1. GLOBALISATION AND FOOD SECURITY: THE ROLE OF LAND AND WATER USE[1]

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1.1 Introduction

At the dawn of the 21st century, the soaring demand for virtually all commodities to meet human needs is putting huge pressure on global resources. Major concerns are still the hunger suffered by nearly one billion people and the appalling poverty of over a billion people earning less than 1 dollar a day. Concerns for energy supply and attempts to reduce greenhouse gas emissions (GHG) have recently led to the compulsory blending of fossil fuels for transport with biofuels and subsidised production of energy from biomass, as in the EU, USA and Brazil. This adds a new and potentially huge demand on global natural resources. It is unclear whether these demands can all be met whilst preserving biodiversity and bringing more social and economic equity to the world.

However, these concerns are important for promoting optimal use of the world's resources for sustainable development. Agriculture must make a major contribution to resolve many of these issues. The role of agriculture as a motor for overall economic growth has been recognised. Food production must increase dramatically in the coming decades, yet it is agriculture that makes the greatest claim on natural resources, including land and water.

In this paper we will discuss food security in a globalising world. In particular, we will focus on the pressures on natural resources and on the challenges these pressures entail for land and water use.

1.2 Food security today

Estimates of global food production potential based on a production-ecological approach counter Thomas Robert Malthus' prediction that 'the power of population is indefinitely greater than the power in the earth to produce subsistence for man' (*An essay on the principle of population*, 1798). As could be shown, global production potential surpasses food requirement even if the global population exceeds 10 billion consuming a meat-rich diet. The analyses however revealed great differences in production potential between global regions. Asian countries lack production capacity to be self-sufficient in food whilst other global regions, such as Latin America, have surplus capacity. This suggests that a global redistribution of food is essential to secure food for all.

1 The text of this chapter is largely taken from: Bindraban, P.S. and Rabbinge, R. (2011) European food and agricultural strategy for 21st century, *Int. J. Agricultural Resources, Governance and Ecology*, Vol. 9, Nos. 1/2, pp. 80-101. See this article for additional explanation and references. The authors wish to thank Adri van den Brink for his excellent job in compiling this paper.

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Current food production, demand and trade values show that virtually all the food consumed in Europe is produced on its own territory. Over 250 million tonnes of cereals are produced against a total consumption including feed of slightly less than 250 million tonnes. Meat net trade is a fraction of consumption only. Europe is a net exporter of commodities, such as eggs, potatoes and milk, and a net importer of fruit and vegetable but with total per capita supply doubling amounts strictly needed for a healthy diet. Europe imports about one-third of its vegetable oils and fats and is fully dependent on imported soya beans. This situation of food self-sufficiency is not likely to change much in a business as usual scenario in the coming decades, nor even under full trade liberalisation.

As shown in Figure 1.1, some global regions will barely be able to be self-sufficient in food as production will be constrained by the availability of land and water. This will even apply with the most efficient use of natural resources. A ratio above two in Figure 1.1 can be considered secure because it assumes that half the modelled production levels would be attainable worldwide by the year 2040. For example, potential grain yields are calculated to reach 11 Mg ha^{-1} y^{-1} in temperate regions, whilst actual European yields reach 6 Mg ha^{-1} y^{-1}, with maximum yields exceeding 10 Mg ha^{-1} y^{-1} in some specific locations only such as the Netherlands. On the other hand, current cereal yields in most African countries hardly exceed 1 Mg ha^{-1} y^{-1}, while calculated yields reach 5 to 6 times these amounts.

