Woody biomass in the 21st century: A global perspective

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Abstract

In the 21st century, the production of crude oil is expected to peak and decline afterwards, as oil fields are exhausted. Natural gas and coal supplies will last longer, but ultimately they will also start to decline. As a consequence of increasing production costs of fossil fuels from difficult deposits and due to political instability in major production zones, prices have gone up. In order to lessen the dependency on fossil fuels, reduce greenhouse gases and signal less dependency on politically incalculable suppliers, the European Union and other countries promote renewable energy. Biomass of woody plants is one option, as it can be produced on poor soils with less input of fertiliser than annual herbaceous crops and is suitable for direct conversion into thermal energy by firing and, more importantly from the perspective of industrialised countries, into easily transported and used biofuels. Simultaneously, the demand and, consequently, the price for timber and wood fiber has gone up, too, as competing, oil-derived synthetic materials have become more expensive. The rapid change in global trade and policy on biomass in industrial countries will potentially affect developing countries in various ways. Obviously, there are direct effects of rising oil prices on local fuel markets with a shift back to fuel-wood and other biomass. Bright market perspectives for woody biomass such as timber, raw material for industrial use, as well as biofuels will promote new tree plantations, which compete for food production and water. Carbon emission trading has introduced professional international companies into the woody biomass game. For people in rural areas with limited land resources, the competition for arable land and water may bring more hardship. In regions with abundant land, large commercial plantations will have an impact on social structures and biodiversity. In any case, a pre-emptive, knowledge-based approach is needed in order to cope with potential risks and recognise new chances.

1. Introduction

Biomass form forests and woodlands have played an important role throughout the history of mankind. The intelligent use of fire is an attribute of human development and thus the use of wood as fuel is very conspicuous. However, for people living in or near forests, biomass from these forests used to be an important food source, too. Edible parts of forest plants can be directly used as food, while the gathering and hunting of herbivores provides animal fats and proteins. Over time more complex systems for exploiting forest biomass have evolved. Livestock was grazed in forests and the foliage from tree canopies that was beyond the reach of livestock was brought down by people as fodder. Forests were transformed into home gardens which were enriched by useful plants and whose soils were managed in such a way to minimise nutrient loss. In shifting cultivation, the aboveground biomass of trees, which had shaded out weeds and lifted mineral nutrients from deep soil horizons, was burnt to allow crops to be grown on forest soil fertilised by the ashes of the trees. Composting forest biomass together with animal dung and using it to fertilise arable land was an efficient system to utilise unpalatable biomass from conifer forests for food production.

When man started to use metals, biomass from forests became an indispensable source of thermal energy, both in the form of wood and charcoal. Torches made from resinous wood lighted mines and houses. Until well into the industrial age, forests provided a plethora of raw materials for trades and crafts. Potash (potassium carbonate) was made by burning forest biomass and refining the ashes. It was indispensable for glass and soap making and required large tracts of forest to be burnt before salts from salt mines replaced it. Soot was needed for printing, fibers for making rope, turpentine and resin were traded for many uses, and bark from trees was the most important ingredient for tanning leather. Non-timber forest products are still an extremely important category of forest biomass in large regions of the world.

After fossil fuels had started to replace wood as a source of energy in the industrializing world, forestry focused on the refinement of woody biomass generated by nature in forests into timber and industrial wood. Landlocked Germany was leading in this process because of its limited and potentially insecure access to timbers from overseas colonies. In the highly developed world forests are nowadays seen as sources of timber and industrial wood, as places for recreation, as sources of clean water, as reservoirs of biodiversity, as barriers against natural disasters, but to a much lesser degree as sources of biomass for thermal use or sources of basic food. During the last few years this picture has begun to change and the energetic use of biomass from forests has become a hot topic.

2. The current biomass boom

In the 21st century, the production of crude oil is expected to peak and decline afterwards, as oil fields are exhausted. Natural gas and coal supplies will last longer, but ultimately will start to decline, too. As a consequence of increasing cost of production of fossil fuels from difficult deposits and of political instability in major production zones, on the long run the prices will all but go up. In order to lessen the dependency on fossil fuels, reduce greenhouse gases according to the Kyoto Process (visit www.globalcarbonproject.org/budget.htm) and signal less dependency to politically incalculable suppliers, the European Union and other countries promote renewable energy. Biomass of woody plants is one option, as it can be produced on poor soils with less input of fertiliser than annual herbaceous crops and is suitable for direct conversion to thermal energy by firing, in addition to many options for conversion to easily stored and transported products from charcoal to bio-fuel.

