7 Dryland Agriculture in Asia: Ideas, Paradigms and Policies

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INTRODUCTION

Dryland ecosystems, where most of the world's poor live, are characterised by extreme rainfall variability, recurrent but unpredictable droughts, high temperatures and low soil fertility. The underdevelopment in the dryland[1] region of Asia reflects the pervasiveness of poverty, as demonstrated by continuing concerns about malnutrition, migration due to frequent droughts, growing constraints of the natural resource base (water scarcity and land degradation), lack of infrastructure, poor dissemination of improved technologies and effects of government policies, and further economic liberalisation (GT-SAT Futures 2002). Dryland areas indeed present significant constraints to intensive agriculture.

The Green Revolution of the 1960s and 1970s — with its package of improved seeds and chemical fertilisers, and enhanced farm technology and irrigation — successfully attained its primary objective of increasing crop yields and augmenting aggregate food supplies. In Asia, where the package was most widely adopted, food production increased substantially during those decades. 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. Moreover, vast expanses of dryland regions were bypassed by the Green Revolution. They had failed to attract commercial investments in agricultural technology due to small or non-existent markets.

Development planners and policymakers are now increasingly eyeing the hitherto less-favoured dryland regions, where agricultural transformation is yet to take off. Due to issues of equity, efficiency and sustainability, the need to improve the productivity of dryland agriculture has become more compelling, given that the growth opportunities in irrigated areas are being exhausted.

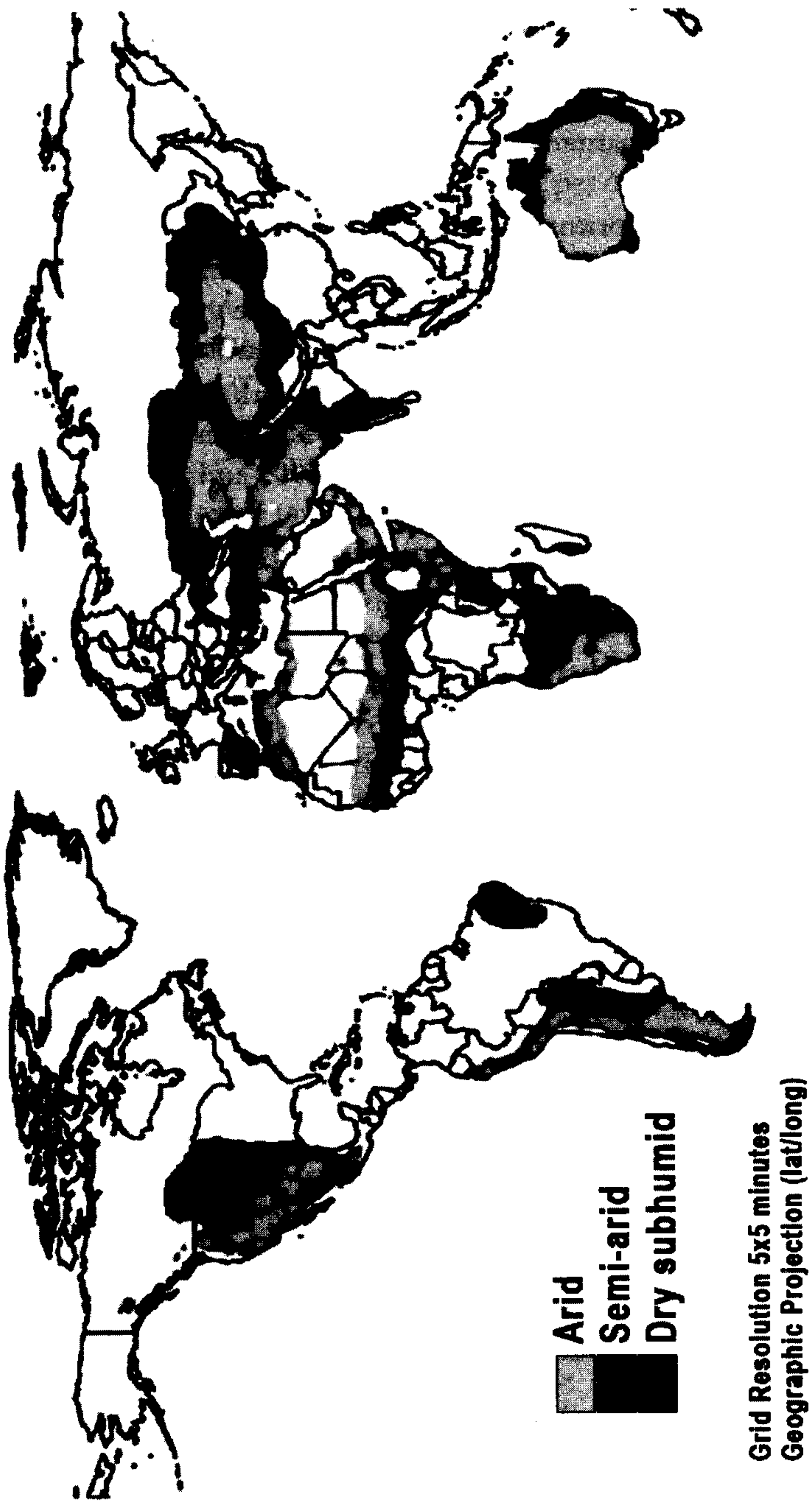
This paper summarises the major challenges in achieving food security, income growth, poverty reduction and environmental sustainability for the dryland regions of Asia. It also identifies future strategies and priorities as it highlights emerging issues that threaten the sustainability of dryland agriculture 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 agricultural diversification, trade liberalisation, 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 dryland agriculture.

