BIBLIOTEQUE SYNTHESIS

FORECASTING STUDIES ABOUTS
WATER AND AGRICULTURE AT
GLOBAL SCALE : OVERVIEW AND
WAYS OF DEVELOPMENT

DOUSSET Emma
emma.dousset@agroparistech.engref.fr

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ABSTRACT:

As water is a key parameter to estimate the balance between agricultural production and food consumption, it is considered with varying levels of detail in the different world food futures studies. Agricultural water demand (for irrigation) is usually evaluated; water demands for other sectors are less often assessed. The pressure on water resource can be estimated through dedicated indicators, and the equilibrium between uses and resources is sometimes ensured using allocation rules that share out water between the different sectors in case of shortage. The use of dedicated models makes the consideration of water in futures studies easier. Nevertheless, qualitative issues related to water management (pollution, soil degradation, loss of biodiversity…) and their impacts are not evaluated. Finally, futures studies must face up to difficulties due to the lack of data, to methodological problems and to the inclusion of climate change effects. Some studies show that there will be enough water in 2050 to meet global demand for food. However, these results are not entirely reliable. New studies taking into account climate change, the issues related to water management, the resiliency of agricultural socio-ecosystems and carefully considering the levels of food consumption and the geographical grid will be more accurate.

KEY WORDS:
Strategic foresight, futures study, agriculture, food, water, world, water demand, resource and uses, irrigation, model

SYMBOLS ET ACRONYMS

CAWMA  Comprehensive Assessment of Water Management in Agriculture
FAO  Food and Agriculture Organization
GAEZ  Global Agro-Ecological Zones (travail de la FAO et de l’IIASA)
IFPRI  International Food Policy Research Institute
IIASA  International Institute for Applied Systems Analysis
IWMI  International Water Management Institute
MEA  Millennium Ecosystem Assessment
Mha  Million hectare
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INTRODUCTION

According to the United Nations assessments, global population should rise from 6.8 billion people today to 9.1 billion people in 2050. This increase should mostly take place in developing countries. The upward trend to urbanization will intensify and almost 70% of global population will be urban in 2050 (compared with 49% at the moment). The level of income will also rocket. The Food and Agriculture Organization (FAO) estimates that to meet the food requirements of this larger, more urban and wealthier population, agricultural production (not regarding agricultural products used to produce biofuel) must grow by about 70% (World Summit on Food Security, 2009).

In addition, the issue of undernourishment remains a central consideration. Indeed, if the average food intake per capita in developing countries has been increasing since the sixties, a significant part of population is still not concerned by these developments. Worse, if the number of chronically undernourished people declined at the end of the twentieth century (from 816 million people in 1990-92 to 777 million in 1997-99 according to the FAO), the recent financial crisis and the last surge in agricultural prices reversed the trend. Thus, the FAO estimates that this number has exceeded one billion in 2009 (World Summit on Food Security, 2009).

Consequently, the question of whether or not global agricultural production will increase enough to meet the growing food requirements and to cope with undernourishment has arisen. The answer is all the more difficult to find since a lot of parameters, such as biofuel demand & climate change, must be taken into account.

A number of strategic foresights, based on food production and consumption balance at international level have been carried out to try to answer this question. Water is a determining factor of the analysis, since it can restrict the agricultural production, but it is taken into account with varying degrees of detail. The objective of this synthesis work is to have an overview of the knowledge available for futures studies about the balance between water resources and agricultural water uses at the international level, with the objective of meeting food requirements.

The first part of this report sets out the different futures studies works that have been conducted and their approach concerning the evaluation of alimentary commodities demand and supply balance and the consideration of water. The main causes of the uncertainty of the scenarios results are also examined.

The second part focuses on the three works in which water is taken into account in an interesting level of detail.

Finally, the third part summarizes the key results of the studies and lists the main discussion points and some ideas in order to improve the quality of futures studies.
FOOD AND AGRICULTURE FUTURES STUDIES : KEY POINTS

This part will focus on the diversity of existing works. First, the studies vary in their nature. Among futures studies, different ways of working can be chosen, hence the multiplicity of work and the conflicting results. However, there is a common point between all the studies, since supply and demand for food are always estimated. As for the balance between agricultural water resources and uses, it is considered with varying degrees of detail. We will see it is the same for other issues related to agricultural water management. Finally, all these studies had to face some difficulties which will be addressed. Particular attention will be given to the inclusion of climate change.

THE STUDIES CONSULTED

Futures Studies (from (Jouvenel De, 1999))

Among the studies on agriculture and food requirements that have been realized, some are forecasting studies centred on agricultural demand and supply tendencies while others are more integrated models that tackle the problem from a global point of view (we then talk of futures studies or strategic foresights). These works take into account all the drivers of the system and the interactions that link (or will link) them. Moreover, they do not rely on the principle of continuity and consider breaks in trend. Finally, they mix both qualitative and quantitative approaches.

The strategic foresight approach can be split up in different stages. First of all, the issue and the time horizon must be specified. Then, all the drivers and stakeholders, and the relations between them must be identified. The next stage is to collect data on these elements. From the analysis of past evolutions, trends and possible breaks in trends are defined. Hypotheses on the evolution of parameters can then be made.

There are different methods to estimate the possible evolutions. One is based on models. Its results are quantified and accurate. However, using this method, the risk of using erroneous hypotheses in input and thus to obtain erroneous results is high. On the contrary, the scenario method gives vaguer results (tendencies) but is usually more reliable. For each scenario, a base, a course and a final vision are specified. Scenarios can be exploratory (changes in parameter values are brought about and the evolution they imply are analysed) or normative (the final vision is fixed and a course to reach it is searched for). Usually, both these methods are used in a given study, mixing quantitative and qualitative approaches.

Futures studies are useful to help decision-makers.

Choosing between the model method, the scenario method or a combination of the two, and then choosing the hypotheses, the kind of scenario etc., make a study unique. There are thus numerous differences between two strategic foresights focusing on the same subject.

The multiplicity of existing works

Among strategic foresights focusing on agriculture and food, the approaches and angles of attack varied a lot.

The FAO study (Bruinsman, 2003) is an exercise of anticipation, presenting the most likely future and concentrating on agriculture and food requirements.

