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Biomass as an energy source and the impact on global food markets

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Abstract

In the past energy supply and food supply hardly interfered with one another, but through the increasing use of biomass as energy source both systems become intertwined. This paper addresses developments in the demand for food, livestock feed and energy. We first analyze historical trends and then develop a simple model for assessing global biomass needs in the near future.

We distinguish between developing countries needing extra food for their growing population, transition countries needing extra livestock feed due to increased meat consumption and developed countries requiring biomass as sustainable energy source.

Our analysis shows that the future extra needs for biomass as fuel are in the same order of magnitude as the needs for food and feed (around 1000 MT each). This huge demand for biomass from the energy system is likely to cause large instabilities in the global agricultural markets.

Keywords
food, livestock feed, biofuels, global demand, competition

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1. Introduction

The current food production system is mainly a consumer of energy (diesel for tractors, electricity for cooling, heat for glasshouses etc.). However, with the emphasis on biomass as a possible energy source, the food system and the energy system are becoming increasingly intertwined. For instance, cereals are converted into ethanol which is used as transport fuel, and rapeseed is used as feedstock for biodiesel. Crop residues and waste streams from food processing such as nutshells and straw are used to generate electricity, and biogas is produced from wet biomass streams.

In February 2008, when food prices on the world market rose rapidly, increased meat consumption in China, as well as the use of cereals for ethanol production in the USA were mentioned as possible underlying causes of the global shortage of cereals. Recent FAO and OECD reports also mention these emerging impacts of the energy system on the food system (FAO, 2008, 2009, OECD-FAO, 2009).

This paper addresses the developments in the demand for food, livestock feed and energy. We first analyze past trends at a global scale during the 20th century and pay attention to variations between countries. Based on this historical analysis we then assess the demands for food, feed and fuel in the near future (20 years). We conclude with a discussion on the impacts of the increased demand for biomass as energy source on the availability of livestock feed resources.

2. Developments in population growth

The main driver for global food demand is population size. More people require more food. Figure 1 shows the world population from 1750 onwards. In 1750 the world population was less than 1 billion people, it doubled in the next 200 years up to 1950 and from then on a steep increase was observed: it nearly tripled within just 50 years. During this 250 year period the food production sector was able to feed the increasing population. Up to the 2 billion people mark the increased need for food was mainly fulfilled by increasing the area under cultivation. Later on the green revolution, through improved crop varieties, application of fertilizer and pesticides etc., led to large increases in crop yields per hectare, while the area under agriculture remained almost constant (Evans, 2001).

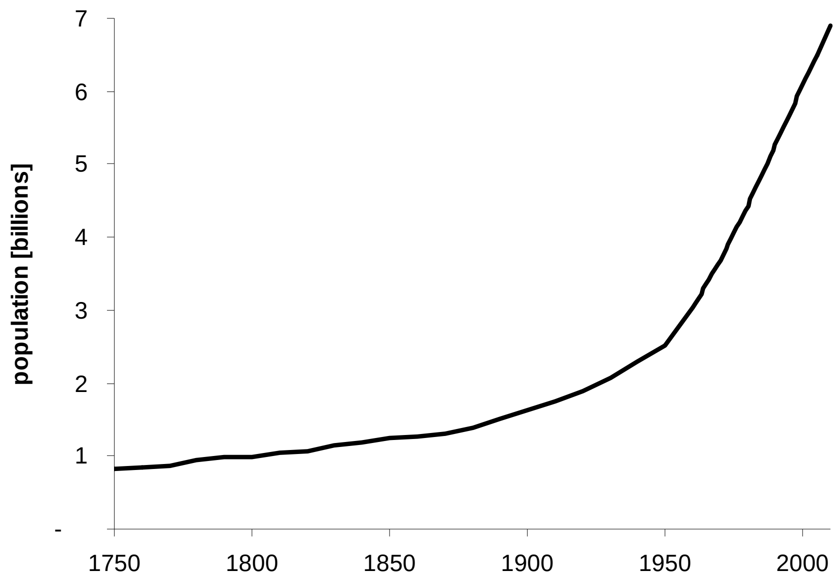

Figure 1: World population from 1750 onwards (Evans, 2001).

Presently, large differences among individual countries can be found with respect to population growth. Figure 2 visualizes this variation, providing data on the the development of population growth rates for countries ranging from very poor countries in Africa to the rich countries in Western Europe. Population growth is plotted against the GDP per capita, which we use as indicator for the economic development of a country. The developed countries are positioned on the right hand side of the graph, the developing countries on the left hand side.

