Dryland Agriculture: Dynamics, Challenges and Priorities

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Science with a Human Face

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Abstract

The developments in the dryland region reflect the pervasiveness of poverty, which is demonstrated by the growing constraints of water, land degradation, continuing concerns about malnutrition, migration due to frequent droughts, lack of infrastructure, poor dissemination of improved technologies, and effects of government policies and further economic liberalization on the competitiveness of dryland crops. This research bulletin reviews past trends, summarizes the major constraints to income growth, food security, poverty alleviation, and environmental sustainability, and identifies future strategies and priorities. The discussion uses the semi-arid tropics as a focal point where poverty, food insecurity, child malnutrition and gender inequalities are widespread. A synthesis of evidences and lessons learned from ICRISAT Village Level Studies (VLS), conducted since 1975, is presented to provide empirical evidence on the vulnerability of the poor to various risks and shocks, as well as their capacity to access physical, financial and social resources and networks in the risky environments of the drylands. An analysis of available evidences provided a basis for identifying major policy issues that need to be addressed. Priority development interventions are identified to accelerate the pace of development of dryland agriculture: a) water as a catalyst for development; b) reorientation of public policies and better targeting of development interventions to dryland farmers, especially since they relate to key factors constraining agricultural productivity, and hence poverty reduction; c) diversification with a higher focus on crop-livestock development; d) innovative, cost effective and community-based management of wastelands and common property resources; e) marketing, commercial orientation and competitiveness of dryland agriculture; and f) institutional innovations, building partnerships, linkages and capacity. The development of dryland agriculture requires synergy among technologies, marketing systems, input supplies, credit, policies and institutions. A broadbased sustainable growth and development in the drylands of Asia and sub-Saharan Africa is viewed as a key strategy for addressing rural poverty in the Asian and sub-Saharan region.

Dryland Agriculture: Dynamics, Challenges and Priorities

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Patancheru 502 324, Andhra Pradesh, India

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About the authors

MCS Bantilan Principal Scientist and Global Theme Leader, Institutions, Markets, Policy and Impacts, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

P Anand Babu Scientific Officer (Planning), Institutions, Markets, Policy and Impacts, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

GV Anupama Scientific Officer, Institutions, Markets, Policy and Impacts, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

H Deepthi Data Analyst, Institutions, Markets, Policy and Impacts, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

R Padmaja Senior Scientific Officer, Institutions, Markets, Policy and Impacts, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

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Contents

Introduction

The marginalization of the dryland (Appendix 1) regions of Asia and sub-Saharan Africa[1] is reflected in the pervasiveness of poverty and continuing concerns about malnutrition, growing constraints of the natural resource base (water scarcity and land degradation), lack of infrastructure, poor dissemination of improved technologies and further economic liberalization. Dryland ecosystems, where most of the world's poor live, are characterized by extreme rainfall variability, recurrent but unpredictable droughts, high temperatures and low soil fertility. Indeed, dryland areas present significant constraints to intensive agriculture. But despite extreme conditions, agriculture and related land use have always played a leading role in dryland economies and societies. Even as they are constrained by limited water and soil resources, optimization of these resources is often a matter of survival for dryland rural economies (FAO 1999).

The Green Revolution of the 1960s and 1970s – with its package of improved seeds, chemical fertilizers, enhanced farm technology and irrigation – successfully attained its primary objective of increasing crop yields and augmenting aggregate food supplies. In Asia and parts of North Africa, where the package was most widely adopted, food production increased substantially during those decades. However, despite its success in increasing aggregate food supply, the Green Revolution, as a development approach, has not necessarily translated into benefits for the lower strata of the rural poor in terms of greater food security or greater economic opportunity and well-being. It bypassed many areas with large numbers of rural poor (Freebairn 1995; Pachico et al. 2000; Evenson and Gollin 2003). In particular, vast expanses of dryland regions were bypassed by the Green Revolution. They had failed to attract investments in agricultural technology among smallholders as well as the commercial sector due to small or non-existent markets. So far, the policy regimes have favored the irrigated regions and failed to address the continuing marginalization of the drylands. Past policies on drylands have failed in another respect: they focused primarily on the presumed limitations of the natural resource base rather than on the people, their knowledge, skills and capacity for innovation in overcoming or circumventing environmental constraints (Anderson et al. 2003).

Recognizing the need to reach the poor in marginal environments, development planners and policymakers are now increasingly eyeing the hitherto less-favored dryland regions, where agricultural transformation is yet to take off. The issues of equity, efficiency and sustainability reinforce the need to improve the productivity of dryland agriculture given that the growth opportunities in irrigated areas are slowly being exhausted. A well-targeted approach is sought to address the neglected rural dryland areas that are yet to benefit from improvements in agricultural technology and policy.

This research bulletin summarizes the major challenges in achieving food security, income growth, poverty reduction and environmental sustainability for the dryland regions of Asia and sub-Saharan Africa. It also identifies future strategies and priorities as it highlights emerging issues that threaten the sustainability of dryland agriculture and future sources of growth. The next section presents an overview of the dynamics of dryland agriculture. It is followed by an analysis of the persistent challenges facing it, and identifies opportunities such as income diversification, market and rural/urban linkages, private sector investments, trade liberalization, the commercial orientation of agriculture and institutional innovations. Finally, implications for policy, research priorities and development pathways are drawn, followed by a vision for Asian and sub-Saharan Africa dryland agriculture.

Dynamics of dryland agriculture

Dryland ecosystems span over 40% of the earth's total land surface (Figure 1). Every continent contains dryland regions, but drylands are most extensive in Africa (nearly 13 million km^2) and Asia (11 million km^2) (White et al. 2002).

Agriculture is the primary occupation of those residing in the drylands. Since three quarters of

1. The drylands of sub-Saharan Africa are spatially heterogeneous – overlain on the rainfall gradient are rivers and wetlands within the drylands, a wide variety of soil types, and differences in land use, infrastructure development and market accessibility (Anderson et al. 2003).

the world food supplies consisting of rice, wheat, maize, sorghum, millets and potato are grown in this region (FAO 1999); increasing the productivity of dryland agriculture is vital to ensure world food security.

Inherent features of dryland agriculture

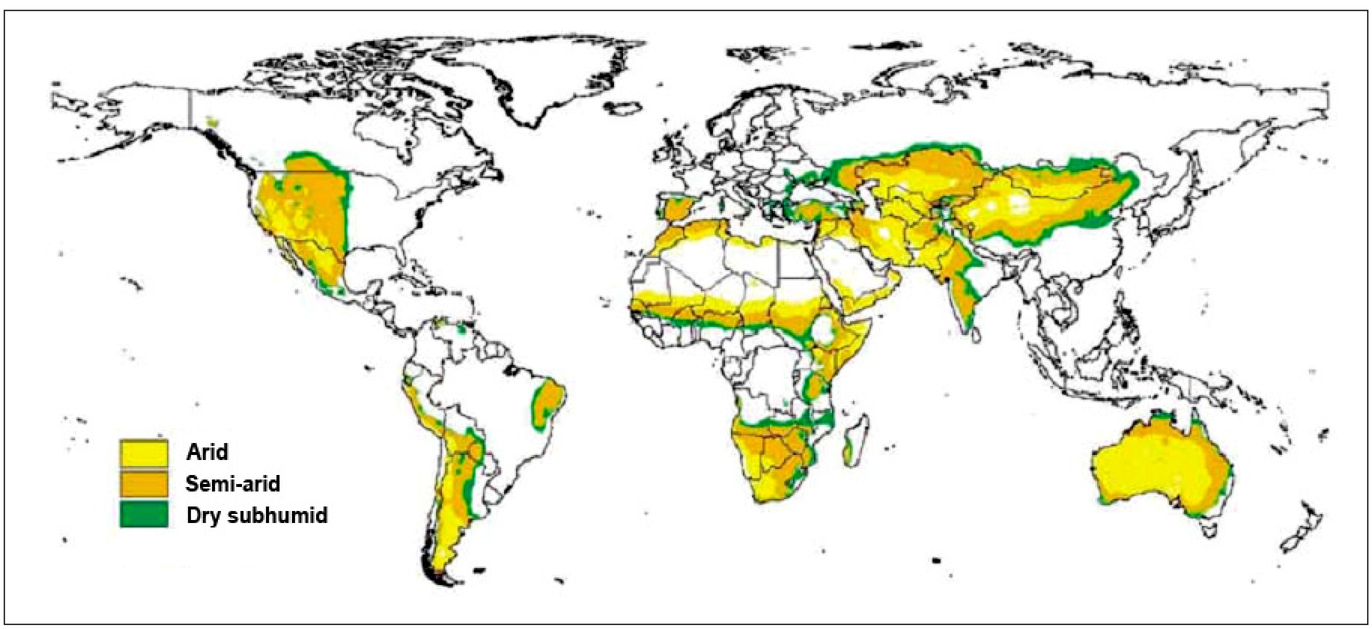
The four inherent features of dryland agriculture that reflect its dynamism and potential and are essential in developing a strategy to stimulate growth as well as in drawing implications for policy reform, are:

a) diversity,
b) fragile ecosystem requiring sustainable agricultural intensification,
c) people resiliency and adaptability, and
d) complementary investments in infrastructure and policy reform.

Diversity. The drylands are diverse in agro-climatic conditions and hence display diverse potential for agricultural growth. For example, on the one hand, there are vast expanses of dryland areas receiving as much as 200 to 800 mm of highly seasonal and unpredictable annual rainfall, such as in the semi-arid and sub-humid tropics, where the pathway for development is sustainable intensification of agriculture through favorable policies and public agricultural investments. On the other hand, there are regions receiving little, erratic or no rainfall in the extreme arid and hyper-arid zones, which oftentimes fails to provide an economically viable basis for improving incomes and welfare. In this case, pathways for development may be through development of the rural non-farm economy, that is, diversification to other major sources of income including out-migration, provided there is access to markets, infrastructure and facilitating institutions.

Sustainable intensification in a fragile ecosystem. Appropriate strategy for the development of dryland agriculture may differ from the high input, monoculture approach of the Green Revolution that successfully transformed the more favorable agricultural areas of Asia and parts of North Africa (eg, Egypt). Ensuring food security, reducing poverty and managing agricultural development for the rapidly growing populations of Asia and sub-Saharan Africa increasingly depends on the sustainable intensification of land use, as much of the land suitable for agriculture has already been used. Creating an environmentally sustainable production system must address the twin challenges of productivity improvement and improved management of natural resources.

People resiliency and adaptability. Identifying the pathways to agricultural transformation requires an understanding of the poor in dryland areas. A large number of the dryland poor are subsistence arable



Source: FAO, 2002.

Figure 1. The global extent of drylands.

and livestock farmers who have been adapting their livelihood strategies in ways that ensure their subsistence in a risky environment. Risk-reducing adaptive strategies will influence the choice of agricultural technology, decision-making behavior and investments in new innovations.

Complementary investments. Complementary investments in infrastructure, markets and institutions, along with policy reform, are critical in enabling dryland farmers to contribute to food self-sufficiency and stimulate economic growth, while simultaneously sustaining the productivity of the natural resource base.

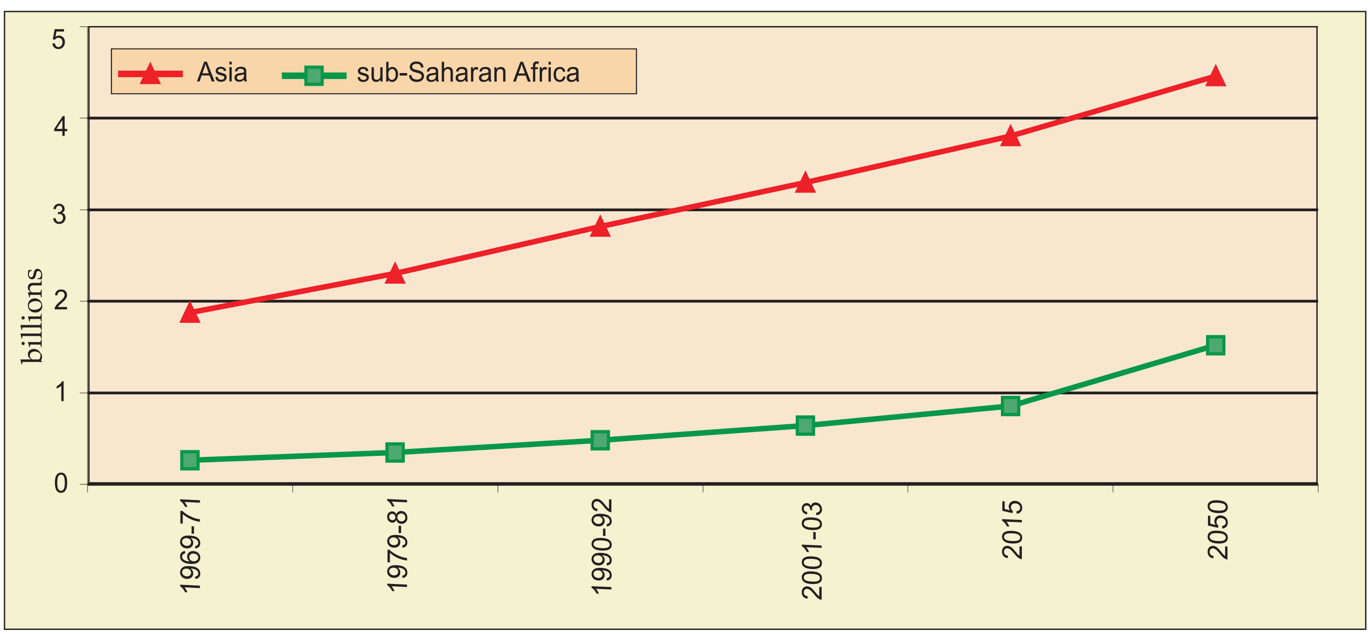
Trends and future projections: population, malnutrition and productivity

Time series data covering several decades since the 1950s is used to examine the dynamics of dryland agriculture and to draw lessons about the sources of growth in dryland agriculture and entry points for effective technology and policy interventions.