The approaches chosen in the studies Agrimonde (CIRAD & INRA, 2009), World Water and Food to 2025 (Rosegrant and al., 2002) and Water for Food, water for life (Comprehensive Assessment of Water Management in Agriculture (CAWMA), 2007) are more similar to the scenario method, although each one uses a model to quantify its hypotheses. Agrimonde, for example, explores two different scenarios, one taken up from the Millennium Ecosystem Assessment1 and the other normative since it presents the course needed to maximize sustainability in 2050. As the drivers impacting the system were too numerous, the scenario method was modified, and the analysis was restricted to key parameters. Both a quantitative model and qualitative analyses are used in Agrimonde. The qualitative side of the study ensures the coherence of the scenarios.

The main difference between the three works quoted above lies in the angle of attack that has been chosen in each one. Agrimonde focuses on the capacity for each region to meet its food requirements.

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World Water and Food to 2025 specifically analyses the relation existing between water availability and agricultural production whereas the CAWMA study concentrates on agricultural water management, with the objective to meet food requirements in 2050.

Other studies, focusing on a specific topic, can be used in strategic foresights on food and agriculture. For example, the study of the International Food Policy Research Institute (IFPRI) (Nelson, 2009), which concentrates on the impacts and costs of climate change in the agricultural field, could contain new ways of development to include climate change in agricultural futures studies. Finally, works which are not futures studies, or foresights that focus on a particular area can identify new ways of development or limits. It is thus interesting to consult them too.

In spite of all these differences, methodological or related to nature, a common point to all these works exist. Indeed, in all futures studies, demand and supply for food are estimated.

**DEMAND AND SUPPLY FOR FOOD**

An estimate common to all futures studies...

This evaluation is realized at different scales according to the studies. It often begins at the smaller scale (country or aggregate of countries). The linking of these values at global scale is then done by considering international trade.

The parameters used to assess supply and demand for agricultural products are similar between studies. Thus demand mainly depends on population, incomes and diet (calorie intake & kind of food). Supply depends on the cultivated surface, the yields, themselves depending on the cost of labour, capital and food, the technical innovations, the kind of soil, the climate etc...

If the estimate of supply and demand is realized in all studies, some differences exist. They can be related to the use of different data, to diverse hypotheses or to varying level of detail.

... even though a few differences remain

The United Nations usually publishes its world population prospect revisions every two years. As the different studies were not released at the same time, they use different population data: the estimates vary from 8.9 to 9.3 billions people in 2050. Data used to evaluate national income are also changing from one work to another. Most foresights are based on World Bank values, but a few have chosen to refer to other works, such as the estimates from the Millennium Ecosystem Assessment.

Moreover, the hypotheses on diets are diverse. In the main, the evolutions foreseen in each country depend on the way of life (and thus on the level of income) and on local customs. However, in some scenarios, another hypothesis is held, such as the equality of the caloric intake around the world in the normative scenario of Agrimonde.

Finally, the level of detail available is not the same in all the studies. Thus, the geographic split-up (country or aggregate of countries) and the agricultural products considered vary.

In Annex 1, a table summarizes the different data used in each study.

**Using a quantitative model**

The quantitative estimates of supply and demand for food are usually realized using models. If some of them are quite similar, others operate in a totally different way.

IMPACT is a model realized in the 1990’s (Rosegrant and al., 2008). The level of detail reached is interesting. Supply and demand depend on numerous parameters, among which prices. By searching for trade balance at global scale, demand, offer, prices of agricultural products and exchanges volumes are determined at local, and then global level. This model was improved in IMPACT WATER to consider water issues. This last version is used in World Water and Food to 2025 (Rosegrant and al., 2002).

WATERSIM model (Fraiture De, 2005), which is used in the study Water for food, water for life (Comprehensive Assessment of Water Management in Agriculture, 2007), was created by the
International Water Management Institute (IWMI). Its food module refers to the IMPACT model; they are thus quite similar.

AGRIBIOM model was developed within the framework of the project Agrimonde (CIRAD & INRA, 2009). It is quite different from the previous two. Indeed it realizes the balance between food biomasses production and their uses. Agricultural products are shared out among five big compartments, and the unit used is the food calorie. Food production functions have been created to convert vegetal calorie into animal calorie. Balances are first carried out at regional level and then at global level. The hypotheses on the parameters are adjusted in order to reach global balance. This model makes moving backwards and forwards between qualitative thoughts and quantitative estimates easy.

**TAKING WATER INTO ACCOUNT: DIFFERENT LEVELS OF DETAIL**

**Considering water requirements: from qualitative to quantitative approach**

On one hand, in the study Agrimonde, water issue is included through qualitative thoughts only. There is not quantification of this subject. Indeed, in the normative scenario that was created, water was not perceived as a parameter that could restrict the increase of agricultural production that is needed almost everywhere. The values of the irrigated area expansion are given for information only; they were determined by a brief qualitative analysis.

On the other hand, in other strategicforesights, water requirements are quantified. But these estimates are carried out at varying levels of detail. Thus, the geographic unit can be the country or the basin. The degree of coverage also changes from a study to another; the FAO restricted work to 93 developing countries while the others cover almost the entire world.

In the main, the same key parameters are used to estimate agricultural water requirements; namely irrigated area, evapotranspiration, effective rainfall and the efficiency of irrigation systems. Data, grids, calculation methods used to evaluate evapotranspiration, hypotheses on irrigated area and irrigated system efficiency differ from study to study. The result is that estimated withdrawals for irrigation can change significantly. Indeed, withdrawals needed to meet world requirements in irrigation in 2050 vary from 2,760 km³/year to 4,120 km³/year (compared to 2,630 km³/year in 2000) in accordance with the different hypotheses of the CAWMA study.

Non agricultural water requirements are not estimated in FAO work, whereas they are in Rosegrant and CAWMA ones. There are a few variations between the two methods of calculation, however industrial water demand mainly depends on Gross National Product while domestic water demand depends on demographic growth, incomes and water prices.

**What about water resources?**

If the methods used to quantify water requirements in each study look alike, there are more differences between the estimates of water resources. On one hand, the FAO simply evaluates renewable water resources in the 93 developing countries it analyses. On the other hand, other studies (CAWMA, Rosegrant) go further by separating water recharging groundwater, runoff generated on the basin, water issued from inter-basin transfers, water running from upstream basins and other sources.

