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Water and food security: integrated scientific and governance based solutions

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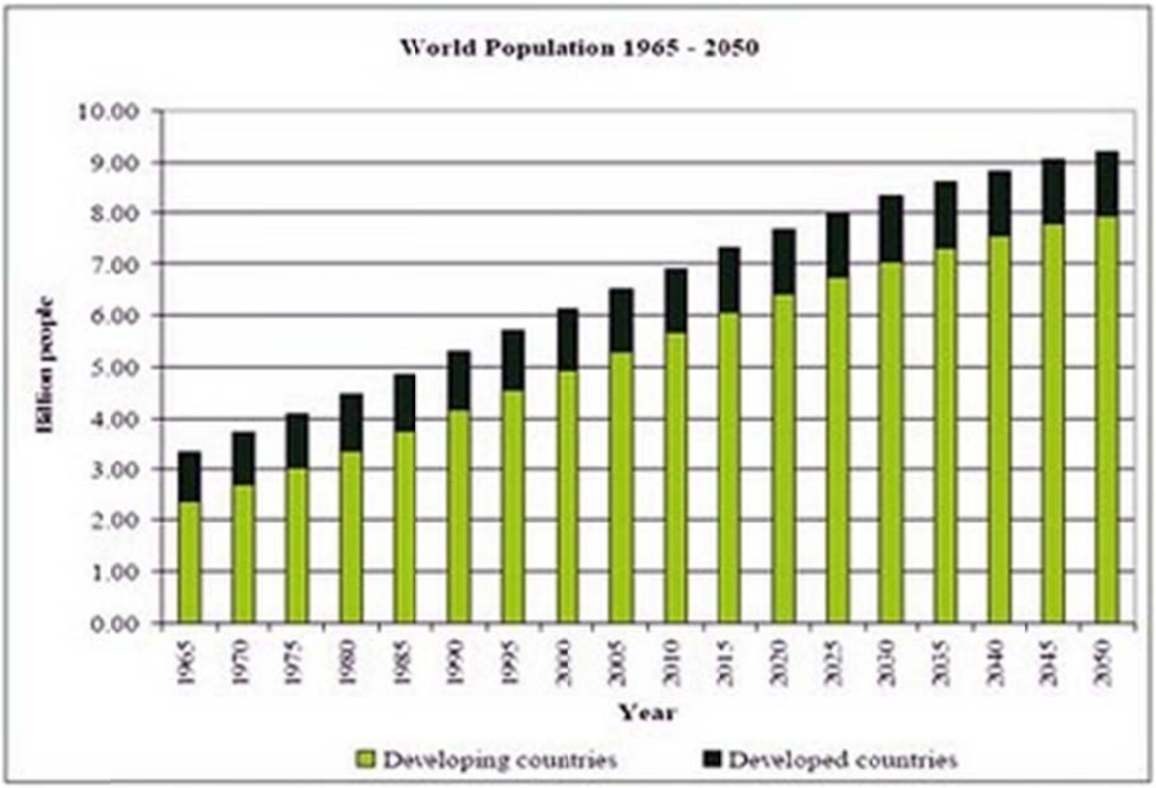
Abstract

By 2050 we will have to feed approximately 2.5 billion more people. Many experts have suggested that this will require food production to increase by 70% on today's levels. If current levels of productivity remain static in the developing world, it is also feared that many countries will simply not have the available water resources to significantly increase production. Does this mean that we will have to increasingly rely on Europe, the USA and the ex USSR countries to step up production or can we foster a second green revolution to help increase productivity elsewhere? If we are to foster such a revolution, this time it has to be a blue-green revolution that recognizes the critical role of water in production systems. Unfortunately, the continued disciplinary separation of agronomy and natural resources management in many institutions won't help in this regard. Similarly, the neglect of governance systems for natural resources will also have to be dealt with in many developing countries. This paper considers the drivers of food and water scarcity and look to both generic and actual solutions that have to be applied to the problem.

Introduction

As scientists we tend to compartmentalize many issues, disciplines and even sub-disciplines. Our curiosity as to how things work also drives us down increasingly reductionist pathways. In fact, we try to reduce complexity in order to understand function and processes. In many cases this has led to, and will in the future, lead to amazing discoveries that have generally been of great use to humankind. The “Green Revolution” of the 1960s and 70s, that some claim saved a billion people from starvation, had its roots in relatively straightforward, but critical improvements to wheat and rice genetics that could be delivered with conventional breeding approaches. These improvements were bolstered by better access to fertilizers and irrigation, and were delivered in a relatively straightforward fashion from the laboratory to the farmer. These scientific advances saw crop yield climb steadily until the end of the last century. However, since then yields have plateaued and growth has largely stagnated. Some commentators put this down to the declining investment in agricultural research and development, particularly in the Consultative Group on International Agricultural Research (CGIAR). To an extent, this may be the case, but the world of the 21st century is also a very different place from that of the 20th century.

