# Renewable energy resources: Fuel or Food?

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## Abstract
In the 21th century a doubling of the global food and feed production is foreseen. This growing demand will further increase the pressure on the use of land, water and nutrients. At the same time, the political move to renewable energy sources has been accelerating the use biomass, including crop produce, commercially for biofuel and power plants. Government directives, incited by climate change, high oil prices and geo-political tensions, promote partial replacement of fossil fuel by biofuels. Prices and availability of commodities, used as staple food and feed, becoming already affected by the growing demand for bioenergy.

Many implications of this additional demand for biofuel on the resource base (land, water, biodiversity), environment, rural economy, food prices and social impacts are unknown. There are gaps in our knowledge regarding the global capacity for sustainable plant-based bioenergy production, while maintaining food security. It is evident that commercial biomass production will compete with food crops for arable land and fresh water resources. A quantum leap in crop productivity and resource use efficiency is needed to meet the demands for food, feed and fuel of a global population in an environmentally sound and socio-economically beneficially way. Opportunities and constraints will be discussed.

**Keywords:** land use, food security, bioenergy, biofuel, resource use

## Introduction
Shifting society's dependence away from fossil energy to renewable biomass resources is generally viewed as an important contributor to providing sustainable energy supply for developing and developed countries and effective management of greenhouse gas emissions (Ragauskas *et al.*, 2006). The UN Earth Summit Conference in Rio de Janeiro in 1992 launched a convention on the limitation of greenhouse gas emissions to the atmosphere. This convention is made operational in so-called Kyoto Protocol. The Johannesburg Summit on Sustainable Development in 2002 defined both energy and water as vital elements for sustainable development (Varis, 2007).

Bioenergy has two components: conventional-rural (traditional) and commercial-industrial (modern) energy services. Conventional-rural bioenergy is still the most important source to household (cooking, heating, etc.) energy supply for the 2.5 billion people, mainly in Asia and Africa, living in a rural (83%) or peri-urban (23%) environment (Sagar & Kartha, 2007). Bioenergy contributes for decades a quite stable fraction (about 12 %) of total primary energy consumption; over the last three decades total energy consumption rose with 80 %. So, bioenergy has been playing a vital role in the provision of energy services on the household level for centuries; however, at the beginning of the 21th century in the developed countries large scale, commercial use of biofuel is the most rapidly growing renewable energy source.

In 2001 the global use of energy amounted to 10.2 Gigaton oil-equivalents and an average use per capita of 1.67 ton. The division of energy sources over oil, coal, gas, traditional biomass (wood, etc.), nuclear power, hydroelectric power, modern biomass (energy crops) and other renewable sources (e.g.: wind, solar) amounted to: 35, 23, 22, 9, 7, >2, >1 and <1%, respectively (Wilkinson *et al.*, 2007). A fuel is considered a biofuel if it is derived from recently produced biomass, such as wood and agricultural products or residues (Granda *et al*., 2007). Ideally, a biofuel should be carbon neutral; therefore, it should not contribute to the overall accumulation of carbon in the atmosphere. Carbon in crops is derived from the photosynthetic conversion of carbon dioxide in the atmosphere (capturing $CO_2$) determined by solar radiation during the growing season and natural resources (climate, water, etc.) and external inputs (fertilizers, pesticides, etc.). Bioenergy and food production are both strongly linked with water use. Thus, under water-limited conditions food as well as bioenergy production will be restricted. The external inputs are mostly manufactured by using fossil fuels as is the case for transporting and processing the biofuels. The 'greeness" of a bioenergy crop is therefore highly dependent upon the resource use efficiency of external inputs. Therefore, the trade-off's between the use of land and water resources for food as well as for bioenergy should be taken into account.

Presently, bioenergy production is expanding, especially in Brazil, the United States and South-East Asia, where sugar cane, corn and palm oil are converted into ethanol or biodiesel. Also the European Union (EU, 2003) set directives to increase the use of biofuels. There are three key factors in driving interest in bioenergy for commercial use:
- economic-driven rise in consumption, resulting in higher prices for fossil fuels;
- energy security and geo-political dependence of regions with a high volatility;
- anthropogenic-based $CO_2$ – emissions and climate change.

The rapid expansion will have a big impact on land use and therefore also on food and feed production.