Population. Between 2001-2003, the world population exceeded 6.2 billion and with an annual growth rate of about 1.3%, it is expected to reach about 8.9 billion by 2050. Demographic trends vary extensively in different regions of the world with 60% of the world's population living in Asia, 13% in Africa, 12% in Europe and the remaining 14% in the Americas and Oceania.

The population in Asia is expected to double to over 4 billion from 1985 to 2050, while that in sub-Saharan Africa will more than triple from 420 million in 1985 to nearly 1.5 billion by 2050 (Figure 2, Appendix 2). The population growth rate of China and India, the two most populous countries in Asia, during 1995-2000, was 0.90% and 1.61% respectively. Currently, the population of China is 1310 million whereas that of India is 1094 million. The rate of population growth in sub-Saharan Africa is extraordinarily rapid at 2.48% during 1995-2000. This rapid population growth in sub-Saharan Africa is now the highest in the world resulting in slowing the development and sharply reducing the possibility of raising living standards in the region. Note that by 2050 the two regions of Asia and sub-Saharan Africa alone will approach a population of 6 billion people.

Food demand and malnutrition. In addition to population growth, income growth also increases the demand for food. Even with modest income growth in developing countries, the demand for food in 2025 will be more than double the current levels of production (McCalla 1994). Furthermore, urbanization in conjunction with income growth



Source: FAO, 2006.

Figure 2. Population in Asia and sub-Saharan Africa.

will cause a shift in the composition of food demand. The character of diets tends to shift away from roots and tubers and lower quality staple grains to higher quality cereals such as rice and wheat, livestock products, and vegetables. Consumers demand more diverse and higher-quality diets and need foods that can be transported and stored.

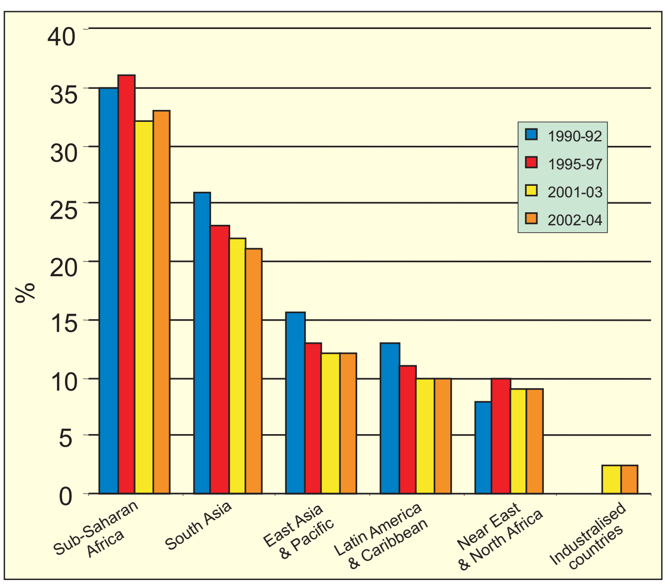
Wide regional differences in the severity of hunger and malnutrition are observed. The comparative statistics illustrated in Figures 3a and 3b indicate that sub-Saharan Africa and South Asia have been facing the highest extent of malnutrition and food insecurity (also see Appendix 3).

The latest statistics indicate that 863 million people were undernourished worldwide in 2002–2004: 832 million in developing countries, 22 million in the countries in transition and 9 million in the industrialized countries. South Asia (299 million) and sub-Saharan Africa (214 million) have a disproportionate share of the world's hungry compared to East Asia and Pacific (81 million), Latin America and Caribbean (52 million), Near East and North Africa (37 million) and Industralised countries (9 million). The highest prevalence of undernourishment is approaching 35% in sub-Saharan Africa while the largest number of undernourished people (almost 300 m) are living in South Asia.

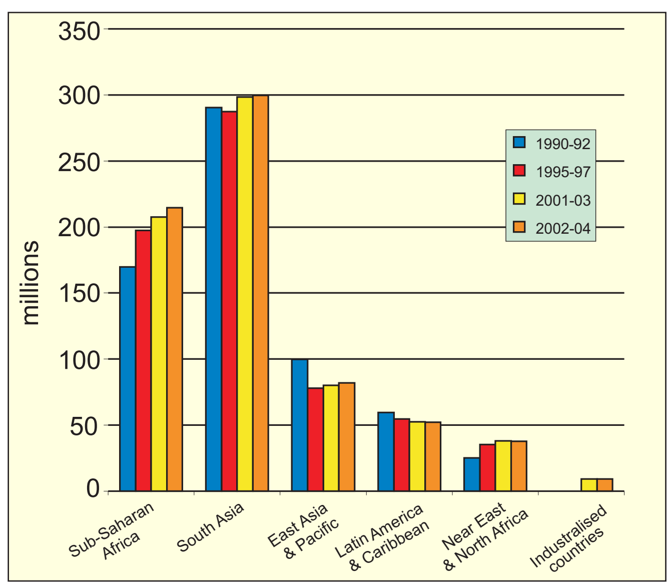
The underlying cause of more than half of all child deaths is malnutrition. Children are at great risk to disease, and many of them never become adults. It is noted that while the relative adequacy of food improved substantially between the 1970s and 1990s, the energy consumption by the poor has not increased and more than 800 million people remain chronically undernourished.

Productivity dynamics. In the last forty years, the doubling of cereal output resulted from three sources – area expansion, increased intensity of land use (mainly through expanded irrigation), and yield increases. While irrigated area more than doubled from 1950 to 1980, its rate of growth has since slowed substantially as has area expansion in rainfed areas. The current view is that the next doubling of food production must come primarily from increased productivity (ie, yield).

While yields of total cereals have generally doubled (Figure 4), the yields of coarse cereals such as maize, sorghum, and millet have shown less rapid increase (Figure 5). To again double the wheat and rice yields and more than double the yields of other basic food products will be problematic without increased research and development efforts. Biotechnology holds the promise of significant genetic improvements, but that promise is becoming a reality much more slowly than earlier forecasts suggested.



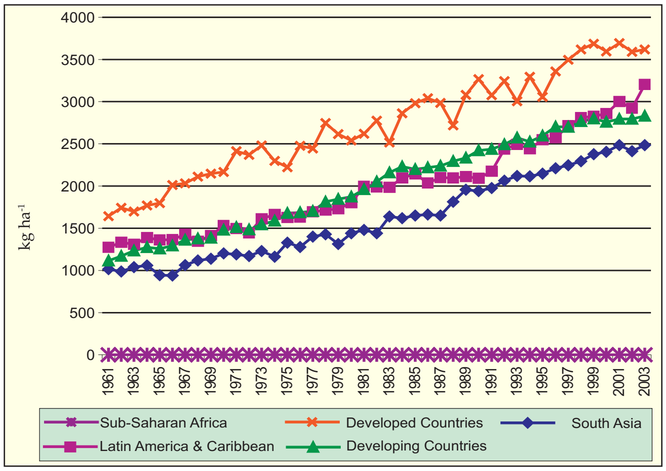
a. Prevalence of undernourishment (%) in various regions.



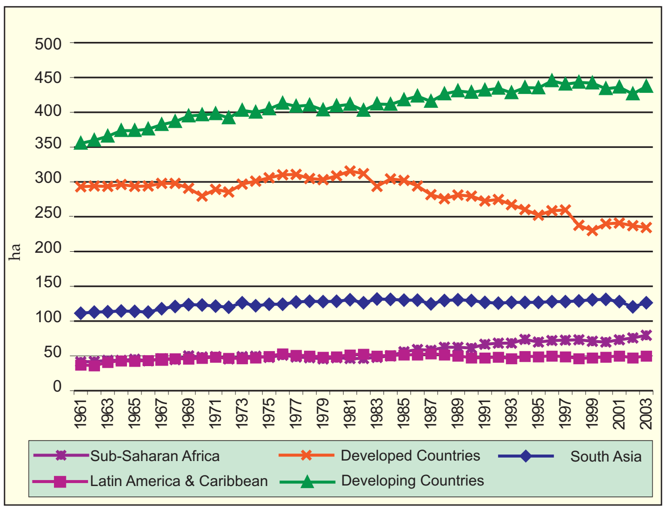
b. Number of undernourished persons (millions) in various regions.

Source: FAO, 2006.

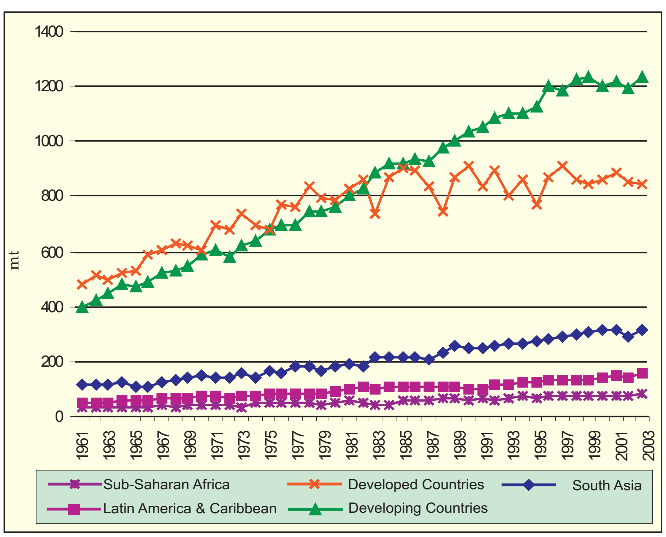
Figure 3. Prevalence of undernourishment (%) and number of undernourished persons (millions) in various regions.



a. Total cereals yield in various regions, 1961 to 2003.



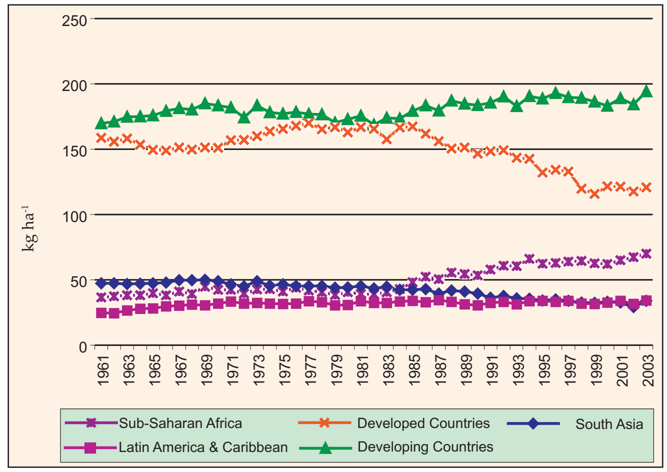
b. Total cereals area in various regions, 1961 to 2003.



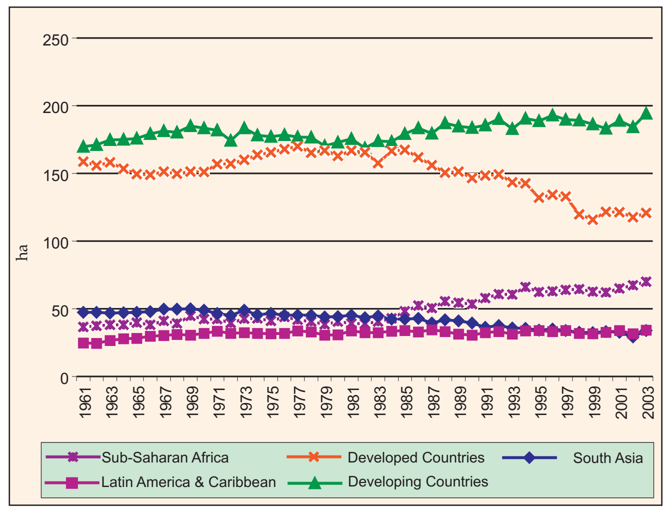
c. Total cereals production in various regions, 1961 to 2003.

Source: FAO, 2006.

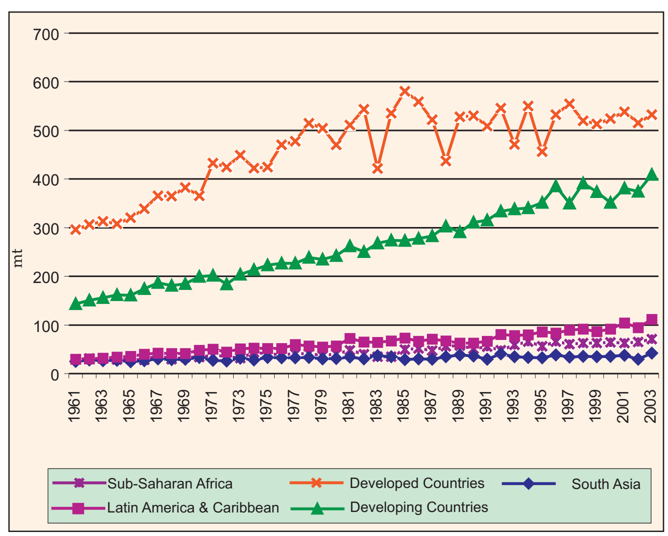
Figure 4. Total yield, area and production of cereals in various regions.



a. Coarse cereals yield in various regions, 1961 to 2003.



b. Coarse cereals area in various regions, 1961 to 2003.



c. Coarse cereals production in various regions, 1961 to 2003.

Source: FAO, 2006.

Figure 5. Coarse cereals yield, area and production in various regions.