Population growth driven by improved healthcare and availability of food has been rampant. In 1960 there were approximately, 3 billion people on the planet, compared with about 7 billion today and a forecast of over 9 billion by 2050 (Figure 1).



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2007)

Figure 1. World Population growth 1965 - 2050

Competition for arable land and water resources has become intense not only from food and fibre producers, but also from growing urbanization and industrialization, and more recently from biofuel production. People's diets in the developing world are also changing fast as their spending power increases with a trend towards higher protein animal based products that require more cereals to be grown to feed the animals and more water to grow the cereals. Finally, we have the spectre of climate change (Figure 2). In spite of the uncertainty surrounding this area in terms of detailed impacts, there is growing evidence to suggest that crop yields will be increasingly affected by rising temperatures and more erratic rainfall patterns and that water supplies will also be impacted in many countries.

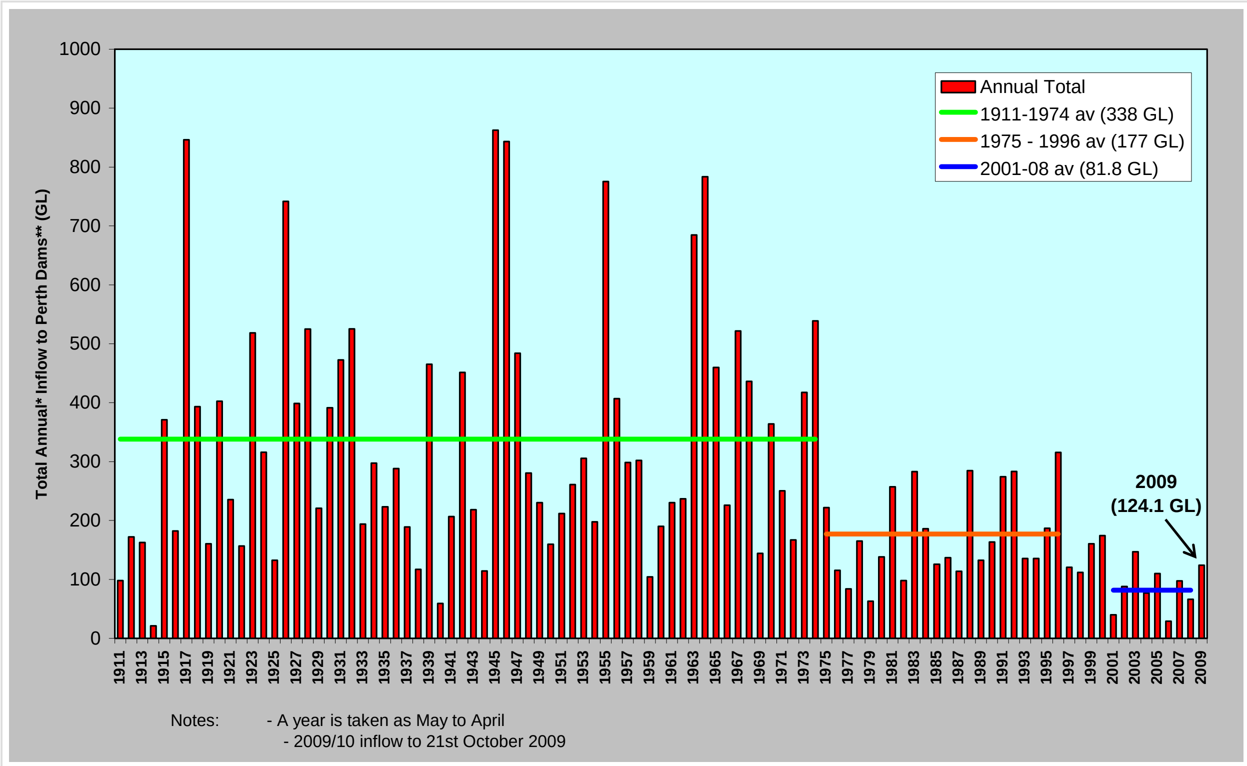


Figure 2. Impact on Water Availability - Reduced Inflows to Dams (acknowledgments to the Water Corporation, Australia)