**Trends in global and European food demand and supply**

Crop yields stagnated for hundred of years showing only an annual increase of only 0.5 – 1.0% (Evans, 1999). Since about 1960, when dwarfism was introduced in wheat and rice and new genotypes became more responsive to external inputs (nitrogen, water, pesticides) yields were raised by 2-3% per year. This green revolution took place in irrigated wheat and rice cropping systems, especially in India and South-East China, but also in the temperate regions of Europe growing winter wheat. The innovative technologies were based on a match of improved genetic traits and advanced crop management (*dosing* and *timing* of inputs). Thus, agronomic development in north-western Europe over the past four decades has shown remarkable successes in raising yields per unit of land. The gap between actual and potential yields declined considerably, which applies for crops such as winter wheat (Spiertz, 2004) and potatoes (Haverkort & Kooman, 1997); however, not for sugar beet (Jaggard & Semenov, 2007). Thus, for some crops genetic yield improvement should get priority while for other crops yields can be raised by further improving crop management practices. In hot and dry environments, like the Mediterranean climate, crops suffer from multiple stresses. For such environments improvement of yield capacity and stability can be more effectively achieved by taking into account genotype-environment-management (G×E×M) interactions (Reynolds & Trethowan, 2007).

The trend in past, present and future of global food security is characterized by a change from shortages to surpluses, resulting in the food affluences in the developed countries during the last decades; however, the trend to the future is reversed by:

- a rising demand due to a growing global population and a change in diet.
- the steep increase in the conversion of food crops into biofuel.
- a decline of cereal stocks due to climate-induced crop failure (drought, etc.).

It is still unclear to what extend the growing global demand can be met by taking more land into production or by a further increase of crop productivity. Cassman et al. (2003) argue that a quantum leap in crop productivity and resource use efficiency is still needed to meet the demands of a global population of about 8 billion in 2020. Currently food prices for poor people are at risk, despite the huge increases in productivity of rice, wheat and maize. Food scarcity still exists for poor people (800 million) in regions with severe drought, diseases and political instability. Runger & Senauer (2007) estimated that the number of hungry people will increase with about 16 million for each percentage increase of food prizes. When the current trend in food prizes will sustain, then the number of people with chronic food insecurity could rise from 800 million to 1.2 billion in 2025.

**Global diversity in land and water resources for food and fuel production**

What are the needs and demands of societies at a global scale? To analyze demands and resources we should differentiate between continents and regions. In a birds-eye view some major trends are presented:

*1. Europe*

A continent with large resources of fertile land, but a sharp decline in population growth and therefore a stagnating demand for food (Rounsevell *et al.*, 2005). The question is to what degree the policy shift from agricultural production to ecological and human services will affect the European role on the world food and bioenergy market? Europe does have ample resources (land, climate, infrastructure, processing industry, etc.) and a vast knowledge base to continue to play an important role to support a growing world population with food, feed and biofuel. Van Dam *et al.* (2007) calculated that in Central and Eastern Europe 44 million ha of agricultural land can become available for the production of biofuel when high-technology cropping systems securing a high crop productivity would be introduced.

*2. Russia and former soviet states*

Land resources are vast. Furthermore, labour and energy costs are low. At the moment production costs of wheat production in the Ukraine are only one-third of those in France. This region can become very competitive in producing commodities like maize and cereals, when crop management practices are improved and transportation of grain is facilitated by a better infrastructure. It is expected that the growth in commercial biomass production in the former USSR states will be higher than in Western Europe (Varis, 2007).

*3. Asia*

A sustained, economic growth for almost several decades did increase prosperity in China. This economic boom did already change the demand for food towards protein-rich diets (Chen, 2007). The consumption of rice decreased and of dairy, fish and (white meat) products increased. As a consequence, less of the crop produce is directly used for human consumption and more cereal-based products are needed for feeding the growing animal industry (Tong *et al.*, 2003). This change in diet will require more land to feed the population, because productivity per unit land area is already quite high. In China, 20 % of the world population is fed from only 7% of the global agricultural land and 30 % of the arable land is used for double or triple cropping. The limits of sustainable crop production are almost reached; in regions with intensive cropping systems there is already an overuse of fertilizers and in some regions a fast depletion of the fresh water in aquifers and rivers. However, this intensive cultivated land is only 13% of the total land area (960 million ha); about 25% is used as forest and 27% as pasture. More of the so-called 'unused land' in the North-western part of China will be brought into cultivation for the production of food, feed as well as biofuel (Mol, 2007; *pers. com.*: Guanghui Xie). The same trends apply also for countries like Korea and Vietnam. In Southeast Asia, especially Malaysia and Indonesia, the palm oil – biodiesel industry is becoming an important sector, creating employment opportunities and economic benefits. However, the transition of native forest into palm oil plantations creates major side-effects on the environment (GHG-emissions, loss of biodiversity, etc.)