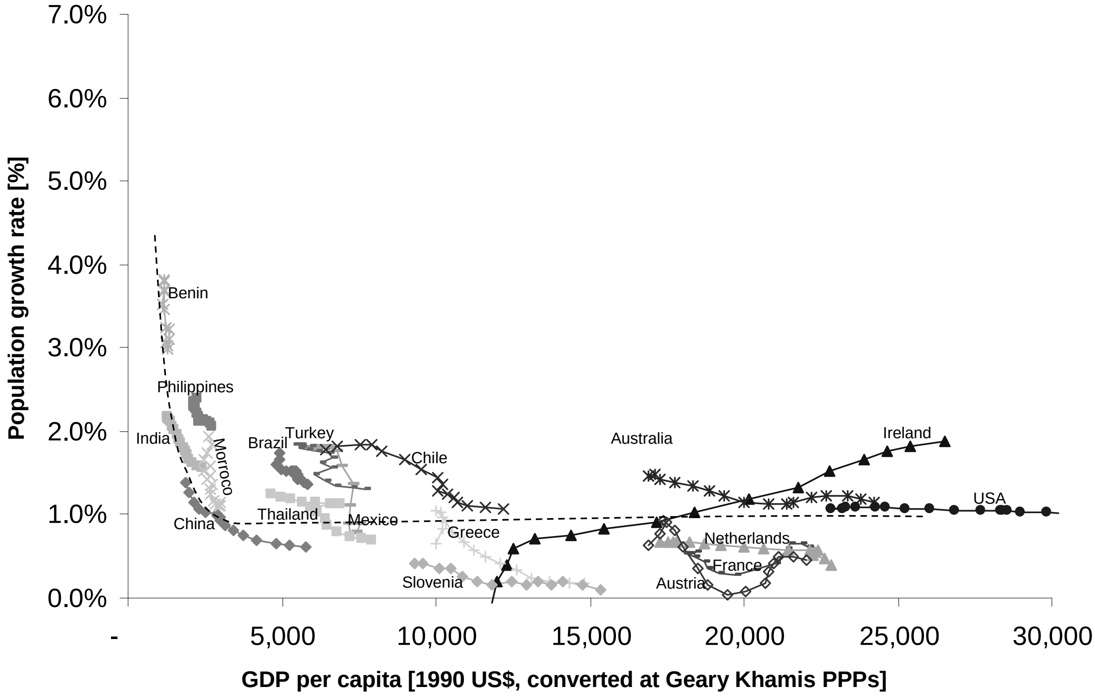

Figure 2: Population growth as function of GDP per capita. Dotted line shows general pattern used in this paper. (Data are for the years 1990 – 2005; sources FAOSTAT, 2007; GGDC, 2007)

Figure 2 shows population growth rates in developing countries at around 2-3 % per year, a rapid decline with increasing GDP levels, and a leveling off at rates around 1% in developed countries. It should be noted that population growth rates, not birth rates are shown in Figure 2. For instance, the increase in population in Ireland during the last 15 years results from Irish returning to Ireland, after having left for the US during the economic crisis in the 1980s.

3. Developments in meat consumption

Besides population size, consumption patterns play a crucial role in demand for agricultural produce. Affluent consumption patterns, containing meat, dairy, exotic fruits and vegetables, beverages such as coffee, tea, beer and wine, require more resources than consumption patterns mainly based on staple foods, such as rice. Over 35% of the cereals produced globally are presently fed to livestock (Trostle, 2008**)** and meat consumption greatly influences global cereal demand.

Figure 3 shows global meat consumption from 1960 onwards. In the last 50 years meat consumption increased from around 70 to 250 Mt. This steep increase was mainly due to increased consumption in the developing world, since meat consumption in the developed countries was more or less stable from the 1980s onwards.

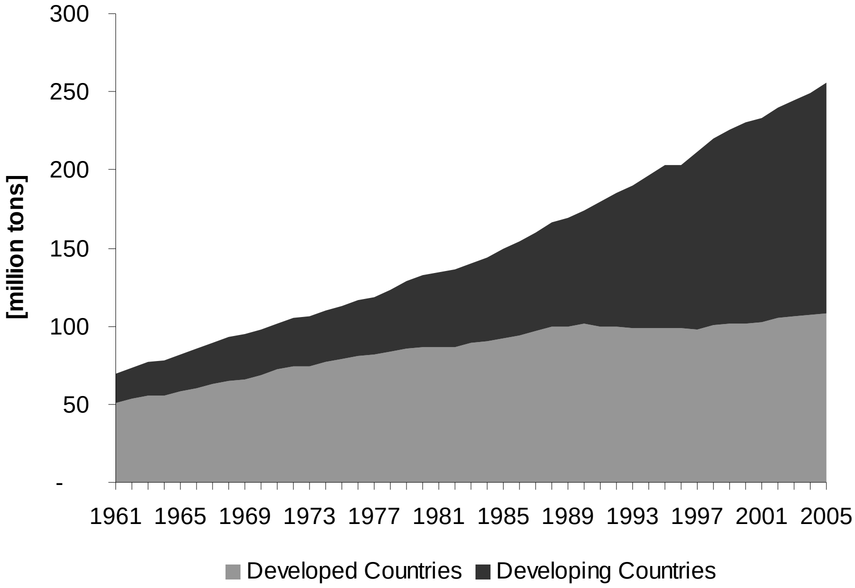

Figure 3: Trends in global meat consumption (source: FAOSTAT, 2007).

The pattern of stabilizing meat consumption in Western Europe and the USA can also be observed in Figure 4. This graph shows the changes in consumption of animal based food products (meat, milk egg, fish) over the past 15 years for the same countries as in Figure 2. The consumption of animal products is expressed as percentage of total calories consumed.