DYNAMICS OF DRYLAND AGRICULTURE

Dryland ecosystems span over 40 per cent of the earth's total land surface (Figure 7.1). In fact, more than 60 per cent of Asia's arable land is devoted to rainfed[2] agriculture, ranging from the dry and semi-arid areas of Pakistan, India, Burma, Thailand and the People's Republic of China, to the dry and sub-humid regions of Indonesia and the Philippines.

Figure 7.1 The Global Extent of Drylands



Source: FAO (2002)

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, the optimisation of these resources is often a matter of survival for dryland rural economies (FAO 1999).

Agriculture is the primary occupation of those residing in the drylands (FAO 1999). Since three-quarters of the world food supplies consisting of potato, wheat, rice, maize, sorghum and millets are grown here, increasing their productivity is vital to ensure world food security.

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 7.1).

*Table 7.1 Total Cereal Area, Yield and Production in Rainfed Asia: 1995 Baseline Data Compared to 2025 Projections**

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

Source: Rosegrant et al. (2002).

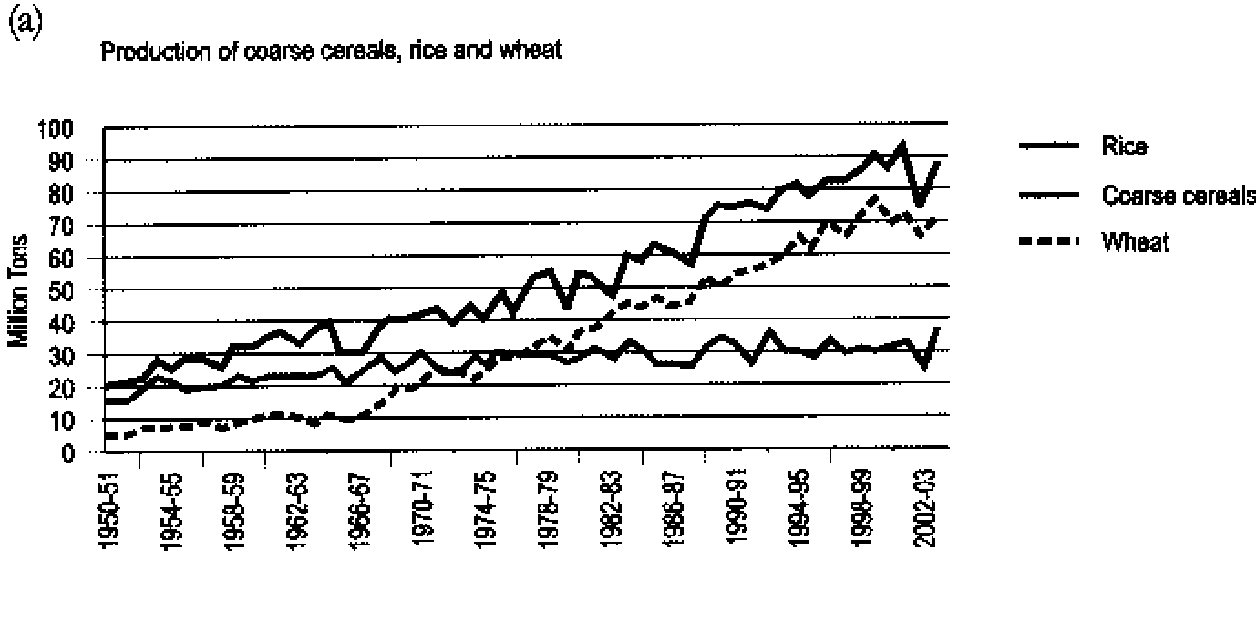
*Projected figures are enclosed in parentheses.