Table 1. Total cereal area, yield and production in rainfed Asia and sub-Saharan Africa: 1995 baseline data compared to 2025 projections.[1]					
Country	Area (m ha)	Yield (mt ha^{-1})	Production (m mt)	Rainfed area (%)	Rainfed production (%)
South Asia	67.9 (55.3)	1.20 (1.65)	81.5 (91.24)	54.1	36.2
India	62.3 (49.8)	1.20 (1.63)	74.6 (81.4)	62.2	42.7
Pakistan	00.8 (00.9)	0.60 (0.93)	00.5 (00.8)	07.4	02.3
Bangladesh	01.9 (01.6)	1.35 (2.03)	02.6 (03.3)	24.9	13.5
Other South Asian countries	02.9 (03.0)	1.35 (2.16)	03.9 (06.5)	43.5	39.2
Southeast Asia	29.8 (31.4)	1.61 (2.46)	47.9 (77.8)	60.8	45.0
Indonesia	05.6 (05.9)	1.70 (2.44)	09.6 (14.5)	38.1	23.3
Thailand	08.8 (09.1)	1.52 (2.08)	13.3 (19.0)	80.7	70.4
Malaysia	00.3 (00.3)	1.45 (1.78)	00.4 (00.5)	35.9	25.6
Philippines	03.9 (04.5)	1.49 (2.46)	05.9 (11.2)	60.1	50.8
Vietnam	03.6 (03.5)	1.68 (3.19)	06.0 (11.3)	48.8	33.5
Myanmar	05.3 (05.7)	1.87 (2.80)	010 (16.0)	85.3	79.8
Other SE Asian countries	02.2 (02.4)	1.22 (2.22)	02.7 (05.3)	92.9	88.8
East Asia	27.1 (30.5)	3.54 (4.59)	95.7 (133.47)	29.5	26.1
China	26.2 (29.6)	3.59 (4.65)	94.0 (137.5)	29.6	26.3
S Korea	00.2 (00.1)	3.29 (6.01)	00.6 (00.8)	16.1	12.5
Japan	00.2 (00.2)	3.28 (3.72)	00.7 (00.8)	09.7	07.5
Other East Asian countries	00.6 (00.6)	1.57 (1.70)	01.0 (1.00)	36.2	24.8
Sub-Saharan Africa	53.2 (74.0)	0.83 (1.18)	44.3 (86.8)	96.4	93.0
Northern sub-Saharan Africa	29.0 (40.6)	0.65 (0.98)	18.8 (39.7)	96.4	92.1
Eastern sub-Saharan Africa	6.5 (8.3)	1.42 (1.88)	9.2 (15.5)	98.0	97.1
Central & Western sub-Saharan Africa	9.6 (14.5)	0.91 (1.21)	8.7 (17.6)	98.0	95.8
Southern sub-Saharan Africa	8.1 (10.6)	0.95 (1.33)	7.7 (14.0)	93.4	87.6

[1] Figures in parentheses are projections.

Source: Rosegrant et al. 2002.

A comparative analysis of the 1995 benchmark data on area, yield and production of cereals in Asia, with projected estimates for 2025, shows the changing role of rainfed agriculture between 1995 and 2025 (Table 1). In Southeast Asia, the area under rainfed cereal is projected to reach 31.4 million hectares in 2025, a 5% increase over the area planted in 1995. The aggregated rainfed cereal yield is projected to increase significantly to 2.46 mt ha^{-1} which is 53% higher than the average yield in 1995 and total rainfed production is projected to increase by 62% over 1995. A similar growth pattern is seen in East Asia.

However, in South Asia, the area under rainfed cereals is projected to cover only 55.3 million hectares in 2025, an 18.5% decline over the area planted in 1995. A significant decline in area under rainfed cereals is evident in India. The aggregated rainfed cereal yield is projected to be 37% higher than the yield in 1995 and the total rainfed production 12% over the production in 1995.

Similarly for sub-Saharan Africa, the area under rainfed cereals is projected to reach 74.0 million hectares in 2025, a 30% increase over the area planted in 1995. The aggregate rainfed cereal yield is projected to increase significantly to 1.18 mt ha^{-1} which is 42% higher than the average yield in 1995 and the total rainfed production is projected to increase by 96% compared to 1995.

Irrigated and rainfed cereal yields for 1995 and projections for 2025 are shown in Table 2. The irrigated yields for South Asia are expected to grow at the rate of 46% in 2025 whereas for the rainfed it is expected to grow only at 38.3%. Similarly, in sub-Saharan Africa the irrigated yields are projected to grow at the rate of 35% as compared to 42% in rainfed conditions. Concomitantly, Figure 6 shows irrigated and rainfed cereal yield in several countries for 1995 and 2025.

National level data available for 1950-51 through 2002-03 in India reflects significant growth rates (Figure 7a) in rice and wheat production (2.7% and 5%) compared to coarse cereal grains (<1%). These dynamics in production are explained by the rapid growth rates in rice and wheat yields and area grown, compared to those of coarse cereals (Figures 7b and c). In fact, the area grown to coarse cereals has continued to decline over the past decades. Irrigation investments during the Green Revolution period clearly benefited rice and wheat production (Figure 7d), bypassing rainfed regions where most of the coarse cereals grains are produced.

Disaggregated district level data available for over three decades in India show the long-term trends in rainfed and irrigated regions for specific major cereal crops. Figure 8 shows the changes in rice, wheat, sorghum and pearl millet yields for irrigated and rainfed India between mid 1960s to late 1990s. Figures 8a and 8b depict irrigated and rainfed crop yields for rice and wheat, where it is clear that irrigated crop yields are higher compared to rainfed crop yields, with notable gaps between them consistently increasing over time. Figures 8c and 8d depict yield changes for sorghum and pearl millet in irrigated and rainfed areas, showing evidence of lower yields and higher variability compared to rice and wheat. The descriptive statistics (Table 3) for crop yields (rice, wheat, maize, sorghum and pearl millet) show consistently higher yield instability in rainfed areas for all crops.

Table 2. Irrigated and rainfed yields (mt ha^{-1}) of total cereals, 1995 and 2025.

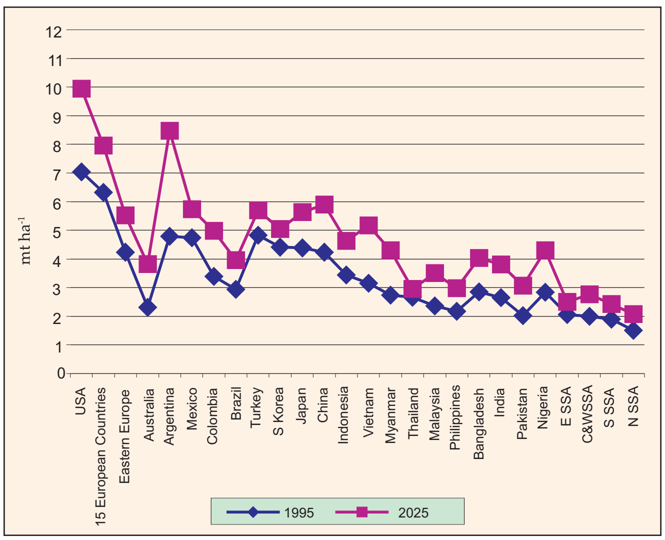
Region	Irrigated			Rainfed		
	1995	2025	Growth rate (%)	1995	2025	Growth rate (%)
Sub–Saharan Africa	1.71	2.31	35.1	0.83	1.18	42.2
South Asia	2.49	3.63	45.8	1.20	1.66	38.3
Southeast Asia	3.05	4.26	39.7	1.61	2.46	52.8
East Asia	4.20	5.83	38.8	3.54	4.60	29.9
Latin America	4.07	5.44	33.7	2.07	2.92	41.1
World	3.48	4.79	37.6	2.18	2.77	27.1
Developed countries	4.44	5.96	34.2	3.17	3.89	22.7
Developing countries	3.25	4.52	39.1	1.51	2.08	37.7

Source: Rosegrant et al. 2002.

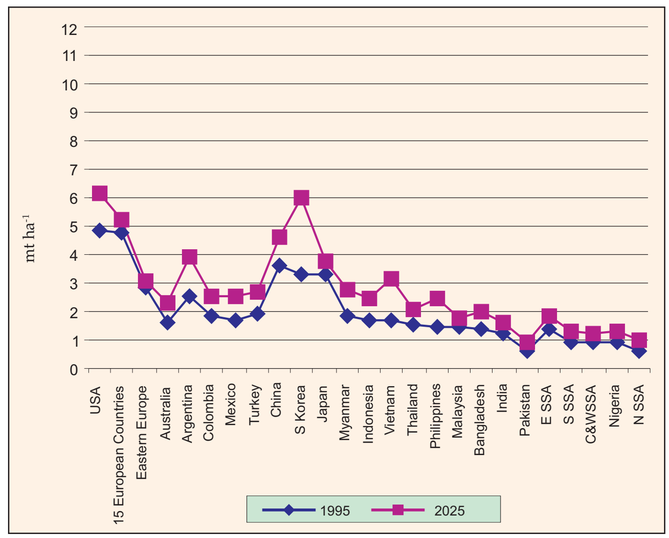
Table 3. Descriptive statistics of crop yields in rainfed and irrigated India, 1966-1997.

Rainfed areas	Rice	Wheat	Maize	Sorghum	Pearl millet
Mean	1234.9	1375.4	1144.4	680.6	464.8
Standard deviation	247.7	305.9	215.1	115.4	72.6
Coefficient of variation	20.1	22.2	18.8	17.0	15.6
Irrigated areas					
Mean	1990.2	2396.1	1377.5	628.8	822.0
Standard deviation	369.1	434.1	228.6	89.1	156.3
Coefficient of variation	18.5	18.1	16.6	14.2	19.0

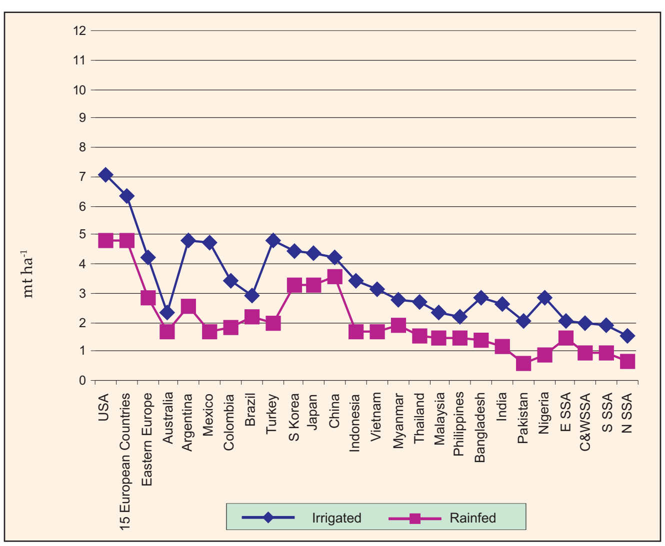
Source: ICRISAT District Level Database, 1966-1997.



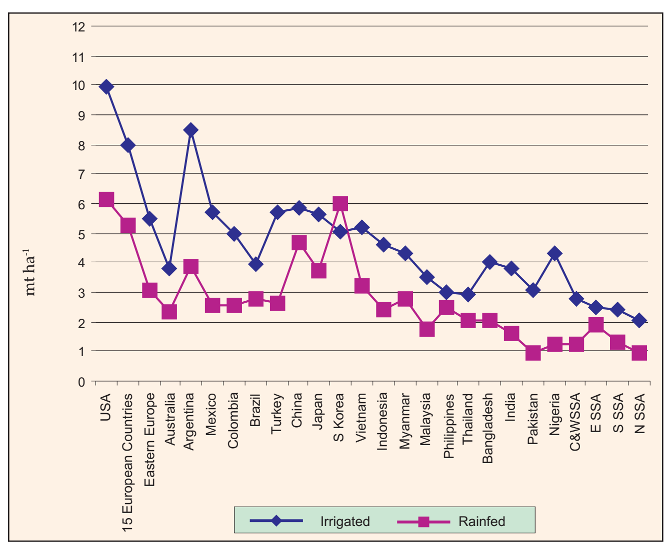
a. Irrigated yield, 1995 and 2025.



b. Rainfed yield, 1995 and 2025.



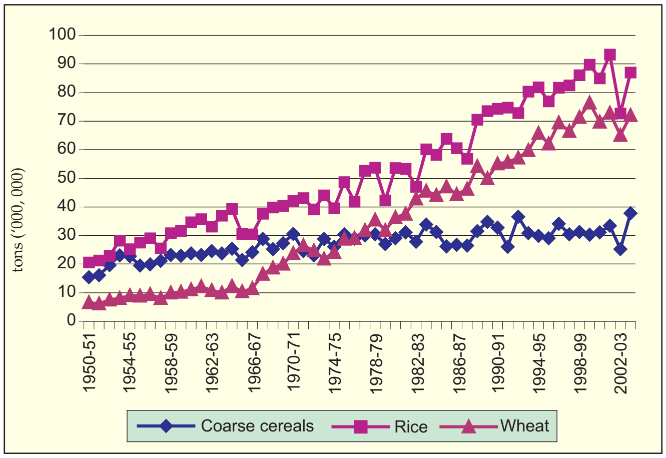
c. Irrigated vs rainfed yield, 1995.



