mostly reduce the quantity of coarse woody debris, leaving logging residues behind. This could mean that saproxylic species associated with finer debris are not endangered because logging residues are left in the forest.[45]

42 Siitonen, J. (2001): 'Forest management, coarse woody debris and saproxylic organism: Fennoscandian boreal forests as an example'. *Ecological Bulletin* 49:11-41

43 Berg, A., Ehnström, B., Gustafsson, L. Hallingbäck, T., Jonsell, M. & Weslien, J. (1994): Threatened plant, animal, and fungus species in Swedish forests.' *Forest Ecology and Management* 132:39-50

44 deJong, J., Dahlberg, A. & Stokland, J. (2001): Dod ved i skogen. Hur mycket behovs for att bevara den biologiska mangfalden?' *Svensk Botanisk Tidskrift* 98:278-297

45 Jonsell (2008): 'The effects of forest biomass harvesting on biodiversity.' In Röser et al. (eds.) (2008): *Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region.* 258 pp. Springer, Dordrecht, The Netherlands

46 Kryus, N. & Jonsson, B. (1999): 'Fine woody debris is important for species richness on logs in managed boreal spruce forests of northern Sweden'. *Canadian Journal of Forestry* 29:1295-1299

47 Schiegg, K. (2001): 'Saproxylic insect diversity of beech: limbs are richer than trunks.' *Forest Ecology and Management* 149:295-304

48 Norden, B., Ryberg, M., Gotmark, F., Olausson, B. (2004): 'Relative importance of coarse and fine woody debris for the diversity of wood inhabiting fungi in temperate broadleaf forests.' *Biological Conservation* 117:1-10

Saproxylic species have wide-ranging requirements for habitat. The factors that are important in estimating optimal woody debris are: tree species, sun exposure, diameter, decay stages and tree part.[50] Most saproxylic insects and fungi discriminate between tree species, with the biggest difference between conifer and deciduous tree species.[49] That means that the composition of woody debris by tree species is an important factor for local biodiversity and the retained debris should be from all of the species present in the forest. Some tree species (such as aspen in boreal forest) are more important as they harbour more endangered species. Many insects prefer woody debris that is exposed to the sun, probably because of the lesser degree of decay or the warmer habitat.[50] This linkage could be explained by the fact that hundreds of years ago, forest fires were abundant large-scale disturbances, which created dead wood in open areas.[54] Thus the collection of logging residues could target these species formerly adapted to forest fires. Most of the logging residues left are exposed to the sun because of the wide spread use of clear cuts. This could also mean that current species are more apt to use sun-exposed debris because the ones adapted to debris in shadow have already suffered from the deficiency of debris in forests.

For coarse woody debris, the association with a particular diameter class is not very strong[55] but for finer residues almost two-thirds of species were strongly associated with a diameter class.[51] This means that for optimal biodiversity there has to be fine woody debris of all size classes. During the decay of wood there is a succession of species, but it depends greatly upon tree species and circumstances. For example, the insects' primary colonisation takes one or two years[47] from the initial depositing of the debris; and the highest number of beetle species is to be found after three and five years[56]. These times vary a lot depending on the species.

Normally, it is thought that residues affect only saproxylic species, but impacts could be more far-reaching as other species could be dependent on logging residues. These might include species that are adapted to closed forests and which can survive the open phase in refuges under logging residues.[52] High levels of nutrients and organic

49 Jonsell, M. (2007): 'Effects on biodiversity of forest fuel extraction, governed by processes working on a large scale.' *Biomass and Bioenergy* 31:726-732

50 Lindhe, A, Lindelow, A., Asenblad, N. (2005): 'Saproxylic beetles in standing dead wood density in relation to substrate sun exposure and diameter.' *Biodiversity and Conservation* 14:3033-3053

51 Jonsell, M., Hansson, J. & Wedmo, L. (2007): 'Diversity of saproxylic beetles in logging residues – comparisons between tree species and diameters.' *Biological Conservation* 138:89-99

52 Astrom, M., Dynesius, M., Hylander, K., Nilsson, C. (2005): 'Effects of slash harvest on bryophytes and vascular plants in southern boreal forest clear cuts.' *Journal of Applied Ecology* 42:1194-1202

matter can also be important for foraging soil-dwelling invertebrates as there is much more diverse microfauna.[53]

Also important is the potential of dead wood to hold nutrients and water. Coarse and fine dead wood is important for fungal growth in forests, and in the case of disturbances such as storms or clear cuts, fungi are quick to gather all the nutrients and decrease potential run-off. These fungi are spread by rotting woody debris, and debris can also provide the microclimatic conditions for their growth after major disturbances. Decaying logs also decrease erosion as (depending on the diameter, climate and tree species) the rotten log transforms into highly durable and nutrient-rich humus.

Nutrient imbalance

Intensive forestry practices could seriously harm nutrient balances in forests. Nutrient levels could be affected in many ways. The most easily estimated is nutrient-loss from wood taken from the logging site. More difficult to calculate is nutrient-loss associated with nutrients in soil and in roots. These could be lost due to disturbances in the soil or erosion by water run-off. Also logging itself leaches nutrients from tree roots and, together with stronger erosive forces, contributes to nutrient-loss.[54]

A direct way of measuring the effects of logging on the nutrient balance is to measure nutrients in the soil itself. In Spain, the loss of phosphorous in the soil is attributed to intensive forestry practices;[55] in Central Europe the possible combined effect of acid rain and whole-tree harvest could lead to the depletion of magnesium[56]. Generally though, most of the studies focus on nitrogen levels. It seems that anthropogenic nitrogen emissions balance the effects of harvests.[57] Therefore, in areas where the air deposits only small amounts of nitrogen, nitrogen levels should be examined. In Northern Europe, nitrogen is suspected to be the

53 Persson, I.-L., Pastor, J., Danell, K. & Bergstrom, R. (2005): 'Impact of moose population density on the production and composition of litter in boreal forests.' *Oikos* 108:297-306

54 Also for further information on soil processes: Kreutzweiser, D.P., Hazlett, P.W. & Gunn, J.M. (2008): 'Logging impacts on the biogeochemistry of boreal forest soils and nutrient export to aquatic systems: A review.' *Environmental Reviews* 16:157-179

55 Blanco, J.A., Zavala, M.A., Imbert, J.B. & Castillo, F.J. (2005): 'Sustainability of forest management practices: Evaluation through a simulation model of nutrient cycling.' *Forest Ecology and Management* 213:209-228

56 Katzensteiner, K., Eckmuellner, O., Jandl, R., Glatzel, G., Sterba, H., Wessely, A., Huttl, R.F. (1995): 'Revitalization experiments in magnesium deficient Norway spruce stands in Austria.' *Plant and Soil* 169:489-500

57 Federer, C.A., Hornbeck, J.W., Tritton, L.M., Martin, C.W., Pierce, R.S. & Smith, C.T. (1989): 'Long-term depletion of calcium and other nutrients in eastern US forests.' *Environmental Management* 13:593-601

limiting nutrient for tree growth[58] but there has not been an increase in forest growth due to nitrogen deposited from the air. Overall, the picture is hazy and many studies are contradictory.

