4. Competing claims on natural resources

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Global food production is strongly dependent on the availability of sufficient natural resources. Chapter 4 studies different competing claims that may reduce the availability of land and water resources. We discuss two competing claims on farm food production capacity: (I) on-farm production of biofuels and (II) the production of different types of fibres.

The size of the competition for resources between biofuels and food depends partly on the future demands for renewable energy. Shell researchers have identified three main drivers for adopting renewable energy sources: (I) energy resource scarcity (II) new technologies and (III) social and personal priorities.

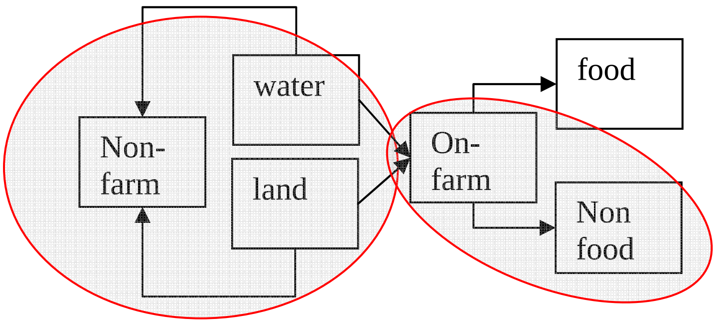
Given these three drivers of energy demand, it is difficult to make estimates about the way technology will develop and scarcity will arise as a true market constraint. However, the social influences identified as a driver may indicate that there will be a need to promote biofuels and biomass as renewable sources of energy. The type of market pulls needed to realize sustained commitment to replacement of fossil fuels by renewable energy sources rely on a range of uncertainties. Given the assumption that oil prices will not rise over the next 20 years but will remain constant at around 40 USD/barrel, it can be argued that a shift towards renewables is unlikely to be generated by market forces alone. This is due to the range of improvements still achievable in the extraction, transportation, processing and conversion of fossil fuels into energy. In this case, no considerable extra competing claims are to be expected. On the other hand, we can expect growing competition between fibre crops (mainly cotton) and food crops as currently almost 2.5% of the area suitable for agriculture is being used to grow fibre crops.

In addition to on-farm competing claims of land and water through production of non-food products, the competing claims of other sectors have been examined as well. When considering the competing claims of other sectors concerning water, we can conclude that water availability for the agricultural sector may decrease in the future, whereas future food requirements depend greatly on the expansion of irrigation. The prospect of food deficit in certain areas is worrying as the proportion of water used by the agricultural sector is more likely to decrease than increase, and can therefore not provide a solution. The area currently irrigated cannot expand any further, so it is unreasonable to expect any food production gains from an increase in the area under irrigation, as happened during the green revolution. As the growing industrial and domestic water uses are given higher priority than agriculture uses for political and economic purposes, their portion of water use is likely to increase vis-à-vis agricultural production. Competing claims emerging from environmental concerns are of less importance. Some countries have strict regulations that rivers should keep a certain base flow to sustain the fluvial ecosystem, but agriculture, industry and domestic use are generally given priority over environmental uses.The consulted literature is not conclusive about how much water should be kept available for the environment (for instance, the amount of base flow in rivers). However, it is clear that the water available for agricultural production is limited and that, in the future, the area under irrigation will most likely not increase but decrease.

Urbanisation forms a competing claim on land as well. In order to determine the size of this claim, the area needed for settlements was studied. Currently, the land cover of urban areas is a mere 2% of the total earth's land cover. Generally, cities are established on relatively suitable, fertile, agricultural land.

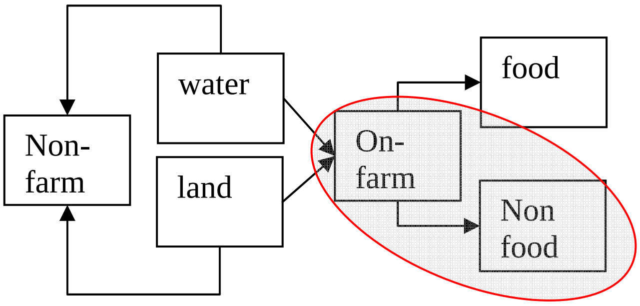
How the competing claim of human settlement on the land resources will develop is not very clear. However, historically we have witnessed a gradual, upward urbanization trend. Whereas in 1950 the rate was only 29.2%, it soared to 41% by 1980 and now lies at around 50%. Economic development in the South is coinciding with a rapid increase in urbanization. Africa has seen the most dramatic increase with current annual growth rates of 5 per cent (Sen, 2001). If this trend continues, it can be expected that more land will be needed for human settlement. A large share of the claim will probably be taken from agriculture, and thus also from food production.