Additionally, we are faced with a very much more significant human footprint on the environment than was apparent 50 years ago. This footprint is not only responsible for the consumption of natural resources at a rate faster than their replenishment, but also for widespread and serious environmental degradation that is threatening the ecosystem services on which we rely. So, we are entering an era of much greater complexity than was faced by the fathers of the Green Revolution, Norman Borlaug and M. S. Swaminathan, to whom we owe so much. This complexity leads us to the question as to what will be the best approaches to deal with the issues facing food production and natural resources management in the future. Will they be reductionist in nature and dependent on laboratory breakthroughs in plant breeding for higher yields and greater environmental tolerance, or will they be based on better marshaling of what we have and know now and more integrated analysis and understanding of our agro-ecological systems? Only time will tell, but this paper aims to provide detail of the food and natural resource management challenges confronting us and looks at some potential solutions.

How much food and water will we need in 2050?

There have been a number of attempts to estimate total food production requirements by 2050 and all of these generally hinge around adoption of the UN median estimates of population growth (c.9 billion by 2050), assumptions of individual calorific needs (Figure 3), allowances for wastage at harvest and post purchase, and the proportions of animal products in the diet. The FAO (2009) has estimated that food production will need to increase by 70% and that annual cereal production will need to rise to about 3 billion tonnes from 2.1 billion today and annual meat production will need to rise by over 200 million tonnes to reach 470 million tonnes.

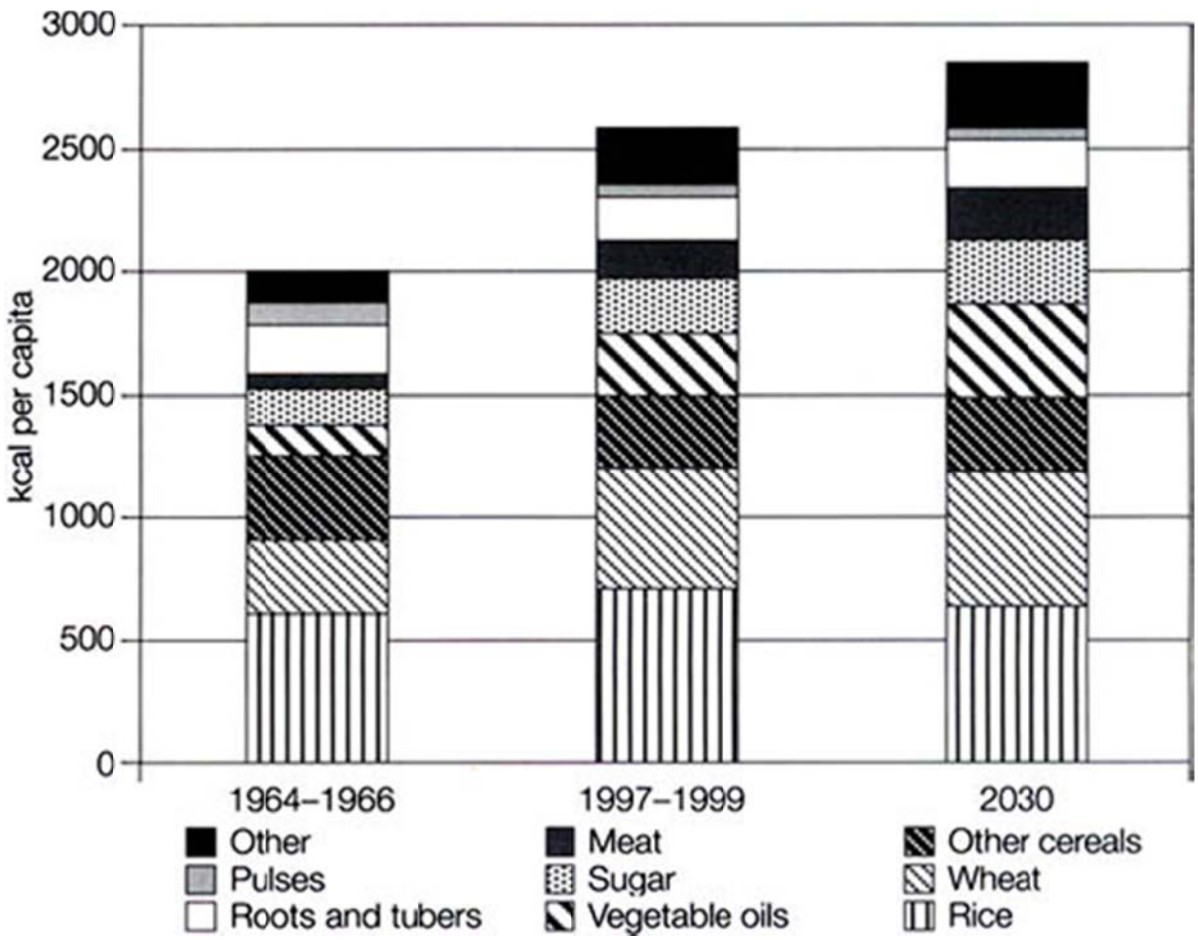


Figure 3. Calories from major commodities in developing countries
(http://www.fao.org/DOCREP/005/AC911E/ac911e05.htm)