Figure 4 shows that in developing countries animal product consumption is low, at 5% to 10%; with rising GDP levels, it increases fast to around 35% of the total calories. At GDP levels of about 10.000 GK$ per capita, a saturation level appears to be reached and animal product consumption levels remain at around 35%. In high income areas such as the USA and Western Europe, consumption of animal products did not increase over the past 15 years. It should be noted that the values in Figure 4 include all products from animal origin (also dairy and eggs). This leads to higher numbers for France and The Netherlands than for the USA. Meat consumption in the USA is the highest in the world, but since in the USA relatively little dairy products are consumed, countries with a large share of dairy in their menu end up higher in the graph. The largest changes in animal product consumption occurred in the fast growing economies in Asia (China and India). These countries have GDP levels above $2,000 per person, with high rates of growth. Figure 4 shows that consumption of animal products per person in China doubled during the past 15 years. Poleman and Thomas (1995) showed that the relation between GDP and the consumption of animal products holds for many more countries than those in the sample presented here.

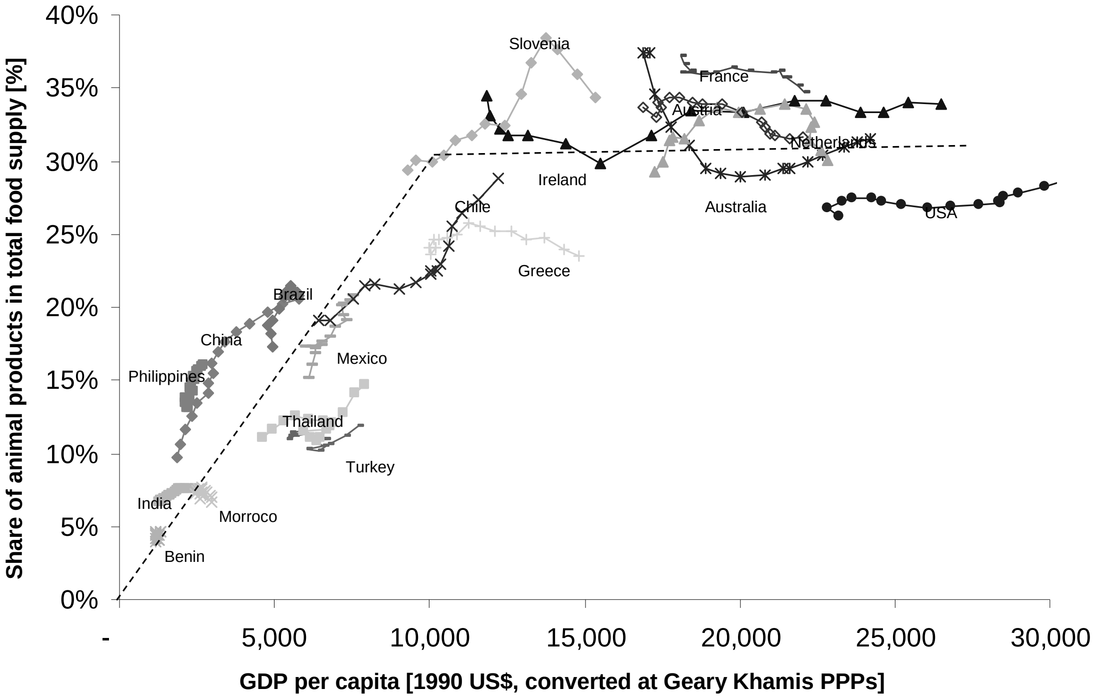

Figure 4: The relative consumption of animal origin food products (share in total calories consumed) in relation to GDP per capita. The dotted line shows the relation between GDP and consumption of animal products used in this paper. (Data are for the years 1990 – 2005; sources FAOSTAT, 2007; GGDC, 2007).

4. Developments in energy use

Figure 5 shows the development of global energy use since 1850, according to main energy sources. Before the industrial revolution total use levels were low, and energy conversion was limited to burning of fuelwood for heating and cooking. Humans, horses, wind- and watermills provided mechanical power.

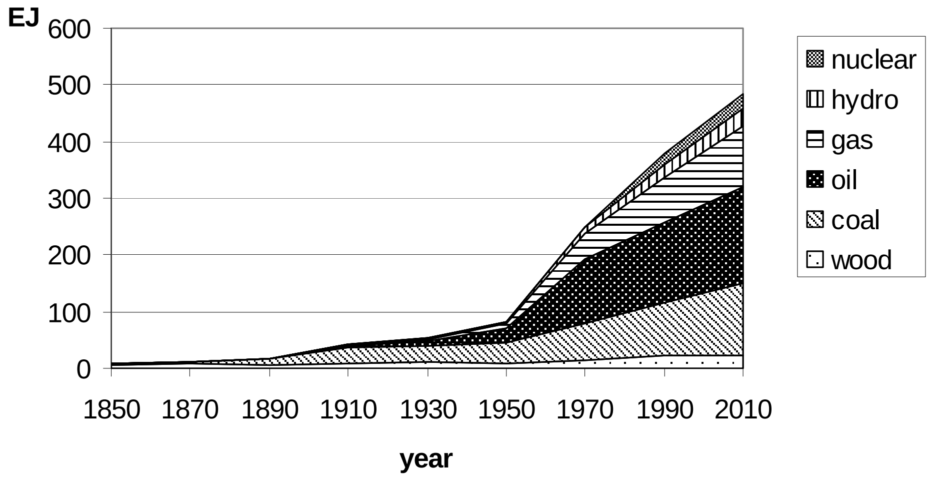

Figure 5: Development of global primary energy use according to main energy sources 1850 – 2010; (adapted from Grubler and Nakicenova, 1997, using data from IEA 2009a).