The official homepage http://europa.eu/pol/ener/index_en.htm on Activities of the European Union on Energy provides detailed information on European energy policy and legislation. In the context of this paper, the Biomass Action Plan is of particular interest. Key statements are:

a) In the face of Europe's increasing dependency on fossil fuels, using biomass is one of the key ways of ensuring the security of supply and sustainable energy in Europe. This communication sets out a series of Community actions aimed in particular at increasing the demand for biomass, improving supply, overcoming technical barriers and developing research.

b) Biomass currently meets 4% of the EU's energy needs (69 million tons of oil equivalent =toe). The aim is to increase biomass use to around 150 million toe by 2010. An increase of this magnitude could bring such benefits as: diversifying Europe's energy supply; significantly reducing greenhouse gas emissions (209 million tons); direct employment for 250 to 300.000 people; and potentially lowering the price of oil as a result of lower demand.

c) In its strategy, the Commission defines the role that renewable sources of biofuels * produced from biomass may play in the future as a source of renewable energy serving as an alternative to the fossil fuel energy sources (chiefly oil) used in the transport sector. It also proposes measures to promote the production and use of biofuels.

d) The Commission also wants to support developing countries with potential in terms of biofuels.

As Europe competes with other energy-hungry regions for future supplies of biofuels, investments into securing biomass resources for the future have taken place, are negotiated or are planned on the global scale. China, in particular, is interested in securing energy resources for its fast-growing economy (see e.g.: http://www.uofaweb.ualberta.ca/chinainstitute/resources.cfm, http://www.iags.org/n1115044.htm, http://www.undp.org.cn/index.php. But the US, too, are increasingly committed to renewable energy and US investors take part in the global biomass rush. Tropical countries with sufficient precipitation, high climatic growth potential and underutilised land, e.g. secondary vegetation after forest destruction, are prime targets. While most investors praise their schemes as a new chance for impoverished countries of the South, critical voices talk about "Resource Imperialism" or "Eco-Imperialism" (Driessen 2003) and liken the current development to the rush for gold and diamonds in colonial times. An excellent unbiased source is Louise O. Fresco's Duisenberg Lecture (2006) "Biomass for Fuel or Food: Is there a dilemma?" (http://www.rabobankgroep.nl/download/Lecture_Fresco_Biomass_for_food_or_fuel_tcm43-38549.pdf).

In the context of this paper, the ecological implications of the current energy policy are of particular interest. Even though the future developments in renewable energy markets cannot be predicted in detail, due to speculation on resources and political instabilities, it is evident that the growing demand for biomass will provide new chances and markets for agriculture and forestry. As fossil energy declines and becomes more expensive, biomass production must, out of necessity, become less dependent on fossil energy. Soil fertility and its conservation and management will therefore be a central issue for further generations, restoration of degraded lands an urgent priority.

3. The future role of woody biomass

Woody biomass has a long tradition as fuel and industrial raw material. In the industrialised world, the use as fuel has declined after fossil fuels came into use. For the consumer fossil fuels, particularly oil and gas proved to be more convenient than fuel wood and for forest owners it was profitable to refine the net primary production on forest land into high price timber through silviculture and sophisticated forest management. Table 1 compares herbaceous agricultural crops grown for energy generation or non-food industrial use with tree and forest biomass.

On the global scale biofuels rank top among new concepts for biomass utilisation, because they can easily be stored and transported with conventional technology and used to fuel motor vehicles. For this reason there is massive investment in research on technology to convert biomass into biofuels (Vertes *et al.* 2006). While there is a substantial tradition in processing sugar cane into ethanol or rapeseed and sunflower into biodiesel, palm oil has recently become a prime source of biodiesel. Indonesia, a member of the Organization of Petroleum Exporting Countries, is planning to operate biofuel-fired power plants in 2007. The plants would use palm oil as their main energy source. Malaysia is predicted to export 1 million tons of biofuel next year (Watkins 2006). However, the focus has most recently shifted towards converting woody biomass into ethanol. The first reason is that biomass from trees, including palms, has a high content of carbohydrates which can be converted into ethanol by a variety of emerging new technologies. The second reason is that trees grow all year round on suitable sites, have a low demand on soil quality and require less fertiliser than agricultural crops.