*4. North America*

The USA is a technology and profit driven society, where multinationals and retailers play a dominant role in the food chain and trading of agricultural commodities (e.g.: Cargill). It is still the major exporting country of crop commodities, such as maize, wheat and soybean. However, the booming ethanol production from maize grain since the last 5 years caused an unbalance between demand and supply of maize. As a consequence, maize prices rose abruptly (Cassman & Liska, 2007). To meet the growing demand for maize the current trend in yield increase of about 110 kg $ha^{-1}y^{-1}$ (a relative rate of 1.2%) have to be doubled. Large seed companies (Monsanto) are optimistic that they can develop drought-tolerant maize cultivars that will accelerate the current rate of yield improvement.

*5. Latin America*

This continent does have still vast land resources, however, the inequity in land rights and weak governance causes exploitation of fragile land. With adequate knowledge and new technology in some countries a large potential exists for food and feed production as well as the production of sugarcane-based ethanol production. Brazil is the world leader in producing bio-ethanol, but also using it as a renewable resource replacing fossil fuels.

*6. West Asia and North Africa (WANA-region).*

Most of these countries suffer from a stagnating economy, a booming population growth, poverty and degraded resources (land, forest, water, etc.). Most countries are also vulnerable to climate change effects, such as heat and drought. These countries become increasingly dependent on imports of grain; as a consequence they import also "virtual water". The prospects for producing more food and feed are not promising; producing biofuel will not be viable, because of the limited resources (land and water). Regarding the climatic conditions, solar energy would be the first option. However, it will require huge investments to upscale new technologies.

*7. Sub-Sahelian region and Southern Africa.*

These countries are struggling with poverty and/or an epidemic HIV-outbreak causing starvation. In many countries the physical and knowledge infrastructure is lacking due to political instability and / or weak governance. Land resources are rapidly declining because of poor management, soil degradation and nutrient mining. New initiatives by international donors are taken to reverse the current trend. Food security is still the first priority; however, forest residues and agricultural residues are still important as an energy source for cooking.

**Demand for biofuel and potential supply by renewable resources**

Bioenergy consumption has been important in many countries, e.g. Brazil, China and Scandinavian countries, for a long time. Wright (2006) reviewed the energy consumption in 2002 for some large countries and regions. The contribution of biomass to the total energy consumption in large countries ranged from 2.8 (USA) to 27.2% (Brazil) and in Europe from 1.3 (The Netherlands) to 20.0% (Finland). Since the mid-1970s many research initiatives were taken to increase the biomass resource base for production of bioenergy. Perennial, including short rotation woody crops (e.g.: *Eucalyptus*, willow, palm oil, sugarcane, switch grass) as well as annual crops (cereals, rape seed) were considered. It was concluded that energy crops have been most successful in penetrating the energy market where subsidies or tax incentives have been applied by governments. However, the energy market has dramatically changed since 2002; fossil fuel prices rose from less than 50 $ to about $ 100 per barrel. With the high rate of economic development of China and India the demand for fossil energy will continue to increase, while at the same time the exploration of new oil and coal fields faces more constraints (costs, geo-political tensions, environmental regulation). To what extent low-carbon biofuels can meet future demands depends also on the trade-offs with food production, GHG-emissions and native habitat conversion. The GHG-advantages of crop-based biofuels are challenged by Fargione *et al.* (2008); they conclude that these biofuels will create a 'biofuel carbon debt' instead of a net profit. The sustainability and vulnerability of biofuels was analysed from the perspective of a sociology of networks and flows (Mol, 2007). In his study, it was concluded that further development of biofuels will take place in global integrated networks that require certification and labelling systems to guarantee quality and sustainability standards.

## Conclusions

The rapidly growing demand for food, feed and fuel requires a 3rd Green Revolution, aiming at a quantum leap in increasing crop yields and resource use efficiencies (water, nitrogen, etc.). Adaptation to climate change and a better tolerance to biotic and abiotic stresses by genetic improvement will be of key importance. Furthermore, knowledge-based tools should be developed to manage diverse cropping systems in a sustainable way and to exploit the genetic potential of crop species and cultivars. A life-cycle assessment of resource use efficiencies and economic profitability may guide the choice of crop species and cultivars to be grown in a target environment depending on the added value for specific purposes: food, feed or fuel.

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