The introduction of the coal powered steam engine resulted in large changes within the energy system. It presented the first large scale conversion from fossil energy into power. At the beginning of the 20th century, global energy use had increased to about 50 EJ y^{-1} and coal had become the most important energy carrier (Figure 5).
The introduction of electricity as an energy carrier (supplying light, heat and power) and the development of the internal combustion engine triggered the second transition: the introduction of oil as energy carrier, followed by the introduction of natural gas. At the beginning of the 21st century, total energy use equalled 450 EJ y^{-1} and this amount was supplied by a variety of sources: natural gas, oil, coal, hydropower, nuclear power and wood.

The main developments from 1850 onwards were an increase in total energy use and drastic changes in source composition. The situation in individual countries deviates from the global average. Differences are found in the total amount of energy used, the used energy carriers and the timing of changes from one carrier to the other. Figure 6 shows per capita energy use for the same group of countries as shown in Figures 2 and 4. A fairly linear relation between GDP and energy use can be found. Developed countries require nearly 5 times as much energy per capita as developing countries. However, also large differences between countries at the same income level can be found. An average person in the USA uses around 350 GJ/year, while for an average Irishman, being at the same income level, this level is only at around 200 GJ/year. Next to the total amount the used carriers differ greatly. For instance, in the developing countries biomass (wood), is still an important energy source (38%), while in the developed world it only accounts for 3% of the energy supply (IEA, statistics 2009b).

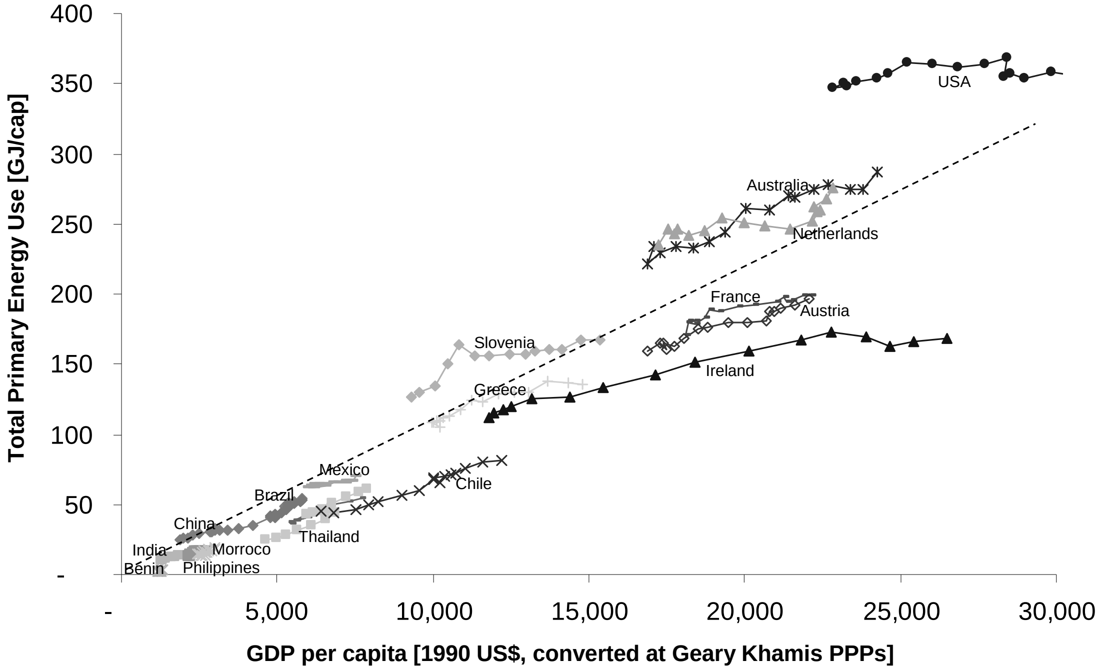

Figure 6: Energy use per capita as function of GDP. Dotted line shows relation used in this paper. (Data are for the years 1990 – 2005; sources FAOSTAT, 2007; EIA, 2007).

At present, coal, oil and gas account for over 90% of the global energy use (Figure 5). These are fossil energy carriers, originating from prehistoric plant material and their combustion leads to CO_2 emissions. Historical data on atmospheric CO_2 concentrations reveal fast increasing global levels from 1950 onwards (Figure 7).