In Southeast Asia, the area under rainfed cereal is projected to reach 31.4 million hectares in 2025, a 5 per cent increase over the area planted in 1995. The aggregated rainfed cereal yield is projected to increase significantly to 2.46, which is 53 per cent higher than the average yield in 1995 and total rainfed production is projected to increase by 62 per cent 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 per cent 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 per cent higher than the yield in 1995 and the total rainfed production 12 per cent over the production in 1995.

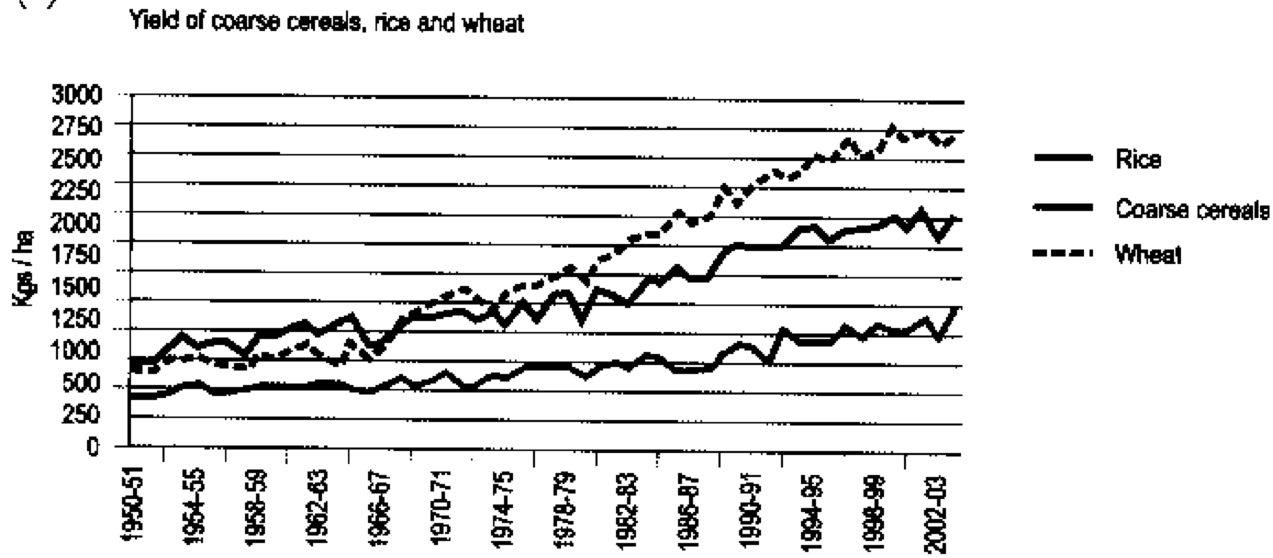
National-level data available for 1950-51 through 2002-03 in India reflect significant growth rates (Figure 7.2a) in rice and wheat production (2.7% and 5%) compared to coarse cereal grains (<1%). These dynamics in production are explained by the rapid growth rates in rice and wheat yields and area grown, compared to those of coarse cereals (Figures 7.2b and 7.2c). 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 7.2d), bypassing rainfed regions where most of the coarse cereals grains are produced.