Schematically, the two kinds of competing claims on natural resources can be represented as follows:



Section 4.2 focuses on claims on farm resources for non-food applications. It deals with the competing claims on resources that are used on-farm, but not for food production. The examples discussed are biofuels and fibre production. Section 4.3 shifts the focus to the non-farm claims on land and water resources. Unlike in the previous section, water and land will be discussed separately.

4.2 Non-food claims to farm production capacity



Bioenergy and food availability

UN population forecasts indicate a further growth in the world population, which could reach a ceiling of 10 billion by 2075. At the same time, annual economic growth is expected to continue for another fifty years at a rate of about 3.5 per cent annually. Under the most favourable assumptions on investment and adoption of current and future technological innovations, energy consumption might have doubled by 2050 (Kindall and Pimentel 1994).

Against this backdrop, dependence on fossil energy sources (oil, natural gas and coal) has been increasingly described as problematic. Record levels of oil prices at almost 60 USD/barrel estimates pointing to an irreversible decline in oil stocks from 2004 onwards (Hallock et. al., 2004) and concerns over climate change have led to an increased interest in sustainable energy. Advantages of using renewable energy sources are commonly related to the objective of mitigating greenhouse gas emissions, which is now widely incorporated into climate policy.

Given the fact that increased energy demand coincides with increased demand for food, a shift towards renewable energy sources poses a potential threat to global food availability. Especially where renewables imply the extraction of biomass otherwise used for food, animal feed or plant residues intended to regenerate soils, mutual excludability is imminent. Hence, we focus on biomass production as a critical non-food claim on farm production capacity. This section explores the potential production of biomass for energy use, the drivers rationalizing its use, and the way it may compete for land with food production.

Biomass for energy production

In general terms, biomass refers to 'all forms of organic matter, including wood, agricultural crops and residues, animal dung and human waste' (Energy from Renewable Resources, p. 73). In the context of energy sources, it also relates to products of biomass such as bio-ethanol. The conversion processes to turn biomass into energy are biochemical (e.g. wood (residues) from forestry), thermo chemical (in the case of energy crops) and physical or chemical when waste products are processed (e.g. harvest residues, household- and industrial waste products) (Swaaij, 2004; p10).

Biomass is one of several renewable energy sources. Other renewables gaining importance in the global energy market are hydropower, wind energy, solar power and, to a lesser extent, geothermal energy. Comparing biomass production to other forms of renewables is difficult due to the impossibility of considering all the environmental aspects and the highly variable conditions in which energy crops can be grown (Ericsson et. al., 2004; p206). To understand the complexity in estimating the future potential of biomass for energy, we need only consider the different crops that can be used with reasonable efficiency for energy production given their conversion ratios, climate conditions and variable inputs.

The benefits of biomass production for energy relate to the fact that it is naturally replenishable. In other words, if adequate management practices are employed, it will not be exhausted over time. Biomass energy sources such as energy crops and forestry residues are also carbon-neutral over their life cycle and have the potential to make a significant contribution to the mitigation of global warming. Biomass used as a fuel is CO_2-neutral in that the CO_2 released when the fuel is used is equivalent to that taken from the atmosphere by the plants as they photosynthesise (Duurzame energie in Nederland, 1999).

Biomass energy sources vary in their technical feasibility and their land requirements. Besides being used directly as a source of heating, biomass can be used for producing bio-ethanol, which can replace fossil fuels. To this end, specific energy crops can be grown, or crop residues (lignocellulosic biomass) can be used from the seven major food crops of corn, barley, oat, rice, wheat, sorghum and sugarcane (Kim and Dale 2004). Bio-ethanol for combustion engines produced from sugarcane and cereals through fermentation processes (e.g. in Brazil and the United States) are considered mature technologies, whereas extraction of energy from crop residues or herbaceous crops like switch grass is very much in the process of development.