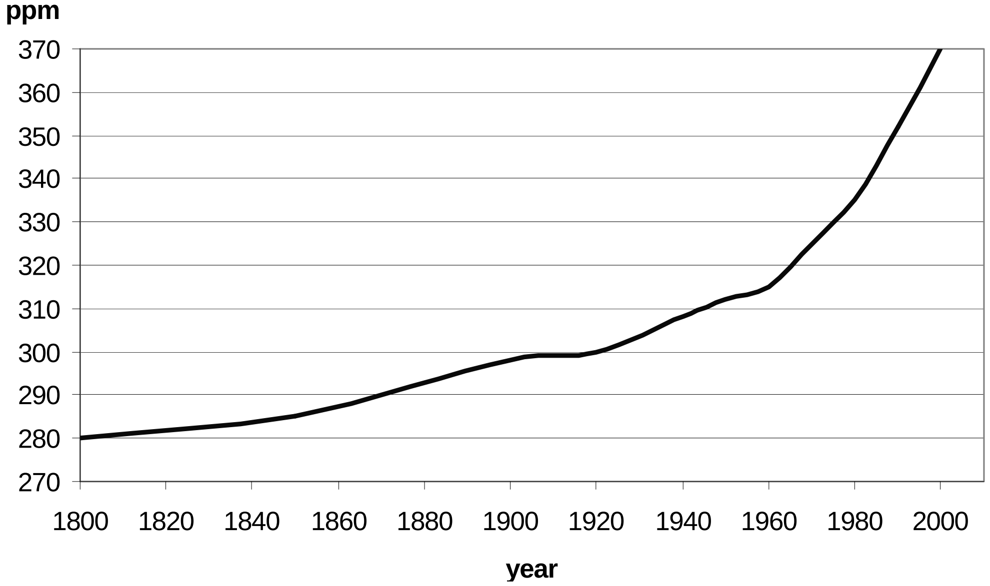

Figure 7: Historical trends in atmospheric CO_2 concentration (Solomon et al., 2007). Data before 1960 are based on ice core data, data after 1960 are measurements.

As rising CO_2 levels are affecting global climate, OECD countries have put forward policy plans aiming at the reduction of national CO_2 emissions. Biomass as an energy source plays an important role in these plans. Both in the EU and in the USA, policy programs aimed at deriving 10% of total energy use from biomass by the year 2020 exist (FAO, 2008, Steinbeck, 2007). These programs include the use of biomass as feedstock for electricity generation as well as the use of biofuels (ethanol and biodiesel) as transport fuel. Ethanol and/or biodiesel are obtained from food crops such as wheat, maize, sugarcane, rapeseed, oil palm; and they tend to compete with food production. So-called second generation biofuels use other types of biomass as feedstock. However, techniques to produce second generation biofuels are still under development and not yet available on the market. Since these technologies are not expected to supply relevant shares by 2020, we do not include them in our short term outlook model below.

5. Assessing future food, feed and fuel need in various parts of the world

In the previous paragraphs we described past and present needs for food, feed and fuel in various parts of the world. When talking about future needs, one has to realize that the drivers behind changing demands differ between countries. In some countries population growth is large, in some countries there is a strong increase in the demand for meat and in other countries new energy policies are put into practice. We simplify the large variety in welfare throughout the world into three groups: poor people living in developing countries, rich people in Western Europe (EU) and the USA, and people in the so-called transition countries showing a fast economic development.

In developing countries (GDP up to $ 2000 per capita) consumption of meat and energy is very low, but population growth is large (around 2%). This implies that in the coming decades these countries need extra food to fulfill the needs of their growing populations. At present these countries accommodate around 3 billion people (Worldbank, 2008). Assuming population growth at 2%, this population will increase to 5 billion within 20 years. Since, in these countries, economic development is slow, neither major changes in meat consumption nor an increase in the use of biomass as an energy source are expected.

About 2 billion people are living in the so-called transition countries; these countries show fast economic development with GDP growth rates of around 6% per year. This implies that within 20 years their GDP will grow from around $ 2.000 to 10.000 per capita. Following the relation shown in Figure 4, their animal product consumption will reach saturation levels of around 35% of total calories consumed. This implies for transition countries that present levels of meat consumption are still low (5-10%), but the needs for livestock feed will increase continuously.

The EU and the US together have about 1 billion inhabitants. In these countries population increase is low and their animal product consumption has reached the saturation levels. Therefore no drastic changes with respect to biomass needs for food and feed are to be expected. However, these countries are putting energy policies aimed at combating the effects of climate change into place. Biomass, often considered a carbon neutral energy source in this context, is playing an important role in these policies. Most policy plans mention a target of 10% of total energy supply from biomass for 2020/2030 (Steinbeck, 2007; OECD-FAO, 2009). Present energy use in developed countries is at 200 to 400 GJ per person per year. The policy goals therefore imply that at least 20 GJ of energy should be obtained from biomass within 20 years.