Such a large increase in food production will also require very significant amounts of fresh water to grow it. In the last 30 or 40 years, we have moved relatively quickly from a world of land, water and ecosystem abundance to one of increasing scarcity. The absolute amount of freshwater and land available remains finite, but the number of people competing for the use of these resources continues to grow. Globally, agriculture currently uses 70% of the world's developed freshwater, and in some developing countries up to 90%. The need for water to support ecosystems plus the growing demands for water from industry and people in cities and towns will require significant changes in the way we use water.

The Comprehensive Assessment of Water Management in Agriculture (CAWMA, 2007) concluded that at current levels of water productivity, water requirement would increase from about 7,000 km^3 in 2000 to 13,000 km^3 in 2050 (Figure 4). Similarly arable land would need to increase from about 1,200 million hectares in 2,000 to 2,400 million hectares in 2050.

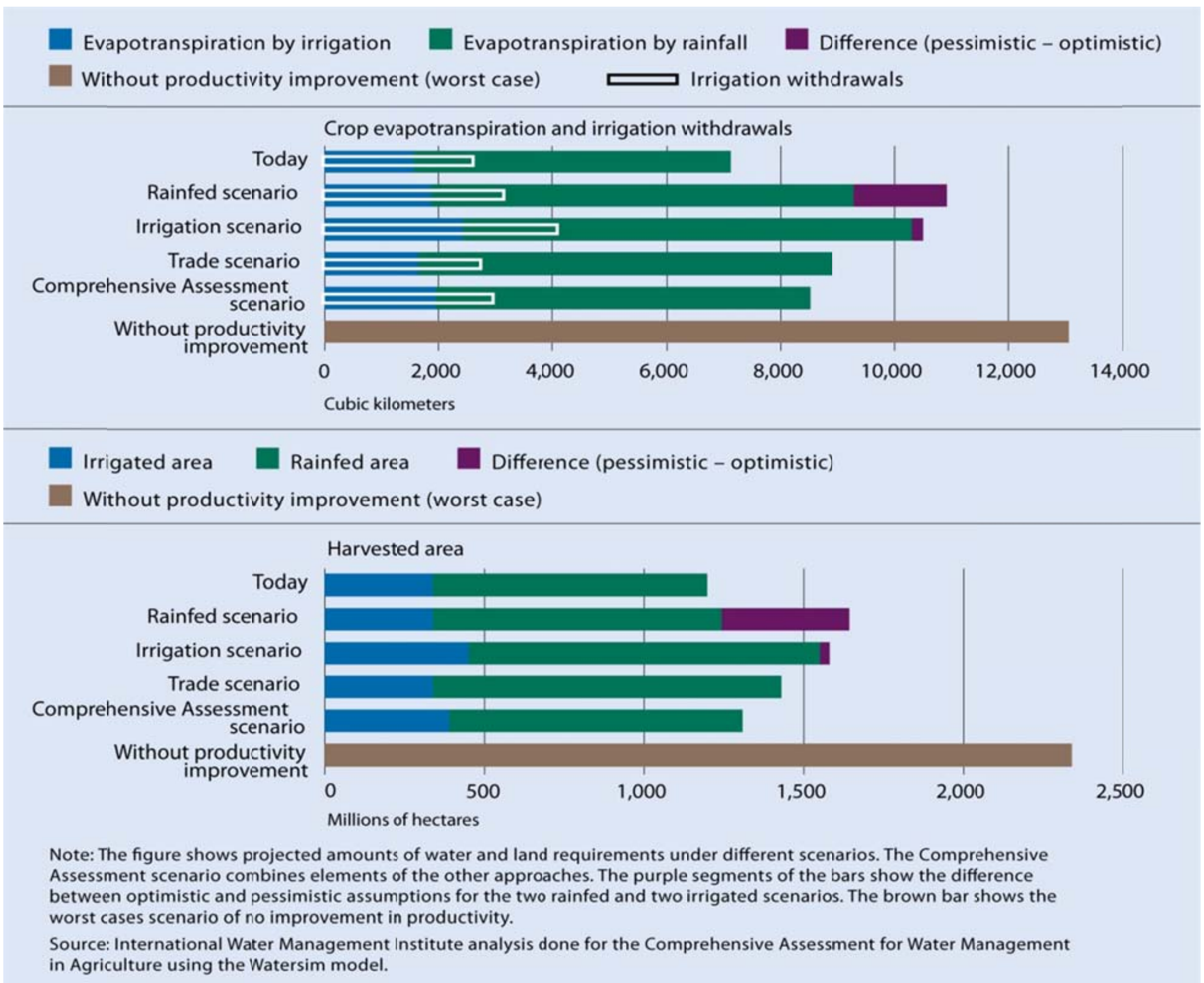


Figure 4. Scenarios from the 'Water for Food, Water for Life', CAWMA. 2007

Chartres and Varma (2010) similarly estimated that to feed 9 billion people a diet of 3000 calories per day, which allows for some wastage, we would need to utilize a further 2500 –