However, if biomass is used in a process of fermentation and distillation, as when it is converted into ethanol fuel, the environmental equation is not so balanced. The large amount of waste water produced in the process, the transportation costs involved in moving the organic matter to processing plants, and the pesticide and fertilizer use in growing the feedstock crops mean that this kind of energy production itself involves significant environmental impacts (Pimentel, 2003; p129-p131]. Thus it can be argued that the CO_2-neutrality mainly refers to the use of biomass as fuel wood for household purposes in areas where organic matter is found in abundance.

In general, criticism of the expansion of biomass for energy production relates to the environmental impacts of large-scale biomass processing and ethical concerns over using food crops that could otherwise serve to meet growing demand for food. The current use of biomass energy in developing countries is also a major cause of deforestation, as most of the biomass used is wood. Its utilization is probably not sustainable and its use (wood fires) represents a considerable health threat.

Present and future extent of biomass for energy use

Biomass is considered to be one of the key renewable resources. It currently only supplies 14% of the world's primary energy consumption. For three quarters of the world's population living in developing countries, biomass is still the most important source of energy. On average, biomass produces 38% of the primary energy in developing countries (80% in some countries) (Venturi, 2003; p236). This high percentage can be attributed to the extensive farming systems and woodlands that provide wood, waste from crops, and manure for household needs. Maintaining this high percentage in future is unlikely, given the rise in energy demand from the Developing Countries (DC). Total energy consumption in the DCs is expected to exceed the levels of energy consumed in the industrialized nations by 2020, thereby increasing reliance on gas and oil (Shell, 2001: p90).

In the industrialized nations, biomass is also increasingly being used for energy. A number of developed countries use this source quite substantially, e.g. in Sweden and Austria 15% of the primary energy consumption is covered by biomass (this is mainly provided by forestry residues and forestry products, e.g. wood pellets). Sweden has plans to further increase the use of biomass as it phases down nuclear and fossil-fuel plants into the next century (Shell, 2001: p90). The contribution of biomass to energy supply is expected to increase over the next few years, partly because of subsidies that generate a market pull for the transition to renewables. The European Commission for one has set a target of increasing the contribution of renewables to 12 percent of energy consumption by 2010, whilst aiming for a tripling of the biomass production (European Commission, 1996) After the increase, biomass would still produce less than one percent of the total energy demand. Achieving higher percentages of energy produced out of biomass would also involve the development of international trade in biomass. Regions rich in biomass such as South America, North America, Central Africa and Oceania could become exporters of biomass to the industrialized nations that have the technical means and infrastructure to process it in bio-refinery installations (Energy from Renewable Resources, Chapter 5; p10). The demand for energy is higher in the industrialized nations, and because energy is more difficult to transport than fuel, the fuel will be exported and not the energy. However with higher energy demands, biofuel energy production may take place in the nations rich in biomass.

Drivers

The main drivers for adopting renewable energy sources have been described by researchers of Shell (Shell, 2001). They define three main determinants for the shift to renewable energy sources (in general, not exclusively biomass): energy resource scarcity; new technologies; and social and personal priorities.

Discrepancies between the growth in energy demand and the supply of fossil energy will have important effects on any prospective shift to renewable energy sources. Sustained high oil prices enable alternative energy sources to be developed and compete with fossil fuels. Research and development into renewable energy sources could for instance lead to more efficient storage systems and carriers of new forms of energy, which now represent constraints to extensive use of wind and solar energy (Turner, 1999). The rising depletion costs of natural gas and oil, estimated to continue to 2025, may however also be compensated by improvements to the current system of transporting fossil fuels (reducing losses) and gaining access to previously unattainable stocks (Shell, 2001: p24). Thus, although depletion of fossil fuels is inevitable in the coming fifty years, and prices of crude oil may remain at prices over 60 USD/barrel, it is not certain whether this is enough to steer investments to renewable energy sources.