Figure 7.2 All-India Production, Yield, and Cultivation Area of Coarse Cereals, Rice and Wheat, 1950-2003

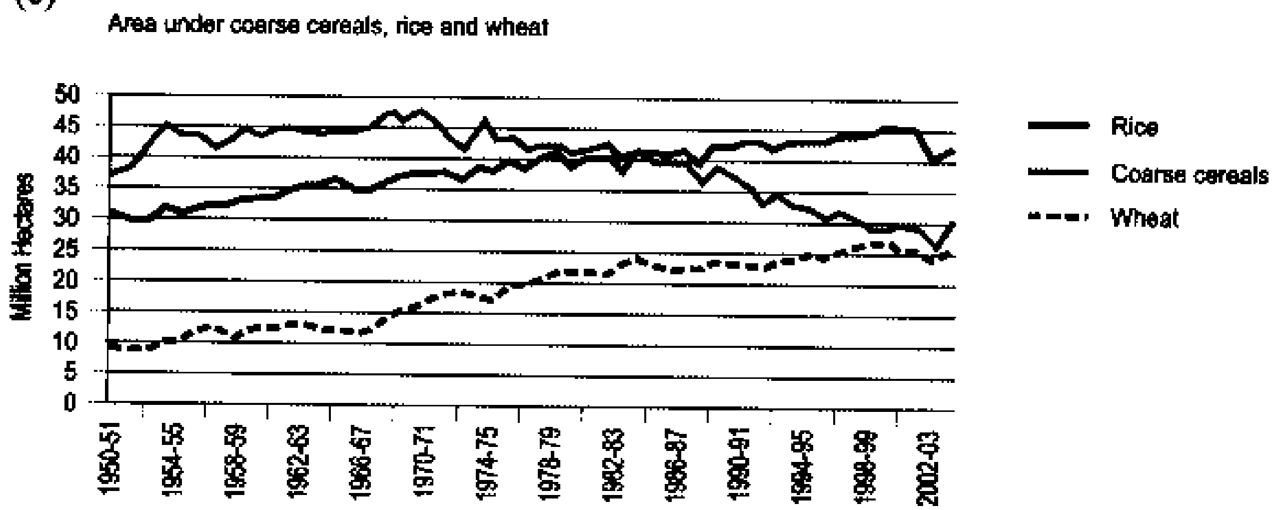
(a)



(b)



(c)