From this varying level of detail in estimating water resources follows very diverse assessments of water requirements and resources adequacy. This point will be addressed in the next paragraph, after a short summary of the situation for next decades.

**Adequacy between water requirements and resources**

If there is no improvement of water productivity and no major shift in agricultural production schemes, 12,000 to 13,000 km³ of water per year will be needed to supply the world with food in 2050 (compared to 7,100-8,300 km³/year at the moment) (Marsily De, 2006). This estimate is of the same order of magnitude as the volume of renewable water resources (10,000 to 12,000 km³/year at global
scale). Therefore, how can we meet these future demands for water? We can contemplate different kinds of solutions (Marsily De, 2006):

- Improving irrigation, by expanding irrigated area or by increasing water productivity in irrigation systems
- Desalinating sea water. However, the energy costs of this technology are too high at the moment to apply its use all around the world.
- Increasing yields (and thus water productivity) through genetic improvement. But physical possibilities remain restricted as evapotranspiration is necessary to photosynthesis.
- Advancing rainfed agriculture. There are a lot of things to do in this field. The increase in rainfed production could come from the expansion of harvested land, from the intensification of culture (reducing fallow periods, multiplying harvest) or from higher yields. The respective parts of these different ways of development could be 20%, 10% 70% (Bruinsman, 2003).
- Favouring effectual global trade. Indeed by considering the relative advantages of each area and by promoting international trade, the volume of water needed to feed the world can be minimized. However, the environmental, social (food security) and geopolitical risks are significant.

None of these solutions can be envisaged alone. Those emphasizing water productivity, and thus reducing the volume of water required, are necessary (Marsily De, 2006). Moreover, ecosystem protection requires a carefully thought out expansion of harvested surface, since one third of potentially arable land is already cultivated and that the two last thirds are mainly forest-covered (Bruinsman, 2003).

Some studies consider the issue of the adequacy between water requirements and resources. However, the approach varies a lot and solutions to reach the balance are not always searched for. In the FAO work for example, the objective of the estimate of irrigation water requirements is just to quantify the pressure of irrigation on water resources. An indicator is thus used to assess the number of countries were the situation about water is critical. It also indicates countries affected by impending water scarcity. But issues related to conflict of use or to scarcity caused by non-agricultural uses are not considered.

In Rosegrant's and CAWMA studies, blue water requirements for agriculture and other sectors and resources are estimated at basin scale. In case of water penury at this scale, an allocation system shares out the resources between sectors and between crops. In most cases, this system favours environmental requirements. The domestic and industrial demands follow and the agricultural needs are considered last. The choice of allocation rule, that ensures the adequacy between uses and resources, is very significant in terms of water management.

In World Water and Food to 2025, the analysis of scenarios focusing on particular choices of policies (water flows reserved to environment, investment and research on irrigation...) results in a better understanding of their impacts on the balance between water uses and resources and on agricultural production. In Water for Food, Water for Life, diverse scenarios are contemplated to meet food requirements at global scale in 2050. They take up some of the solutions listed above. Moreover, the qualitative analysis related to the scenarios is elaborate. The technical, political and social choices that have to be done in each case are addressed.

Rosegrant uses indicators that compare water demand and water actually available for each sector. Thanks to them, it is possible to better feel the pressure on water resources and to better see the impacts of allocation rules. Such indicators are not used in CAWMA study.

Water and models

Using a model can help taking agricultural water management into account in strategic foresights and forecasting studies. Different models can be used. Their angle of attack, and thus their accuracy vary.

PODIUM model (IWMI, 2004), created by the IWMI is based on a balance approach. It determines current and future (2025) demands for water and food. The user specifies demographic growth, changes in diet and improvements in agricultural and/or water productivity for the studied period. The model then estimates water demand in different sectors (agriculture, industry, domestic water, environment flows) at national scale.

IMPACT WATER model (Rosegrant and al., 2008) is a revised version of the IMPACT model, developed to take into account the balance between water resources and the uses of different sectors at regional (281 units) and global scale. A water module, that compares basins to reservoirs, was
added to the IMPACT module. This new module can identify areas suffering from water shortage and can, when necessary, share out water resources between sectors and between crops according to allocation rules. The module also estimates the volume of water available for each crop (for rainfed and irrigated agriculture) in each geographical unit, over the studied period. These results are then used in the food module, where harvested area and yields depend on the kind of agriculture and on the volume of available water. The user can enter himself the rainfall data in the model. Climate Change can thus be included. Contrariwise, there is no feedback from the food module on the water module.

WATERSIM model (Fraiture De, 2005), created by the IWMI, includes both a food module and a water module. This latter draws its inspiration from both the PODIUM balance approach and the IMPACT WATER reservoir approach. The model obtained is thus quite complete. By using allocation rules, it can share out resources between sectors and crops in case of shortage. As in IMPACT WATER, the cultivated surface and yields in the food module depend on available water resources estimated in the water module. However, the bond between the two modules is tighter since some parameters are common to both of them. The model iterates until a balance between modules is reached. By using this operating mode, the quantitative impacts of agriculture in water resources are taken into account.

If models make the inclusion of water resources management in foresights easier, they also have limits. We can detect them in WATERGAP model. This latter is among the most elaborate models developed at the moment. It is used in the European research program SCENES (Finnish Environment Institute, 2009). Its geographic grid is thin and it considers basins characteristics, committed flows for environment and even includes a qualitative part. If it was necessary to work at a smaller scale to obtain more accurate results, it also brings about new difficulties. Indeed, data needed to operate the model are more numerous and it is thus harder to collect them. Moreover, phenomena such as the management rules of dams, whose impacts could be not considered for a larger grid, are quite significant in this case. However, they are not taken into account at the moment (Rieu, 2010).

Qualitative issues related to water management

Besides quantitative water resource management, the issue of qualitative management is often addressed in the foresights. The points presented are:

- Water pollution (by fertilizers, pesticides or animal dejections). No quantitative estimates of the subject are realized. Ways not to worsen or even to improve the situation are given in FAO and CAWMA studies.
- Biodiversity loss, that can be due either to a degradation of water quality and habitat or to a lack of water related to human overexploitation. Only this second aspect is sometimes considered quantitatively (through committed flows for environment).
- Soil degradation related to bad water management, specifically soil salinity and waterlogging. These two last issues are addressed in all studies. The FAO goes further by estimating the net irrigated area expansion, that’s to say considering losses of irrigated lands related to these issues or to water scarcity. It assesses that every year 2.5% of irrigated surface must be rehabilitated or replaced.