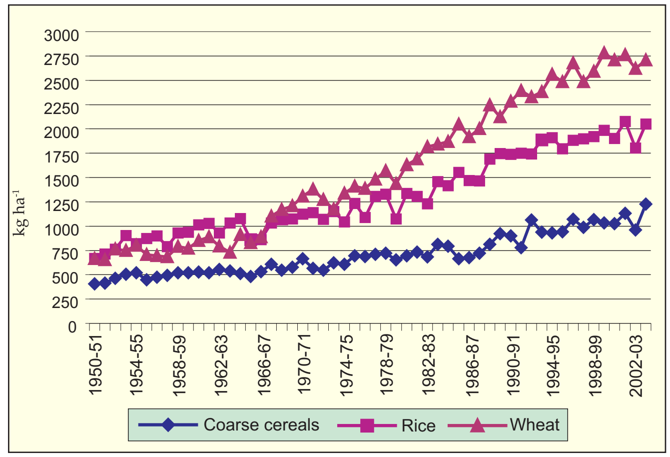
d. Irrigated vs rainfed yield, 2025.

Source: Rosegrant et al. 2002.

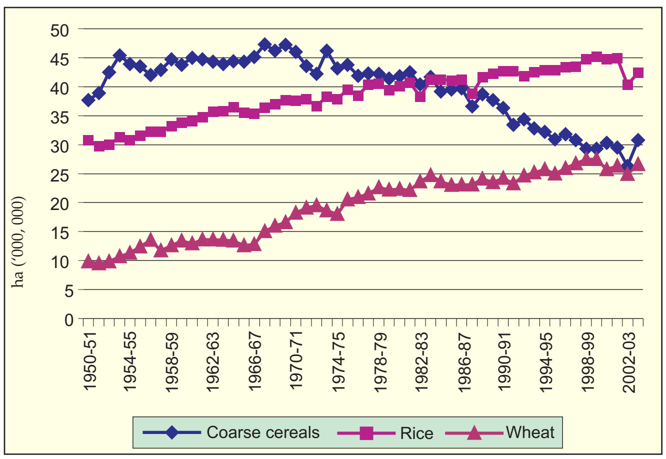
Figure 6. Irrigated and rainfed yield for 1995 and 2025.



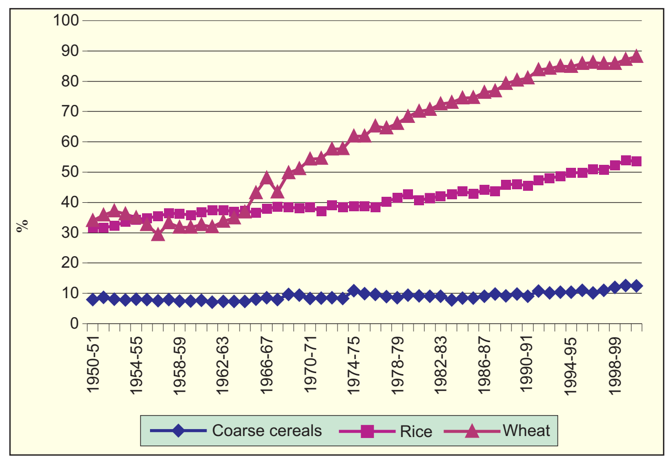
a. Production of coarse cereals, rice and wheat.



b. Yield of coarse cereals, rice and wheat.



c. Area under coarse cereals, rice and wheat.



d. Area (%) under irrigation.

Source: GOI (Government of India), 2004.

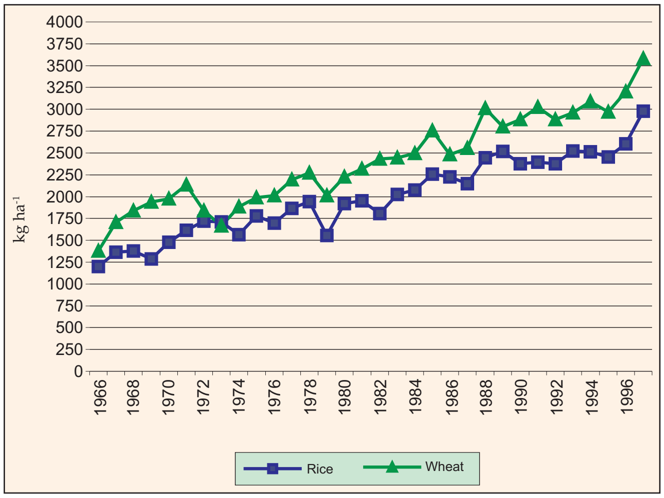
Figure 7. All-India production, yield and cultivation area of coarse cereals, rice and wheat, 1950-2003.

One issue debated is: As the developing countries are unable to meet their growing cereal demands, does this imply that the developed countries must fill the gap with greatly expanded trade? Trade enters the scenario in a limited way. If food demands double, grain consumption – of wheat, rice, and maize – will increase from 1.9 billion metric tons to 3.8 billion metric tons. Trade is now around 200 million metric tons, or approximately 10% of the supply, and is not likely to grow as a percentage. Further, China is losing nearly 1 million hectares or 1% of its cropland per year to industrialization. Brown and Kane (1994) predict that China will follow a path similar to Japan, South Korea and Taiwan, where their combined grain areas decreased from 8 million hectares to 4 million hectares from 1950 to 1990.

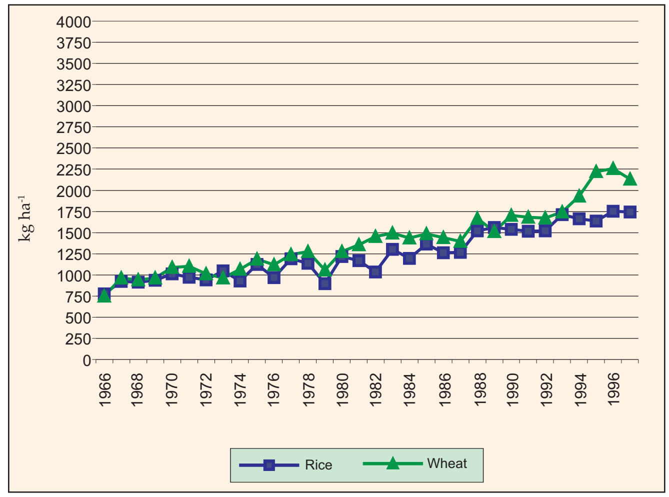
If developing countries are to grow their own food, and if population increases 2% per year, then their food production must rise by 2% per year. Serious constraints are experienced in sub-Saharan Africa and South Asia, particularly where problems of malnutrition are most severe. This identifies the problem of access to food, which is a poverty problem and not a food problem.

Challenges and opportunities facing dryland agriculture

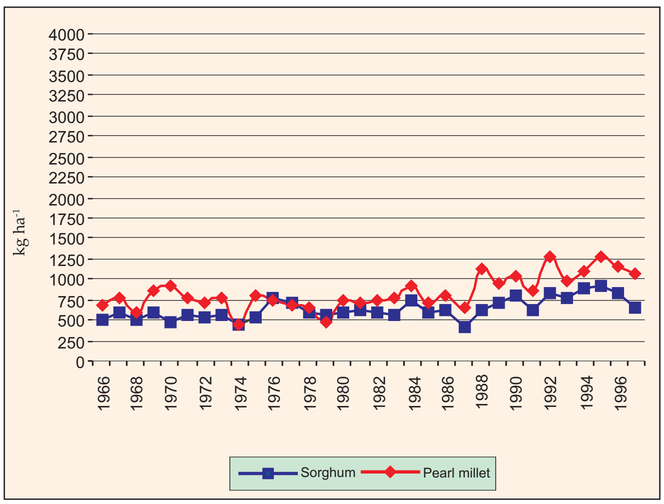
The challenges facing dryland agriculture are enormous. Despite the highly visible agricultural achievements during the last 40-50 years, dryland agriculture in sub-Saharan Africa and Asia faces persistent challenges which have a bearing on



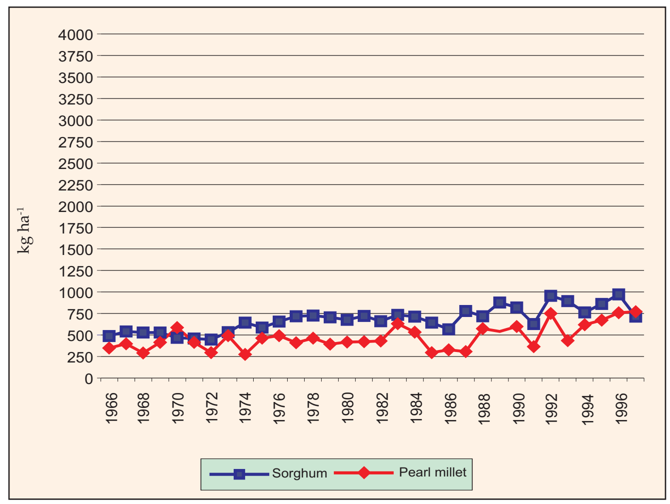
a. Rice and wheat yields in irrigated India, 1966-97.



b. Rice and wheat yields in rainfed India, 1966-97.



c. Sorghum and pearl millet yields in irrigated India, 1966-97.



d. Sorghum and pearl millet yields in rainfed India, 1966-97.

Source: ICRISAT District Level Database, 1966-97.

Figure 8. Yields of cereal crops in irrigated and rainfed India, 1966-1997.

its potential contribution towards poverty reduction, food security and sustainable productivity growth. Much of this relates to the lack of technological change and the stillborn agricultural transformations that not only threaten the sustainability of agriculture and the future sources of growth in the economies of these regions, but also amplify the process of marginalization in much of the rainfed areas. Moreover, as growth opportunities in irrigated areas are being exhausted, the need to improve the productivity of rainfed regions is becoming more compelling. Increasingly, development planners and policymakers are looking towards the hitherto less-favored rainfed regions.

The challenge of dryland development is to create an enabling environment in which local people are able to improve their livelihoods by using their resources more productively. Research has shown (Anderson et al. 2003) that even the poorest can be regarded as autonomous, responsible, experimental, and, though risk-averse, also innovative and opportunistic. Constraints, not ignorance, deter the poor. They must be offered choices of, and access to, appropriate technologies, practices, information and experience within a rewarding economic and institutional environment.

This section elaborates on the continuing challenges facing dryland agriculture: persistent poverty, water scarcity, climate change, land degradation, and others. An elaboration of these challenges is presented, after which the opportunities for dryland agriculture are discussed.

Challenges confronting dryland agriculture

Persistent poverty. Reducing poverty remains a central challenge in South Asia and sub-Saharan Africa. An estimated 1.85 billion people or 57% of the region's population lived on less than $2 a day in 2003. Of the rural poor, it is estimated that around 380 million (38%) reside in the arid/semi-arid tropics and another 500 million (50%) in the humid/sub-humid tropics. Among these agro-ecological zones, dryland areas have marginally more poor people than do the more irrigated areas (Ryan and Spencer 2001).

Data compiled from different sources indicate that in most agro-ecological zones in developing countries in Asia and sub-Saharan Africa, the incidence of poverty is higher in rainfed areas than in irrigated areas (Table 4). Other recent findings (IFAD 2001) support this trend with the risk emanating from poor soils, low rainfall and adverse climate change. Thus, although the extent of poverty is high in irrigated areas in Asia, its relative incidence and severity is expected to be high in rainfed and less-favored regions (Shiferaw and Bantilan 2004).

Table 4. The number of rural poor (in millions) in developing countries categorized by agro-ecological zone, 1996.

Eco-region	Developing countries	Sub-Saharan Africa	Asia
Arid and semi-arid	379	79	237
Rainfed	199	76	89
Irrigated	180	3	148
Humid and sub-humid	500	120	343
Rainfed	259	120	104
Irrigated	241	0	239
Temperate/cool	116	43	49
Rainfed	89	43	27
Irrigated	27	0	22
Total	995	242	629

Note: The poor are defined as those subsisting on US$ 1 or less per day.

Source: Ryan and Spencer, 2001.

The UNDP Human Development Index (HDI) for the 36 countries in the semi-arid tropics (SAT) was 0.60 in 2003, compared to 0.70 for non-SAT developing countries (calculated from UNDP sources). Since 1975, the non-SAT countries have improved their HDI by 37% while the SAT countries have shown an improvement of 35%. A closer analysis shows that the Asian SAT is better off than the African SAT, because all the regions in the former have shown an improvement in their HDI since 1975. The HDI of six large SAT countries has improved to 48% since 1975 compared to 32% for the medium SAT group and only 5% for the small group. Hence, the countries where the SAT dominate agricultural land area, have fared much better in human development in the last quarter century than those where the SAT is less important.

In Figure 9, HDI value for sub-Saharan Africa, Asia and developed countries and countries with HDI value greater than 0.8 for the year 2003 is presented. HDI levels are high across all developed countries and at variable rates in Asia and exceptionally low in sub-Saharan Africa. An HDI of 0.8 or more is considered to represent *high development*. This includes countries of northern and western Europe, North America, the East Asian Tigers, Australia, New Zealand, and some nations in the Middle East. An HDI value of below 0.5 is considered to represent *low development* and the countries in that category are located in sub-Saharan Africa. In sub-Saharan Africa human development is one of the major challenges faced today. The lethal interaction of economic stagnation, slow progress in education and the spread of HIV/AIDS has produced a free fall in HDI ranking in sub-Saharan Africa (UNDP 2005). Countries such as Niger, Sierra Leone, Burkina Faso, Mali, Chad, Guinea-Bissau, Central African Republic, Ethiopia, Burundi, Mozambique, and Democratic Republic of the Congo had registered lower scores on the HDI in 2003. The highest-scoring sub-Saharan country, South Africa, is ranked 120th (with an HDI of 0.658), which is well above most other countries in the region. Of the countries in Asia, the lowest HDI levels are noted for Yemen, Bangladesh, Nepal, Pakistan, Bhutan, Laos, Cambodia and Myanmar.