The social and personal choices refer to energy choices made by individual consumers and governments. Future attitudes, such as the need for energy self-sufficiency and environmental concerns, will greatly influence the development of the energy market. However, the influence of these attitudes on practical developments will depend on the future availability of technology to improve the energy balance of renewable energy (Shell, 2001). According to Kindall and Pimentel (1994: p9), a large-scale adoption of new technologies based on new energy sources, with improved conversion and end-use efficiencies, would require 40 years at minimum, even in favourable circumstances. In some cases, these new technologies may develop faster. In 2005 half of all new cars sold in Brazil have the ability to use either petrol or alcohol as fuel. The technology of these hybrid cars is only a few years old. But alcohol as fuel has been available for much longer.

All three drivers are affected by uncertainties and competing claims from various interested parties. The scarcity of fossil fuels remains a debated issue, as does the expectation that new technologies will deliver affordable alternatives to fossil fuels over the medium term. In order to enable the shift to renewable energy sources, the pivot may lie with the 'social and personal priorities' to create a market pull (Swaaij, 2004). This could, for instance, involve the adoption of policies to promote the use of biofuels by creating incentives for producers, investors and the industry.

Bioenergy and competition for land
The influence of the aforementioned social and personal priorities on the competition between bioenergy production and food production also depends on the total landmass that is available for biomass production.

Assumptions and estimates have been made about the landmass that could be used for biomass in future. One such study conducted in 1993 by Johanssen and associates developed a scenario whereby biomass would contribute an astonishing 30 percent of the global energy demand in 2050. In this case, 429 million ha of land would be used for biomass production, an acreage that represents 14.3 percent of the total land (3,000 million hectares) that is currently being used as cropland or rangeland (European Commission 1996; p78).

The second scenario study used the Limits-to-Food production model to estimate the room for bioenergy production in alternative scenarios based on varying assumptions about diets and population growth, and on two types of agriculture, namely a high external input (HEI) and a low external input (LEI) variant. The mean global yield of biomass production for energy was assumed to be equal to rain-fed grass production. This implies that biomass production is done on marginal lands without laying claim to water that is required for irrigated cropland. Effects of energy extraction from biomass that would otherwise be used for soil fertilization were not taken into account. Assuming that total agricultural land would have increased to 4,500 million hectares by the year 2050 (a 50 percent increase), the study concludes that with all agriculture under the HEI system, a low-to-medium population growth and affluent diets, 55 percent of the global land area that is suitable for agriculture would be required for future food supply. The remainder could be used for the production of biomass to meet energy demands. The study does however emphasize that if for reasons of nature conservation, only the current extent of agricultural land were to be available for either bioenergy or food production, only half of this area (22.5 percent of 3,000 million hectares) could be used for biomass production. Under LEI agriculture under the similar conditions, all land would be required for food supply, leaving no room for bioenergy production.

Conclusion
Given the three drivers of energy demand, it is difficult to predict how technology will develop and whether scarcity will arise as a true market constraint. If oil prices did not rise in the next 20 years but remained constant at around 60 USD/barrel, a shift towards renewables might not be generated by market forces alone. This is due to the range of improvements still achievable in the extraction, transportation and processing of fossil fuel and its conversion into energy.

The question of whether biomass production for energy, if incorporated as a key component of climate control, constitutes a competing claim to global food availability cannot readily be answered. The extent to which the production of biomass for energy will form a competing claim on food production depends largely on what type of fuel is used and on what type of land this production takes place. If land is selected that is less suitable for agriculture or ranging, the impact will be smaller.

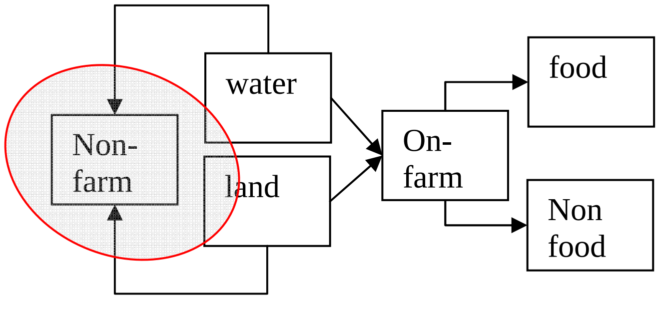
Farm production of fibres

Bioenergy is not the only non-food product that may claim farm capacity in the future. Another product group that could do so is fibres. In 2002, almost 33,000 thousand ha, or about two and a half percent of the total global (arable and permanent) agricultural land, were used for this production (FAOSTAT, 2002).

