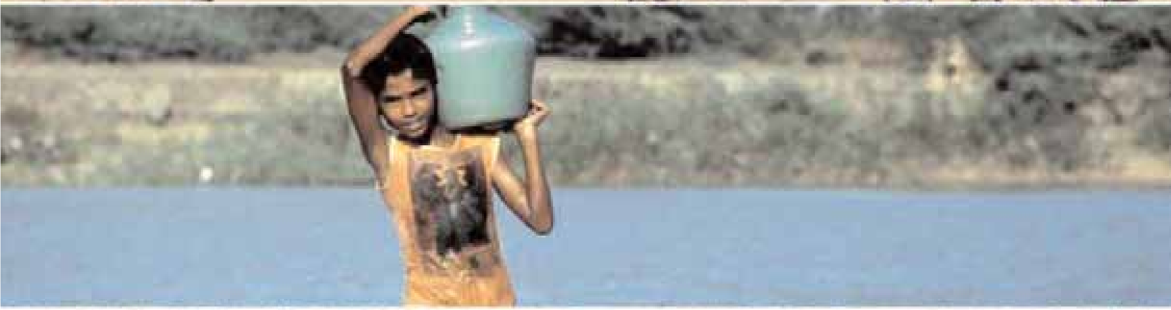

WATER AND CEREALS IN DRYLANDS

Water and Cereals in Drylands

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CA Conservation agriculture
CBT Conservation bench terrace
CRP Conservation Reserve Program
GHG Greenhouse gas
GIS Geographical information system
HYV High-yielding variety
IFPRI International Food Policy Research Institute
LAI Leaf area index
LGP Length of growing period
PET Potential evapotranspiration
PES Payment for Environmental Services
SOM Soil organic matter
SWC Soil Water Conservation
UNCCD United Nations Convention to Combat Desertification
WH Water harvesting

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PREFACE

The world's food supply is obtained either directly or indirectly from the abundance of plant species, but fewer than 100 are used for food. Worldwide, about 50 species are cultivated actively, and as few as 17 species provide 90 percent of human food supply and occupy about 75 percent of the total tilled land on earth. Eight cereal grains –wheat, barley, oat, rye, rice, maize, sorghum and millet– provide 56 percent of the food energy and 50 percent of the protein consumed on earth (Stoskopf, 1985). Cereals continue as the most important source of total food consumption in the developing countries where direct consumption of grains provides 54 percent of total calories and 50 percent for the world as a whole (FAO, 2006). Wheat and rice are by far the most widely consumed cereals in the world. Maize is a major crop for both direct and indirect human consumption because it is a major energy feed for animals. Wheat, rice, and maize make up approximately 85 percent of the world's production of cereals.

As food and water needs continue to rise, it is becoming increasingly difficult to supply more water to farmers. The supply of easily accessible freshwater resources is limited both locally and globally. In arid and semiarid regions, in densely populated countries and in most of the industrialized world, competition for water resources has set in. In major food-producing regions, scarcity of water is spreading due to climate change and increased climate variability. In light of demographic and economic projections, the freshwater resources not yet committed are a strategic asset for development, food security, the health of the aquatic environment and, in some cases, national security. In large parts of the drylands, no irrigation water is available – rainfed crop and pasture yields are both low and uncertain. Runoff, evaporation and deep percolation from the soil surface drastically reduce the proportion of rainfall available for plant growth. However, even small amounts of additional water would significantly increase yields in drylands at very high water-use efficiencies, if other factors – including plant nutrient availability – were adequate. Several approaches can make such additional water available to crops and pasture from the local rainfall with low-cost low-risk land and water management techniques. Runoff can be used more productively and infiltration increased in arid areas by pitting or tied ridges, and by increasing surface roughness. In semi-arid and dry subhumid areas, maintaining a cover of crops or crop residues on the soil throughout the year in a zero- or minimum-tillage system can be even more effective. Recent experiences of conservation agriculture bring about multiple benefits for farmers while addressing local and global environmental concerns (Pretty & Koohafkan, 2002). Where such measures still do not provide the crop with adequate moisture throughout the growing period, water-harvesting approaches such as "runoff farming" to supplement rainfall on a smaller area may be viable options.

Where rainfall is distributed sparsely throughout the year, dry farming may be an option. This approach entails capturing rainfall during a fallow period and storing it in the soil for use during the subsequent cropping period. Storage efficiency can be increased by reduced tillage or no-tillage where crop residues can be maintained on the soil surface as mulch.