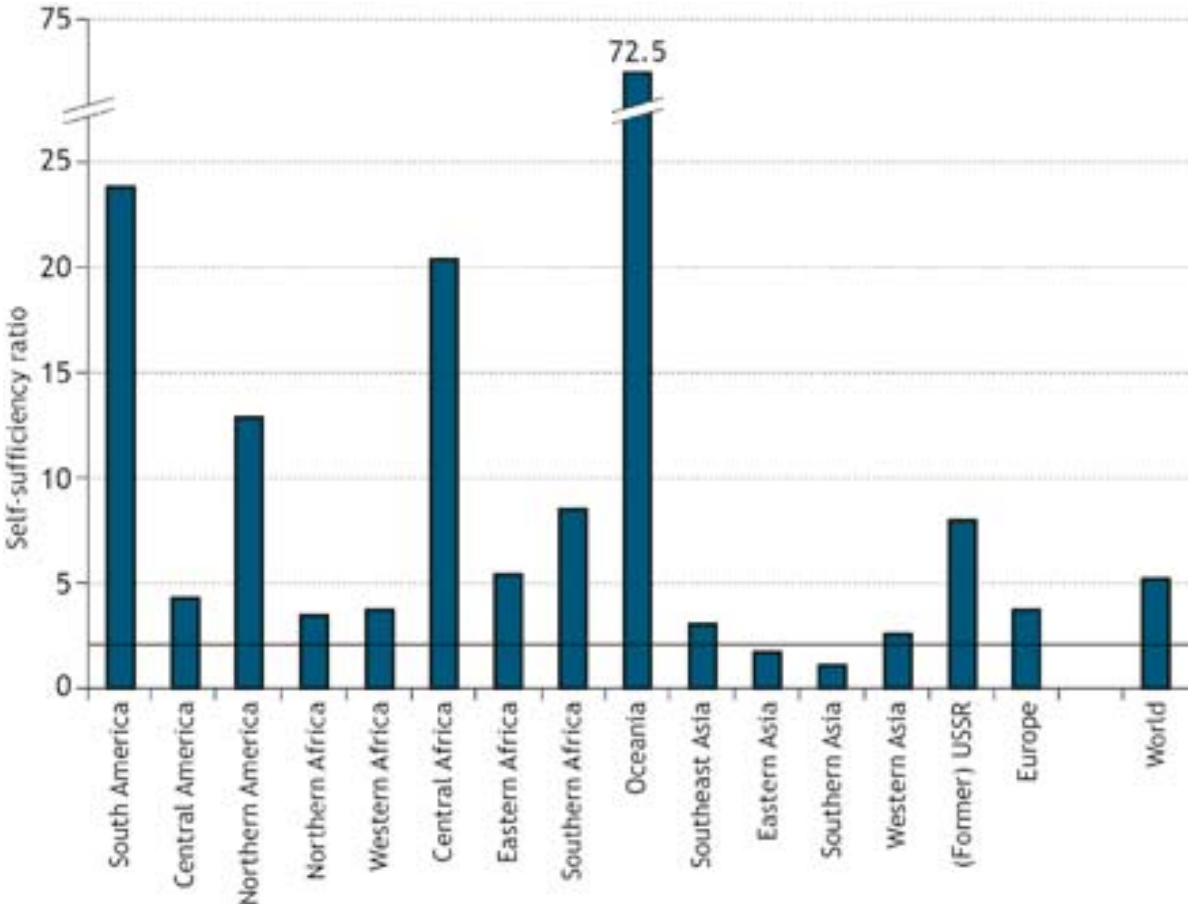

Figure 1.1: Self-sufficiency ratio for global regions consuming a meat-rich diet for a medium population projection of 9.4 billion in 2040.

Southern Asia, comprising India and the Near East, and Eastern Asia primarily representing China, will hardly be able to feed their own population. The production potential in North America, the former Soviet Union and Australia exceed food requirements. The same applies to Europe, while Latin America has the greatest potential, also in absolute terms. The production potential of the African continent exceeds demand by the African population too, indicating that the current food shortages result from underdeveloped agriculture. These regional differences also illustrate the need for a physical redistribution of food among regions to attain food security worldwide.