The fibre produced on by far the largest proportion of this area is cotton (more than ninety percent of the agricultural fibre production). Other fibres like jute and sisal occupy much smaller areas (little more than one percent of the area) In view of its area demand, fibre can be considered as a modest yet significant competitor of food production (FAOSTAT 2004). Land used for fibre will probably increase in the future. Although new artificial fibres are being developed and used, cotton is still used in the majority of cloths. The demand for clothes is expected to rise because of growing buying power in Eastern Europe and South-East Asia in combination with lower prices.

However, some scientists expect that a larger role for nanotechnology may lead to the development of new types of fibres (www.etcgroup.org), which in turn may lead to a reduction in the demand for cotton. Overall, no great extra competing claim on land for fibre production is to be expected. But the current claim may be maintained.

4.3 Non-farm claims on land and water



Non-farm claims on land

Land is an essential resource of food production. Besides non-food claims on farm production capacity, non-farm claims on land will affect the future supply of food. This subsection gives an indication of non-farm claims on lands that are suitable for agriculture. The claim will be quantified for the current situation and possible future. In particular, the claim for human settlement will be discussed.

Conflicting interests in the use of land are common, but take different forms in different parts of the world. Results of unsustainable use of land and water resources are visible on a global scale: reduction in agricultural potential and poor food quality and security, deforestation, congested cities and urban sprawl, poor housing, deteriorating biodiversity, etc. (European Union 2000), In the literature, all human settlements (housing and industry) are generally labelled as human settlement. Currently, urban areas cover a mere two percent of the total earth's land surface (Lambin, 2001). This may not seem a lot but humans have historically settled on or close lands that are suitable for agriculture. The total land surface of the earth is 13,000 million hectares. Of this, only 4500 million hectares (23%) is used as, or is potentially suitable for crop- and rangeland (IFPRI, 2000). The pressure of human settlements on the amount of land available for agriculture may be much higher.

How the claim of human settlement on land will develop is not very clear. Historically, we have witnessed a gradual, upward urbanization trend. Whereas in 1950, urban dwellers constituted only 29.2 percent of the world population, their share soared to 41 percent by 1980 and now lies at around 50 percent. Economic development in the South is accompanied by a rapid increase in urbanization. Africa has seen the most dramatic increase with current annual urban growth rates of 5 per cent (Sen, 2001). If this trend continues, it can be expected that more land will be needed for human settlement. In all probability, a large share of this land will be taken from the agriculture, and thus also food production, as has happened throughout history.

Competing claims to fresh water

Availability of fresh water and food availability are linked in a world where the population and demand for food increase steadily. Although water covers 97 percent of the earth, only 2.5 percent of the total water volume is suitable for domestic, industrial and agricultural uses. Besides the quantity of suitable water supplies, quality and distribution are critical factors determining future food production.

This subsection explores the various competing claims on the limited water supplies and discusses how the competition for water may affect future food availability. Firstly, we discuss the availability of water and the distribution of this resource over the different sectors (domestic, industrial and agricultural). Secondly, we deal with the occurrence of water scarcity in the light of ongoing urbanisation processes. Thirdly, we discuss the effect of new crop varieties and technologies on the availability of water for global food requirements. Finally, we give a short list of measures that may alleviate possible water shortages.

Is water a scarce resource?

The answer to this question is not simiple. Groundwater reserves or aquifers and other fresh water sources such as rivers, lakes and swamps supply a total of 14,000 trillion cubic meters a year that can be used by humans (Sherk, 2002)[1]. This amount is constant and unlikely to increase in the future. Pollution of supplies, rendering them unfit for human use, is a threat due to the extensive use of pesticides and nitrogen fertilizers in agriculture and the dumping of industrial contaminants that find their way into aquifers (Turton & Warner, 2002). Estimates indicate that with careful management, current water supplies could support a global population of 18 billion people (New Internationalist, 2003).