Soil fertility and nutrient cycle could also be assessed by microbial activity, microbe mass and species composition. It seems that taking away logging residues could result in a decrease in microbial mass, activity and species number, but the details are unknown.[59] This might be attributed to changes in nutrient cycle or, for example, shading of logging residues. There is no knowledge about how changes in the microbe community affect forest viability. They do not seem to harm tree growth, but there are also opposite claims.[60]

When harvesting takes place, the amount of nutrients lost from forests depends on the type of harvesting. Extensive biomass harvesting, including thinnings, whole-tree harvest and stump uprooting, could take 100 times more nutrients from the forest than stem-only removal.[61] Most of the nutrients in the tree are located in leaves, fine branches and roots, so harvesting these takes a lot more nutrients out of the forest than stem-only harvest. When harvesting only the stem there were no differences between species in nutrient loss from the forest. When harvesting the whole tree and uprooting the stumps, Scots pine and Norway spruce harvest took many more nutrients away than birch harvest.

Soil acidification could be caused when air pollution brings acidifying sulphur and nitrogen compounds into the soil. The weathering capacity of the soil might be compromised because of the loss of base cations, i.e. calcium, magnesium and potassium. Through the nutrient balance approach, it has been noted that calcium levels could drop quickly after extensive harvest.[62] Because dead wood can also buffer the effect of acid rain, the loss of coarse woody debris could accentuate the problem. The problem with acidification is more pronounced in Southern and Central Europe; in Northern Europe however, no clear signs of acidification of soils have been observed

58 Binkley, D., & Högberg, P. (1997): 'Does atmospheric deposition of nitrogen threaten Swedish forests?' *Forest Ecology and Management* 92:119-152

59 Smolander, A., Levula, T. & Kitunen, V. (2008): 'Response of litter decomposition and soil C and N transformations in a Norway spruce thinning stand to removal of logging residue.' *Forest Ecology and Management* 256: 1080-1086

60 Coleman, D. (2008): 'From Peds to Paradoxes: Linkages Between Soil Biota and Their Influences on Ecological Processes.' *Soil Biology & Biochemistry* 40:271–289

61 Raulund-Rasmussen, K., Stupak, I., Clarke, N., Callesen, I., Helmisaari, H., Karltun, E. & Varnagiryte-Kabasinskiene, I. 'Effects of very intensive forest biomass harvesting on short and long term site productivity.' In Röser et al. (eds.) (2008): *Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region.* 258 pp. Springer, Dordrecht, The Netherlands

on a large scale.[66] This could be because the boreal forest soil has a quite good buffering potential.[45] There is evidence however for a significant loss of base cations,[62] which has not yet caused acidification. There is not enough information to make a prediction about how plausible acidification is.

It is worth noting that the soil stores a substantial amount of carbon — about two times more than the vegetation or the atmosphere.[63] Forestry practices could increase the amount of carbon in the soil (carbon sequestration); decrease it by emitting carbon dioxide into the atmosphere; or be carbon-neutral. Soil carbon has a two-fold impact on forest biodiversity: the direct impact comes from changes to the plant community when available carbon levels change. The indirect impact comes from potential changes in atmospheric carbon dioxide, leading to global climate change.

So far, soil carbon has been neglected from a soil point of view. There have been a lot of studies on water reserve impacts but not so many on soil impacts because the loss of carbon is thought to be insignificant compared to the amount of carbon retained in harvested wood and soil. Carbon retained in the soil has primarily been considered as an indicator of soil erosion: the less carbon is left, the stronger the erosion is. The role of carbon is important because the amount and quality of humus is vital to retain the nutrients and water. The most stable humus is formed from coarse woody debris. Soil–atmosphere interactions are also a big problem, but not so much in European forests where carbon pools in forest soils are already depleted.

Carbon dioxide is not the only GHG coming from soil: nitrogen oxides also emerge when it is disturbed. The extent of this nitrogen leaching is not yet known, as only basic research has been carried out so far.

Water reserves

Nutrient cycling and mobilisation in the forest ecosystem could lead to increased nutrient and particle flows to nearby river systems. Forestry management disturbances can result in microbial activity whereby non-mobile nutrients are converted to mobile forms.[59] Fellings usually increase nutrient run-off from forest sites and could therefore increase nitrification of water reserves. The machinery needed for fellings has a direct

62 Olsson, B.A., Bengtsson, J., Lundkvist, H. (1996): 'Effects of different forest harvest intensities on the pools of exchangeable cations in coniferous forest soils.' *Forest Ecology and Management* 84:135-147

63 Jandl, R., Lindner, M., Vesterdal, L., Bauwens, B., Baritz, R., Hagedorn, F., Johnson, D.W., Minkkinen, K., Byrne K.A. (2007): 'How strongly can forest management influence soil carbon sequestration?' *Geoderma* 137:253-268

physical impact because it disturbs the soil leading to the death of fine roots, which releases nutrients. The collection of logging residues could increase this run-off and erosive effect by taking away the protective layers of residues.[45]

Further problems could result from excessive soil disturbances, which lead to increasing nutrient run-off. Understory vegetation, which is important for nutrient balance and decreasing water run-off, recovers more slowly after extensive soil disturbances such as stump uprooting.[45]

One of the major concerns is run-off on slopes. This effect can be exaggerated because the soil structure, the amount of coarse woody debris and the plant composition can lead to even more important combined effects than the slope alone.[64] Hillsides also have shorter water residence times, which means that water is not as easily saturated with particles and nutrients as the flow on lower slopes.[65] Nevertheless, slopes are more susceptible to erosion and, in many parts of the EU, felling on slopes is restricted. The lack of coarse woody debris can significantly change the geomorphology of a water catchment and lead to an incision of streams. This leads to the loss of a stream's ability to hold nutrients and run-off is drastically increased.[66,67]

It seems that loss of soil carbon is less than has previously been predicted[68], but the amount of soluble carbon, phosphorous and nitrogen ending up in water systems can be substantial. The effects of this are poorly understood, but it probably has both positive and negative impacts.[59] Kreutzweiser et al.'s review of nitrogen and phosphorous flows reveals that the impacts of forest practices are highly site-dependent and difficult to predict.[114] Forestry disturbances certainly have a huge effect on nitrogen cycles, but effects on biodiversity are difficult to pinpoint and hard to predict.

64 Hazlett, P.W., Broad, K., Gordon, A.M., Sibley, P.K., Buttle, J.M. & Larmer, D. (2008): 'The importance of catchment slope to soil water N and C concentrations in riparian zones: implications for riparian buffer width.' *Canadian Journal of Forestry Research* 38:16-30

65 Prepas E.E., Burke, J.M., Whitson, I.R., Putz, G., Smith, D.W. (2006): 'Associations between watershed characteristics, run-off, and stream water quality: Hypothesis development for watershed disturbance experiments and modeling in the Forest Watershed and Riparian Disturbance (FORWARD) project.' *Journal of Environmental Engineering Science* 5:S27-S37

66 Webster, J., Golladay, S., Benfield, E., Meyer, J., Swank, W. & Wallace, J. (1992): 'Catchment disturbance and stream response: An overview of stream research at Coweeta Hydrologic Laboratory: 231–253.' In Boon, P.J., Calow, P., & Petts, G.E. (eds.) (1992): River conservation and management, John Wiley & Sons Inc, 484 pp., Hoboken, NJ, United States of America

67 Gurnell, A.., Piegay, H., Swanson, F. & Gregory, S. (2002): 'Large wood and fluvial processes.' *Freshwater Biology* 47:601-619

68 Yanai, R.D., Currie, W.S. & Goodale, C.L. (2003): 'Soil carbon dynamics after forest harvest: an ecosystem paradigm reconsidered.' *Ecosystems* 6:197-212

Forests with wetlands nearby are much more susceptible to providing high loads of nutrients to aquatic systems.[69] Sustainable forestry guidelines establish buffer-zones around water systems such as streams, ditches or springs. Radical changes in plant composition could also significantly disturb evaporation and transpiration patterns in forest areas. In temperate and boreal forests this is not likely to have detrimental effects on future forest growth.