Thus, from study to study, water is taken into account with varying level of details. Agricultural water requirements can be quantified or not, available water resources may be estimated, the issue of adequacy between resources and uses is not always raised... Using a model often makes the evaluation of water supply and uses easier; it can even ensure the adequacy between them. Finally, qualitative issues related to water management (pollution, soil degradation, biodiversity loss) and the consequences of policy and investment choices are more or less detailed in each study.

DIFFICULTIES TO BE FACED

In most works, the problems that had to be faced during the elaboration of the study are listed. The more recurrent difficulties are presented below.
Lack of data and reliability issues

The biggest data problems are related to irrigation (irrigated area for each crop, irrigation system efficiency, irrigated production yields, shares of surface water and groundwater...). The studies are usually based on AQUASTAT database (from the FAO). It is filled in by countries themselves. However, many developing countries cannot afford to keep those data up to date. Many values are thus lacking or out of date. This ends up in significant divergences in evaluations of irrigated area: according to the FAO, world irrigated area was close to 265 millions hectares (Mha) in 1999 whereas a study from the IWMI, (realized the same year by remote-sensing and counting irrigated multiple-crops) gives a surface of 480Mha (Thenkabail & al., 2006 quoted in (Comprehensive Assessment of Water Management in Agriculture, 2007)). It is thus impossible to certify the robustness of irrigation water requirements estimates. Moreover, data on irrigation system efficiency are not only rare but also scattered in different databases and reports. It makes the collection of information harder, and assessments of the evolution of these parameters over the next decades are thus more difficult.

Additional studies on losses of irrigated surface by salinization or waterlogging are needed (Bruinsman, 2003). It is the same for studies of the interactions between water and livestock production and between water and aquaculture (Comprehensive Assessment of Water Management in Agriculture, 2007).

Diverse evaluation of water demand

There are also other issues, related to methodology rather than to data. First of all, water demand must be well defined: according to authors, this phrase refers either to water withdrawals or to water actually consumed. Then, the distribution between the volumes of water actually consumed, of water recycled and of water returning to environment significantly impacts the results. The estimation of this parameter is quite difficult since there are a lot of links between each element of the system, and since some of them are not well-known. For example, it is hard to evaluate the effects of rainfed agriculture and of rainfall harvesting technologies on downstream area: a part of this water will be consumed and will not infiltrate or stream to a watercourse.

Besides these problems related to data and methodology, there is another obstacle to foresights and forecasting studies, namely the consideration of Climate Change.

The difficulties faced to consider Climate Change

Links between agriculture and climate change are tight (Bruinsman, 2003). Agriculture releases greenhouse gases, may sequester carbon dioxide and is finally very sensitive to the effects of climate change (extreme events, temperature raises, rainfall changes...). If there are a few quantified estimations of the impact of climate change on agriculture, most of the studies consider this phenomenon only from a qualitative point of view since the quantification requires facing various difficulties.

One of the main difficulties is related to the vagueness of rainfall estimations. A study comparing 19 climate models (operating with similar hypothesis of greenhouse gas concentration increase in input) showed that if all the models give tallying results at global scale, they are not accurate enough to localise exactly areas of convergence (heavy rainfall) and areas of subsidence (tropical desert). There is a difference of 10° of latitude between some models. It is thus delicate to foresee the climatic modulation of water resources in future in particular areas (especially in subtropical Africa), and consequently difficult to specify the impact of climate change on agricultural production (Marsily De, 2006).

It is also hard to estimate the impact of Climate Change on the expanse of potentially arable land (Treyer, 2009). Most of the foresights are based on FAO and IIASA (International Institute for Applied System Analysis) work on Global Agro-Ecological Zones (GAEZ)\(^2\) to estimate the expansion of cropland. However, this work does not currently consider Climate Change.

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\(^2\) GAEZ (Global Agro-Ecological Zones). This work consider climate, soils and landform, and land utilizations types to determine the agricultural potential of a soil (potential yield that could be reached).
Difficulties quoted above generally prevent impacts of climate change from being considered in food and agriculture futures studies. However, some exercises focusing on this particular topic are beginning to be released. They contain new ways of development that could be used to include this subject in agriculture strategic foresights. The IFPRI published in 2009 the results of a study whose goal was to evaluate the impacts of climate change on agriculture production, consumption and trade and on food security. It uses a model simulating supply and demand for agricultural products (IMPACT WATER) combined with a biophysical model foreseeing plant growth according to climate. The idea is to isolate the effects of climate change from other parameters. Two numerical climate models are used with the same input hypothesis on greenhouse gas concentration. The use of both of them is interesting since it puts in evidence the incertitude related to climate models. The impacts on yields (rainfed and irrigated agriculture), on renewable water resource and on agricultural water requirements are estimated. These particular results are reported in Annex 2. These evaluations are interesting for food and agriculture foresights. This approach could thus be used again in future exercises.

This part presented key points of futures studies on agriculture and food. After assessing methodological differences that can exist from study to study, we saw how the balance between demand and supply for food was estimated in foresights. If that evaluation is always realized, the assessment of water resources and water uses balance is not. Moreover, in the main, qualitative problems related to water management are not quantitatively considered. Finally, the difficulties faced have been addressed.

In the next part, three studies will be detailed. The choice was directed towards the FAO, Rosegrant and CAWMA studies. Indeed, in those works water is taken into account with an interesting level of details.

GOING FURTHER: IN-DEPTH STUDY OF THREE STRATEGIC FORESIGHTS

In this part, three futures studies will be detailed. The emphasis will be placed on the consideration of water in these works. The estimates of supply and demand for food will thus be left out. The differences between these studies and the strong and weak points of each one will be stressed.

- WORLD AGRICULTURE TOWARDS 2015/2030 : SIMPLE BUT EFFECTIVE

General presentation

This study is an exercise of anticipation. It sets out one scenario only, stating the most likely future (breaks in trends are taken into account). The analysis focuses on two questions: how the world will feed itself in the future and what the need to produce more food means for its natural resource base. 1997-99 (the three-year-average of each parameter is used) is the base year and 2030 the time horizon. The study covers 140 countries (analysed one by one) and considers 32 food products. The average level of calorie intake reached in 2030 is 2,980 kcal/per/day. However disparities remain: 6% of world population (that’s to say 443 million people) still suffer from undernourishment.