However, water is distributed unevenly. Certain regions and countries face acute shortages whereas others enjoy relative abundance. World Bank calculations indicate a structural water shortage for about 20 countries (mostly located in Africa and the Middle East). Although the world is not faced with a global water shortage per se, there is a series of many chronic regional and local water shortages (Serageldin, 2001).

Future projections are generally pessimistic and alert us to a growing strain on current supplies. Typical estimates indicate a 40 percent rise in the global demand for water by 2025, leading to a situation whereby two-thirds of the world population faces water stress (i.e. water availability between 1,000 and 1,700 cubic meters/person/year) and thirty countries may face acute water scarcity (i.e. water availability under 1,000 cubic meters/person/year) (New Internationalist, 2003). Linked to this scenario, we find widespread concerns over international and local conflicts about the access and allocation of scarce fresh water supplies (Sherk, 2002)].

Current distribution of water

Human water consumption is roughly distributed over three uses, namely domestic, industrial and agriculture. Globally, domestic uses (e.g. drinking water, cooking and sanitation) account for eight percent of total consumption, industrial uses (e.g. boiling, cleaning, cooling, processing, air conditioning, transportation and energy production) represent 22 percent of the total, and the remaining 70 percent is attributable to agriculture (Rosegrant & Ringler 1998, Rockstrom 1999, New Internationalist 2003). The greatest share of the water used for agriculture, approximately two-thirds, is taken up by irrigation systems. However, not all available water is utilized due to variability in water availability over the year. Through using the water in times of high availability, more water may be used without competing with other sectors. Furthermore, many possibilities exist in using water more than once. On the whole, no data has been found on the exact amount of extra available unutilized water. But the various studies indicate that the water availability is limited and a smaller proportion of water will be available for food production.

[1] 1 cubic metre equals 908 litres

Water needs and urbanisation
The upward urbanization trend discussed above has special implications for the available amount of water. Although the land cover of the urban areas is a mere 2% of the total earth's land surface, urbanization effects on natural resources relate to the dependence of the urban population on forest, agriculture and water systems that exceed the actual acreage of the urban areas manifold (Lambin, 2001). The urban population generally has easier access to drinking water, leading to higher amounts of water used per person. Furthermore 'if standards of living are to rise, water consumption per capita is also likely to rise.' (Sullivan, 2002) Altogether, with the increasing urbanisation, as access to drinking water becomes easier for more people and the standard of living increases, larger quantities of water will be needed.

The quest for safe drinking water for the urban population has prompted governments and private investors to expand their water systems further and further afield for supplying clean water but also for disposing of wastewater. For developing countries, this has meant an increased strain on a system of pipes, drains and streams suffering from poor maintenance and subsequent leakages. Losses of fresh water from inefficient water uses in urban systems may reach levels of 30 to 50 percent (Sherk, 2002). Chemical and organic pollution from industries and domestic uses is an increasing threat to scarce water supplies, as poor management of waste can lead to contamination of groundwater reserves, and possibly lead to irreversible degradation of these supplies (Walsh, C.J. 2000).

Scarcity of clean drinking water in urban areas has also led to the politicization of this natural resource. In a bid to curb the strain on the limited supply, governments have been incited to invest in large-scale irrigation and drinking water projects that come at a vast environmental expense (Sherk, 2002). A recent example is the Three Gorges Dam project in China that, through provision of employment and safe drinking water, reflects the medium-term strategic objectives of a government seeking to appease the growing urban population.

Irrigation, food availability and the Green Revolution
The 300 million hectares of irrigated land in the world (10 percent of total land under cultivation) now account for 40% of the global food production and thus play a critical role in meeting growing food demand (Serageldin, 2001). The large quantity of water now available for agricultural production may not be sufficient if ample food is to be produced for the growing world population. As stated in a recent report, meeting the food requirements of the developing world in 2025 would require another 35 million hectares of farming land to be irrigated, representing a 20% increase (Serageldin, 2001). Such demands on the limited water supply may prove problematic, given the large portion of water already used for irrigation purposes (around two-thirds of the total water put to agricultural use).