This volume discusses the drylands and their land uses, with an emphasis on cereal production. It includes an outline on the recent development of competing use of cereals for the production of ethanol biofuel. This paradigm shift could have far-reaching consequences (social, environmental and for food security), potentially encouraging production in even more marginal lands. The volume touches on the roles of livestock, placing the various technologies and practises that enhance water availability to crops in drylands in their technical, agro-ecological and socio-economic perspective. The predicted future impacts of human-induced climate change on dryland systems are briefly noted.

I therefore appeal to the international community to join FAO in its continuing efforts towards alleviating poverty and hunger through the promotion of agricultural development, the improvement of nutrition and the pursuit of food security throughout the world. With your help, success is at the end of our efforts, perseverance and commitment.

Jacques Diouf
FAO DIRECTOR-GENERAL

INTRODUCTION

World food crop production has more than kept pace with the rapid growth in population in the past four decades. World population increased from 3 billion to 6.6 billion between 1960 and 2006 (UNFPA, 2008), food consumption measured in kcals per capita increased from 2 358 to 2 803 between 1964 and 1999 (WHO, 2008), and food prices fell between 1961 and 1997 by 40 percent in real terms (FAOSTAT, 2007). However, these global statistics do not fully reflect the wide range of differences between and within individual countries.

Cereals are by far the most important source of total food consumption in the developing countries. Direct food consumption of cereals in these countries provides 54 percent of total calories and 50 percent for the world as a whole (FAO, 2006). There are, however, wide variations among countries. Only 15-30 percent of total calories are derived from cereals in countries where roots and tubers are dominant (e.g. Rwanda, Burundi, the two Congos, Uganda, Ghana, etc.) and in high-income countries with predominantly livestock-based diets (e.g. U.S., Canada, Australia, etc.). These latter countries, however, consume large amounts of cereals indirectly in the form of animal feed for the livestock products consumed as food. Approximately 37 percent of the world's cereals are used for feed (FAOSTAT, 2007). Production of cereals increased 2.6 times between 1961 and 2005 compared to an increase in population of 2.1 times. This increase in per capita cereal production alleviated hunger problems in several countries and contributed to an increase in meat consumption in developing countries from about 9 kg per capita in 1961 to more than 30 kg per capita in 2005 (FAOSTAT, 2007).

The growth rate of cereal production has slowed in recent years. Production of cereals grew at a rate of 3.7 percent per annum during the 1960s, but slowed to 2.5 percent, 1.4 percent, and 1.1 percent per annum during the subsequent three decades to 2001 (FAO, 2006). Per capita food use of cereals seems to have peaked in the early 1990s, and this is true for the world as a whole. World conumption per capita fell from 171 kg/person/year in 1989/91 to 165 kg in 1999/01; in the developing countries , from 174 kg to 166 kg (FAO, 2006). It is not clear why cereal consumption had decreased in developing countries when so many of them are far from having reached adequate levels of food consumption. The use of cereals for all uses reached 329 kg/person/year in 1989/91 and fell to 309 kg in 1999/01. FAO (2006) projects that total usage in 2050 will be 339 kg. Even though per capita cereal usage has declined slightly, and world population growth has slowed somewhat from earlier forecasts, FAO forecasts that cereal production will need to increase from 1.9 billion tonnes in 2001 to 3 billion tonnes by 2050. This is a challenge that should not be taken lightly in view of the increasing pressures and competition for soil and water resources.

Recently, the future of cereal production and consumption has changed dramatically since the rising cost of fossil fuels and the need for greener energy use has resulted in some cereals (principally maize – also sorghum and wheat) being used to produce ethanol for fuel. Although it is too early to determine the long-term impact that this development will have on the supply and cost of food, the fact that both food and fuel systems are competing for cereals is likely a profound development that could have unintended environmental, social and food security consequences of major importance. Although energy prices tend to influence the food and agriculture sector because of the effect on the price of fertilizer, fuel, transportation, etc., it is only recently that the price of grain has been directly linked to the price of oil. Brown (2008) states that in this new situation the world price of grain is drifting up toward its energy-equivalent value, since when the fuel value of a crop exceeds its food value, the crop will enter bio-fuel production.

Wheat, rice and maize make up about 85 percent of the world's cereal production (FAOSTAT, 2007).Wheat and rice are by far the most widely consumed cereals in the world in the direct form, while maize is important for both direct and indirect human consumption as a major feed ingredient for animals. Cereals are grown on 49 percent of the world's harvested area, with 65 percent being grown in developing countries in 2005 (FAO, 2006). World population, currently 6 700 million, is projected to reach 8 000 million by 2025, with more than 97 percent of the growth occurring in developing countries (FAO, 2003c). Cereals will continue to be an important food source, particularly in developing countries and consequently, it is vital that production continues at a pace to match consumption. If significant volumes of cereals produced in developed countries are used for ethanol production, the price of cereals is likely to increase and the amounts available for export and for reserve are likely to decrease. Brown (2008) estimated that one fifth of the entire U.S. grain harvest in 2007 will be used to produce ethanol. This will likely increase the necessity for developing countries to become more self-sufficient in cereals.