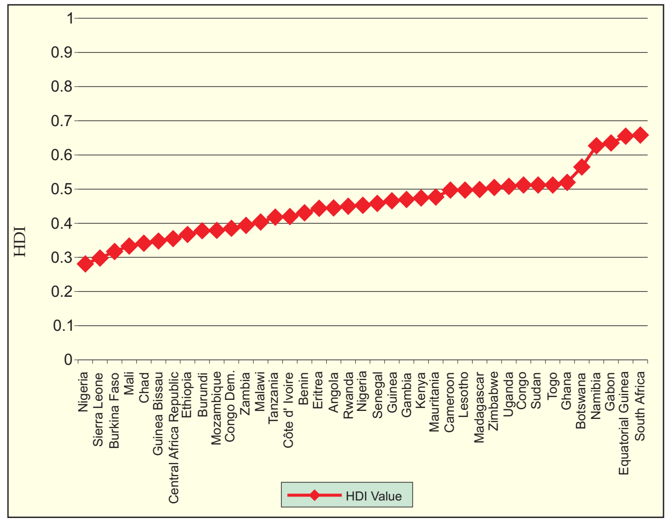
The UNDP Human Poverty Index (HPI) shows greater poverty in the semi-arid tropics – 32% in 36 SAT countries in 1998 compared to 24% for all non-SAT countries. The HPI has declined by almost 10% since 1995 in the SAT countries compared to an increase of more than 3% in non-SAT ones. Smallholders inhabiting the tropical drylands are unable to extricate themselves from the two realities of their ecosystem – the unreliable rainfall and the consequent unpredictable dryland farming that is characterized by periods of intense and exhausting work separated by periods of relative inactivity.

In Figure 10, Human Poverty Index, an indication of the standard of living in a country, for Asia and sub-Saharan Africa for the year 2003 is presented. The figure depicts that depth of poverty is greater in sub-Saharan Africa than anywhere else in the developing world. The region not only has the highest proportion of poor people, but also has the fastest 'human poverty' growth rate. Six countries are shown to have HPI exceeding 50%: Niger, Burkina Faso, Mali, Chad, Ethiopia and Sierra Leone, which means more than half their people are living in human poverty. Similarly, for Asia six countries: Bangladesh, Cambodia, Yemen, Nepal, Laos and Pakistan, experience highest HPI exceeding 35%.

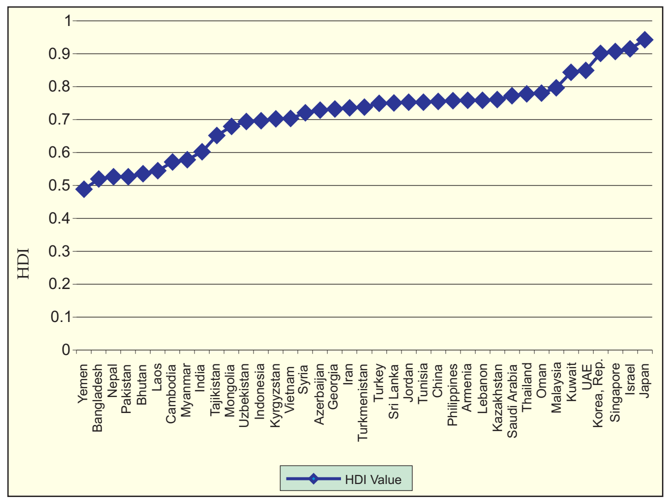
Data from the National Sample Surveys of India indicates that a large number of India's poor depend on dryland regions. Of an estimated 147.5 million rural poor in India (1999-2000), 41% or 60.2 million poor were concentrated in the SAT. By and large, areas with low irrigation have the highest incidence of poverty among all these regions. The less irrigated areas in the humid and SAT zones have a high concentration of poor social groups comprising of Scheduled Castes and Scheduled Tribes. The rural poor from dryland regions display a relatively low utilization of anti-poverty programs, highlighting the issue of constrained access.

Data from Village Level Studies (VLS) of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducted since 1975, provides empirical evidence of the vulnerability of the poor to various risks and shocks, as well as their diminished capacity to access physical, financial and social resources and networks in the drylands. The VLS captured welfare indicators involving the level of human development and the extent of vulnerability and insecurity among individuals or households (Rao et al. 2005).

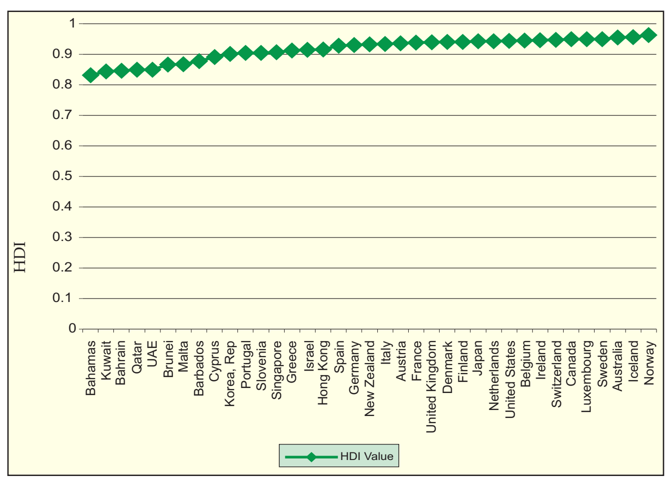
Water scarcity. Water is increasingly becoming scarce. In South Asia, international water conflicts



a. HDI for sub-Saharan African countries, 2003.



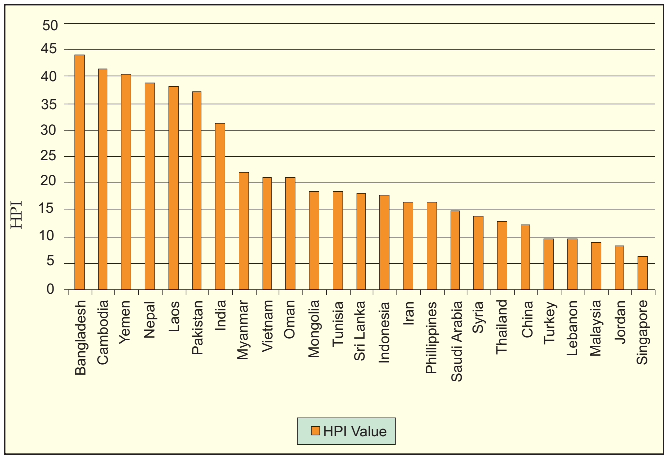
b. HDI for Asian countries, 2003.



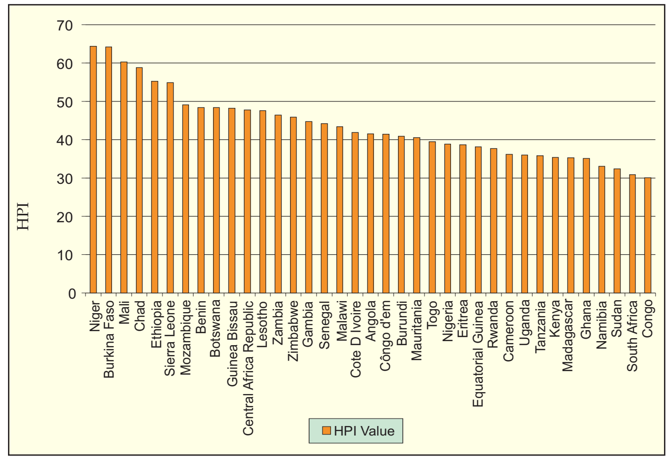
c. Developed countries and countries with HDI > 0.8, 2003.

Source: UNDP, 2005.

Figure 9. HDI value: SSA, Asia and Developed countries and countries with HDI > 0.8, 2003.



a. HPI for Asian countries, 2003.



b. HPI for sub-Saharan African countries, 2003.

Source: UNDP, 2005.

Figure 10. HPI value: Asia and SSA, 2003.

are brewing and riots over water have become commonplace. Minor irrigation sources have increasingly become more important than major and medium sources, especially in the drylands. However, very often, farmers dig deeper and deeper wells to steal a part of the neighbor's water rather than really adding new water areas. The desire to get away from dryland farming is so intense that they sometimes ruin themselves as well as their neighbors in pursuit of scarce groundwater. As a result, there is a lowering of water tables and a reduction in yield from wells.

Given this scenario, water-constrained dryland agriculture critically requires the following water-related interventions: a) adopting an efficient watershed management approach; b) reducing vulnerability through rainwater harvesting and storage; c) recharging depleted groundwater aquifers and strictly regulating groundwater extraction; d) pricing water and power to reflect their opportunity costs; e) enlisting government support for water-saving options, eg, drip irrigation or dryland crops; f) specifying and enforcing clearly defined water rights in watershed communities; g) enabling stronger collective action for community development in agriculture and resource management; and h) enhancing the scientific and technological support to watershed programs.

Climate change. Climate change is expected to have a negative impact on crop and livestock activities, which underpin the livelihoods of most of the poor in the drylands. Crop yields are projected to decrease and therefore exacerbate hunger, forcing changes in livelihood or coping strategies and the sale of physical assets such as small tractors, bicycles, household assets and farming implements. In rural areas, where climate change is leading to more frequent droughts and floods, the poor may have to regularly draw on these physical assets, thereby undermining the long-term sustainability of their livelihoods. Where economic diversification is low, income opportunities and hence options for developing alternative livelihoods in response to climatic changes may be limited (Bantilan and Anupama 2002).

Climate change will increase the number of people at risk of hunger. It has been noted, however, 'impending global-scale changes in population and economic development over the next 25 years will dictate the future relation between water supply and demand to a much greater degree than will changes in mean climate' (Vörösmarty et al. 2000). The impact of climate change on food security will be greater in countries with low economic growth potential but with high current malnourishment levels. In developing countries, production losses due to climate change may drastically increase the number of undernourished people, severely hindering progress in combating poverty and food insecurity (FAO 2005).

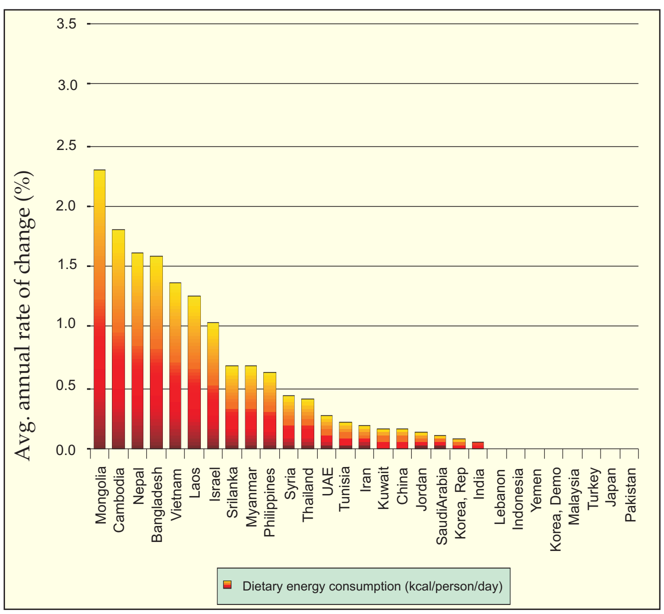
Land degradation. Land degradation is a serious threat to the economic and physical survival of the dryland farmer. Article 1 of the United Nations

Convention to Combat Desertification (UNCCD) defines land degradation as, 'a reduction or loss… of the biological or economic productivity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical and biological or economic properties of soil; and (iii) long-term loss of natural vegetation.'

Poor farmers, primarily those with small landholdings, have neither the resources to combat land degradation nor the options to meet short-term disasters, such as drought or pest attacks (ADB 1989). Land degradation – which manifests variously as escalating soil erosion, declining soil fertility, loss of biodiversity, salinization, soil compaction, agrochemical pollution, desertification[2] and water scarcity, and nutrient depletion – often results in loss of soil biota, plant and animal species, with concomitant risks to the sustainable production of food and ecological goods and services.

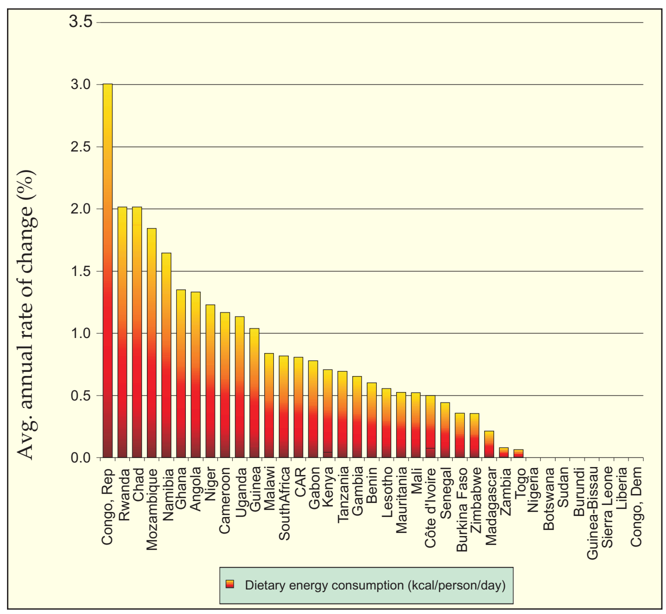
Other important emerging challenges

Nutrition and health threats. Micronutrient malnutrition or 'hidden hunger' has become more conspicuous in the dryland regions. The trends presented in previous section noted that more than 860 million people do not have enough food to meet their basic daily energy needs. Far more – an estimated three billion – suffer from the insidious effects of micronutrient deficiencies because they lack the money to buy enough meat, fish, fruits, lentils and vegetables. Women and children are most vulnerable to disease, premature death and impaired cognitive abilities because of diets poor in crucial nutrients, particularly iron, vitamin A, iodine and zinc. A great proportion of the 10 million children in developing countries who die each year of malnutrition are from the dryland regions. Today, micronutrient malnutrition diminishes the health, productivity and well-being of over half the global community, with its impact primarily on women, infants and children from low-income families. The consequences consist of 1) greatly impaired national development efforts; 2) reduction in labor productivity, educational attainments in children, school enrolments and attendance; and 3) increase



a. Food consumption average annual rate of change (%) in Asia.