Irrigation was an important part of the Green Revolution of the 1960s. Although the new high-yielding varieties assisted greatly in meeting the food requirements at the time, they also required significantly higher amounts of water than the traditional crops. Consequently, the six-fold increase in human water consumption in the past century has partly been attributed to a 'wasteful model of agriculture' in terms of water management (Sherk, 2002). It has to be considered that a large proportion of water is extracted from the system in an unsustainable manner, causing groundwater levels to decrease and become polluted through the intensive use of herbicides and pesticides (Serageldin, 2001). Changing farming practices in favour of low external input and rain-fed agriculture may be the necessary step to replace current systems that are unsustainable and which may cause irreversible damage to freshwater sources. New crops have already been developed that only require half the water needed by the current high-yielding varieties (Sherk, 2002). Adoption of these new technologies may lead to a second Green Revolution that combines the high yields of the 1960s technology and the resistance of the traditional crops. Although these cultivars are very successful in yield per litre of water, in terms of production per unit of land these strains do not even yield half of the currently used varieties. Farmers are not yet paying market prices for their irrigation water, therefore they are more likely to look at the yield per hectare than per hectolitre. The mid-1990s saw a steady decrease in investment in irrigation schemes. At the same time the costs of developing new irrigation systems rose sharply. This development entails that even if the water were to be available, it is not likely that irrigation systems will be developed on large scale as happened in the Green Revolution of the 1960s.

Box 4: Cereal production

Sixty-nine percent of all cereal area is rain-fed, including 40 percent of rice, 66 percent of wheat, 82 percent of maize and 86 percent of other coarse grains. Worldwide, rain-fed cereal yield is about 2.2 metric tons per hectare, which is about 65 percent of the irrigated yield (3.5 metric tons per hectare). Rain-fed areas currently account for 58 percent of world cereal production [10].
Cereals differ greatly in the average water (litres) needed to produce one kilo of food [1]:
Maize: 1,400 litres/kilo; Wheat: 1,450 litres/kilo; Rice: 3,450 litres/kilo.

Future distribution of water and challenges for food production
Overall, we can conclude that water availability for the agricultural sector will be tighter in the future. As the growing industrial and domestic uses are given higher priority than agriculture for political and economic purposes, their portion of water use is likely to increase compared to agricultural production. In absolute amounts, this does not mean that there is no possibility for increasing the amount of water for agriculture,

since not all water is being utilized. How much extra water can be used is not clear. No comprehensive study has been found estimating the total extra available unutilized water.

Competing claims emerging from environmental concerns are of less importance, given that food security and safe drinking water are generally given priority over issues of soil degradation and biodiversity. The consulted literature is not conclusive about how much water should be kept available for the environment (for instance, the amount of base flow in rivers).

What has become clear is that the room for expanding the area under irrigation is small and that water shortages are likely to occur in existing irrigation systems. As mentioned before, scarcity of water will be hardest felt in certain regions like Sub-Saharan Africa and the Middle East. Acute shortages have not yet been reported, but during the coming fifty years a situation of water scarcity (less than 1,000 cubic meters/person/year) may affect one-sixth of the world population (Wallace and Gregory 2002). Considering the total water requirements for producing regional diets, less than $1000m^3$ annually per year is not sufficient to produce enough food for survival.

A possible solution can be found in managing the limited water more efficiently by saving water, decreasing pollution and establishing international rules that govern access and allocation of water. Several water-saving methods have already been developed for the agricultural sector. Water can be saved through improved management and water harvesting in irrigation systems and through expanding rain-fed agriculture (Serageldin, 2001).

In theory, there is considerable room for improvement in irrigation systems. In current, open canal surface-irrigation systems, often less than ten percent of the water finally reaches the crop. Improved irrigation systems with pipes rather than canals, and drip irrigation rather than, for example, furrow irrigation, can raise effective water use by up to 70 percent. Using irrigation as a supplement to rain-fed agriculture, and decreasing water waste in food processing cycles are examples of water-saving strategies. Other possibilities may lie in the development of water saving and drought-resistant crops. Since expansion of rain-fed agriculture comes at a huge environmental cost in terms of land use, a combination of increased efficiency in irrigation, better crop deployment, agricultural research in all areas and changes in dietary profiles will be required.