3000 km^3 of water every year based on the assumption that to produce 1 calorie of food requires 1 litre of water on average.

Do we have enough arable land and water to grow more food?

The above estimates present us with a major problem in that, although theoretically there is enough land and water available globally to increase production to required levels, they are generally not in appropriate places geographically and climatically. Furthermore, even if the food can be grown elsewhere from where it is consumed, there are major issues as to whether some food and water scarce developing countries have the money available to import it. Water scarcity is of serious concern in many regions of the world (Figure 5).

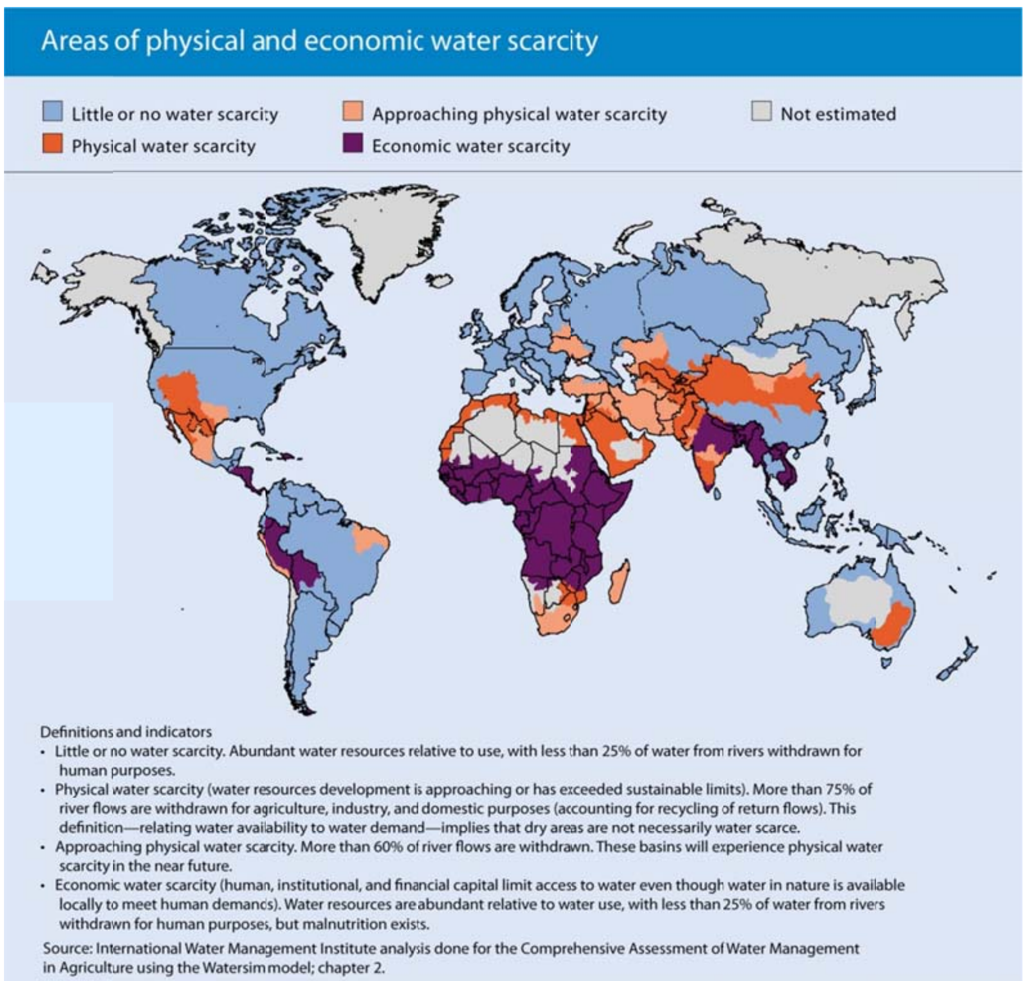


Figure 5. Water Scarcity from 'Water for Food, Water for Life' , CA 2007

It takes two forms; the first is physical, in which the majority of the total available water resources are already being used, and the second, economic, in which there has not been sufficient investment to deliver water to where it is needed for agriculture, drinking, or urban/industrial uses. Given competition for water from other sectors of the economy and the environment, and due to climate change induced reductions in availability (at least at the right time and place) it is highly likely that agriculture's share of available water resources will decline