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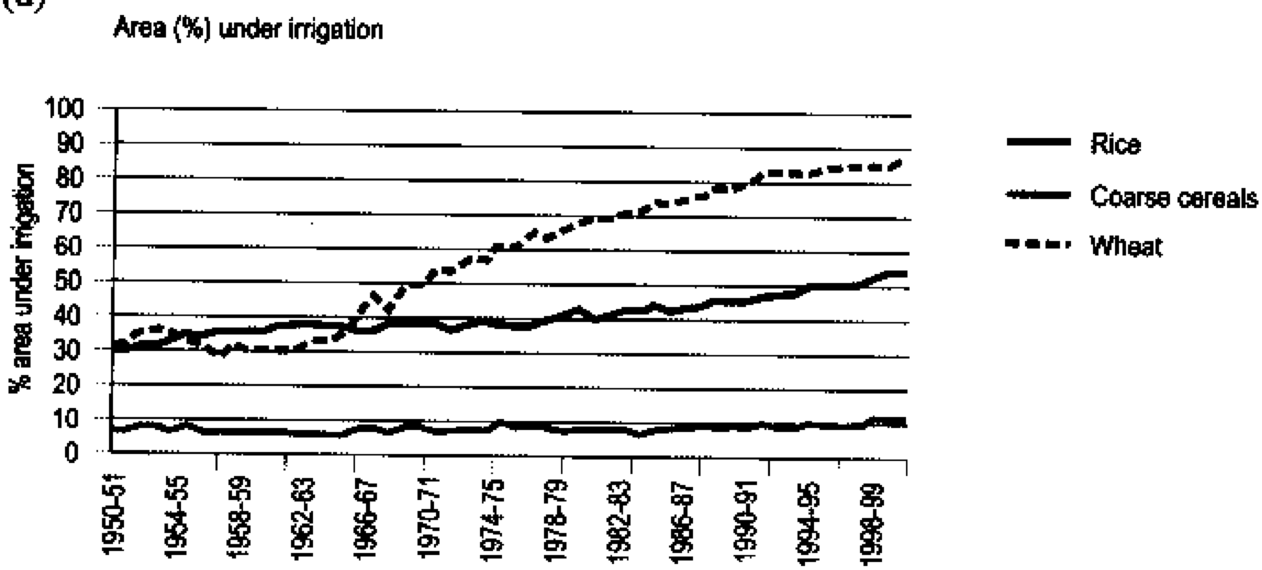
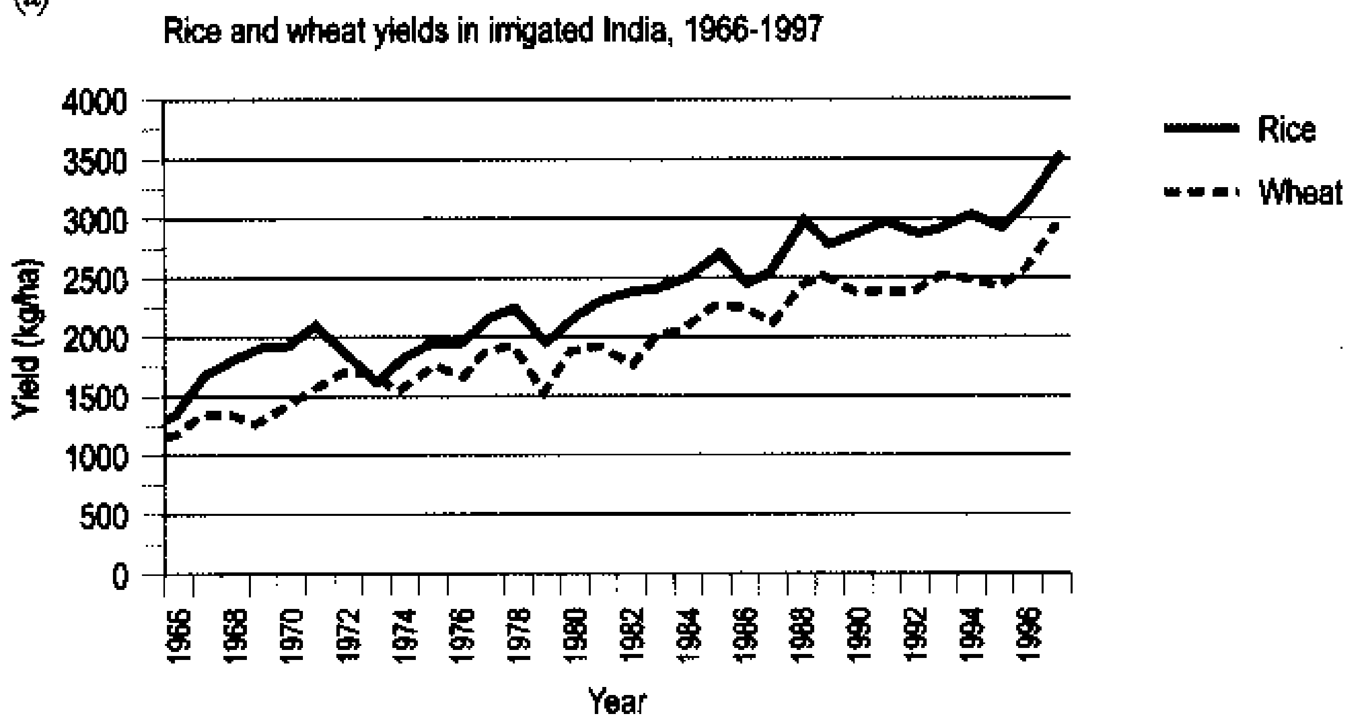


Source: Government of India (2004).