Source: FAO, 2006.



b. Food consumption average annual rate of change (%) in sub-Saharan Africa.

Figure 11. Food consumption average annual rate of change (%) in Asia and sub-Saharan Africa drylands, 1995-1997 to 2001-2003.

2. Desertification is the degradation of land in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities. Modern desertification often arises from the demands of increased populations that settle on the land in order to grow crops and graze animals.

in mortality and morbidity rates, and health-care costs.

Food consumption expressed in kilocalories (kcal) per capita is used for measuring and evaluating the food situation. In Figure 11, food consumption with average annual percent rate of change in Asia and sub-Saharan Africa for 1995-1997 to 2001-2003 is presented. Analysis of data shows that dietary energy measured in kcals per capita per day had been steadily increasing in Asia and sub-Saharan Africa, notably Cambodia, Nepal, Bangladesh, Vietnam in Asia; and Rwanda, Chad, Namibia and Mozambique in sub-Saharan Africa.

The dryland regions are particularly vulnerable due to limited opportunities for earning cash incomes, leading to high levels of mobility and migration and greater probability of contracting HIV/AIDS. At the household level, the immediate impact is on the availability and allocation of labor. This poses new challenges for agricultural research and development.

Incidence as high as 35% has been documented in sub-Saharan Africa, notably in eastern and southern Africa. UNAIDS reports that in 2003, South Africa had the largest HIV-infected population in the world (UNAIDS and WHO 2003). Next was India, projected to overtake South Africa within the year. By the end of 2005, as many as 5.2 million Indians were living with HIV. Over one million people were newly infected with HIV in Asia and the Pacific, bringing the total number of people living with HIV/AIDS in the region to a staggering 7.4 million. Until the late 1980s, no Asian country had experienced a major AIDS epidemic, but by the late 1990s, the disease was well established across the region.

Migration. Among the many factors causing vulnerability is the migration of people engaged in dryland agriculture. Migration of workers from less-favored areas to more favorable ones has grown over the last few decades. Migration, whether seasonal, semi-permanent or permanent, is the predominant coping strategy adopted by the poor in the drylands to get out of the poverty trap. As a matter of fact, informal markets for migrant labor play an important role in balancing the regional supply and demand for casual labor. While informal migrant labor markets continue to increase, their efficiency could be improved and many more poor could benefit from an institutionalized system of collecting and disseminating information about supply, demand and wage rates from the local to the regional levels. State governments may effectively intervene in labor markets and ensure that wage rates are fair, and exploitative practices such as bonded labor are done away with.

Opportunities in dryland agriculture

Institutional innovations and empowerment. Dryland dwellers need to be empowered and their capacity built through education, training and provision of technical information and institutional credit to enable them to participate in and contribute to mainstream economic, social and political activities. It is important to build the capacity of supporting institutions and enable institutional learning and innovation. The challenge lies in providing an enabling institutional environment and incentives that will accelerate agricultural growth. National and regional programs with participation by the public and private sectors are essential, given that actions at the individual level are inadequate to reverse the situation in the drylands.

Partnerships between the public and private sectors have been evolving over time. In the 1980s, for example, the ICRISAT played a nurturing role to the fledgling seed industry and provided breeding material, often through informal networks. During the early 1990s, as private seed industry grew, the partnership was enhanced by developing significant research capability and using ICRISAT-bred improved breeding materials. In this process, the private sector became a major channel for delivering ICRISAT-based hybrids to farmers. It was quickly recognized that the private sector presents an effective delivery mechanism for improved technologies and facilitating farm-level adoption. The private sector had the advantages of well-established marketing channels and regular monitoring of farmers' choice based on market surveys through seed traders and other networks. With the government providing a supportive policy environment, the private sector can play a major role in developing dryland agriculture by leading in investments in agribusinesses, machinery, input enterprises and logistical support systems throughout the complete range of the market chain. To attract more private sector investment requires governments to create an enabling environment, not only in providing basic infrastructure and services, but also in considering options for underwriting investment, tax incentives or credit at preferential rates.

Commercial orientation of agriculture and trade liberalization. Dryland agriculture needs to keep pace with the changing world trade regime which is characterized by globalization, interdependence, international competitiveness and commercialization of agriculture, and the changing food habits of people in favor of livestock products, fruits and vegetables. It is crucial that dryland farmers have a clear market orientation to make decisions about the crops they should grow. Access to good markets, which can ensure a fair price to the producer, is essential to increase the production and profitability of dryland agriculture. The use of Information and Communication Technology (ICT) can stimulate creative interaction between farmers and agro-industries and help keep farmers informed about prices prevailing in regulated markets and facilities available. Contract farming and other institutional innovations for vertical coordination are the emerging alternatives to open markets. Farmer associations could tie-up with processing industries and thus share the benefits of value addition.

The World Trade Agreement (WTA) of 1994 led to the setting up of the World Trade Organization (WTO) in place of the General Agreement on Trade and Tariffs (GATT). The Agreement on Agriculture (AOA) has sought to reform international trade in agricultural commodities by making it obligatory for countries to open their markets to products from other countries and by partially reducing production and export subsidies. Its paradoxical predecessor combined the thorough liberalization of trade in industrial commodities with highly protected markets for agricultural commodities. To enhance food security, virtually every country aimed at enhancing the production of food grain commodities, ignoring the principle of comparative advantage. With the WTA taking the first step towards liberalization and globalization of trade in agricultural commodities, most developing countries are finding it difficult to adjust to the new scenario. Also, there is resentment in developing countries that the agreement carried many asymmetries in favor of the developed countries. In particular, like other marginalized regions, the drylands are affected by WTO negotiations. Potentially improved access to global commodity and labor markets are offset by competition from subsidized producers elsewhere in the world by sanitary and phytosanitary controls and by restrictions on migration. Enabling environments may be created in many ways. For instance, the removal of barriers to trade, achieved through international agreements, or the implementation of economic reforms aimed at improving market conditions for dryland producers.

Also, some developed countries resort to various methods of protection while implementing the agreement. There are apprehensions that a flood of subsidized imports may harm the interests of small farmers in developing countries in general, and dryland farmers in particular (Gulati and Kelley 1999). So, there is a clamor for exemptions and safeguards to protect the immensely risk-prone dryland farmers plagued by crop losses due to biotic and abiotic factors. In any case, reduction in unit cost of production is the best strategy to cope with the competition in the global market. A strong research and development backup for dryland agriculture will help in better resource use, efficiency and competitiveness. The basic question is how dryland agriculture in Asia can be organized or diversified to overcome complex challenges and capture emerging opportunities so that the benefits of globalization, technology, policy and institutional innovations can be harnessed to reduce poverty and resource degradation, so as to prevent further marginalization of the dryland regions.

This dynamism notwithstanding, risks, poverty, natural resource degradation and biodiversity loss persist and are projected to worsen under the impacts of globalization, modernization, climate change, disintegrating community organizations and inadequate and ineffective public sector interventions.

Agricultural diversification and crop-livestock interaction. Though the Green Revolution shortened the growing period of irrigated crops, thus facilitating two or more harvests a year, progress has been relatively slower in the dry regions. However, growth rates in agricultural production and total factor productivity have been moderate, if not high. Modern technologies such as high-yielding varieties (HYVs) are increasingly being used. Agricultural research scientists are combining a medley of measures to allow farmers to reap more than one harvest a year, eg, quicker growing plants that mature before the summer heat and water-harvesting techniques that allow concentration of available water where it is most needed. Better water management methods have helped farmers optimize the use of water. As a result, cropping pattern shifts are taking place and coarse cereals are being replaced by soybean, pigeonpea and lentils. Significant dietary changes are also occurring across all income baskets.

Growing importance of livestock. Population growth, urbanization and increasing per capita incomes are fuelling a rapid growth in demand for animal-based foods in developing countries, especially in the drylands. Hence, in addition to improving crop production, it is important to seek ways to improve dryland livestock production and crop-livestock systems. Vast tracts of arid and semi-arid lands are unsuitable for crop production but support livestock, especially small ruminants such as sheep and goats. The livestock is not only a vital source of protein but also constitutes an important sector of the economy which makes use of land that would otherwise be unproductive, thereby providing livelihood to around 300 million pastoralists worldwide. In order to fulfill crop needs like manure and animal traction, farmers move towards crop-livestock integration. Globally, mixed farming is highly important, producing 90% of the global milk, 54% of cattle meat and 100% of buffalo meat (McIntire et al. 1992).

Diversification with a focus on crop-livestock development is both a coping strategy against risk and an income enhancing opportunity that allows efficient utilization of land, labor and capital over space and time. Since the poor in dryland regions hold a major share of the livestock, diversification towards milk and meat production reduces interpersonal disparities in income.

The diversification away from staple food production is triggered by rapid technological change in agricultural production, improved rural infrastructure and diversification in food demand patterns. A recent FAO/World Bank study on farming systems and poverty has suggested that diversification is the single most important source of poverty reduction for small farmers in South and Southeast Asia (Dixon et al. 2001).

Yet, in almost all South and Southeast Asian countries, agricultural policies and institutions have favored self-sufficiency in cereals. The inertia in this system will act as a strong disincentive for diversification unless drastic changes in policies and institutions are adopted. This is illustrated by the fact that the share of cereals in the value of agricultural output has generally remained unchanged in South Asia as a whole. In general, the export prospects are unlikely to affect a majority of farmers even if some specialized production for niche export markets were to take place. Such production would be on a limited scale, at least with respect to the total agricultural population. Therefore, the dynamics would largely be driven by domestic demand (Parthasarathy Rao et al. 2005).

Implications for policy and research priorities for dryland agriculture

As discussed earlier, food security and productivity growth in agriculture in Asia and sub-Saharan Africa are increasingly dependent on the improved utilization of new technologies and the productivity growth in rainfed areas. If future technology growth is to benefit the poor, the overlooked potential of rainfed areas must be explored, and suitable strategies and policies designed to stimulate productivity growth. Reorienting public policies and a better targeting of development interventions to dryland farmers are called for.

Implications for policy

Any policy initiative supporting dryland agriculture starts with an implicit recognition of the policy bias in favor of irrigated agriculture. Therefore, it becomes imperative to address the adverse policy outcomes suffered by dryland farmers.

The following list of policy recommendations was formulated based on a review of previous studies, including the analysis of micro-level VLS data and a nationwide poverty analysis using the National Sample Surveys of India. The studies provided the basis for identifying the major policy issues that need to be addressed to strengthen livelihoods in the dryland regions.

Raise public investment in technology and infrastructure. Since low levels of input use and low productivity levels characterize dryland agriculture, it is important to step up the level of private and public investment in improved technologies. Farm and non-farm incomes in the drylands are constrained by deficient infrastructure. Constraints in seed availability and other input supply also emphasize the importance of an effective public and private sector in reaching the rural poor. Earlier results (Fan et al. 2000) show that marginal returns on investment in infrastructure and technology in dry areas are higher than those in irrigated areas. Investment in rural infrastructure will particularly have a direct impact on food security.

Rationalize subsidies on agricultural inputs. Fertilizer subsidy is a major issue. While fertilizers can be used in both irrigated and dryland areas, most of them have been used for irrigated crops. Due to the non-availability of moisture, dryland farmers consider it quite risky to apply fertilizers, using them only in small doses. However, Governments and banks are providing farmers cheap credit for irrigated crops.

Like fertilizers, irrigation water and electricity are two other inputs that are heavily subsidized. While the benefits of investments in irrigation are meant to be shared by the whole society, the dryland farmer is unfortunately discriminated by this policy. Non-recovery of irrigation capital costs is the first among the many policies that have been discriminatory. Policies on subsidies on agricultural inputs need to be reviewed and their direct and indirect impacts on different categories of farmers must be carefully assessed. There is a need to streamline the delivery system to ensure wide and equitable distribution of benefits from subsidies. This objective will remain a mirage unless dryland farmers receive a higher priority in the allocation of funds for subsidies on farm inputs (Rao 1999).

Cover more crops under minimum support price schemes. Rainfed crops suffer substantial discrimination in the Government's procurement and public distribution policies. Although minimum support prices are also announced for rainfed crops, they are seldom backed by procurement operations (Bantilan et al. 2004). For instance, the heavily subsidized Public Distribution System (PDS) and rice and wheat markets in India have eroded the competitiveness of coarse cereals and altered market price ratios. Substituting PDS with a food stamp system leaves beneficiaries the option of buying grains of their choice. Unless these policy initiatives are taken up vigorously, rainfed crops and farmers growing them may be further marginalized, forcing them to seek livelihood options outside agriculture.

Cover more households under crop and livestock insurance. With rising cultivation costs and the existing risks and uncertainties of dryland agriculture, farmers are anxious about the investments they make and the returns expected. Hence the need for a major policy initiative in the form of crop insurance in dryland areas (Bantilan et al. 2004). Like the National Agricultural Insurance Scheme launched by the Ministry of Agriculture in India, crop and livestock insurance coverage should be extended to all dryland farmers at subsidized premiums.

Address chronic trade deficits in pulses and oilseeds. Shortage of pulses and oilseeds and import dependency are chronic problems, especially in India. While the Technology Oilseeds Mission (1986) helped reduce edible oil imports for some years, there has been a steady growth in imports since the 1990s. As these crops are predominantly grown in the drylands, a renewed emphasis on oilseeds and pulse production can help reduce the unnecessary and foreign exchange-depleting imports.