Forest disturbances also affect water reserves in forests. As soil surface run-offs could increase, this results in less water reaching subsurface systems. Disturbances in soil by machinery tracks and tilling can also create superficial ditches and ponds for water. This could lead either to drying or wetting of the ground level.

Disturbance dynamics

Intensified forest use means more machinery tracks on forest ground. Regular stem-only harvest normally requires machinery to be used twice, but whole-tree harvest and stump uprooting may need machinery to be used up to five times per harvest cycle. This could lead to soil compaction that in turn could lead to increased water run-off, erosion and siltation of local water reserves.[70] Compaction could also limit the growth of roots and mycorrhizae because the density of the soil increases and the amount of oxygen drops.[45] Tracks left by machinery are also one of the biggest sources of siltation in forest areas.

Normally in Northern Europe during felling, logging residues are used to protect the ground from moving machinery.[45] This protects the soil from compaction but decreases the quality of logging residues for saproxylic organisms. However, this is not possible on sites where logging residues are collected. Furthermore, in northern areas felling could be done during the winter as the ground is frozen and less susceptible to damage. Stump uprooting cannot be done when the ground is frozen so both the removal of logging residues and stump uprooting pose serious threats to the forest soil.[45] If mobilisation leads to more fellings and thinnings, it will also lead to more frequent disturbances.

Another major disturbance is tilling to prepare the logged forest for plantations of new

69 Devito, K.J., Creed, I.F., Rothwell, R.L. & Prepas, E.E. (2000): 'Landscape controls on phosphorous loading to boreal lakes: implications for the potential impacts of forest harvesting.' *Canadian Journal of Fisheries and Aquatic Sciences* 57:1977-1984

70 Forestry Commission (2009): *Stump harvesting – Interim guidance on site selection and good practice*. 19 pp., Forestry Commission Publications, Wetherby, UK

seedlings. When planting oak or pine monocultures, tilling is necessary. This process does have merits as newly planted trees grow better and weed growth is much lower, but it has its negative effects too as tilling and site preparation decrease the amount of soil carbon.[68] The effects on nitrogen recycling are much more complex, which is shown by the fact that leaching and run-off of nitrogen compounds can be increased or decreased. Also, the effect on plant composition in the short term is remarkable as the tilling opens the forest ground to invasive species.
Understory vegetation is very important for nutrient recycling in deciduous forests. They prevent nitrogen leaching during early summer when trees are not yet ready to use nitrogen but soil microbes are actively nitrificating.[71]

Residues and coarse woody debris are important for natural regeneration because they protect small shoots against grazing by large herbivores.

Disturbances are not only linked to impacts on soil and plants. Bigger animals can also be disturbed by forestry practices. Machinery disturbs birds and mammals, even outside their breeding season. Forestry practices also lead to further fragmentation of suitable habitats, which in turn harms endangered species. Frequent disturbances also have a direct effect on smaller animals in forests. For example, stump uprooting might kill amphibians hiding in stumps, but the real effect of this direct killing on population viability is not known.

The storage of logging residues in felled areas could have a "trapping" effect.[50] Residues might lure saproxylic insects and other fauna to lay their eggs. If these species have enough time to lay their eggs and then the residues are removed, the effect on saproxylic animal numbers could be drastic.[54] It could even lead to local extinctions. It might be wise to leave the outermost twigs and branches of residue piles in the forest, because laid eggs are concentrated on these.

Other negative effects

The most problematic issue is the effect of intensified use on the higher trophic levels; or more concretely: what does the loss of biodiversity at a lower trophic level mean for biodiversity at a higher level? The problem is that all the effects on the base trophic level are so little known, that it is difficult to even guess what would happen to the top predators.[50]

71 Olsson, M.O. & Falkengren-Grerup, U. (2003): 'Partitioning of nitrate uptake between trees and understory in oak forests.' *Forest Ecology and Management* 179:311-320

There are several possible ways in which biodiversity might be affected. If loss of biodiversity comes at the same time as an overall decline of animal and plant biomass, it could lead to fewer top predators. Fewer top predators may enable a higher number of pest or invasive species. Of course, loss of biodiversity does not necessarily mean that biomass production is affected but losing numbers of specialised predator species could lead to an increase in pest or invasive species. It is also possible that some native species could become more dominant than is found under normal conditions. This could lead to widespread changes in the species composition of the whole ecosystem. If the species number does not decline, but the number of individuals does, then the ecosystem gets more exposed to diseases, parasites and invasion by alien species.

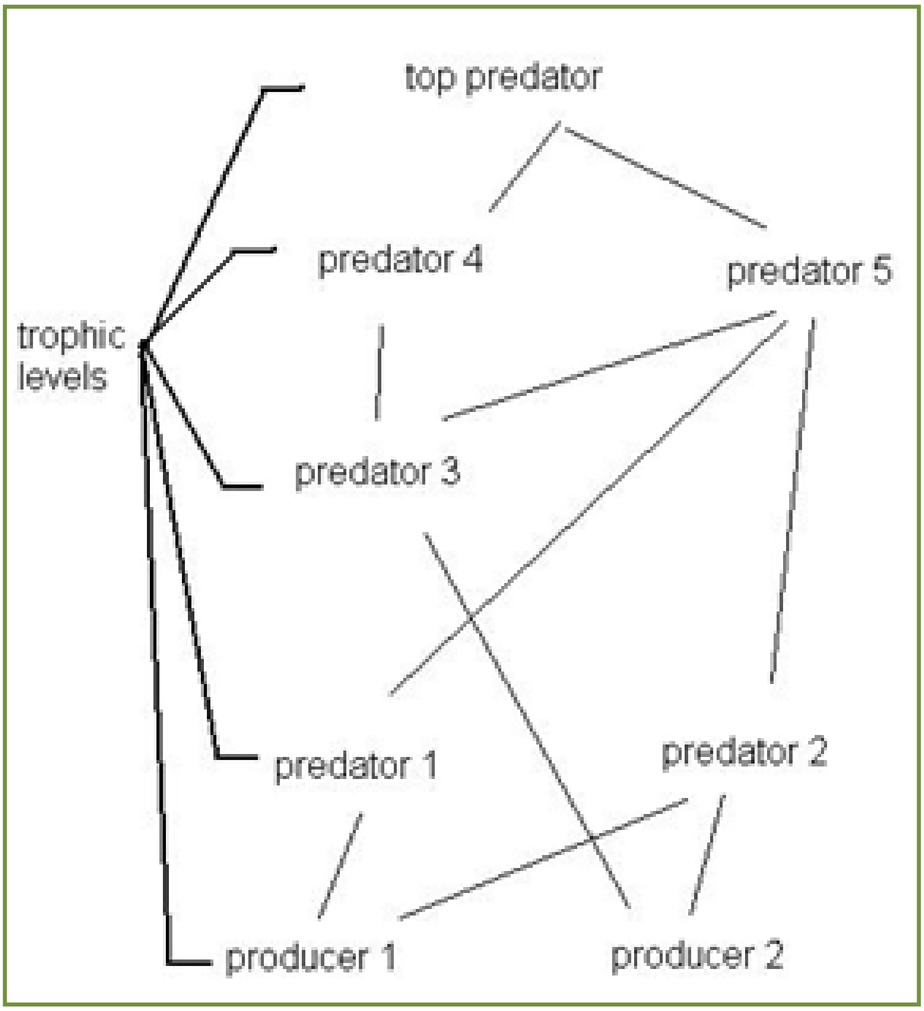
The EU has tried to reach an agreement on a Directive concerning soil protection.[72] The Directive would have worked not only against erosion but also other aspects of sustainability in soil processes, such as loss of soil carbon and compaction. Several Member States have expressed their reservations about the directive and the process is blocked.