Considering water

Since three quarters of the world’s irrigated area is localised in developing countries, the FAO chose to concentrate on this part of the world, detailing water issues in 93 developing countries only. In this territory, the expansion of irrigated area is assessed from existing irrigation expansion plans, potential for irrigation expansion and needs to increase crop production. Irrigation water requirements are then evaluated for each country for 2030. Once hypotheses on the evolution of irrigation efficiency (water consumption/ water withdrawal) are set, irrigation water withdrawals are calculated. The pressure on water resources is evaluated through the criticality ratio, which compares water withdrawals to renewable water resources. Water scarcity is impending when the ratio is above 20%, and the situation is critical when it is above 40%.
Results

The study foresees an expansion of irrigated area (Table 1), specifically affecting areas where arable land is scarce. Net expansion is calculated: losses due to soil degradation or water scarcity are considered. The total investment in irrigation on the projection period in developing countries must encompass some 200Mha, and not 40Mha, the difference corresponding to rehabilitation or substitution works. Moreover, as the expansion in harvested area points out, the irrigated agriculture intensifies (multiple cropping, shorter fallow periods).

Water withdrawals increase slowly compared to irrigated harvested area (Table 1). This is the result of the improvement of irrigation efficiency, which particularly takes place in water scarce area.

The number of countries (among the 93 studied) affected by water scarcity increases from 18 in 1997-99 to 20 in 2030. However, the criticality ratio is calculated at the national scale, and regional difficulties cab thus be hidden.

<table>
<thead>
<tr>
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<th>1997/99</th>
<th>2030</th>
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<tbody>
<tr>
<td>irrigated area (cultivated/harvested)</td>
<td>202 Mha / 257 Mha</td>
<td>242 Mha (+20%) / 341 Mha (+33%)</td>
</tr>
<tr>
<td>Share of total cultivated area</td>
<td>21%</td>
<td>22%</td>
</tr>
<tr>
<td>Irrigation contribution to global production</td>
<td>40%</td>
<td>47%</td>
</tr>
<tr>
<td>Water withdrawals for irrigation</td>
<td>2128 km³/an</td>
<td>2420 km³/an (+14%)</td>
</tr>
<tr>
<td>Irrigation Efficiency (%)</td>
<td>38% (From 25% in Latin America to 44% in South East Asia)</td>
<td>42% (From 25% in Latin America to 53% in Northern Africa)</td>
</tr>
</tbody>
</table>

Table 1: evolution of irrigation and agricultural water requirements in the FAO perspective (for 93 developing countries)

Limits

The analysis of water issues is restricted to 93 developing countries and is realized at national scale and not at basin scale. The latter would be suited to a study of water resource. Moreover, many points are not quantified (water pollution and groundwater overexploitation and their impacts on food production, non-agricultural water demand…) and climate change is not considered in the stated scenario. However, an entire chapter is dedicated to this topic. It points out that if the impacts on agricultural production should be limited by 2030, significant differences should exist between regions. Indeed, the evolution of cereal yields by 2020 should be of -0.5% on average in the world, but it could vary from -2.5% to +2.5% according to the regions.

○ WORLD WATER AND FOOD TO 2025 : FUTURES SCENARIOS AND ANALYSIS OF SPECIFIC INTERACTIONS

General Presentation

This strategic foresight specifically analyses the link between water availability and agricultural production. It is halfway between the scenario and the model approaches. Indeed for each scenario, the qualitative thought results in estimating the values of some parameters. These ones will be entered in the IMPACT WATER model that is used to quantify the hypotheses.

The study covers the period 1995-2025. It is realized at global scale and considers 16 food products.

Three scenario illustrating possible futures are set out. Business As Usual (BAU) presents the future in case current trends for water investments, water prices and management are broadly maintained. In Water Crisis (CRI), its pessimistic variant, policies in water field and food field worsen. On the contrary, Sustainable Water Use (SUS) is more optimistic (bigger committed flows for environment, full water connection, and agricultural production similar to BAU).

Eleven other scenarios review the impacts of specific policies choices (water prices, investment in irrigation, environment friendly policies…) on agricultural production and on the balance between human and environmental water requirements.
Results (Table 2)

In this study, the emphasis is placed on the impacts of water availability on agricultural production for different choices of policies and investments. The following indicators have thus been created:
- An indicator on Irrigation Water Supply Reliability (IWSR), comparing effective and potential (water needed to fulfill plant’s water requirements) water consumption in irrigation.
- The criticality ratio: ratio between water withdrawals and renewable water resources.

In BAU scenario, the demand for water in all sectors increases. However, water resource becomes scarcer and irrigation water demand can less and less be fulfilled (decline of IWSR), hence a slower yield growth.

Trade becomes essential to supply numerous developing countries (particularly in Asia) in food. Moreover, it helps saving water and land. However, this situation results in growing food security issues in many regions (particularly in subtropical Africa), since the economic growth is not sufficient to finance the required food imports.

In CRI, the surge in water withdrawals do not compensate for the collapse of water efficiency that is observed in every sectors. IWSR thus decline. On the contrary, in SUS, the rise of water prices limits water withdrawals in all sectors and encourages the improvement of basin efficiency. This partly offsets the fall in irrigation water consumption and restricts the decline of IWSR.

In CRI, cereal production decreases of 10% at global scale (fall in harvested area and yields) whereas in SUS the increase in rainfed cereal production makes up for the decline in irrigated production. Agricultural prices surge in CRI. Issues of food security thus regain (per capita food consumption is lower than 1995 levels). Moreover, the part of population connected to water supply decreases. Consequently, sanitary problems risk multiplying. In SUS, agricultural prices and food consumption are similar to BAU levels.