6. Quantifying biomass needs for food, feed and fuel per capita

Since it is not possible to compare kilograms of rice, liters of milk, kWhs of electricity and liters of gasoline, for our study all biomass demands should be converted into one common unit. In food security studies this common unit is often the so-called grain equivalent (Penning de Vries et al., 1997). All food products are converted into grain equivalents. This equivalent can refer to the amount of grain needed to produce the food product (like livestock feed to produce milk, eggs and meat, and barley for making beer). But the conversion can also take place via the land required to grow a certain product; when land is used to grow vegetables the same land cannot be used to grow wheat. Therefore, for instance, the yield of a hectare of tomatoes is compared to yield of a hectare of wheat. Luijten (1995) provides grain equivalents for many food products and the grain requirements for various diets. He concluded that basic diets in developing countries require about 1.3 kg of wheat per person per day, while affluent food consumption patterns in Western Europe require up to 5 times as much.

For our simple calculations, we assume that a simple diet in developing countries requires 400 kg of wheat per year. For the sake of simplicity, we only add numbers for livestock feed for meat for affluent diets. These diets contain around 100 kg of meat per year, and it takes about 4 kg of wheat to produce 1 kg of meat (Nonhebel, 2007). This implies that affluent diets require an additional 400 kg of cereals as livestock feed. For our simple model calculation, the total need for food and feed for affluent diets is therefore 800 kg per person. This is far less than the values in grain equivalents for affluent diets as given by Luijten (1995). This is because, in this paper we do not aim at assessing grain equivalent demands for affluent diets but an estimate on biomass needs for livestock feed.

We extend the methodology developed in food security studies by including the energy supply system. For this we calculate the amount of grains needed to produce a certain amount of an energy carrier. There are different routes to convert biomass into energy: it can be combusted in a power plant yielding electricity, grains can be fermented providing ethanol that can be used as a transport fuel, but biomass can also be used in a digester, producing methane (gas). Using biomass as a feedstock for electricity generation provides the largest CO_2 savings; in that case biomass is replacing gas, or coal (Wahlund et al, 2004). The heating value of dry biomass is 18 MJ/kg. This factor can be used to convert energy, expressed in Joule, into biomass needs (grains). For our example, the production of 20 GJ of energy requires about 1100 kg of biomass.

7. Comparison of biomass needs for food, feed and fuel on a global scale

We now use this basic categorization and assumptions to assess (additional) global biomass needs in the near future. Figure 8 shows the overall results in 4 different graphs: the upper two show the results per person (kg/capita) and the lower two show the results in absolute terms (MT). The 1 billion people in the developed part of the world require 400 kg cereals for food and 400 kg for feed (A). The other 5 billion people (3 billion in developing countries and 2 billion in the transition countries) have very simple menus, containing only very small amounts of affluent products. They require only 400 kg of cereals per person. At the global scale, this results in a total need for cereals of about 2800 MT per year. The largest share, 2400 MT, is for food, 400 MT is needed for livestock feed, for meat consumption in the developed countries. Note that a person in the EU/USA requires twice as much grain as a person in Africa. The total need for food is largest in developing countries (1200 MT) due to the number of people living there (C). The total cereal demand in transition countries (2 billion people) is as large as the demand in developed countries (1 billion people).

Assuming changes in biomass demand as discussed in the section 5, the following picture emerges: consumption patterns in the developing countries remain at the same basic levels; therefore still 400 kg of cereals are needed per person. In transition countries higher shares of animal product enter the diet, implying an additional need for livestock feed of 400 kg per capita. In developed countries, menus do not change, but biomass is needed as a result of changes in the energy supply system. As a consequence, in these countries the need for biomass for fuel is considerably larger than the combined need for food and feed (B).

At the global scale, (D) the large population increase in the less developed countries leads to an additional need for food of 800 MT, while the cereal needs for food in the other parts of the world remain the same. The need for livestock feed in the transition countries leads to a cereal demand of 800 MT of, equaling the additional need for food in developing countries. Finally a large cereal demand as energy carrier (1100 MT) in developed countries emerges.
The overall result of this basic model calculation is that within 20 years the global demand for cereals will almost double from 2800 to 5500 MT.