A critical question is the maintenance of forest soil fertility under heavy extraction of biomass for treethanol production. While wood has indeed a very low content of plant nutrients, as already pointed out by Justus von Liebig (1840), not all woody biomass is wood. The physiologically active parts of trees such as foliage and meristematic tissue contain similar amounts of nutrients as many herbaceous plants (Glatzel 1991). If only timber and industrial wood of diameters larger than 10 cm are harvested, the export of nutrients is indeed quite low and most forests are able to compensate losses from deposition of aerosol, weathering of rocks in the subsoil and biological N fixation. Extracting small diameter branches and foliage may amount only to an additional 10 or 20 percent of biomass, but may exceed the amounts of nutrients in the wood fraction. In Central Europe litter raking and lopping, i.e. the harvesting of nutrient rich biomass from forests to subsidise agricultural crops with nutrients, has caused a marked decline in forest soil fertility, and had left acidified soils of low productivity (Glatzel 1991). Thus exhaustive extraction of biomass from forests and tree plantations without returning the nutrients amounts to mining and will not be sustainable in the longer run. Fertiliser application in forests is not so easy from the surface and when done from the air by helicopter the costs of energy and money are high.

If forests, particularly tropical rain forests, are converted to plantations with heavy extraction of biomass (e.g. oil palm fruits and trunks for bioethanol), the systems will inevitably lose carbon from the soil compartment (Brown and Lugo 1990). Thus the question of total carbon balance has to be critically evaluated in view of the claim that all forms of bioenergy contribute to climate change protection by reducing greenhouse gas emission. On the other hand, carbon trade investments into forest biomass plantations can significantly contribute to bringing trees back to degraded land.

As major changes in land-use affect water quality and quantity in watersheds, the potential effects on the hydrology have to be considered. This must include potential pollutant emissions from the conversion of biomass to biofuel.

4. Conclusions

Bright market perspectives for woody biomass as timber, raw material for industrial use, as well as biofuels, will promote new forest plantations, which compete with food production and water. Carbon emission trading has introduced professional international companies into the woody biomass game. For people in rural areas with limited land resources, the competition for arable land and water may bring more hardship. In regions with abundant land, large commercial plantations will have an impact on social structures and biodiversity. New concepts of the production of woody biomass by smallholders are urgently needed as such schemes would bring the benefits of expanding markets to a larger number of people in rural areas and could generate cash income. In any case, a pre-emptive, knowledge-based approach is needed to cope with potential risks and recognise new chances and opportunities.

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Table 1: Advantages and disadvantages of energy generation from herbaceous agricultural crops and from forest and woody plant biomass.

	Herbaceous plants in agriculture	Woody plants in forests and plantations
Potentially available land	Limited; only 11 percent of the land surface is potentially arable without irrigation (FAO www.fao.org/AG/agL/). Competition with food crops.	Substantial land areas which are not suitable as arable support forests and can be used to grow wood plants. Competition with timber production. Potential conflicts with conservation and water use. Conversion of primary forests into plantations may result in a negative carbon balance in view of climate protection.
Demand on soil fertility	high	Woody plants can be grown on poor soils
Demand on water	While some crops need irrigation, other crops have been adapted to dryland farming.	For high productivity of forests, there is high demand for water. Irrigation only in tree plantations
Maintaining soil fertility	Fertiliser use and soil management well established.	Fertiliser application on forest land difficult and costly. Potential conflicts with water management, conservation and tourism.
Breeding and genetic engineering	High potential by well-established technology.	High potential; breeding well established, biotechnology less established. Potential conflicts with conservation.
Harvesting and storage	Simple; if fruits are used, usually highly seasonal; need for long time storage with risk of spoilage or discontinuous processing.	More complex, but harvesting time less critical, often year round. Tree crops are usually more robust than herbaceous crops.
Use as fuel	Mainly residues used directly as fuel; use of animal dung for fuel is highly extractive on plant nutrients and degrades soils. Increasing potential for gasification	Locally particularly in developing countries still the most important resource for thermal energy. In the industrialised world decentralised heat/power generation and novel products for storage and transport (e.g. pellets). Gasification by thermal processes explored
Conversion into biofuels	Fairly simple; but many crops for biodiesel (sunflower or rape seed) have low energy balances: typically corn for gasoline 1.3-1.8 (output/input), compared to the much more energy efficient sugar cane, where the output to input ratio is 8.6.	New technologies for conversion of woody biomass into ethanol (treethanol) by Fischer-Tropsch synthesis or enzymatic conversion. Forests and plantation accumulate usable biomass over years and decennia and thus reach high energy densities per area. Danger of overexploitation by biomass "mining".
Non-food/fodder industrial use	Well established for a large variety of specialised uses.	Still increasing market for pulp and paper; if access to sea is given, long distance ship transport of wood chips.
Breeding and genetic engineering	High potential by well-established technology.	High potential; breeding well established, biotechnology less established. Potential conflicts with conservation.
Maintaining soil fertility	Fertiliser use and soil management well established.	Fertiliser application on forest land difficult and costly. Potential conflicts with water management, conservation and tourism.