Whilst there may be sufficient arable land available to significantly increase food production, up to half the world's agricultural land is degraded to some degree. The Global Assessment of Human-Induced Soil Degradation (GLASOD) was the first attempt to estimate the extent of soil degradation globally (Oldeman, *et al.*, 1991). Based on expert opinion, it remains the main source of degradation data (Figure 6). According to GLASOD, degradation of croplands is most extensive in Africa, affecting 65% of cropland areas, compared with 51% in Latin America and 38% in Asia (CA, 2007). Land degradation, coupled with impending shortages of artificial fertilizers, in particular phosphate, further exacerbates the challenge of increasing food production.

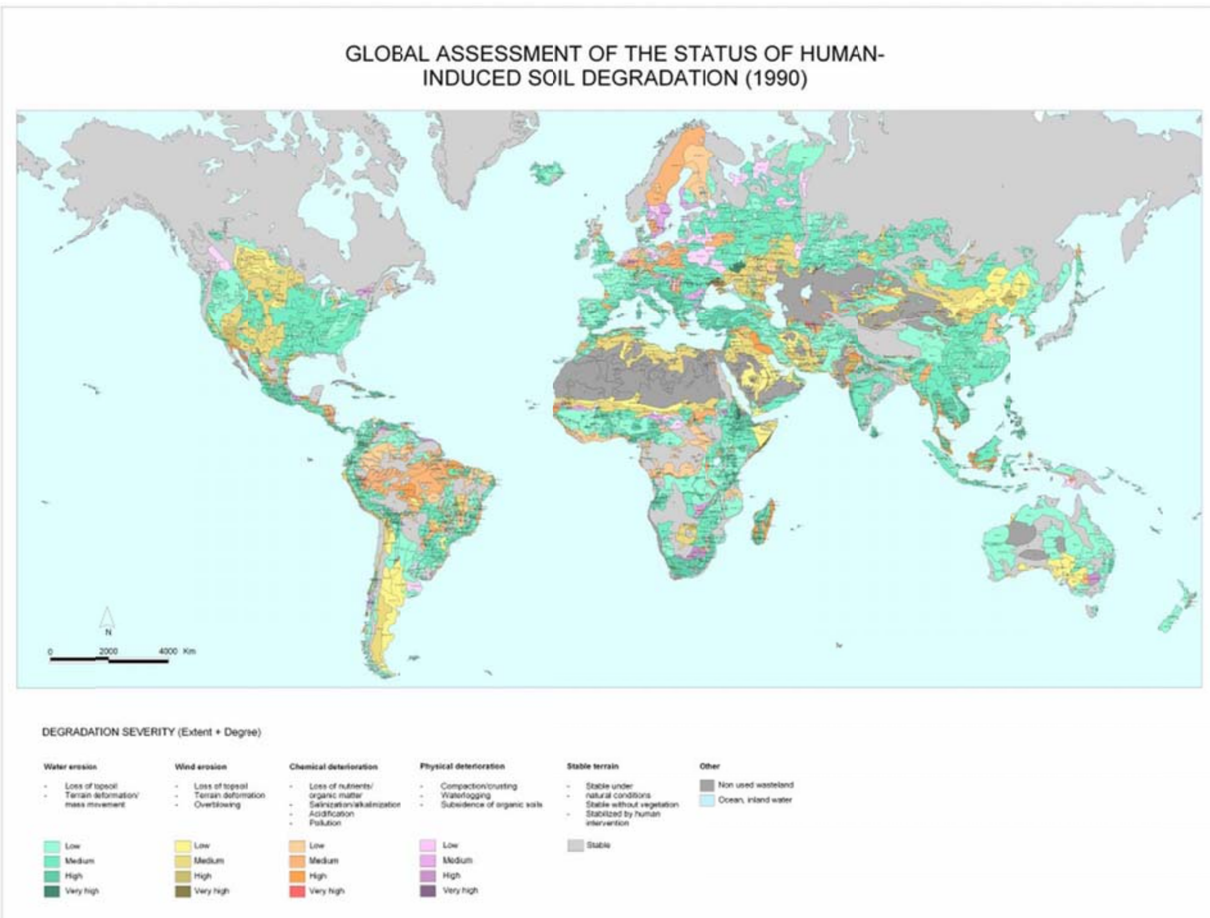


Figure 6. (http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/GLASOD.htm)

So we have a paradox that requires us to grow much more food, with the same amount of water or less while, at the same time, causing less environmental damage. In physically water scarce regions, this means that intensification of food production and increasing water productivity in poorer countries are vital challenges. The following sections look at how this paradox may be overcome.