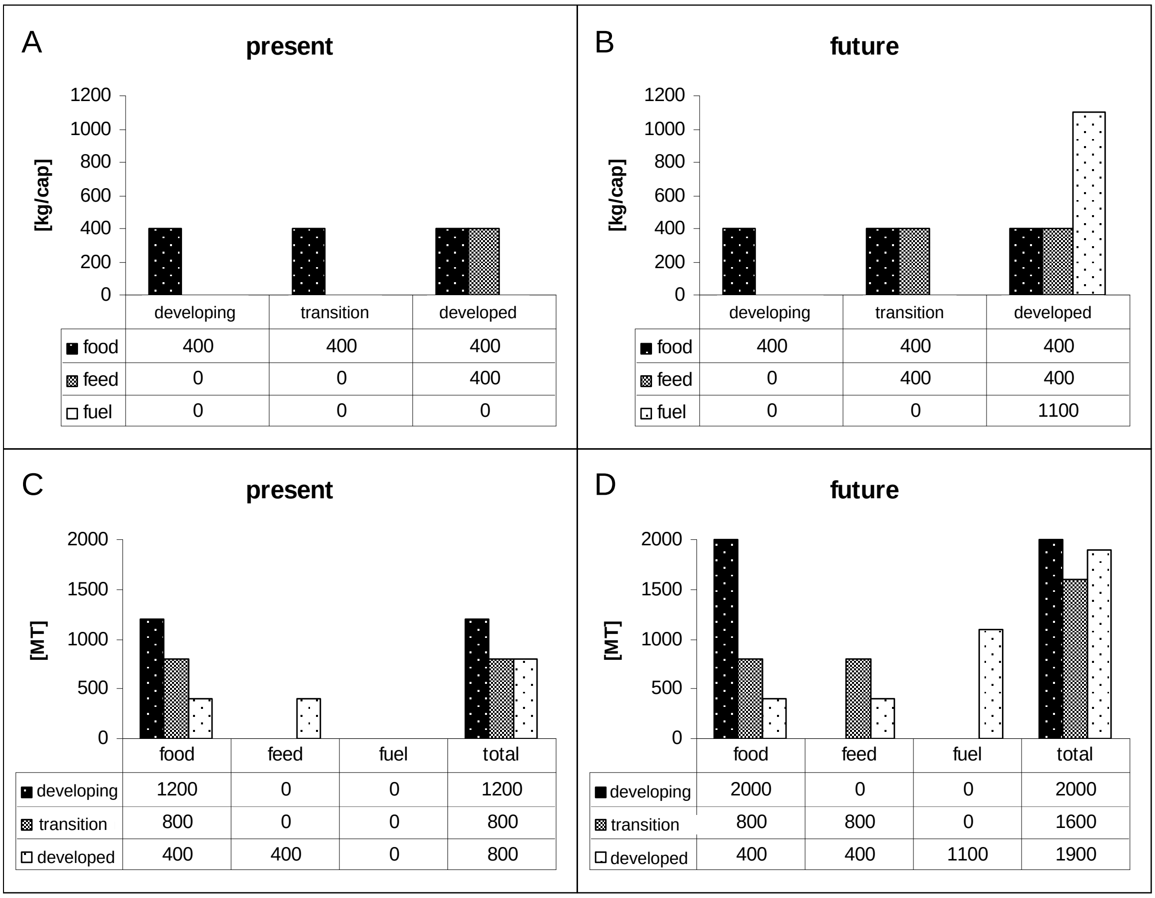

Figure 8: Demands for food, feed and fuel as calculated with the model presented in this paper. (A) Present per capita demand, (B) near future per capita demand (2 decades), (C) present needs on a global scale, and (D) near future needs on a global scale.

8. Discussion

The model presented in this paper involves large simplifications. It only considers two different diets and one type of renewable energy in three different economies. The actual situation shows much more variation around the globe and for forecasting future needs for food, feeds and fuel more detailed models will be required. The goal of this analysis, though, is to determine the order of magnitude of the need for biomass as an energy source within the next decades in comparison with the needs for food and livestock feed. Therefore we only discuss the results of the model according to their order of magnitude.

The present need for food and feed at a global scale is calculated to be 2800 MT cereals per year (figure 8). The present global production of cereals is 2100 MT, which is far lower than the model output. However, the model assumes that all needs are fulfilled with cereals, while in practice cereals only supply 70% of the calories consumed on global scale (the remainder is fulfilled with potatoes, beans etc. (FAOSTAT, 2007)). Moreover it is assumed that meat is obtained from livestock fed with cereals, while in practice a large share of the animal products originates from ruminants fed with roughage. Correcting for this, the model outcomes reflect the actual situation quite well.

With respect to the future needs the model outcomes show an increase of cereal demand by 1600 MT (50%) for food and feed within 20 years; this is in accordance with FAO estimates. The OECD-FAO (2009) report on biofuels and food claims that half of the extra needs for cereals in the near future will be due to the use of biomass for energy purposes. In our model this value is 30%; this difference can be again explained by the fact that we assume that all food is provided by cereals, and therefore the fraction needed for energy purposes will be smaller.

With respect to the need for food, feed and fuel within the next decades, the results of our basic model show the same pattern as those provided by more complex models used by FAO and OECD. This implies that the values presented are in accordance with the estimates available in this research field. We can now focus on the consequences of our findings for the food supply system.

First it is striking that the need for biomass for energy is huge in comparison with the need for food and feed. The policy goal of obtaining only 10% of the energy needs from biomass is going to more than double the biomass needs in developed countries. Presently 400 kg is needed for food, 400 kg is needed for livestock feed, and the need for energy will be at 1100 kg per person per year (Figure 8). According to these values, the need for energy will be nearly three times as large as the need for livestock feed. Therefore a person in the developed world, with a luxurious diet and obtaining 10 % of his/her energy from biomass requires four times more biomass resources as a person in a developing country on a simple diet and without access to comparable energy sources. The value is still more than twice the amount of biomass per person used in the transition countries. This large difference results from the high energy use levels in the developed part of the world: Figure 6 shows that they are above 200 GJ per person per year. The average food consumption per person equals only about 10 MJ per day (2500 kcal): on annual basis this is 3.6 GJ. When 10 % of the total energy demand is to be fulfilled with biomass, 20 GJ is needed: this is five times the need for food. This huge difference also indicates the limited potential of rest streams from the food system as energy source. Since the demand from the energy system is 5 times as large as from the food system it is obvious that residues from the food system will never be enough to full fill the energy needs, which implies that extra crops have to be grown.