Summary:

- The harvesting of logging residues and stumps could mean even less dead wood for saproxylic species
- Intense harvest regimes could lead to nutrient losses and nutrification of nearby water systems
- Increased use of machinery could compact soils and have adverse effects on forest growth and biodiversity.

72 European Commission (2006b): *Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/53/EC.* COM(2006)232

FIGURE 2 : TROPHIC LEVELS



The effects of intensified forest use

The previous chapter looked at the effect that biomass production in general could have, but in addition to these concerns, intensified forest use may lead to further negative effects that have not yet been considered in this report.

Given the right context, there are several viable options for the production of biomass for energy use. But without a coherent overall strategy, any one of these options is likely to fall short of contributing to the overall objective of increasing the volume of biomass available for energy use. Such a strategy must consider the most desirable cascade of biomass use within cascading energy use.

Provided that the choice of crop and management is made in the context of such a wider strategy, the following issues need to be considered to ensure that negative environmental and social impacts from the growing of biomass are avoided.

Conversion of forests to plantations

Tree plantations are areas that are dedicated to wood production for forest, paper, energy or other industries.[73] They are normally established on agricultural land or clear cuts of natural forests and for the most part they are strictly even-aged monocultures. Environmental NGOs have extensively highlighted the environmental and social impacts of tree plantations, such as their lower levels of biodiversity than natural or managed secondary forests.[74]

73 O'Hara, K. (2001): 'The silviculture of transformation – a commentary.' *Forest Ecology and Management* 151:81-86

74 Brockerhoff, E., Jactel, H., Parrotta, J., Quine, C. & Sayer, J. (2008): 'Plantation forests and biodiversity: oxymoron or opportunity?' *Biodiversity and Conservation* 17:925-951

Agricultural land has very little carbon in the soil. Switching production to perennial energy plants could mean significant carbon sequestration because soils in these plantations contain much higher amounts of carbon. These benefits are not possible under annual energy plants.[75] However, uncultivated lands and pastures normally contain much more soil carbon compared to cultivated lands, which means switching them over to energy crop production or tree plantations would not necessarily sequestrate more GHGs.

Change from forest to field could release 30 per cent of the soil carbon. In reverse, agricultural lands changed to forests could sequestrate atmospheric carbon. It has been suggested that carbon sequestration in afforested areas could count for a 10 per cent net reduction in GHG emissions.[76] This would be hard to prove however because most of the models are at best seriously incomplete.

Whole-tree harvest

Whole-tree harvest refers to harvesting of all the logging residues. There are different methods for doing this, but normally branches and twigs are collected at the same time as the tree is logged. The trees could be left to dry out and shed their leaves or they could be transported directly for further processing. Sometimes, whole-tree harvest is combined with stump uprooting, which we deal with in a later section.

Whole-tree harvest affects the availability of both coarse and fine woody debris for saproxylic organisms. It is estimated that whole-tree harvesting recovers 60–70 per cent of the logging residues during harvesting[77] but the fine and coarse wood that is left on site is disturbed by the heavy machinery. About two thirds of the residues are destroyed, or of a weakened quality, after removal of logging residues. Only 10–20 per cent of good quality fine and coarse wood is left in the forest, compared to when all logging residues are left on the site. The problem is that it is not possible to know what percentage of logging residues should be left after logging, but we are aware that contemporary levels of fine and coarse woody debris are a lot lower than those of hundreds of years ago.[55] In northern boreal forests, the amount of good quality fine woody debris is in any case lowered, because logging residues are used to protect the ground from forest machinery tracks.[45]

75 Anderson-Teixeira , K., Davis, S., Masters, M. & Delucia, E. (2009): 'Changes in soil carbon under biofuel crops.' *GCB Bioenergy* 1:75-96

76 Ovando, P. & Caparros, A. (2009): 'Land use and carbon mitigation in Europe: A survey of the potentials of different alternatives.' *Energy Policy* 37: 992-1003

77 Hakkila, P. (2004): *Developing technology for large-scale production of forest chips. Wood Energy Technology Programme 1999-2003, Final Report,* 99pp., Tekes, National Technology Agency, Helsinki

The portion of available biomass from logging residues varies greatly depending on the tree species. It could be as high as 70 per cent of the above-ground biomass (spruces in Northern Finland[45]). This poses both a remarkable economical incentive to collect and use the logging residues and a serious threat to dead wood left in the forests. In most of the forests, logging residues are 30-40 per cent of the above-ground biomass.

The problem is that, as a habitat for species, lost fine woody debris cannot be replaced with coarse woody debris, as the species composition is different.[56] It means that there needs to be high-quality fine and coarse woody debris left on the logging sites. There are similar amounts of saproxylic species living in different tree species, but deciduous tree species have more threatened saproxylic species.[56]

Whole-tree harvest and the removal of logging residues has a negligible effect on the plant community compared to the effects of soil preparation.[45] Tilling causes a more intensive disturbance than the harvesting of logging residues *per se*.

Apart from the loss of dead wood, another consideration is the loss of nutrients. Most of the nutrients stored in trees are in small branches, twigs and leaves. Compared to conventional stems-only harvesting, the most intensive biomass scenario causes increases in nutrient exports of up to six to seven times, whereas the biomass export increases only up to two times.[78] In a study of coniferous soils in Sweden, nutrient-loss was significantly higher in the southernmost study area.[67] This might be caused by stronger wood growth, which means a higher need for nutrients. It could mean that in Central and Southern Europe, the effects of whole-tree harvests could be even more pronounced. Researchers studying the issue in Spain said clearly that no whole-tree harvest could be recommended because phosphor levels were quickly depleted.[60]

Because of whole-tree harvest, at least in the short term, there have been decreases in tree growth for 10–20 years in Swedish pine forests.[79] In another study of coniferous forests in Wales, whole-tree harvest negatively affected the growth of the second tree generation.[80] There were no changes in soil organic matter, but a decline in nutrients,

78 Stupak, I., Kukkola, M. & Varnagiryte-Kabasinskiene I. (2007b): 'Biomass and nutrient removals in Norway spruce, Scots pine and birch over one rotation – the influence of harvesting intensity, site productivity, target diameter and nutrient concentration in leaves.' (manuscript)

79 Jacobson, S., Kukkola, M., Mlkönen, E. & Tveite, B. (2000): 'Impact of whole-tree harvesting and compensatory fertilization on growth of coniferous thinning stands.' *Forest Ecology and Management* 129:41-51

80 Walmsley, J.D., Jones, D.L., Reynolds, B., Price, M.H. & Healey, J.R. 2009 Whole tree harvesting can reduce second rotation forest productivity *Forest Ecology and Management* 257:1104-1111

so the reduced growth was explained by the loss of nutrients.