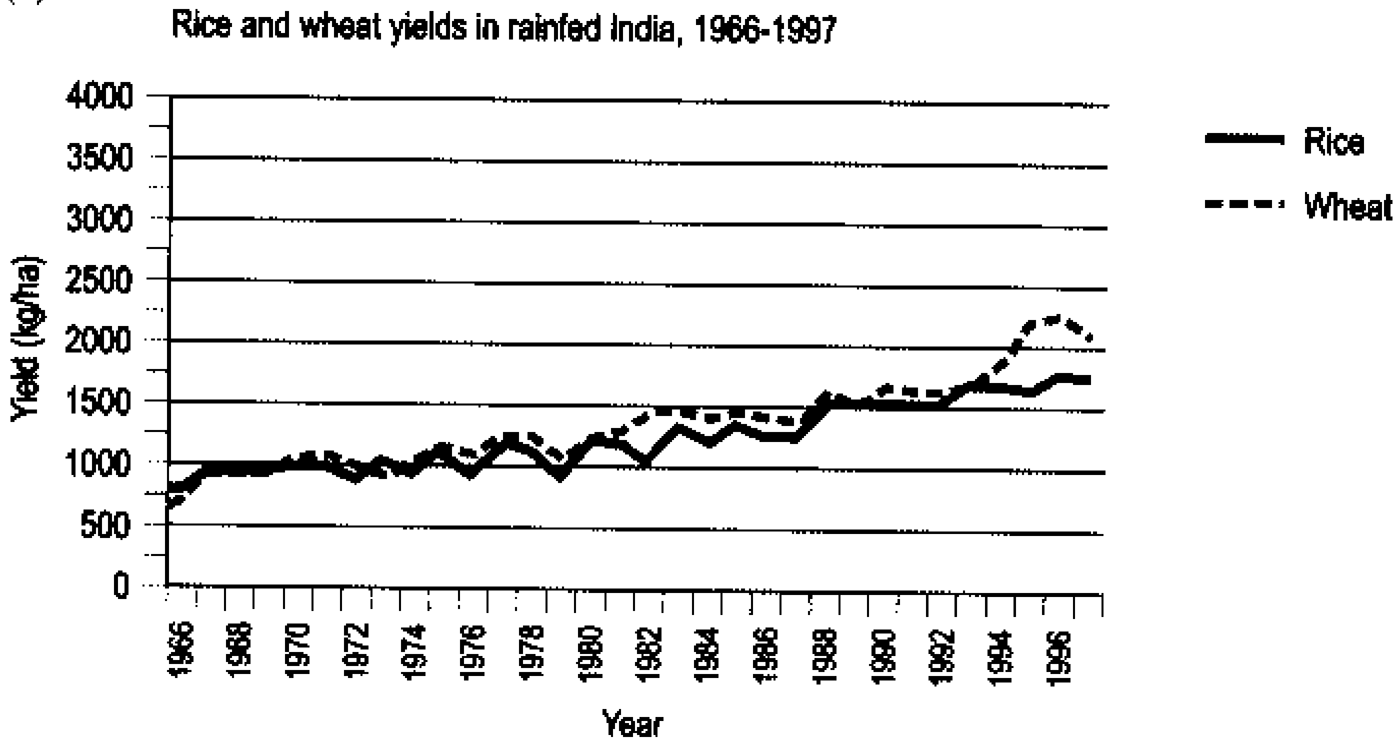
Disaggregated district-level data available for over three decades in India show the long-term trends in rainfed and irrigated regions for specific major cereal crops. Figure 7.3 shows the changes in rice, wheat, sorghum and pearl millet yields for irrigated and rainfed India between 1966 and 1997. Figures 7.3a and 7.3b 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 7.3c and 7.3d depict yield changes for sorghum and pearl millet in rainfed and irrigated areas, showing evidence of lower yields and higher variability compared to rice and wheat. The descriptive statistics (Table 7.2) for crop yields (rice, wheat, maize, sorghum and pearl millet) show consistently higher yield instability in rainfed areas across all crops.