1.3 Declining availability of land and water resources

The availability of natural resources per person is steadily declining and access to resources, particularly by poor people, is rapidly shrinking. A growing population and growing demand for food, feed and fuel, with local problems of water pollution and soil degradation may trigger social tension. The unbridled purchase and long-term lease of extensive land areas by developed and wealthy nations, coined as land grabbing, mostly in sub-Saharan Africa, may lead to increased social tension. A less obvious claim on land is the control of production volumes of agricultural commodities by multinationals, such as in the soya bean chain.

The availability of suitable agricultural land is severely limited in most Asian countries with little space for expansion. The amount of agricultural land per person has steadily declined and will continue to decline due to population growth. India has virtually no permanent pastures into which it can expand its arable land and little natural land to take into cultivation. So far, the acreage per person could be maintained in China by the conversion of natural lands into pasture and arable land. Bangladesh is worse off and has to feed itself with 635 m^2 per person (Table 1.1). Even with a double crop and with increasing rice yields, the population could barely afford itself a vegetarian diet. Even though China has twice as much land per person and 50% higher rice yields than Bangladesh, the figures indicate the overall need for food imports by Asian countries. Furthermore, much of the most suitable fertile lands are occupied by growing cities and other hard infrastructure.

Land is abundantly available in Latin America, reflecting the huge potential to export food, certainly with the expansion of the agricultural frontier. A relatively large availability also applies to large European countries. Densely populated regions have inadequate amounts of cropland, like the Netherlands which has a mere 1179 m^2 per person. The Netherlands could certainly meet a vegetarian diet under an organic system without the use of fertilisers. However, it is unclear why that should be done, as environment and health do not require such a ban. While the Netherlands is a net importer of food and the second exporter of agricultural produce in the world, Europe as a whole holds a surplus production potential, up to four times its requirements. In sub-Saharan African countries, land is abundantly available relative to the low population densities.

Table 1.1: Agricultural land per person, required and actual cereal yields.

	Arable land 2005 m^2	Agricultural land 2005 m^2	Required yield		Actual yield 2005 Mg ha^{-1}
			Vegetarian diet Mg ha^{-1}	Meat diet Mg ha^{-1}	
Bangladesh	593	635	8.6	24.1	3.7
China	1181	4204	1.3	3.6	5.2
India	1538	1633	3.4	9.4	2.5
Indonesia	1643	2146	2.6	7.1	4.3
Argentina	7615	33385	0.2	0.5	4.2
Brazil	3573	14141	0.4	1.1	2.9
Paraguay	6980	39393	0.1	0.4	2.1
France	3246	4888	1.1	3.1	7.0
Germany	1463	2060	2.7	7.4	6.7
Netherlands	577	1179	4.6	13.0	8.3
United Kingdom	964	2831	1.9	5.4	7.2
Ghana	2887	6664	0.8	2.3	1.4
Kenya	1670	7888	0.7	1.9	1.6
Mali	3580	29205	0.2	0.5	1.1
South Africa	3313	21007	0.3	0.7	3.3
Tanzania	2700	8962	0.6	1.7	1.5

Production constraints are also imposed by the lack of water. Food production is almost linearly related to water use, approximating 1000 litres of water for 1 kilogram of grains. It therefore takes 1500 litres water to produce a vegetarian diet to over 5000 litres for a meat-rich diet per person per day, which converts to 547 and 1825 $m^3\ p^{-1}\ y^{-1}$, respectively. These values are similar to estimates by other authors of the water requirement for food production of 600-900 $m^3\ p^{-1}\ y^{-1}$ for African and Asian diets and 1700-1800 $m^3\ p^{-1}\ y^{-1}$ for North American diets. The availability of water per person in India and China is sufficient for food production and is declining, while use for other purposes has still to be accounted for.