Solutions

There have been plenty of suggestions regarding what has to be done to facilitate the production of enough food to feed the world in 2050, although less attention has been given at policy level at national and international scale to ensuring availability of water resources. With respect to food security, the FAO Expert Consultation held in 2009 laid out a number of prerequisites. These included:

- Enhancing investment in sustainable agricultural production capacity and rural development,
- Promotion of technology change and productivity growth, and
- Better use of trade, markets and support to farmers

If we accept the assumption based on economic and foreign trade grounds that much of the food required has to be grown in the developing countries, then the above actions present a considerable challenge. Since 1980 the proportion of overseas development assistance to agriculture has dropped from almost 12% to less than 5%, whilst total ODA has increased about five fold. Similarly, investment in research and development in the CGIAR has stagnated. The average annual rate in cereal yield growth has declined from 3.2% in 1960 to 1.5% in 2000. Exacerbating these factors was the 2007-2008 food crisis which saw a further 68 million people drop below the poverty line as a consequence of higher food prices in the poorest developing countries. Many authoritative scientists and commentators consider that the factors that led to the 2007-2008 food crisis are currently not far below the surface and that the world will see recurrences of similar and probably more severe crisis within the next 10-15 years.

Whilst there is significant concern about the recurrence of food crises and many countries are looking at their own food security issues, one response has been "land grabbing", predominantly in Africa by Middle Eastern and North East Asian countries. Whilst the ethics and arrangements whereby this has taken place still deserve further scrutiny, little attention has been given to the impact that such grabbing of arable land will have on water resources. At the same time, densely populated countries such as China and India, with limited options for expansion of arable land, are seriously contemplating how they can intensify their own agricultural production systems. Whilst food production and water resources availability and scarcity are inexorably linked, the remaining focus of this paper will be on examining how we must not follow a business as usual pattern in water management if food production targets are to be met.

Adapting to Challenges

Chartres and Varma (2010) describe six actions required if we are to overcome water scarcity and associated issues at the global level. These are:

1. Better water measurement
2. Water governance systems reform

3. Agriculture needs to be seen as part of the environment
4. Revitalization of agricultural water use
5. Better management of urban and industrial demand and,
6. Empowerment of the poor and women in water management.

In a sense they all are interrelated. Better water measurement is needed because put simply, "you can't manage what you don't measure." Water governance systems including policies, institutions and regulation are, in many countries, outdated and heavily in need of reform to facilitate dealing with and managing modern day issues. Whilst the European Union Water Framework has recognized the need to maintain and improve water quality, this is often not the case in many developing countries. Agriculture in many such countries is not seen as an integrated part of the environment both responsible for pollution, but equally able if managed better to help maintain environmental and water quality. Revitalization of agriculture in terms of increasing its productivity to deliver the required yields is perhaps the greatest challenge for water resource scientists and policy makers. If it is to be achieved, we need to see major upgrades of Asian irrigation systems including significant governance reform (Shah, 2009), a new and workable strategy for irrigation in sub-Saharan Africa, as well as major improvements in rainfed agricultural production. None of these can happen at the expense of the environment and none will happen unless with get the governance right. Hence the complexity and need for integrated approaches to not just water resources development, but to economic development in general. Whilst the majority of the action with respect to food production will be rural, it is important that we instill in urban dwellers the fact that water resources are finite. This requires industrial and domestic users to minimize unnecessary wastage and focus on recycling from the home to the city levels. Finally, given that many primary water users and farmers in developing countries are women and youth, we need to seek better ways to empower them in decision making and to provide access to new technologies, finance and other forms of assistance that are often primarily targeted historically at men. Similarly, as competition for water between users becomes more intense, we need to look at ways of both identifying and recognizing the water rights of poor rural communities in order to protect their livelihoods.