The removal of logging residues has been extensively studied for its short-term effects on tree growth in Northern Europe.[86] Removal of logging residues after thinning has been shown to slow down the tree growth in pine and spruce forests for at least 10 years. As subsequent thinnings done after 10 years, it is not possible to say what the effect would have been over a longer period. This kind of effect has not been observed in fellings, though there the problem has been long-term acidification, which could last for over 20 years.[81] Thinnings are normally carried out when the changes in forest succession are quick and tree growth is fast. Therefore, removal of logging residues could have a serious impact on the forest ecosystem.[82] Norden et al.[53] call for dense, self-thinning succession forests. These seem to be vital for fungal biodiversity because of the high levels of fine woody debris.

The effects on water run-off of nutrients are poorly understood, but it seems that whole-tree harvests increase nutrient leaching to nearby water systems.[59] Harvesting trees exposes forest soil to erosion; removing debris covering the soil could further exacerbate it. Thus whole-tree harvest could have more adverse effects on over-nutrification of water systems near logging sites, as nutrients already mobilised by logging could end up in water run-off.

The effects of whole-tree harvesting have only been studied for thirty years, or one tree generation. These short-term studies do seem to indicate, however, that whole-tree harvest and the removal of logging residues could pose a threat to forest biodiversity, especially to saproxylic insects.[51]

Stump uprooting

Stumps are the basal parts of the trees that remain after felling.[75] Normally stumps contain vertical above- and below- ground parts such as the taproot, but not lateral roots. Stumps are collected by special mounted machinery which excavates the stump, splits it and shakes it to get rid of the remaining soil. In Finland, uprooting concentrates on spruce, because they are more easily excavated than pine stumps.[45] Birch stumps are even more difficult to excavate, though this is not generally true for deciduous trees.[83] The feasibility of stump uprooting is determined by different

81 Nykvist, N. & Rosén, K. (1985): 'Effect of clearfelling and slash removal on the acidity of northern coniferous soils.' *Forest Ecology and Management* 11:157–169

82 VTT (2001): *Puuenergian teknologiaohjelman vuosikirja 2001*. VTT Symposium 216, Espoo, Finland.

83 Peltola, H., Kellomäki, S., Hassinen, A. & Granander, M. (2000): 'Mechanical stability of Scots

properties depending on the root system's morphology: how much biomass can be easily excavated; how difficult it is to uproot trees; and how much the soil is disturbed by uprooting. Normally, stump uprooting is associated with soil preparation and the planting of new trees, and fighting against root-rot diseases.[84]

Depending on the ecosystem, stumps could hold as much as one-third of the logged wood. This means that at least half of the dead wood in economically-used forests could be stored in stumps. As a habitat for saproxylic insects, stumps are not as good quality as dead tree trunks, because it is much more difficult to access the parts of stumps that are underground. Saproxylic organisms are also associated with different parts of trees which means that insect fauna in stumps differs from that on the upper part of high stumps.[85] Nevertheless, in heavily-harvested forests, stumps are thought to be the reason why dramatic loss in dead wood in boreal forests has not led to more dramatic losses in saproxylic beetle diversity.[86]

Generally, the environmental effects of stump uprooting are poorly known, and existing guidelines do not address the effects on biodiversity. In Northern Europe, uprooting was introduced quickly and without environmental assessments, so the effects remain to be seen. The Forestry Commission's guideline[75] states that the environmental hazards can be summarised as: soil damage, carbon loss, nutrient loss and loss of cations. Stump uprooting has a very high harvesting efficiency — 95 per cent of the stump biomass — as almost every stump can be collected and most of the biomass of the stump can be extracted.[45] This means it will have a clear impact on the amount of dead wood in forests.

Stump uprooting also causes major disturbance to the soil, which could lead to changes in the plant composition. Stump uprooting is especially harmful to plants reproducing clonally and shrubs. For example, in Northern Europe one of the species that could potentially be threatened because of stump uprooting is the blueberry.[45] The blueberry has already seen dramatic declines, with a reduction from 18 to eight per cent in understory vegetation cover because of heavy soil-preparation. This has

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pine, Norway spruce and birch: an analysis of tree-pulling experiments in Finland.' *Forest Ecology and Management* 135:143-153

84 Laitila, J., Ranta, T., Asikainen, A. (2008): 'Productivity of Stump Harvesting for Fuel.' *International Journal of Forest Engineering* 19:37-47

85 Abrahamsson M. & Lindbladh, M. (2006): 'A comparison of saproxylic beetle occurrence between man-made high and low stumps of spruce (Picea abies).' *Forest Ecology and Management* 226:230-237

86 Lindhe, A. (2009): *Stubbarnas biologiska betydelse underskattas! Potentiella konsekvenser av storskalig stubbskörd för den vedberoende biologiska mångfalden*. 17 pp., WWF Sweden, Solna

extensive side effects because blueberries are the single most important resource for herbivore insects, which in turn have wide effects on predators at higher trophic levels. A long-term study found that the effects of uprooting could last over 20 years: stump uprooting led to increasing diversity in graminoid (grasses and grass-like) species and a fall in shrub species.[87] The most alarming finding though, was that stump uprooting strongly favoured introduced species. The processes which induce this change in plant-community composition are not well known, but it is established that stump uprooting causes soil compaction which leads to smaller root diameter and smaller nitrogen uptake in trees.[88]

The nutrient aspects of stumps are still quite poorly studied. The longest-spanning study has been carried out in the Pacific Northwest America, 22–29 years after the stump harvest.[89] It observed permanently lower soil mineral nitrogen and carbon levels, by 20 and 24 per cent respectively.

Furthermore, the GHG neutrality of stump uprooting is still not clearly established. Uprooting directly consumes more energy, and thus produces more GHGs, than the above-ground use of trees.[90] Although the direct GHG emissions from burning stumps are still below the levels emitted by coal burning, the indirect effects are poorly known. There are no studies yet on GHG releases from soils after stump uprooting. The disturbance could induce nitrogen and carbon dioxide emissions as well as permanently lower levels of soil carbon.

Increased fertilizer use

If whole-tree harvesting and stump uprooting becomes a general practice in forestry, it is probable that "compensation" for lost nutrients will follow.[66] Compensation would most probably mean bringing wood ash from combustion plants back to forests. Fertilising would not be a novel thing, as some EU forests are already fertilized as part of forest management practices.

87 Kaye, T.N., Blakeley-Smith, M. & Thies, W.G. (2008): 'Long-term effects of post-harvest stump removal and N-fertilization on understory vegetation in Western USA forests.' *Forest Ecology and Management* 256:732-740

88 Page-Dumroese, D.S., Harvey, A.E., Jurgensen, M.F. & Amaranthus, M.P. (1998): 'Impacts of soil compaction and tree stump removal on soil properties and outplanted seedling in northern Idaho, USA.' *Canadian Journal of Soil Science* 78:29-34

89 Zabowski, D., Chambreau, D., Rotramel, N. & Thies, W.G. (2008): 'Long-term effects of stump removal to control root rot on forest soil bulk density, soil carbon and nitrogen content.' *Forest Ecology and Management* 255:720-727

90 Eriksson, L. & Gustavsson, L. (2008): 'Biofuels from stumps and small roundwood – costs and CO2 benefits.' *Biomass and Bioenergy* 32:897-902

Fertilizer use has been proposed to enhance carbon sequestration in European forests but, so far, study results are highly site-specific.[68] This means that general rules cannot be extrapolated about ecosystems as a whole. It is not yet known what the different interacting factors are, so it is impossible to say beforehand if, and in which cases, fertilizers have a sequestering effect. It is even possible that fertilizing would deplete soil carbon resources and release carbon dioxide into the air.