The agronomic technologies that have allowed steady increases in world food production to date have largely been based on high-yielding varieties (HYVs), fertilizers, pest control and irrigation. Irrigation has been particularly important in developing countries, where the total irrigated area increased from 102 million ha in 1961 to 208.7 million ha in 2002. This compares with 37 million ha in the developed countries in 1961 and 68 million ha in 2002 (Molden *et al.*, 2007; Svendsen and Turral, 2007). Worldwide, 19.7 percent of arable land is irrigated, and it contributes 40 percent of total agricultural production (Svendsen and Turral, 2007). Irrigated agriculture is responsible for approximately 70 percent of all the freshwater withdrawn in the world (Molden and Oweis, 2007). In most developing countries, agriculture accounts for 80 percent of water use (UNDP, 2006). The amount varies widely among countries, however, ranging from more than 90 percent in agricultural economies in the arid and semi-arid tropics to less than 40 percent in industrial economies in the humid temperate regions (FAO, 1996a).

In 1996, 48 percent of cereal production in developing countries (excluding China) came from irrigated lands (FAO, 1996a). Ringler *et al.* (2003) reported that 38 percent of the cereals grown in developing countries in 1995 were on irrigated lands and accounted for 60 percent of cereal production. This is in contrast to many developed countries where cereals are largely grown without irrigation. An estimated 60 percent of the wheat produced in developing countries is irrigated, while only 7 percent of the wheat and 15 percent of the maize are irrigated in the United States of America (USDA, 1997). Brown (2008) estimated that one fifth of U.S grain harvest comes from irrigated land compared to three fifths for India and four fifths for China. The other major cereal-producing areas of developed countries (in Canada, Australia and Europe) are also predominantly non-irrigated systems.

The development of additional irrigated land in developing countries will need to continue in order for food production to keep pace with population growth and to ensure regional food security. This should be coupled with increased water productivity from improved irrigation and water management. However, there are also effective alternatives to irrigation, even in less humid areas, through the development of dryland farming systems.

With the cost of developing additional irrigated lands often ranging from US$2 000 to more than 17 000/ha (AQUASTAT, 2008), it is imperative that alternative water-management and

production systems be considered for at least a part of the anticipated future food demand. Huge capital sums have already been invested to develop irrigation. In comparison, there has been very limited investment focused on raising the overall productivity of drylands. This is understandable because the benefits of irrigated agriculture are significant, immediate, predictable and dependable. In contrast, cereal yields in dryland regions where irrigation is not an option typically range from zero to three or more times the average yield. This high variability limits the effectiveness of inputs such as fertilizers and pesticides, resulting in a high economic risk associated with their use.
However, several soil- and water-management options, such as conservation agriculture, run-off farming and dry farming using fallow storage can increase soil moisture in dryland areas, increasing yields and reducing their variability. Some preliminary estimates show that the average yield of rainfed cereals in drylands could be increased by 30–60 percent by making available an additional 25–35 mm of water to crops during critical growth periods through water conservation and harvesting. These benefits are attainable in most dryland areas of the world and justify investment in water conservation and water harvesting. There are also social and environmental benefits which support the investment costs in water conservation and harvesting far beyond those strictly related to increased grain production.

The objectives of this study were to:

- Emphasize the importance of dryland development for future food production (particularly cereals), food security and poverty alleviation;
- Present water-conservation and water-harvesting approaches and investment options that can increase cereal production in dryland regions;
- Suggest policies for more efficient use of existing natural resources in order to lessen the dependence of agriculture on further irrigation development.

Chapter 1 characterizes and discusses drylands and their land uses, highlighting their importance to the growing populations who occupy them. Chapter 2 reviews global trends in cereal production and considers the constraints on the further expansion of irrigation. Chapter 3 reviews water-conserving technologies and practices for enhancing cereal production in drylands by more integrated and efficient use of existing land and water resources. Chapter 4 reviews some wider environmental issues relating to water harvesting and soil water conservation in drylands. Chapter 5 considers some of the social and economic benefits that result from investing in water-conservation and water-harvesting systems in dryland areas as well as investment constraints and potential. The study concludes with policy considerations and recommendations for future actions.