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>BAU</th>
<th>CRI (+10%/BAU)</th>
<th>SUS (-22%/BAU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Withdrawals (km³)</td>
<td>3,096</td>
<td>4,772 (+22%/95)</td>
<td>5,231</td>
<td>3,743 (-22%/BAU)</td>
</tr>
<tr>
<td>Water consumption for irrigation (km³)</td>
<td>1,436</td>
<td>1,492 (+3.9%)</td>
<td>1,745</td>
<td>1,196</td>
</tr>
<tr>
<td>Irrigated cereal area (Mha)</td>
<td>213</td>
<td>238 (+3.9%)</td>
<td>221</td>
<td>231</td>
</tr>
<tr>
<td>Rainfed cereal area (Mha)</td>
<td>474</td>
<td>514 (+8%)</td>
<td>504</td>
<td>506</td>
</tr>
<tr>
<td>Cereal production : irrigated rainfed total</td>
<td>Base</td>
<td>-11%</td>
<td>-9%</td>
<td>-10%</td>
</tr>
<tr>
<td>IWSR: World</td>
<td>0.78</td>
<td>0.67</td>
<td>0.65</td>
<td>0.73</td>
</tr>
<tr>
<td>Developing countries</td>
<td>0.75</td>
<td>0.65</td>
<td>0.65</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Table 2: Main results from BAU, CRI and SUS scenarios, in World Water and Food to 2025

Strong points and limits

On one hand, this is one of the first studies that quantify more accurately agricultural water demand. Indeed it takes into account the impacts of water scarcity on irrigated area and yields. Moreover, water available for irrigation is better estimated since water requirements of other sectors (human activity and environment) are included. The level of detail gives the opportunity to analyse the impacts of particular choices of policies and investments on water resource preservation and food production.

On the other hand, qualitative issues related to water management are not raised. Moreover, while it is possible to enter any climatic data series into IMPACT WATER, the climate change has not been considered in the study. Finally, the scenarios built up do not try to meet food requirements and to ensure food security for everyone.

WATER FOR FOOD WATER FOR LIFE: DIFFERENT WAYS TO MEET FOOD REQUIREMENTS

General presentation

This study focuses on agricultural water management with objectives to meet world food requirements in 2050. The approach carried mixes the use of WATERSIM model with qualitative thought that ensure the consideration of environmental and social (poverty, equity…) dimensions.
The study covers the period 2000-2050, considers 32 food products and is realized at global scale, the world being divided into basins.

Four scenarios regarding meeting world food requirements in 2050 (the average level of per capita calorie intake is 2970 kcal/per/day), and based on different choices of policies and investments are stated:

- One plays on the improvement of rainfed agriculture productivity (R). Two variants resting on different hypotheses on the productivity increase are set out (one pessimistic (RPes) and one optimistic (ROpt)).
- Another plays on an increase of irrigated production (Irr). According to the variant, this increase can be the result of an expansion of irrigated area (IrrA) or of an improvement of irrigation efficiency (IrrE).
- A third scenario sets out a rise in trade (TRA) to meet food requirements while limiting water withdrawals.
- Finally, the Comprehensive Assessment scenario (CA) combines those diverse strategies, taking into account regional strengths and limitations.

Results

From scenario to scenario, water withdrawals and the expansion of irrigated area change a lot (Table 3). In all cases, irrigation withdrawals increase but this rise can vary from 5% (TRA) to 57% (IrrA).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>Rainfed Agriculture</th>
<th>Irrigated Agriculture</th>
<th>TRA</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
<td>ROpt</td>
<td>R Pes</td>
<td>IrrA</td>
<td>IrrE</td>
</tr>
<tr>
<td>Irrigated Area (Mha)</td>
<td>340</td>
<td>340</td>
<td>340</td>
<td>450</td>
<td>370</td>
</tr>
<tr>
<td>Rainfed area (Mha)</td>
<td>860</td>
<td>920</td>
<td>1320</td>
<td>1100</td>
<td>1140</td>
</tr>
<tr>
<td>Water Productivity in Irrigation (kg/m^3)</td>
<td>0.68</td>
<td>0.84</td>
<td>0.83</td>
<td>0.83</td>
<td>0.97</td>
</tr>
<tr>
<td>Growth (%)</td>
<td>24</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>43</td>
</tr>
<tr>
<td>Water Productivity in rainfed agriculture (kg/m^3)</td>
<td>0.49</td>
<td>0.66</td>
<td>0.54</td>
<td>0.54</td>
<td>0.55</td>
</tr>
<tr>
<td>Growth (%)</td>
<td>35</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Irrigation withdrawals (km^3)</td>
<td>2630</td>
<td>3155</td>
<td>3160</td>
<td>4120</td>
<td>3460</td>
</tr>
<tr>
<td>Growth (%)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>57</td>
<td>32</td>
</tr>
<tr>
<td>Rainwater Consumption by plants (km^3)</td>
<td>5560</td>
<td>7415</td>
<td>9040</td>
<td>8080</td>
<td>7880</td>
</tr>
</tbody>
</table>

Table 3: Main results of the different scenarios of Water for Food Water for Life

Strong points and limits

This study is currently the only study on agricultural water management with objectives to meet food requirements. It is thus used as a reference by some programs such as the Challenge Program on Water and Food that uses it both as a strategic guide book and to evaluate its actions comparing its results to the projections of the diverse scenarios.

However, a few limits remain (Vidal, 2009). Indeed the study focuses on crops while a lot of things can be done to improve water productivity in livestock production and aquaculture. Moreover, climate change effects are not considered.

Three studies and their main results have been set out in this part. The limits and the potential of each one have been addressed. In the next part, key results will be pointed out. We will specifically try to answer the three following questions: will there be enough water to supply the world, how food needs can be met and which level of food consumption will be reached. Debate points between foresights studies will be listed, and ideas to improve forthcoming works will be stated.
RESULTS AND DISCUSSION

The first part placed the emphasis on the differences between studies, such as approach, data or objective. Those differing points must be kept in mind. The main difference between the studies we detailed is related to the fulfilment of world food requirements by the time horizon. The CAWMA study is the only one that ensures it. In the studies from the FAO and from Rosegrant, this is not an objective and it is thus not guaranteed. Moreover, the time horizon differs from study to study.

The results of the three detailed studies are gathered together in Annex 3. The differences between the strategic foresights forbid any in-depth comparison of results. However, some key results must be pointed out. First, according to Water for food Water for life, world food requirements can be met by 2050. Varying ways are envisaged to achieve it. The ones that are used in the CA scenario are interesting. Indeed, this scenario favours the increase of rainfed and irrigated productivity, thus limiting the expansion of cultivated area and agriculture water consumption (for both green and blue water resources). However, the fulfilment of world food needs will not be easy. The study World Water and Food to 2025 indeed shows that bad choices of policies or investments in water and food fields can result in a higher pressure on water resources and in a resurgence of food security issues (CRI scenario).