The huge availability of water in countries like Brazil, Indonesia and Central Africa is due to their tropical climate and land dominated by rainforests. The agricultural corridor in sub-Sahara Africa is situated in the semi-arid and semi-humid regions running from Western to Eastern Africa south of the Sahara and along the east from Ethiopia to South Africa crossing the highlands and great lake area. Though water availability is not high in these agricultural areas, there is still sufficient scope to increase the current low yields because water is not the prime limiting factor to yield but lack of nutrients due to poor soils. This scope to increase yield given the available water applies less to Asian countries where yields are 2-4 times higher than in Africa and where fertiliser application is also high.

1.4 Megatrends in agriculture

Future food security is heavily influenced by a number of developments that can be grouped into six megatrends in agriculture. The first of these megatrends is productivity rise. In the Netherlands, for example, land productivity increased 5 to 6 times in the past century. In the same period, labour productivity increased 200 to 300 times, while energy and other inputs increased 2 to 4 times in their use efficiency. Yields are expected to continue to increase, though levelling off.

The second megatrend can be called ‘From craft to industry’. Whereas agriculture traditionally had to adapt to nature and to environmental uncertainties, it is increasingly able to control production and the use of inputs such as fertilisers and pesticides. There is much scope to further optimise input use, whilst increasing production and reducing environmental impact. Crop modelling techniques make it possible to identify optimal timing strategies for fertiliser application, for example, and nutrient balances can be further closed to minimise losses. Insights into ecological predator-prey principles allow reduction of agro-chemical use to a minimum. Close-sensing allows early detection of plant stress from diseases, and water or nutrient shortages to take timely actions and prevent losses, while global positioning systems with close and remote sensing facilitates precise spatial applications. Farming systems are designed to minimise environmental impact, whilst maintaining high and economically viable production levels. The introduction of non-terrestrial substrate agriculture, especially in greenhouse production, has made it possible

to minimise resource use by computerised circuits to close nutrient and water cycles. During the summer, heat is stored in aquifers for heating during winter and application of additional radiation is minimised by special lamps. Glasshouses are developing from big energy consumers into net energy producers. Robotised milking and harvesting of greenhouse products boost the already high labour productivity. Alignment of agricultural and industrial activities in their regional setting further optimises the reuse of natural resources. These integrated approaches will allow Europe to maintain its leading position in global agriculture that attains high levels of productivity in terms of land, labour and capital, while minimising environmental side effects.

The third megatrend is improved chain management. The subsequent steps in agricultural production up to consumption of (processed) agricultural products are increasingly regarded and managed as the links of a continuous chain ('from spade to plate'). The reverse is also true: agricultural production is increasingly consumer (or retail) driven. The need to supply low cost, safe and high quality food, the need to minimise environmental impact and the demand for convenience foods etc. are important factors in this integrated chain management approach. Logistic efficiency, such as on time delivery, strongly influences the unit cost of production. Value is added on at numerous stages of the chain and accumulates at the end of the chain. The fourth megatrend is implied in the previous ones. This megatrend refers to agriculture that, due to tightening social and political constraints, increasingly aims at multiple objectives besides food production. This means, for example, an environmentally and animal friendly production method (no pollution or waste, good living conditions), and concern for the landscape. In further integrating social, economic and ecological objectives, the challenge is to combine various functions at farm and regional scale. This implies the integration of plant and animal production with environmental care, conservation of nature and the composition of landscape, and care for health and wellbeing, including tourism and recreation.

The fifth and sixth megatrends are the increasing attention for food and health in society and the rise of the bio-based economy. It is generally acknowledged that fruit, vegetables and fish are good for health. Agriculture aims to supply a health inducing component in its products through choices in input, farming systems and consumer-oriented processing (products with less polyunsaturated fats, for example). The concept of Good Agricultural Practices applies to on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, whilst taking into account economic, social and environmental sustainability. This includes land and water conditions. Tracking and tracing systems also strongly contribute to controlling food safety as they enable the rapid identification and reporting of the spread of animal diseases in the production chain or the source of toxicants (BSE, dioxin). Finally, the rise of the bio-based economy challenges agriculture to produce new products such as biofuels and biomaterials, implying the introduction of adapted crops and new systems of production and processing (biorefinery, for example). These new products obviously compete

with food production for a growing world population. Bioenergy as such should therefore never become an aim in itself but as the final residual product in biorefinery and biocascading it may help limit waste.