Wood ash has liming effects — it raises the pH value for ground soil for a long time, with one study showing the effect lasting for 10–19 years.[91] Deeper in the soil profile, changes would be slower and less dramatic and it could take years before any effects might be noticeable. Short-term acidification is also possible, by initial leaching of dissolved salts, this however is much rarer than the liming effect which totally changes the microbiological properties of the soil system. At the moment, the effects of this are little known.

Some sites also showed that increased fertilizer use led to excessive nitrification and nitrogen leaching. Likewise, effects on tree physiology are not well known. It is possible that they disturb tree growth, for example there have been findings that wood ash fertilized areas have slower growth and less above-ground biomass. [92,93,94] Wood ash also decreases the amount of fine roots, though this is not a long-lasting effect. Wood ash might also contain high values of heavy metals or hydrocarbons if it is obtained from burning demolition or wood wastes that have been treated with preservatives.

In any case, the most drastic effects of wood ash applications are on the composition of plant species. Depending on the site, the plant composition might be totally converted[95] or existing plants might be severely damaged.[96] One of the results of

91 Karltun, E., Saarsalmi, A., Ingerslev, M., Mandre, M., Andersson, S., Gaitnieks, T., Ozolincius, R. & Varnagiryte-Kabasinskiene, I. (2008): 'Wood ash recycling – possibilities and risks.' In Röser et al. (eds.) (2008): *Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region.* 258 pp. Springer, Dordrecht, The Netherlands

92 Mandre, M. (2001): *Comparison of the application of wood ash and clinker dust for improving nutrition conditions in forest stands and their effect on lignification processes in conifers.* Report to Estonian Science Foundation, Grant No. 4725. Tallinn

93 Mandre, M., Korsjukov, R. & Ots, K. (2004): 'Effects of wood ash application on the biomass distribution and physiological state of Norway spruce seedlings on sandy soils.' *Plant Soil* 265:301-314

94 Mandre, M., Parn, H. & Ots, K. (2006): 'Short-term effects of wood ash on the soil and the lignin concentration and growth of Pinus sylvestris L.' *Forest Ecology and Management* 223:349-357

95 Moilanen, M. Silfverberg, K. & Hokkanen, T. (2002): 'Effects of wood/ash on the tree, growth, vegetation and substrate quality of a drained mire: a case study.' *Forest Ecology and Management* 171:321-338

96 Arvidsson, H., Vestin, T. & Lundkvist, H. (2002): 'Effects of crushed wood ash on soil chemistry

adding more nutrients could be that species that are more adapted to taking up large amounts of nutrients are favoured. Though wood ash does not contain high levels of nitrogen, results are uniform with studies of, for example, nitrogen fertilizer.[97] Fertilizers could also lead to a lower diversity of species as they can be toxic for grass-species.[98] As forestry science is much focused on tree growth, biodiversity issues have been mostly dismissed from the studies carried out.

Non-native species, GMOs, and monocultures

In Southern Europe, there are many tree plantations that consist of exotic tree species such as *Eucalyptus,* which are used because they are more productive. These plantations are typically monocultures, which are clear cut and replanted.

Kanowski et al.[99] have studied the potential consequences of plantations on biodiversity. The findings were primarily valid for rainforests, but some of them are also relevant for European boreal, temperate and Mediterranean forests. Some of the issues are already covered in previous chapters, but additional impacts are for instance that : they could create habitats that harbour species of plants or animals that are seen as detrimental to native ecosystems or to adjacent agricultural production; they might introduce invasive species; they might lead to hybridisation between native and non-native systems.

Monocultures have widely-known problems: they are more exposed to diseases, parasites and insect outbreaks as these can be spread more easily, and there are normally smaller populations of predators able to rein in growing pest populations. This leads to the use of pesticides and herbicides, which in turn weakens the ecosystem's resistance. Some plantations may consist of clones, where the genetic diversity is non-existent. Tree plantations should have a variety of different tree species in different age classes. By definition, monocultures are poor from a biodiversity point of view. As there is only one tree species used, there are less ecological niches for other forest species and thus fewer species. This loss of biodiversity is even stronger if forests that naturally would have a range of different species are converted to monoculture plantations.

in young Norway spruce stands.' *Forest Ecology and Management* 176:121-132

97 Wedin, D.A. & Tilman, D. (1996): 'Infuence of nitrogen loading and species composition on the carbon balance of grasslands.' *Science* 274:1720-1723

98 Olsson, B.A. & Kellner, O. (2006): 'Long-term effects of nitrogen fertilization on ground vegetation in coniferous forests.' *Forest Ecology and Management* 237:458-470

99 Kanowski, J., Catterall, C.P. & Wardell-Johnson, G.W. (2005): 'Consequences of broadscale timber plantations for biodiversity in cleared rainforest landscapes of tropical and subtropical Australia.' *Forest Ecology and Management* 208:359-372

Non-native species could themselves become invasive or they could transport other species, such as plants, animals or fungi, via the soil or in, or on, themselves. These transported species can in their turn become invasive. They might also create an ideal habitat for non-invasive species, which can then disperse forcefully from the plantations. The general problem with energy crops is that the ideal ecological traits for a good energy plant (for example rapid growth in spring, high water-use efficiency, long canopy duration) also contribute to their invasive potential.[100]

In the case of genetic engineering, research has concentrated on GM poplars. Poplars are easy and fast to grow; and production of clones is economic and efficient.[101] The research has two main areas. The first aims to facilitate biofuel production and to reduce the costs of ethanol production.[102] Genetic modifications make the wood easier to process by having less lignin, or by producing enzymes that destroy cellulose. Low levels of lignin can also facilitate pulp-production. The second area of research concentrates on faster biomass production for roundwood or bioenergy production. More water- and nutrient-efficient growth; better stress resistance; stronger competitiveness for resources; and concentration of biomass in the stem — all help to increase the yields.[103] For tree plantations, a resistance to pesticides, herbicides and diseases also enhances production.[104]

Globally, there have been hundreds of field trials. In China, there are also commercially-operated plantations of GM poplar. In Europe there had been 57 field trials of which only six have been with forest trees.[105] Apart from poplar, fruit trees are the most commonly modified tree species.

The problems with GM species lie in the fact that they might cross-fertilize with natural species and that "runaway genes" could invade natural systems. It is impossible to

100 Raghu, S., Anderson, R.C., Daehler, C.C., Davis, A.S., Wiedenmann, R.N., Simberloff, D. & Mack, R.N. (2006): 'Adding biofuels to the invasive species fire?' *Science* 313: 1742

101 Strauss, S., DiFazio, S. & Meilan, R. (2001): 'Genetically modified poplars in context.' *The Forestry Chronicle* 77:271-280

102 Sticklen, M. (2006): 'Plant genetic engineering to improve biomass characteristics for biofuels.' *Current Opinion in Biotechnology* 17:315-319

103 Tang, W. & Newton, R. (2003): 'Genetic transformation of conifers and its application in forest biotechnology.' *Plant Cell Reports* 22:1-15

104 Halpin, C. & Boerjan, W. (2003): 'Stacking transgenes in forest trees.' *Trends in Plant Science* 8:363-365

105 BioSicherheit (2009): *An abundance of poplars.* http://www.gmo-safety.eu/en/wood/poplar/54.docu.html . Accessed in 27th of June 2009

contain GM plants within plantations. GM tree species can also become invasive by themselves. Genetic modification aims to strengthen species' competitiveness; as a consequence, GM species could out-compete native species. Evidently, pesticide and herbicide resistance leads to the possibility of using more chemicals which might lead to potential large-scale damage to wildlife. GM plants might also have impacts on other species: as all of the organisms are part of the ecological food chain, possible toxic effects could be detrimental to the local ecosystem.