All these results are tinged with uncertainty. Indeed, some hypotheses or some simplifications are debated. Likewise, we can plot some limits that have to be considered in forthcoming future studies.

The first debate point is related to the chosen level of food consumption. It can be either an objective (CAWMA, Agrimonde) or the result of the evolution of other parameters (FAO, Rosegrant). While average levels reached are of the same order of magnitude (around 3000 kcal/per/day in 2050), the national values and the number of persons suffering from undernourishment vary significantly from study to study. It is thus essential to analyse what improvements can be made and how they can be induced in order to choose a plausible value (or to check that the obtained value is plausible).

The choice of the analysis and modelling scale is also crucial in strategic foresights realized for big geographical regions. For example, Rosegrant’s study is commonly criticized because the study analyses the impacts of water policies at global scale, often at the expense of local observations that are fundamental for entire regions (Vidal, 2009). Thus, the rise of water prices risks leading poorest farmers to stop farming, but this point is not addressed in the study. Likewise, the choice of the scale narrows the field of drivers that can be included: some key drivers such as the kind of national governance (that is significant in many developing countries) and the societies’ values were for example left out by Rosegrant (Borron and al., 2008).

The Paneuropean research program SCENES (Finnish Environment Institute, 2009) that must define foresight scenarios on continental water management, currently tests to a new approach by leading analyses at different scales in parallel. At Paneuropean scale, four qualitative scenarios are defined and then quantified. Europe and neighbouring states are divided into four large regions. For each one, basins judged as representative are detailed. Local stakeholders give their opinion by developing in-depth the scenario that seems to be the more plausible for their territory. The objective is to develop a local view, so that everyone can see oneself in the scenarios that will finally be set out. However, it is difficult to link the two working scales (Rieu, 2010). The first question is to know whether or not we can hypothesize that a sum of basins represents a region. There are then difficulties related to the differences between basins or regions: some must face low water while others are concerned with inundations, some favour good water status and others emphasize the solutions to quantitative issues, even biophysical phenomena that come into place vary from basin to basin. Also, how can we develop a model that would be valid for all European countries? And how can we write scenarios that will interest anyone? These issues are common to all strategic foresights realized at global scale.

Finally, even though it is hard to choose the working scale, this stage of the study elaboration must be carefully led since it has significant impacts on the results. The solution that will be chosen to link the different working scales in SCENES should be analysed. Indeed, it could help choosing the working scale in forthcoming world strategic foresights.

The impacts of Climate Change on agriculture and water resources must also be included. Since current climatic models are not accurate, it is interesting to use several of them (as in (Nelson, 2009))
to obtain a range of results, which are more significant than a single result. Likewise, the new GAEZ that consider climate change should be released. They will be a better base of work than the old ones.

Moreover, the resiliency of socio-ecosystems to climate, economic and politic changes, and particularly the resiliency of the poorest population, must be considered. Indeed, the three quarters of a billion of people currently suffering from hunger live in rural area and depend on farming. Their resiliency to change (agricultural prices, water prices…) is very low and the exodus to towns is increasing. New studies must be realized in order to discover ways to increase the resiliency of farming communities and the resiliency of the ecosystems that support them.

Finally, qualitative issues (whether they concern water or land) must be quantified. Indeed, their effects on agricultural yields and population health can not be neglected. To include them, it is possible to use the WATERGAP model that contains a qualitative part which is currently being improved (Rieu, 2010).
BIBLIOGRAPHY


<table>
<thead>
<tr>
<th><strong>ANNEX 1: Different data used in studies and included parameters</strong></th>
<th><strong>World Water and Food to 2025 (Rosegrant et al. 2002)</strong></th>
<th><strong>FAO (Bruinsman, 2003)</strong></th>
<th><strong>Water for food water for life (Comprehensive Assessment of Water Management in Agriculture, 2007)</strong></th>
<th><strong>Agrimonde (CIRAD &amp; INRA, 2009)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic Data</strong></td>
<td>UN 1999 (the 1998 revision) Medium variant 2025 : 7.9 billions 2050 : 8.9 billions</td>
<td>UN 2001 (the 2000 revision), Medium variant 2030 : 8.3 billions 2050 : 9.3 billions</td>
<td>UN 2003 (the 2002 revision) Medium variant 2030 : 8.1 billions 2050 : 8.9 billions</td>
<td>UN 2007 (the 2006 revision), Medium variant 2030 : 8.3 billions 2050 : 9.2 billions</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td>Proper estimate in 2025 : GNP/per Max : 76460$ in Japan Min : 140$ in Sub-Saharan Africa (the weakest growth: 0.8%)</td>
<td>World Bank 2001 Growth of GNP/per from 1997-99 to 2030 : 2.6% (from 2.0% in Sub-Saharan Africa to 5.5% in South East Asia)</td>
<td>Income Estimates from the MEA, scenario techno-garden in 2050 (GNP/per) 18,000$ on average. From 3,000$ in Africa to 74,000$ in OCDE countries.</td>
<td>Unused parameter</td>
</tr>
<tr>
<td><strong>Food Consumption</strong></td>
<td>Estimated by the model : Cereal Consumption/per in kg/year : 1995 : 314 (from 47 in Latin America to 549 in OCDE) 2005 in BAU: 330 (from 58 in Latin America to 623 in OCDE)</td>
<td>Proper Estimate in 2030: Average : 3,050 kcal/per/day Min : 2,540 in Sub-Saharan Africa Max : 3,500 in industrialised countries</td>
<td>Estimated by the model in 2050: Global average: 2,970 kcal/per/day. Other values not given.</td>
<td>Scenario agrimonde GO : uses values from MEA scenario GO (global average of 3,590 kcal/per/day in 2050) Scenario Agrimonde 1 : universal consumption of 3000 kcal/per/day in 2050</td>
</tr>
<tr>
<td><strong>Water Uses:</strong></td>
<td>Quantified Irrigation water (withdrawals) 4,772 km³ (2025) Others uses Quantified</td>
<td>Quantified in Developing C. 2,420 km³ (2030, Ding C.) Not quantified</td>
<td>Quantified 2,975 km³ (2050,scenario CA) Quantified but not given</td>
<td>Not quantified</td>
</tr>
<tr>
<td><strong>Adequacy resources/uses</strong></td>
<td>Ensured by allocation rules. Global and sectoral Indicators.</td>
<td>Criticity Ratio calculated for 93 Developing countries</td>
<td>Ensured by allocation rules. No indicators</td>
<td>Not considered</td>
</tr>
<tr>
<td><strong>Consideration of Climate Change</strong></td>
<td>NO but the model can take it into account</td>
<td>Not in the scenario but there is a dedicated chapter</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>
ANNEX 2: Some quantified results of the study on the impacts of Climate Change (Nelson, 2009)