1.5 Food security: a global responsibility

The world's population is expected to increase from 6 billion people in 2000 to 9 or 10 billion in 2050. These people will need access to a rich calorie diet and access to a diet based on animal products (increasing wealth leads to increasing meat consumption). As a consequence, double the amount of primary products is required in 2050 for food and livestock feed. This can only be achieved by extending farmlands and through higher land productivity. Unfortunately, the potential for increasing agricultural acreage is limited, due to desertification and urbanisation, the protection of biodiversity, and limited water availability. Progress in food production is urgently needed to combat hunger in many parts of the world. It must be noted that hunger today is primarily a matter of access to food. World food production is globally sufficient, but the majority of food is locally produced and consumed. Therefore surpluses in Latin America cannot solve structural shortage in Africa. That requires economic development in Africa, starting with agriculture, as food insecurity is most present in rural areas.

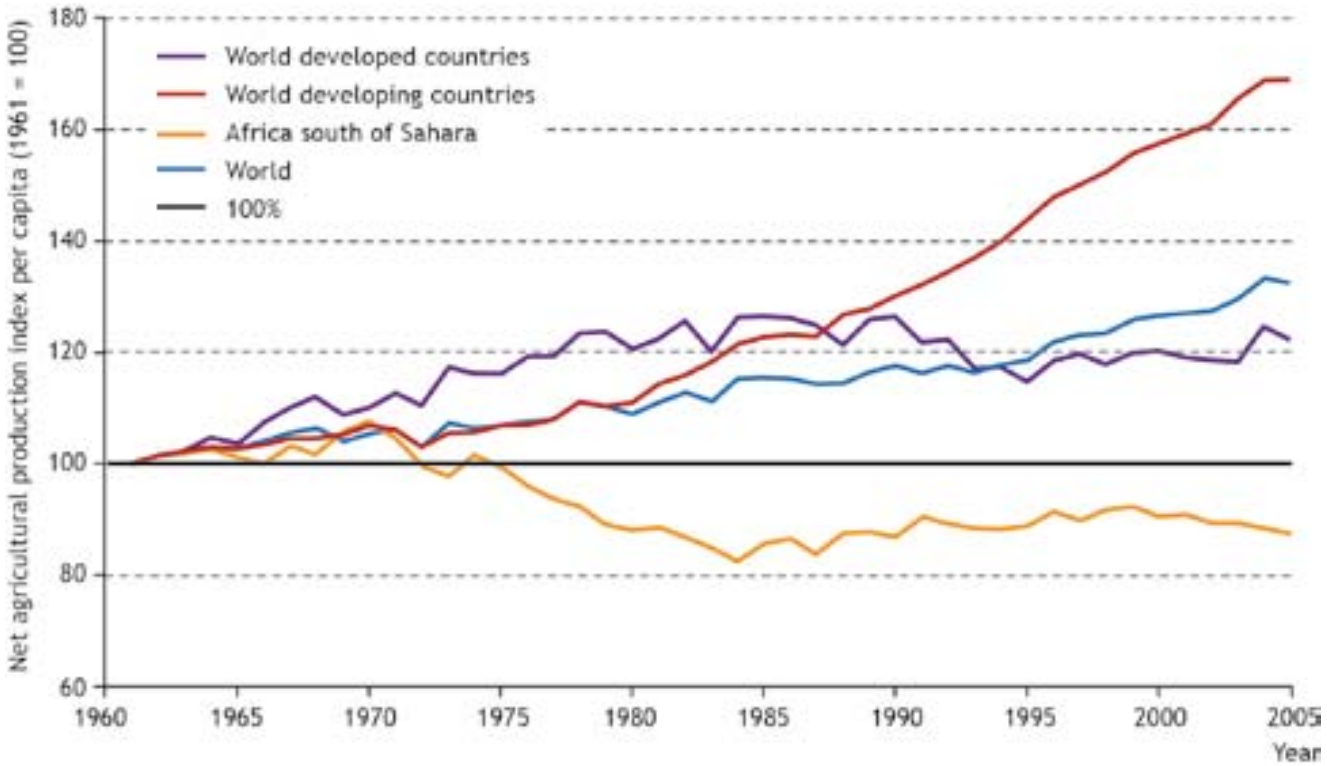

Figure 1.2: Decreasing availability of food per person.

As Figure 1.2 shows, food availability per person has risen considerably in Asia and Latin America in the decades between 1960 and 2000. In China, the accelerated consumption of meat as a result of rising income produces large claims on feed that is increasingly being supplied from

Latin American countries. Imports of soya beans for pigs and chickens by China have increased from 5 million tonnes in 1990 to over 40 million tonnes in 2009. India has increased its soya bean production from a mere 2 million tonnes in 1997 to over 8 million tonnes in 2006 to feed its chickens, whilst imports have yet to take off. The increasing demand for more luxurious food items creates a great export opportunity for Europe. It could thereby emphasise high quality food products like meat, milk and processed food items, but should exploit its own production capacity for the production of its feed and raw material. Cereals and even soya beans or substitute fodder crops could be produced to feed its livestock. Importing feed shifts the pressure on natural resources to other parts of the world, primarily Latin America and Africa, and Europe would not bear its share in redistributing food, i.e. in virtually redistributing land and water. Moreover, nutrient cycles can be better closed with geographically linked feed and meat production as this prevents the transport of nutrients overseas. Europe could turn the slowdown of its internal food market volume into an opportunity to supply the high quality market segment of Asian consumers, which could become a major driver for Europe to revitalise its agricultural sector.