Increase inflow of institutional credit to dryland agriculture. The amount of institutional credit provided per hectare to dryland farmers is markedly lower than that in irrigated areas. It has been observed that dryland agriculture is profitable over a period of three to five years even though it may be a losing concern in any one year. Therefore, it would be an immense help to put in place a new cyclical credit policy (Bantilan et al. 2004) that can meet all the credit requirements of dryland farmers during this period, even if they defaulter after one or more years.

Institute measures to cope with globalization and marginalization. Market reforms that encourage integration and liberalization of import and export markets, production efficiency and competitiveness of agricultural products within the domestic and international markets are becoming an important policy issue in the agricultural sector. Considering dryland agriculture's role as a means of livelihood, enhancing its competitiveness by cutting the unit cost of production is critical for the survival of many small-scale farmers (Bantilan et al. 2004).

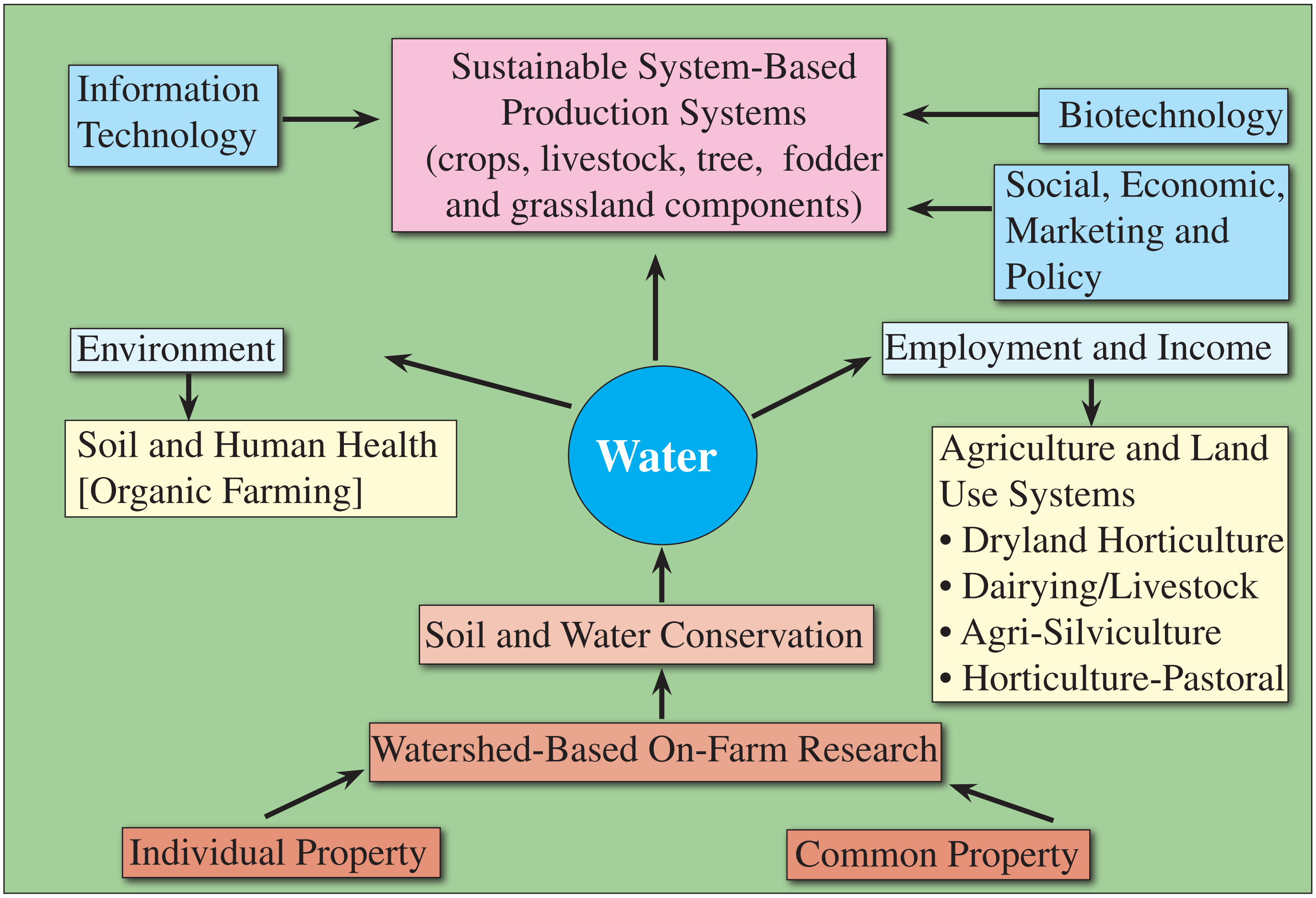
Facilitate migration. Seasonal, semi-permanent, or permanent migration is a predominant coping strategy adopted by the poor to escape poverty. Informal markets for migrant labor (in SAT villages of India) play an important role in balancing the regional supply and demand for casual labor. The efficiency of informal migrant labor markets could be further improved if an institutionalized system of collection and dissemination of information on supply, demand, and wage rates is provided in select dryland regions (Bantilan et al. 2004). Wage rates for female workers are substantially lower (50%) than that of male workers. Policies to address this gender inequality and imbalance are needed.

Implications for research priorities

The emerging evidence of higher impacts on poverty as well as higher marginal productivity gains from public investments, particularly in roads, markets and research, in less-favored regions (Fan et al. 2000), suggests the need to prioritize these hitherto overlooked areas in terms of technology, institutions and policy. Evidence from literature also suggests there have been sweeping changes in village economies in the last few decades (Rao et al. 2005), and these changes demand an assessment of research and development priorities in dryland areas.

The framework in Figure 12 is useful in discussing critical entry points for research and development (Bantilan et al. 2003). The framework focuses on the effective and economic utilization of land and water resources without causing irreparable damage to the environment, to sustain the improvement of the living conditions and livelihoods in the drylands. Technology, institutions, markets and governments play important roles. In this context, strategic initiatives must emphasize on maximization of biomass per drop of water through an appropriate combination of crops, livestock, grasses, shrubs and trees; involvement of communities in these initiatives and providing access to land and water resources for the vulnerable sections by an appropriate framework of 'rights'; and investment in evolving and perfecting alternate technologies and in improving physical infrastructure coupled with domestic market reforms.

There is a need to look beyond productivity and yield increases in dryland agriculture. The inability to reflect on major development constraints and the failure to integrate research and market issues limit the relevance and applicability of research products to wider environments. Research must be targeted to generate improved germplasm, harness biotechnology, protect crops against major pests and diseases, develop watersheds, enhance crop-livestock interactions and innovate approaches for linking farmers to markets (input and output markets). Focused and output-oriented research using participatory approaches needs to be streamlined. Approaches such as expansion of biotechnology, intellectual property rights (IPR), free trade regime and commercialization of agriculture have to be advanced. A summary of priority areas for research in dryland agriculture is given in Box 1.



Source: Bantilan et al. 2003.

Figure 12. Entry points for research and development in dryland agriculture.

Priorities to drive a 'Grey to Green Revolution'. The benefits of the Green Revolution did not percolate to the dry and marginal rural farmlands. These areas, characterized as dry or 'grey', yearn for a strategy for change that addresses the powerlessness of the poor, failing which the tragic result will be more food and yet more hunger.

While the Green Revolution depended on farmers' access to favourable conditions to avoid moisture or nutrient stress, in the marginal dry tropics productivity gains can also be made by adapting the crop to the environment, through less stress, and disease and pest management. This means farmers get more out of their own natural resource endowment and they are better placed in the global market. By managing and optimizing local resources, poor people can turn adversity into opportunity. This way they climb their way out of poverty without depending on costly inputs or external aid.

This new revolution to green the grey areas is not possible without modern tools of science such as biotechnology and information technology. Biotechnology has the potential to substantially increase the rates of return on investments in genetic improvement. Information is a vital resource to aid farmers in making well-informed and timely decisions that optimally use available resources, together with new science tools such as Geographic Information Systems (GIS) and modeling.

The Grey to Green Revolution is not just about increasing crop productivity. It has to do more with empowering the poor to build their own capacities, self-confidence and self-reliance by using modern tools for agricultural transformation and economic growth. Appropriate technology holds the key to sustained food security and poverty alleviation in resource-poor developing countries. Growing concerns about

Box 1. Research priorities in dryland agriculture

Policy studies. Dryland crops have poor market policy support. Increased priority to subsidies for irrigated crops causes serious impediments in the development of rainfed agriculture. Hence increased contribution to policy dialogues at the national, regional and global levels is necessary. A unified and long-term vision and action by all stakeholders must be taken up seriously.

Systems diversification. This high priority area covers three aspects: (a) diversification of income-generation activities at the farm level, (b) value addition, changing market trends, new opportunities, information technology use in agriculture and (c) enhanced food processing and food supply chains and marketing.

Integrated Genetic and Natural Resource Management (IGNRM). IGNRM is a powerful integrative strategy of agricultural research that seeks to maximize the synergies among the disciplines of biotechnology, plant breeding, agronomy, agro-ecosystems and social sciences with people empowerment at its core. Innovation systems are essential, whereby pioneer linkages with different stakeholders from various sectors for generating advanced breeding lines, pest-resistant varieties, trait-specific germplasm, screening techniques for biotic and abiotic stresses and seed systems are involved. A critical mass of expertise in diverse topics (livelihoods, markets, agricultural rehabilitation and strategic thinking), depth and breadth of experience, research and development skills and capacity have to be scaled up. Crop breeders need to work closely with social scientists and NRM specialists to meet agro-biological and socio-economic constraints limiting productivity in the SAT.

Biotic, abiotic and environmental constraints. Degrading natural resources, severe pest and disease infestation, drought, resistance to new breeds (such as genetically modified crops), low productivity caused by poor varieties and inadequate local seed systems are major constraints to agricultural development. Hence the need to provide sustainable solutions to these pressing problems is a real challenge.

Food security. Low productivity growth of coarse cereals and pulses is posing challenges in attaining the Millennium Development Goals (MDGs) and improving food security in the dryland regions of Asia. Lack of productivity due to water scarcity, poor soils and access to markets is a major challenge.

Globalization and WTO. Open markets and globalization are posing unfair competition. Lack of proper policy support further marginalizes poor farmers engaged in dryland agriculture, who are not sufficiently protected from the impact of globalization, continuing subsidies of developed countries and threats of WTO.

Networks and collaborations. Resources need to be leveraged through innovative partnerships and better linkages with regional programs through networks. Powerful global networks, collaborations and partnerships with Advanced Research Institutes (ARI), National Agricultural Research Systems (NARS), Non-Governmental Organizations (NGO), private sector, donors and other stakeholders are required. So also worldwide capacity building with NARS through training and networking activities.

environmental degradation and the sustainability of intensive agricultural systems have given rise to the consideration of alternative technologies, such as low-input agriculture (use of organic nutrients) and Integrated Pest and Disease Management, which are environmentally safe and maintain soil fertility. Recent developments in new science offer considerable potential benefits. Through scientific innovations, dryland agriculture can be a vehicle for economic, social and eco-friendly change in rural societies.

Harnessing the power of technology for development. Productivity gains are essential to achieve universal food security, poverty alleviation and economic viability. To help developing countries attain food security and reduce poverty and malnutrition, the application of biotechnology to dryland agriculture is expected to improve the quality of products, decrease the use of chemical pesticides, and lead to profitable utilization of germplasm and development of novel products. Advances in genomics and bio-informatics will help realize the value of germplasm. Molecular markers will become an essential tool for both plant breeding and diversity assessment studies. Comparative genomics research will reveal new opportunities to unleash the genetic potential of one crop, based on information discovered in another. Genetic transformation will enhance stress, pest and disease resistance; add new quality and nutritional traits; and protect the environment by reducing reliance on toxic insecticides. A better understanding of the physiology of productivity and hybrid vigor will break yield barriers. We can expect varieties with tolerance to drought and waterlogging, and resistance to insect pests. Many more possibilities, some yet unimagined, are likely to emerge. How soon some of the bio-engineered products may become available after testing and the needed safeguards would depend on the quantum of resources devoted to the effort. Biotechnologists estimate that products resistant to abiotic stresses and those with better nutritive value may become available in the next three to five years. Once available, the prevailing regulatory regimes would determine the speed of adoption.

Integrated Genetic and Natural Resource Management (IGNRM). Participatory and interdisciplinary research towards IGNRM takes advantage of an integrated strategy of core competencies to enhance productivity gains with equitable benefits through genetic enhancement and biotechnology, crop breeding, soil and water management, along with social science perspectives. This integrated strategy bears special emphasis on the enhancement of commodities that are particularly important in the diets of the poor.

Research is directed towards reducing the cost of production and improving input use efficiency, combined with the integration of crop management technologies vital to improving response to inputs and stabilizing production. New scientific techniques are harnessed to enhance the nutritive value of food cereals and legumes through biofortification. Genetic enhancement of micronutrient density in sorghum and millets, for example, will further add to nutritional security. In the case of carotene in millets, sources of yellow endosperm have been identified which may even have higher carotene content, and hence higher vitamin A density.

IGNRM tackles the issue of water scarcity on two fronts. The first utilizes natural resource management research to improve rainwater utilization through watersheds and water conservation techniques. The second employs plant breeding and biotechnology research to improve water-use efficiency and drought tolerance in crop genotypes. The benefits have been in the form of reduced runoff and soil loss, improved groundwater levels, improved land cover and vegetation, increased productivity and changes in cropping patterns.