Summary:

- Converting forests or grasslands to tree plantations could affect biodiversity directly, and indirectly via GHG emissions from land use changes
- Whole-tree harvest and stump uprooting have extensive negative effects on biodiversity
- Intensifying biomass harvest could lead to increased fertilizer use (with potential impacts on soil nutrients and biodiversity), and to newly introduced exotic or GM species.

Conclusion: Expectations versus reality

The main problem with bioenergy is that while we may be moving fast, we do not know the direction we are moving in. The setbacks with agrofuels show that the global situation could change quickly and the same could be true with forest bioenergy. The rapid changes in the global market, coupled with ongoing changes in the paper- and forest-products industry, could significantly increase demand for forest biomass and lead to an unsustainable intensification of forest use.

New bioenergy projects should be closely monitored and there should be rapid feedback mechanisms for the identification of adverse effects. For monitoring, there should be a predefined set of indicators to ensure that possible problems are noted. The problem is that ecological relations are so complex that simple assessments cannot reveal them. Individual bioenergy projects should be assessed not only at field level, but also at landscape and regional level[106] because their impacts could go further than the established energy crop or harvested forest. Assessments are even more difficult at higher levels: it is difficult to evaluate the biodiversity effects of EU policies when there is a lack of standard data on forests. There is also a dearth of the tools and models needed to combine the available information to understand all of the considerations of the impacts of increased bioenergy use. Predicting the future is really a challenging job and the greatest dark spot on the crystal ball is future land-use and needs.[107] If the global population keeps growing, diets become increasingly meat-based and over-consumption of resources in industrialised countries is not curbed significantly, then conflicts between different land uses are set to grow.

One of the biggest unknowns is climate change. If temperatures rise and rainfall patterns change drastically, agricultural lands could suffer greatly. This, in turn, could

106 Firbank, L.F. (2008): 'Assessing the Ecological Impacts of Bioenergy Projects.' *Bioenergy Research* 1:12-19

107 Ericsson, K. & Nilsson, L. (2006): 'Assessment of the potential biomass supply in Europe using a resource-focused approach.' *Biomass and Bioenergy* 30 :1-15

lead to pressures to create new agricultural land in other regions. In the EU, this could mean decreases in the agricultural production of Southern Europe but yield increases in northern areas.

Large-scale increases in bioenergy would mean large-scale investments in infrastructure: for producing, harvesting, storing and burning biomass. For example, new power plants would have to be built as not all new bioenergy could (or indeed should) be burned in coal power plants. The paper industry produces substantial amounts of bioenergy and if the industry moves away from Europe, the energy they currently produce from industrial residues would also diminish. They are net electricity producers, so if their electricity consumption goes down, energy production from biomass diminishes. In the short term, decreased competition for forest wood resources could mean a reduced capacity for bioenergy use.

One of the main problems is the contradiction between the intensification of forest use and the EU target for halting loss of biodiversity. In new Member States in particular, intensification of forest use to increase economic return from timber harvests has been prioritised, with questions concerning social or environmental issues seen as secondary. The broader question of what forests can provide sustainably must be considered but recent talks have centred single-mindedly on wood products. Other considerations — from biodiversity, to recreation and tourism, to the role of forests in buffering the effects of climate change — also have to be taken into account.

Over recent years, there has been growing criticism of the EU target to substitute 10 per cent of fossil fuels used in transport with renewable energy. Probably most of this will be substituted by agrofuels. It is highly unlikely that at this scale, production of agrofuels will be sustainable, either now or by 2020.[41,108] The yields of energy crops are optimistically estimated and energy conversion will not always be as efficient as predicted. Reaching the target could in fact seriously harm biodiversity and have significant negative social impacts.

108 Eggers, J., Troltzsch, K., Falcucci, A., Maiorano, L., Verburg, P., Framstad, E., Louette, G., Maes, D., Szabolcs, N., Ozinga, W. & Delbaere, B. (2009): 'Is biofuel policy harming biodiversity in Europe?' *GCB Bioenergy* 1:18-34

THE CASE OF WILDFIRES

One of the common arguments for using logging residues is the prevention of wildfires. Although harvesting logging residues reduces the risk of hazardous wildfires — the less burning matter there is, the less serious the wildfires are — the logging residues are not the reason for forest fires.

Modern forestry practices promote dense forests and accumulation of burning litter.[109] Forest stands are even-aged and homogenous. In this scenario, there is not normally much woody debris, until thinning or felling occurs. Therefore, management procedures to reduce fire risks are compensating for the shortcomings of general forest management.

Historically, Europe has been affected by regular low-intensity fires.[110] Nowadays, these fires are replaced by large-scale fires. This means a whole group of species linked with these burned forests are endangered. As fuel treatment practices always have adverse impacts,[112] the best way to fight wildfires in a sustainable way would be to promote forestry that creates a more heterogeneous landscape.[113]

109 Moghaddas, E. & Stephens, S. (2007): 'Thinning, burning and thin-burn fuel treatment effects on soil properties in a Sierra Nevada mixed-conifer forest.' *Forest Ecology and Management* 250:156-166

110 Delarze, R., Caldelari, D. & Hainnard, P. (1992): 'Effects of fire on forest dynamics in southern Switzerland.' *Journal of Vegetational Science* 3:55-60

112 Rhodes, J. & Baker, W. (2008): 'Fire probability, fuel treatment effectiveness and ecological tradeoffs in Western U.S. public forests.' *The Open Forest Science Journal* 1:1-7

113 Allen, C., Savage, M., Falk, D., Suckling, K., Swetnam, T., Schulke, T., Stacey, P., Morgan, P., Hoffman, M. & Klingel, J. (2002): 'Ecological restoration of Southwestern Ponderosa Pine ecosystems: a broad perspective.' *Ecological Applications* 12:1418-1433

114 Kreutzweiser, D., Hazlett, P. & Gunn, J. 2008. Logging impacts on the biogeochemistry of boreal forest soils and nutrient export to aquatic systems: A review. Environmental Reviews 16:157-179.

Glossary

Acidification: The decrease in the pH of terrestrial or aquatic ecosystems. The main drivers are the anthropogenic sources of nitrogen, sulphur and carbon oxides.
Base cations: are defined as the most prevalent, exchangeable and weak acid cations in the soil. Base cations include ions such as calcium, magnesium, potassium and sodium. These ions, except for sodium, are nutrients for forest ecosystems and vegetation and are thus of importance for the sustainability of the ecosystem. A proportion of the base cations available to the environment come from rock weathering. The base cation deposition is essential for determining critical loads for acidity.[109]
Biodiversity: Biological diversity can be divided into three components: diversity of ecosystems, diversity of species and diversity of individuals (also known as genetic diversity).
Bioenergy: Energy from biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.
Biofuel: A liquid or gaseous fuel for transport produced from biomass.
Black liquor: A by-product of paper pulp manufacturing, which contains all the parts of the pulpwood not used for paper production (hemicellulose, lignin, etc.) and over half of the energy content of the wood.
Carbon sequestration: The storing of atmospheric carbon as soil carbon, biomass or other long-lasting storage.
Cation: A positively charged molecule or atom. For example in soil: calcium, sodium, potassium, ammonium and hydronium cations.
CHP, combined heat and power: Power plants which produce electricity, and also reuse the water used for cooling their turbine gases, to provide heating.
Disturbance: A temporary change in environmental conditions that causes a pronounced change in an ecosystem.
EEA: European Environment Agency, independent EU research agency.