Latin American countries have a relative abundance of productive land and even more importantly, of available fresh water (see Table 1.1). Not surprisingly, virtually all nations in the world have found their way to these countries to satisfy their growing demands for food, feed and fuel. The global importance of Latin America in providing food, feed and fuel to the world is so vast that how Latin American countries manage their natural resources is becoming a concern for the international community. Overexploitation of the enormous biodiversity of the world's largest rain forest area, for example, would not only affect the economy and ecology of Latin America, but of the world as a whole. The efficient use of the natural resources of Latin America and planned exploitation is essential for its sustained development. Poorly planned, abusive and inefficient use of natural resources always comes at a high price, curtailing economic development opportunities, causing social unrest and jeopardising the sustenance of ecosystems (agro-ecosystems and natural ecosystems).

It is for these reasons that some nations, particularly in Europe, are concerned with the sustainable exploitation of the natural resources, inside and outside Europe. In Europe, sustainability criteria such as those presented in agreements on Good Agricultural Practices and stringent conditions for agricultural production are imposed on farmers, but also on other actors and activities along the production chain. It is also in Europe's interest to support the sustainable exploitation of natural resources outside its territories. Europe imports large quantities of soya beans from Latin American countries, for example, and global demand is growing so fast that strong governance is needed for soya bean growth and expansion to become more sustainable.

Platforms are needed and have been installed in recent years (for example the Round Table on Responsible Soy – RTRS) to negotiate the desires of the various actors worldwide who are

directly involved in the chain and stakeholders who have an indirect effect on chain behaviour to arrive at acceptable sustainability principles. A fair representation of all stakeholders throughout the entire supply chain and transparent communication among the stakeholders and with a broader public are essential components of the governance structure of these platforms. Sustainability criteria are collectively developed for all kinds of agri-business related activities that can be implemented under practical conditions. Non-governmental organisations serve as the conscience of the world and its people; the private sector is increasingly assuming its corporate responsibility by considering the people and planet dimension in addition to the profit dimension in their undertaking, and governments are seeking ways to guide global development processes. Research institutions can provide these processes with options for viable ecological, social and economic practices that increasingly comply with sustainability criteria as set by the platform. It is through these mechanisms that Europe could make a great effort to support the development of sustainable production systems.