To illustrate the integrated approaches needed in the future three examples are given that focus on:

- Technology and Investment
- Incentives
- Governance

Technology and Investment

Often the technologies that can have the most impact need not be the largest or the most expensive. The importance of dams, canals and large irrigations schemes in the challenge to improve food security cannot be denied, and much of the success of beating widespread famine in Asia can be attributed to irrigation infrastructure. However, knowing the environmental and social costs of large schemes, there has been a push to look at other ways to deliver, manage and conserve water. The proliferation of groundwater use due to the availability of cheap pumps is one example (Shah, 2009). Another is looking at the idea of water storage as a range of options from large dams and reservoirs, to small tanks and even counting water stored in soil. An understanding of the value of water storage, particularly by comparing the quantity of water per person, per day in developed countries to developing countries paints a stark difference in the water security of people. In some African countries storage is less than $50m^3$ per capita compared with values in excess of 5000 m^3 per capita in the USA (Chartres and Varma, 2010). In the wake of climate change and climate related disasters, increasing water storage in some countries and environments provides insurance against catastrophic disaster and can form the basis of a climate change adaptation strategy. Improving technologies and investment into water storage are important areas in which there is potential for great innovation particularly with respect to low cost, easily up-scalable options at farm and field levels.

Incentives

Change requires incentives and/or the removal of disincentives. One of the biggest barriers to changing our understanding of water issues and practices of water use is the fact that for most of us, water is a free good. This means that there is little incentive to act in ways that conserve or use water more wisely. Experiences of attaching a cost to water, or attempts to value it have been successful in some places; however they do raise political and social concerns. The trade-off between development and conservation in the context of developing countries, where a large number of the world's poor reside, can lead to much harsher consequences. However experimenting with second best solutions, one's that provide more realistic options, can show results. In Gujarat, India, the massive proliferation of groundwater pumping, helped by flat rate tariffs on electricity and easy access to cheap pumps, started to cause a serious environmental problem in one of India's driest states (Shah et al., 2009). The Jyotigram scheme was initiated as a way to provide uninterrupted power to villages, influenced by recommendations from IWMI, the scheme split and rationed electricity supply to farms in order to regulate the use of energy in groundwater pumping. The regulation and separation of agricultural, from commercial and residential electricity supply had a drastic impact on the behavior of farmers and subsequently on the extent of groundwater withdrawal. The example of this scheme illustrates how second best options can result in more implementable outcomes.

Governance

Water governance, or the process by which decisions about water allocation, use and management are made, is complex not least because of the widely held belief that water is a free good that should also be a human right. Rights to water use are usually divided and governed by institutions and organizations that represent different users, or sectors. The management of water through different sectors that do not work together is a major challenge, particularly under conditions where water is scarce and the competition for limited resources is strong (Wegerich et al. 2011). Also, sector-based planning limits an understanding of how to manage water along hydrologic principles within a basin, and also to manage transboundary water. There have been many theoretical frameworks devised and experimented with to overcome the issue of sectoral segregation in water management, with varying degrees of success. In the Ferghana Valley, three countries Uzbekistan, Kyrgyzstan and Tajikistan that fall within the Syr Darya basin have made significant progress to improve the management of shared water resources, in a region where transboundary water is a highly political issue. A project funded by the Swiss Development Cooperation was first initiated to test out and study the impact of new localized institutional arrangements for sharing water that would address conflict and aid cooperation at the field and canal level in. Water User Associations (WUA) and canal management organizations were introduced to the sites based along basin boundaries, in countries where there was no precedent for participation in such organizations – about 30 hydrographic WUAs (coverage: more than 37,000 ha; population of 300,000) and 300 Water User Groups on tertiary canals. More than 700 members of the local water management system, WUA specialists, farmer groups and other stakeholders were trained and equipped with appropriate skills and sufficient capacity to take over management and governing of newly introduced participatory bottom-up institutions. The success of the initiative at improving cooperation and management of water with the involvement of farmers, has led to wider reform of the governance of water in the region and the new structure is being institutionalized and there has also been an improved transfer of information and knowledge between the participating countries. Nevertheless, political hurdles to be overcome still exist between the national governments of the three countries with respect to the establishment of an effective transboundary river basin authority.

Conclusions

Dealing with water scarcity will be one of the most critical challenges that we need to overcome if global food security is to be achieved by 2050. We will not be able to double food production over the next 40 years if we continue with business as usual. This paper has highlighted the need for technological innovation, a better understanding of how incentives and disincentives can inhibit best practice management of water resources and the need for continued reform of institutional and governance arrangements. It has also stressed the fact that, because of the complexity of water management and agricultural production systems, there is a need for more integrated approaches to the development of solutions. It is doubtful whether more reductionist scientific approaches, or individual economic sector approaches will be able to deliver these in the future. What is required is a new blue-green revolution that integrates technical, governance and social considerations for improved water management in an overall context of agricultural production systems.

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