109 http://www.emep.int/assessment/Part1/083-086_05-Basecation-Part1.pdf

Energy crop: A plant grown to make biomass for energy production.
EU15: Member States before 2004.
EU20: EUBIONET2-countries: EU25 minus Luxemburg, Malta, Cyprus, Lithuania and Slovenia.
EU25: Member states before 2007.
EU27: All current (2009) Member States.
Extinction debt: The amount of species that are on their way to extinction because their habitat has diminished and their population sizes are so small that random events could kill the remaining individuals.
Forest residues: Tops, branches and bark from final fellings or thinnings, delimbed small-sized trees and stumps.
Fossil fuels: Fuels such as coal and petroleum are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being formed. The production and use of fossil fuels raise many environmental concerns.
GHG, greenhouse gases: Gases in the atmosphere that absorb and emit radiation within the thermal infrared range and thus cause the greenhouse effect; eg. water vapor, carbon dioxide, methane, nitrous oxide, ozone, CFCs.
Graminoid: Grasses, monocotyledonous and herbaceous plants, consisting of the true grasses (Poaceae), the sedges (Cyperaceae) and the rushes (Juncaceae).
Green certificates: A tradable commodity proving that certain electricity is generated using renewable energy sources. Typically one certificate represents generation of 1 MWh of electricity.
GM, genetically modified: The original genetic material has been altered by creating a new set of genes; genetically modified organisms could be transgenic if they have DNA originating from a different species.
Invasive species: Non-native species which can drive endemic species to extinction by predating them or being stronger in competition for resources.
IUCN protected area categories: IUCN has defined a series of six protected area management categories, based on primary management objectives. Category I combines the strict nature reserves (protected areas mainly for science) and the wilderness areas (protected areas managed mainly for wilderness protection).
Leaching: The loss of water-soluble plant nutrients from the soil due to rain or the loss of mineral and organic solutes due to percolation.
Mtoe, megatonne of oil equivalent: the amount of energy released by burning one million tonnes of crude oil (41,868 PJ).
Metapopulations: Spatially structured populations consisting of distinct units (subpopulations), separated by space or barriers, and connected by dispersal movements.

Natural forest: Forest without extensive human impacts. Other definitions used are *primary* forest for non-logged forests, or *old-aged* forest for forests with old trees.

Nutrification: Increase in the amount of nutrients in terrestrial or aquatic ecosystems. Major anthropogenic sources are fertilizers, sewer waters and leaching caused by land use.

Polyploidy: Organisms which have more than two paired sets of chromosomes. In other words, there are more than the normal diploid set of chromosomes.

Primary energy production: The amount of energy converted from a primary energy source, such as coal, gas, biomass, etc. Primary energy represents the total requirement for all uses of energy, including: energy used by the final consumer; intermediate uses of energy in transforming one energy form into another; energy used by suppliers in providing energy to the market; and also imported energy minus exported energy.

Roundwood: wood in its natural state as felled, with or without bark. It may be round, split, roughly squared or in other forms. Roundwood can be used for industrial purposes, either in its round form, or as raw material to be processed into industrial products such as sawn wood, panel products or pulp (FAO, Forest Harvesting Glossary).

RES directive: A directive which states that by 2020, 20 per cent of the EU's energy consumption should come from renewable energy sources.

Saproxylic: Deadwood-dependent (see separate box).

Soil carbon: Carbon held within soil, primarily in association with its organic content.

Soil profile: The vertical section of soil, which is normally divided into distinct soil horizons. Soil profile compromises the biologically active top soil and subsoil profiles. (See figure 1).

SRC, short rotation coppice: Woody energy crop harvested multiple times with only a few years' interval, and grown again from the shoots.

SRF, short rotation forestry: Woody energy crop harvested once after eight–20 years of growth.

Sustainable: To meet contemporary needs without compromising the ability of future generations to meet their own needs.

Trophic level: The level of species in a food web. The bottom level is for producers and predators are in the upper levels (see figure 2).

Wood mobilization: Logging and harvesting wood from forest and using it economically.

TABLE 1

Study	Total Potential	Year	Area	Forest-related	Type of potential
Nikolau et al. 2003[1]	535	2003	EU25	44,5	Ecological-economic
Ericsson & Nilsson 2006[125]	410	Long term	EU27	29-53	Techno-ecological
Thran et al. 2006[2]	146-207	2020	EU28	61 (technical)	Economic
EEA 2006/2007[3,35]	190/235/295	2010/20/30	EU25	67/-/64,3	Techno-ecological
Smeets & Faaij 2007[39]	450-1400	2050	West and East Europe	112	Ecological-economic
Siemons et al. 2004[4]	210	2020	EU27	67,4	Economic
Alakangas et al. 2007[5]	142,7	2003	EU20	93,8	Techno-economic
Asikainen et al. 2008[40]		2008	EU27	36	Technical
De Wit et al. 2007[6]	461	2020	EU27+Ukraine	23	Techno-economic
RENEW 2008[7]	116	2020	EU27 excluding Cyprus and Malta	20	Techno-ecological
REFUEL 2008[8]	392	2030	EU27+Norway, Switzerland, Ukraine	19.6	Techno-economic

1 Nikolau, A., Remrova, M. & Jeliazkov, L. (2003): *Biomass availability in Europe.* Directorate-General for Transport and Energy, 80 pp., Brussels, Belgium

2 Thrän, D., Weber, M., Scheuremann, A., Frohlich, N., Zeddies, J., Henze, A., Thoroe, C., Schweinle, J., Fritsche, U., Jenseit, W., Rausch, L., Schimdt, K. (2006): *Sustainable strategies for biomass use in the European context. Analysis in the charged debate on national guidelines and the competition between solid, liquid and gaseous biofuels*. Institute for Energy and Environment, 387 pp., Leipzig, Germany

3 EEA (2006): *How much bioenergy can Europe produce without harming the environment?* EEA Report No. 7/2006, Copenhagen, Denmark

4 Siemons, R, Vis, M., van den Berg, D., Chesney, I., Whiteley, M. & Nikolau, N. (2004): *Bio-energy's role in the EU energy market. A view of developments until 2020.* BTG, 270 pp., Enschede, The Netherlands

5 Alakangas, E., Heikkinen, A., Lensu, T. & Vesterinen, P. (2007): *Biomass fuel trade in Europe – summary report*, VTT, 58 pp., Espoo, Finland

6 De Wit, M., Faaij, A., Fischer, G., Prieler, S. & Van Velthuizen, H. (2007): *The potential of European biomass resources and related costs in the EU27 and the Ukraine*. Abstract from 15th European Biomass Conference & Exhibition, Berlin, Germany

7 RENEW (2008): *Renewable fuels for advanced power trains - scientific report WP5.1 Biomass resources assessment*. EC BEREC, 52 pp., Wolfsburg, Germany

8 REFUEL (2008): *Biomass resources potential and related costs. Assessment of the EU/27, Switzerland, Norway and Ukraine. REFUEL Work Package 3 final report*. Energy Research Center of the Netherlands, 59 pp., Petten, The Netherlands

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