Figure 1.2 also shows that progress in food production has been so disappointing for sub-Saharan Africa (SSA) that it faced a 12% reduction in food availability per person over the past four decades and has over 180 million malnourished people. It is increasingly recognised that agriculture plays a pivotal role, not only in food production but also in overall development. After all, agricultural development has served as a stepping stone for overall economic development in developed nations and in newly developing economies in Asia. Today, 90% of the African population lives in rural areas and 70% of the labour force works in the agricultural sector. Agriculture generates 30-60% of GDP which indicates that labour productivity is low compared to other sectors.

Yield is a strong indicator for progress in agriculture and suggests a poor overall development as crop yields have only marginally increased in SSA over the past four decades while the increase in total production is mainly due to the expansion of agriculture area. The harsh biophysical conditions call for concerted action to raise crop and animal production. Much of the continent has infertile weathered soils and little fertile alluvial and volcanic soil; severe pest and disease pressure, fatal animal diseases and an erratic water supply further depress land productivity. However, the potential to increase yields is substantial. Pronounced improvements may be obtained with the simultaneous use of various inputs. The intense geographical variation in the mineral content of soils necessitates location-specific fertilisation strategies to optimise impact on productivity and location-specific breeding strategies to cope with the high variability, where biotechnology might appear a valuable tool. Targeted breeding with biotechnology could be supported by European scientists, which will also enhance their knowledge and insight into a technology that is not yet fully accepted by Europeans. As a result, Europe will improve its global competitiveness in green biotechnology and might even stimulate its own overall economic development. Similarly, integrated approaches on nutrients, pests and diseases, and water management can be stimulated by European scientists to raise productivity.

Inspired by the UN Millennium Development Goals (MDG), various plans were developed to improve the livelihood of the African people, including a strategic plan for harnessing science and technology for agricultural development in Africa and a plan to combat hunger by the Hunger Task Force of the United Nations. Despite many reports and strong political commitment, actual support has been declining, and foreign direct investments in the poorest countries are extremely low. Currently, China is investing heavily in the African continent to secure its own national demands. Also, organisations such as the New Partnership for Africa's Development and the Alliance for Green Revolution in Africa have started to support agricultural development, primarily by emphasising the development of the institutional conditions for input and output markets and capacity building, as well as by extensive programmes on input supply such as fertiliser and healthy seeds and agro-dealer networks. Private charity foundations are leading initiatives in stimulating rural development. Europe could assume a more decisive role in supporting agricultural development in Africa. While this would alleviate the continent from its worst inhumane living conditions, it would also benefit Europe and European agriculture by increasing its agribusinesses in inputs such as seeds and agro-chemicals as well as mechanisation and knowledge and expertise in integrated agriculture. The whole food chain including food industries is pivotal for such development.

1.6 Agro-energy

The demand for agro-energy has suddenly increased in recent years because of policies for compulsory blending of transport fuel and subsidies for the production of biomass for energy. A number of concurrent global problems have fuelled the sense of urgency for biofuels. CO_2 neutral energy from biomass would be a good response to curb climate change, and would allow countries to comply with the Kyoto agreements to reduce CO_2 emissions. The dispersed production of energy throughout the world suits the current geopolitical strategies to reduce the dependence on a few energy suppliers. In OECD countries, biofuels are seen as a way out of misery for the rural population due to the dwindling agricultural sector and have been strongly lobbied for by the agri-business. Investors have also been charmed by the idea that the global potential of biofuels could be high. However, the sudden and uncontrolled interventions in the flow of food commodities have already caused price shocks and insecurity in the food sector, leading to an estimated additional 50-100 million people to go hungry in 2007.