In developed countries, the present use of biomass for energy generation is very small (about 1% of the energy supply) and involves mainly the use of waste streams from the food industry (nutshells etc.) for energy generation and some wheat and rapeseed for biofuels. To reach the 10% policy target within the next 20 years, large quantities of biomass will have to enter the energy system. Presently, the relatively high price of biomass compared to the price of fossil energy carriers limits the use of biomass as an energy carrier. Table 1 shows the price of various biomass streams for both agricultural and energy markets.

It shows the price a farmer gets when he sells his product as livestock feed compared to feedstock for electricity generation. Selling biomass as livestock feed results in higher returns than selling it as energy source. The difference depends on the material used as livestock feed: selling soybean scrap results in nearly €300 per ton, while selling straw only results in € 50 per ton; both biomass streams only yield € 50 per ton when sold as feedstock for energy generation. So presently, energy use is only competitive for biomass with low feed qualities.

Table 1 Comparison between prices of various agricultural products when sold as feed or as energy source. Prices refer to November 2009 values (sources: price as feed: LEI, 2010; Compendium Leefomgeving, 2010; price as energy carrier calculated assuming the energy price at 3€ per GJ).

Product	Price as feed [€/ton]	Heating value * [GJ /ton]	Price as energy carrier [€/ton]
Wheat	150	16	48
Soy bean scrap	290	16	48
Sugar beet pulp	25	2	6
Straw	55	16	48

*Source: Nonhebel, 2007.

If price differences remain, the energy system and the food system will remain separated and it is unlikely that the policy goal of 10% of energy from biomass will be achieved. If governments introduce incentives to promote the use of biomass as an energy source, the food system and the energy system will become more intertwined. Energy producers will enter the food markets to obtain feedstock for energy generation. Since their demand is huge compared to the total volume available on the agricultural markets, this will lead to large instabilities on the food markets.

9. Conclusion

The sustainable energy policies in OECD countries aim at 10 % energy from biomass within the next decades. The amount of biomass required to fulfill these energy requirements is larger than present needs for food and fuel in these countries. Therefore the implementation of these energy policies is likely to result in large instabilities on agricultural markets.

References

Compendium voor de leefomgeving (2010). http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0554-Energieprijzen-en-wereldolieprijs.html?i=6-38

Evans L.T., 2001. Feeding the ten Billion, Cambridge University Press, Cambridge, . 247 pp.

EIA, 2007. International Energy Annual (IEA) - long-term historical international energy statistics. (http://www.eia.doe.gov/iea/)

FAO, 2006. Livestock's long shadow. Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C., FAO, Rome, 407 pp.

FAOSTAT, 2007. FAOSTAT Statistical Database. (http://faostat.fao.org/)

FAO, 2008. The state of food and agriculture 2008, biofuels, prospects, risks and opportunities.

FAO, 2009. The state of agricultural commodity markets 2009. FAO, Rome, 63 pp.

Grubler, A., Nakicenovic, N., 1997. Decarbonizing the global energy system. Technological Forecasting and Social Change 53, 97-110.

GGDC 2007. The Conference Board and Groningen Growth and Development Centre, Total Economy Database, November 2007. (http://www.conference-board.org/economics)

IEA 2009a, Annual Energy Review 2008 Report No. DOE/EIA-0384(2008).

IEA, 2009b. Key World Energy Statistics, IEA, Paris, France.

LEI, 2010. http://www.lei.wur.nl/NL/statistieken/Agrarische+prijzen/.

Luijten, J.C., 1995. Sustainable World Food Production and Environment. AB-DLO Report no. 37. AB-DLO, Wageningen, The Netherlands.

Nonhebel, S., 2007. Energy from agricultural residues and consequences for land requirements for food production. Agricultural Systems 94, 586-592.

OECD-FAO, 2009. Agricultural-outlook 2009-2018, OECD, Paris, France, 279 pp

Penning de Vries, F.W.T., Rabbinge, R., Groot, J.J.R., (1997). Potential and attainable food production and food security in different regions. Phil. Trans. R. Soc. Lond. 352, 917-928.

Poleman, T.T., Thomas, L.T., 1995. Income and dietary change, Food Policy 20, 149-159.

Popkin B.M, 2002 The dynamics of the dietary transition in the developing world. In: Caballlero, B and Popkin B.M (eds). The nutrition transition : diet and disease in the developing world, Academic Press, Amsterdam, 111-121.

Steinbeck, R., 2007. Biofuels at what cost? International Institute for Sustainable Development, Geneva, Switzerland. 72 pp.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.), 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Trostle, R., 2008. Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices, Economic Research Service/ USDA. WRS-0801.

Wahlund, B., Yan, J., Westermark, M., 2004. Increasing biomass utilization in energy systems: a comparative study of CO_2 reduction and cost for different bioenergy processing options. Biomass and Bioenergy 26, 531- 544.

World Bank, 2008. World Development Indicators 2008, Worldbank, New York, USA