Social science perspectives. ICRISAT pioneered the effort to develop a longitudinal panel database, which could be used for tracking development pathways and testing several theories and policy impacts. ICRISAT VLS have proven to be a powerful tool in providing insights into changes in rural livelihoods in the SAT over the last 20 years. Its key findings include a shift in the cropping patterns from food crops to commercial crops, decline in livestock numbers, decline in income from farming due to persistent drought, and increased dependence on non-farm work, migration, services, business and other occupations to support families (Rao et al. 2006). The findings also reflect the forces of globalization and national policies that influence input and output prices and the profitability of agriculture. Many policy interventions are needed in favor of dryland agriculture in the SAT to correct the policy bias and to enhance public investments to alleviate poverty. Evidence from VLS highlights the importance of regional specificity and participatory priority identification to develop innovative strategies for the complex dryland environment.

Institutional innovations. The most effective way to address the critical challenges in dryland agriculture is to develop problem-based, impact-driven strategies for agriculture and make them available through effective delivery systems, strategic alliances and other supporting institutional innovations.

Summary and conclusion

Though the Green Revolution transformed many regions in the developing world, it did not reach the poor in the drylands. Poverty, population explosion, water scarcity, land degradation, migration and other health constraints persist. The low productivity of dryland agriculture, coupled with a changing global environment, further threatens to marginalize agriculture and livelihoods in the drylands of Asia and sub-Saharan Africa. These areas require approaches that differ from the Green Revolution strategy. A broad vision for dryland agriculture would involve reducing poverty, hunger and malnutrition, and ensuring sustainable livelihoods for everyone. This vision can be achieved through a multi-pronged strategy to accelerate the pace of development of dryland agriculture, which requires synergy among technologies, marketing systems, input supplies, credit, policies and institutions. Political will and appropriate policies are needed to not only lift dryland agriculture from stagnation but also to put it on to a higher growth trajectory. The contribution of research and development agencies should focus largely to minimize the effect of recurrent droughts, improve cropping systems, enhance livelihood opportunities, augment agricultural incomes, and participation in trade. Broad-based sustainable growth and development in Asia and sub-Saharan Africa's drylands is the key to addressing rural poverty in these regions.

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Appendixes

Appendix 1. Dryland zones: classification, extent and distribution.

The drylands embrace semi-arid, arid, hyperarid, and dry sub-humid areas. These lands are characterized by low and erratic precipitation which is reflected in relatively low and notably unpredictable levels of crop and livestock production (UNEP 1997). Mainly their dryness lies less in total precipitation as in the negative balance between precipitation and evapotranspiration. Drylands have thus been defined in terms of water stress, as areas where mean annual precipitation (P) is less than half of the potential evapotranspiration (PET= potential evaporation from soil plus transpiration by plants). This in turn is reflected in the number of growing days that constitute the length of the growing period of the crops (FAO 1993).

Typically hyperarid areas receive less than 200 mm of rainfall, while arid areas receive less than 200 mm of winter rainfall annually or less than 400 mm of summer rainfall. Semi-arid areas receive 200-500 mm of winter rainfall or 400-600 mm of summer rainfall and dry sub-humid areas receive 500-700 mm of winter rainfall or 600-800 mm of summer rainfall (FAO 2004). What makes the dryland a difficult environment is not only the lack of water, but also its erratic distribution. Inter-annual rainfall can vary from 20 to 100%, and periodic droughts are common (Zurayk and Haidar 2002).

Dryland zones according to PET ratio and rainfall.[1]

Classification	P/PET[2]	Rainfall (mm)	Area (%)	Area (Bha= 10^9 ha.)
Hyperarid	< 0.05	< 200	7.50	1.00
Arid	0.05 < P/PET < 0.20	< 200 (winter) or <400 (summer)	12.1	1.62
Semi-arid	0.20 < P/PET < 0.50	200 - 500 (winter) or 400 - 600 (summer)	17.7	2.37
Dry subhumid	0.50 < P/PET < 0.65	500 - 700 (winter) or 600 - 800 (summer)	9.90	1.32
Total			47.2	6.31

Aridity zones defined by the index of aridity (P/PET) ratios and the world drylands (m ha).[3]

		Drylands					
		Hyper-arid[4]	Arid	Semi-arid	Dry Subhumid		
	Land Mass[5]	< 0.05	0.05–<0.20	0.20–<0.50	0.50–<0.65	All aridity zones[5]	% of world drylands
Africa	2,965.6	672.0	503.5	513.8	268.7	1,959	31.9%
Asia	4,255.9	277.3	625.7	693.4	352.7	1,949	31.7%
Australasia	882.2	0	303.0	309.0	51.3	663	10.8%
Europe	950.5	0	11.0	105.2	183.5	300	4.9%
North America	2,190.9	3.1	81.5	419.4	231.5	736	12.0%
South America	1,767.5	25.7	44.5	264.5	207.0	543	8.8%
Total	13,012.6	978.1	1,569.2	2,305.3	1,294.7	6,150	100
% of world drylands		16%	26%	38%	21%	100%	

[1] Dryland categories according to FAO (1993) classification and extension (UNEP 1992).

[2] P/PET ratio where p=mean annual precipitation and PET = mean annual potential evapotranspiration.

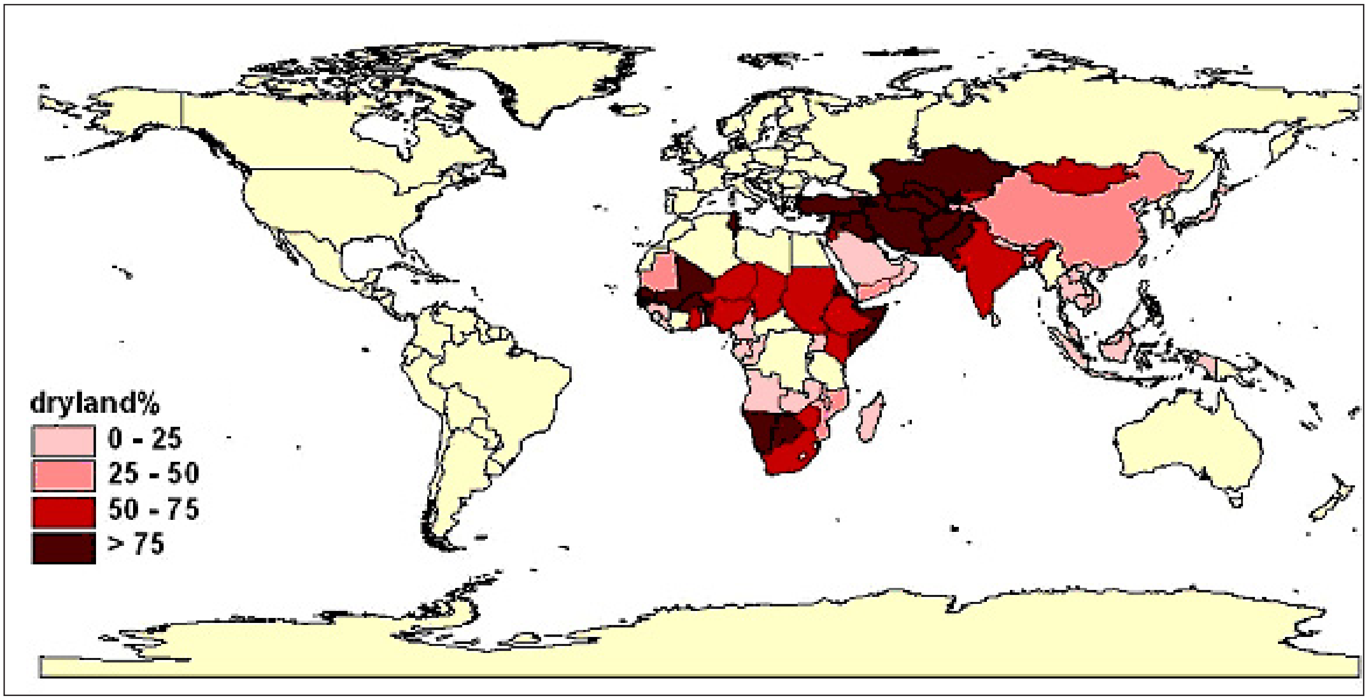
[3] Reynolds and Stafford Smith. 2002.

[4] Such as the Atacama, Gobi, Arabian, and Sahara deserts.

[5] Millions of hectares.

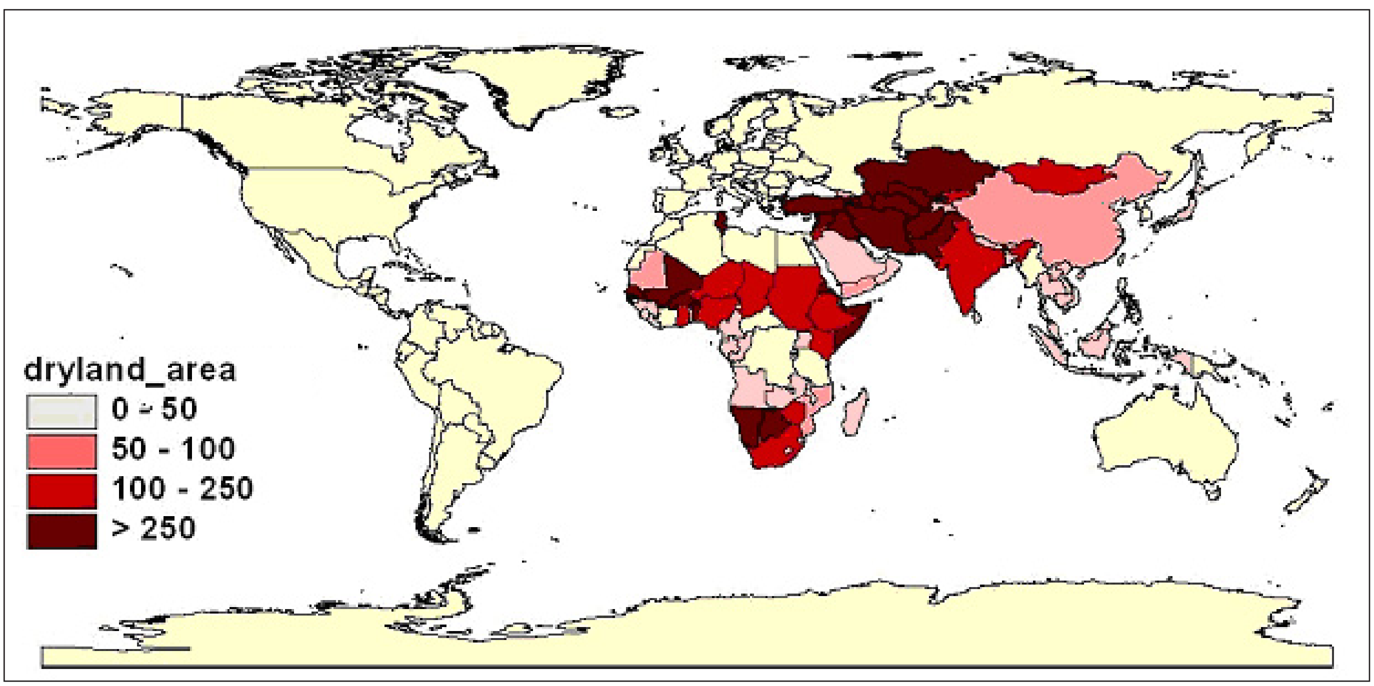
Appendix 1 (cont.)

Extent of drylands (%) and distribution ('000 ha) in Asia and sub-Saharan Africa.



Source: WRI, 2003.

Extent of drylands area (%) in Asia and sub-Saharan Africa.



Source: WRI, 2003.

Distribution of drylands area ('000 ha) in Asia and sub-Saharan Africa.

Appendix 2. Global population and distribution patterns.

Population (Billions)							
Year	World	Developed countries	Developing countries	Sub-Saharan Africa	Latin America	Asia and the Pacific	Near East-North Africa
1969-71	3.6731	1.0589	2.6142	0.2632	0.2601	1.8811	0.1849
1979-81	4.4137	1.1499	3.2638	0.3490	0.3323	2.3102	0.2431
1990-92	5.3483	1.2652	4.0831	0.4812	0.4152	2.8236	0.3287
2001-03	6.2248	1.3250	4.8999	0.6404	0.4974	3.3080	0.4158
2015	7.1973	1.3646	5.8327	0.8576	0.5861	3.8145	0.5321
2050	8.9187	1.3626	7.5562	1.5178	0.7220	4.4762	0.7944
Distribution (%)							
1969-71	100.0	28.8	71.2	7.2	7.1	51.2	5.0
1979-81	100.0	26.1	73.9	7.9	7.5	52.3	5.5
1990-92	100.0	23.7	76.3	9.0	7.8	52.8	6.1
2001-03	100.0	21.3	78.7	10.3	8.0	53.1	6.7
2015	100.0	19.0	81.0	11.9	8.1	53.0	7.4
2050	100.0	15.3	84.7	17.0	8.1	50.2	8.9
Source: FAO, 2006.							

Appendix 3. Undernourished population in the developing regions.

Region	Percentage undernourished					
	1969-71	1979-81	1990-92	1995-97	2001-03	2002-04
Sub-Saharan Africa	36	37	35	36	32	33
Near East and North Africa	23	9	8	10	9	9
East and South East Asia	42	27	17	13	12	12
South Asia	37	37	26	23	22	21
Latin America and the Caribbean	20	13	13	11	10	10
All developing regions	37	28	20	18	17	17
Source: FAO, 2006.						

About ICRISAT®

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

Science with a Human Face

Contact Information

ICRISAT-Patancheru
(Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT-Nairobi
(Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Niamey
(Regional hub WCA)
BP 12404
Niamey, Niger (Via Paris)
Tel +227 20 722626, 20 722529
Fax +227 20 734329
icrisatsc@cgiar.org

ICRISAT-Bamako
BP 320
Bamako, Mali
Tel +223 2223375
Fax +223 2228683
icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 83 8311 to 15
Fax +263 83 8253/8307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297/071/067/057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

Visit us at www.icrisat.org

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