Production of biomass for biofuels will put additional claims on natural land because all current agricultural land will be needed in the coming two or three decades for the production of food and feed. The clearing of natural lands will cause emissions of CO_2 because of the removal of vegetation and decomposition of soil organic matter ranging from 20 to over 350 tonnes C ha^{-1}. The prevented CO_2 emissions from biofuels reach maximum values up to 3 ton C ha^{-1} but could even be negative under poor agronomic and chain management. It may therefore take 20 to over 150 years to recover the initial losses of CO_2 emissions. Also, N_2O emissions help negate

most of the potential CO_2 savings. Biofuels therefore worsen rather than reduce climate change. The growing scientific evidence for the detrimental effects of biofuels on ecology and society has raised political debate in the EU leading to stringent sustainability criteria and the call by civil society organisations to even abolish or reduce the obligatory blending targets. The relative contribution to energy supply is very limited, the GHG emission reduction absent and much land is needed to make a substantial contribution to threatened food supply and rising prices.

1.7 Conclusion: challenges for land and water use

One of the most important components of sustainable development is the efficient use of natural resources. Social and economic sustainability strongly depend on priorities given to human desires and the values attributed to commodities can be manipulated, for example by changing habits or through subsidies and tax exemptions to affect prices. To attain ecological sustainability, however, hard bio-physical principles should be respected, such as water and land availability that limits the quantities that can be produced. These conditions have revealed the need for a global redistribution of land and water resources between surplus and deficit regions in the production capacity of food.

Global water problems in particular call for attention. Worldwide freshwater withdrawals amount to about 4,000 Gm^3. Most of this water is used for agriculture (2,800 Gm^3 or 70%). Water withdrawals for agriculture are expected to increase, due to population growth and the increasing consumption of water-demanding diets (meat), while competition with other water-demanding sectors and water pollution will negatively affect water availability. Overall opportunities to find a way out of these problems include the introduction of other crops and water-saving practices at farm level, the expansion of irrigated land for food and changes in land use, such as the allocation of marginal agricultural lands to nature conservation. Such opportunities may be implemented at farm level as well as at river basin level. In many cases, however, implementation is hindered by the lack of infrastructure, inadequate farmer skills, poor communication between farmers and irrigation engineers, lack of labour force or political opposition.

The production capacity of Europe is sufficient to secure its own food needs on its own territory and to contribute to the required global redistribution of natural resources. Nevertheless, Europe could assume its responsibility to reduce its claims on natural resources, such as indirect claims on land for soya beans in Latin America for the production of meat, whilst hardly affecting its meat consumption. Europe could continue to develop highly productive integrated production systems that close nutrient and water cycles as much as possible to make most efficient use of natural resources, with high labour and capital productivity, applying precision agriculture and other advanced technologies. These highly productive systems will in turn alleviate space for multifunctional agriculture and land use for specific non-food services desired by its wealthy population. In the international arena, Europe can pursue a differentiated strategy towards

different global regions. It could specifically stimulate trade in high value food commodities with Asian countries because of their increasing economic demand. Europe could assume greater responsibility with regard to supporting the development of the agricultural sector in sub-Saharan Africa to secure food and alleviate poverty. Europe could take a leading role in supporting multi-stakeholder processes to govern the sustainable exploitation of the world's natural resources, particularly in Latin America, as this continent will have to assume a major role in supplying the world's food deficit regions. Europe does not need agro-energy to stimulate its agricultural or rural development. It should discontinue its compulsory blending targets and subsidies for biomass production, as these will not contribute to the desired environmental and energy.

While economic forces increasingly drive the developments of agricultural production systems and trade flows, differences in production potential and in consumer desires in the various global regions will increasingly affect these developments. Even in open market conditions, trade takes place between industrial partners and must comply with rules and regulations set by policies. It would be in the European interest to further define its agricultural strategy from a global rather than just a European perspective, benefitting more from differences in ecological conditions.