<table>
<thead>
<tr>
<th>CO₂ fertilization</th>
<th>Without CC</th>
<th>Scenario based on NCAR model</th>
<th>Scenario based on CSIRO model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without</td>
<td>With</td>
<td>With</td>
</tr>
<tr>
<td>Effect of CC on agricultural yields: (in % compared to projections without CC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize irrigated (Developing C/Developed C)</td>
<td>-2.1 / -8.6</td>
<td>-2.8 / -8.7</td>
<td>2.4 / 10.5</td>
</tr>
<tr>
<td>Maize rainfed</td>
<td>-0.4 / 2.5</td>
<td>-2.0 / -5.7</td>
<td>6.6 / 23.9</td>
</tr>
<tr>
<td>Wheat irrigated</td>
<td>-27.2 / 0.0</td>
<td>-34.3 / -4.9</td>
<td>-20.8 / -1.3</td>
</tr>
<tr>
<td>Wheat Rainfed</td>
<td>8.6 / 9.5</td>
<td>-1.1 / 2.4</td>
<td>9.4 / 9.7</td>
</tr>
<tr>
<td>Renewable water</td>
<td>Rise all around the world</td>
<td>Lower ride and decline of 4% in Middle East, in Northern Africa and in Sub-Saharan Africa</td>
<td></td>
</tr>
<tr>
<td>IWSR: Irrigation water supply reliability (water consumption/ water required by the plant) (compared to projections without CC)</td>
<td>IWSR improves on average in Developing Countries (heavier rainfall compensating for hydric needs increased due to temperature rise)</td>
<td>IWSR declines on average in Developing Countries: the heavier rainfalls are still not sufficient.</td>
<td></td>
</tr>
<tr>
<td>Daily calorie intake (kcal/day/per)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing Countries</td>
<td>2886</td>
<td>2632</td>
<td>2410</td>
</tr>
<tr>
<td>Developed Countries</td>
<td>3645</td>
<td>3263</td>
<td>3190</td>
</tr>
</tbody>
</table>

The CO₂ fertilization has a significant impact on results. While almost all the crop yields decline when it is not taken into account, we notice lower falls or even increase in yields when it is considered.

Moreover, if global trends are similar in both scenarios (Developing countries are more affected than the Developed ones, where some increase in yields can even be noticed), there are significant differences between the estimates of the two models. The use of several models can them give a range of results that would be more reliable and significant than a single result since current models are not accurate enough.

The quantification of renewable water volume available in each scenario and the IWSR are not given in the report. However, the trends reported and the ability of IMPACT WATER model to evaluate these parameters let think that they have been calculated.
### ANNEX 3: Table summarizing the results of the three detailed foresights

<table>
<thead>
<tr>
<th>Water for food, water for life : 2050</th>
<th>FAO perspective : 2030</th>
<th>World Water and food to 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAU</td>
<td>CRI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demography (billion of people)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025: 7.9</td>
<td>2050: 8.9</td>
<td>2030: 8.3</td>
</tr>
<tr>
<td>Food Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>330kg cereal /per/year</td>
<td>298kg cereal /per/year</td>
<td>332kg cereal /per/year</td>
</tr>
<tr>
<td>Cereals Production (million of metric tons/year)</td>
<td>2614 (cereals)</td>
<td>2365 (cereals)</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Consumption (km$^3$)</td>
<td>2081</td>
<td>2342</td>
</tr>
<tr>
<td>Total withdrawals (km$^3$)</td>
<td>4772</td>
<td>5231</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Water:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainfed :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface (million ha)</td>
<td>514 (cereals)</td>
<td>504 (cereals)</td>
</tr>
<tr>
<td>Consumption (km$^3$)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Water Productivity (kg/m$^3$)</td>
<td>Cereals except rice DgC: 0.57 DdC 1.52</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation :</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface (million ha)</td>
<td>238 (cereals)</td>
<td>221 (cereals)</td>
</tr>
<tr>
<td>Consumption (km$^3$)</td>
<td>1492</td>
<td>1745</td>
</tr>
<tr>
<td>Withdrawal (km$^3$)</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>IWSR</td>
<td>0.78</td>
<td>0.67</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>61 (BE$^3$)</td>
<td>44 (BE)</td>
</tr>
<tr>
<td>Water Productivity (kg/m$^3$)</td>
<td>Cereals except rice DgC: 0.93 DdC: 1.93</td>
<td>n.a.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Basin Efficiency, meaning water efficiency evaluated at basin scale. It differs from the simple ratio consumption on withdrawals since the possible reutilizations are considered. The values obtain are thus higher than in other studies.
<table>
<thead>
<tr>
<th>Other Water Uses</th>
<th>BAU (Cons.)</th>
<th>CRI (Cons.)</th>
<th>SUS (Cons.)</th>
<th>Rainfed Scenario</th>
<th>Irrigation Scenario</th>
<th>Trade Scenario</th>
<th>Scenario CAWMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry ($km^3$)</td>
<td>240</td>
<td>320</td>
<td>155</td>
<td>617 (withdrawal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic ($km^3$)</td>
<td>290</td>
<td>223</td>
<td>265</td>
<td>681 (withdrawal)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Reliability in those sectors</td>
<td>0.98</td>
<td>0.95</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criticality Ratio

|                      | >0.2 in 15 regions/ 36 | >0.2 in 20 countries/ 93 | 2.6 billion people (28% of world population) live in water scarce area |                |

n.a. : not available
DgC: Developing Countries
DdC: Developed Countries