Figure 7.3 Yields of Cereal Crops in Irrigated and Rainfed India, 1966-97

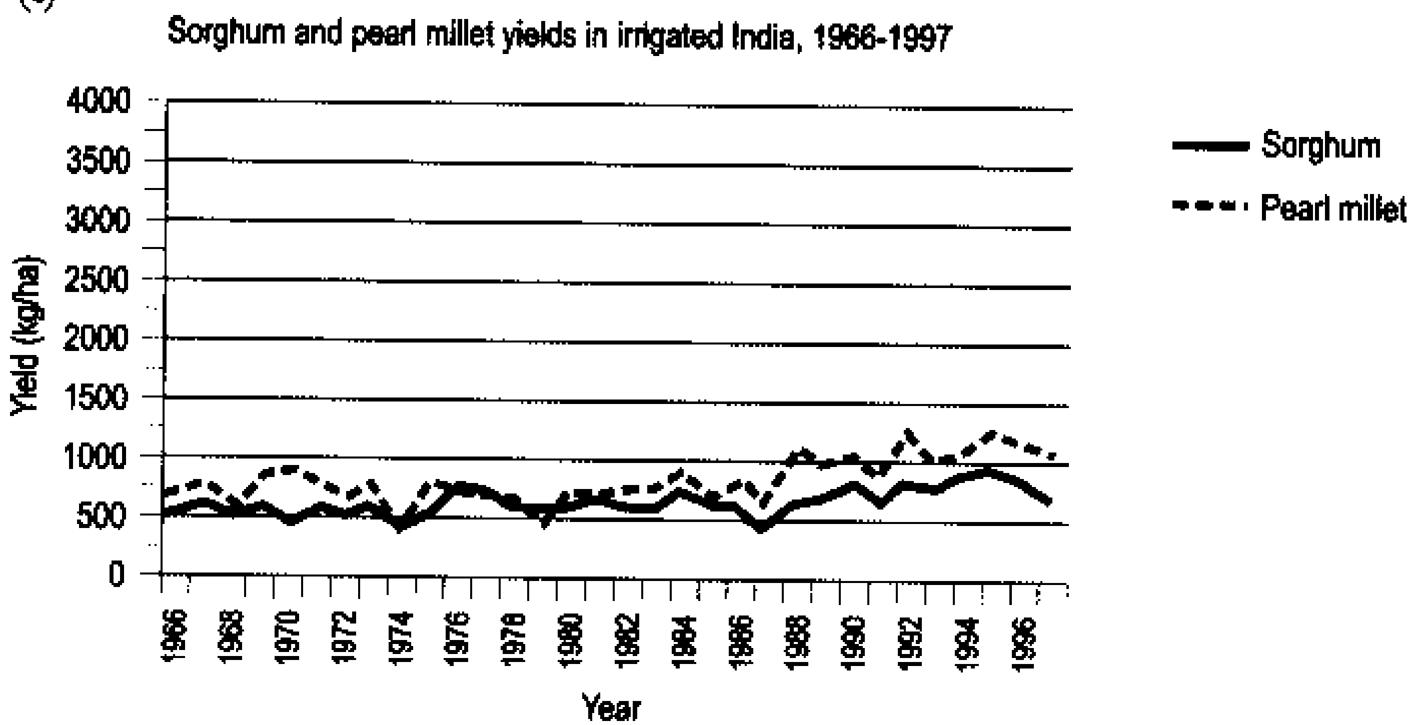
(a)



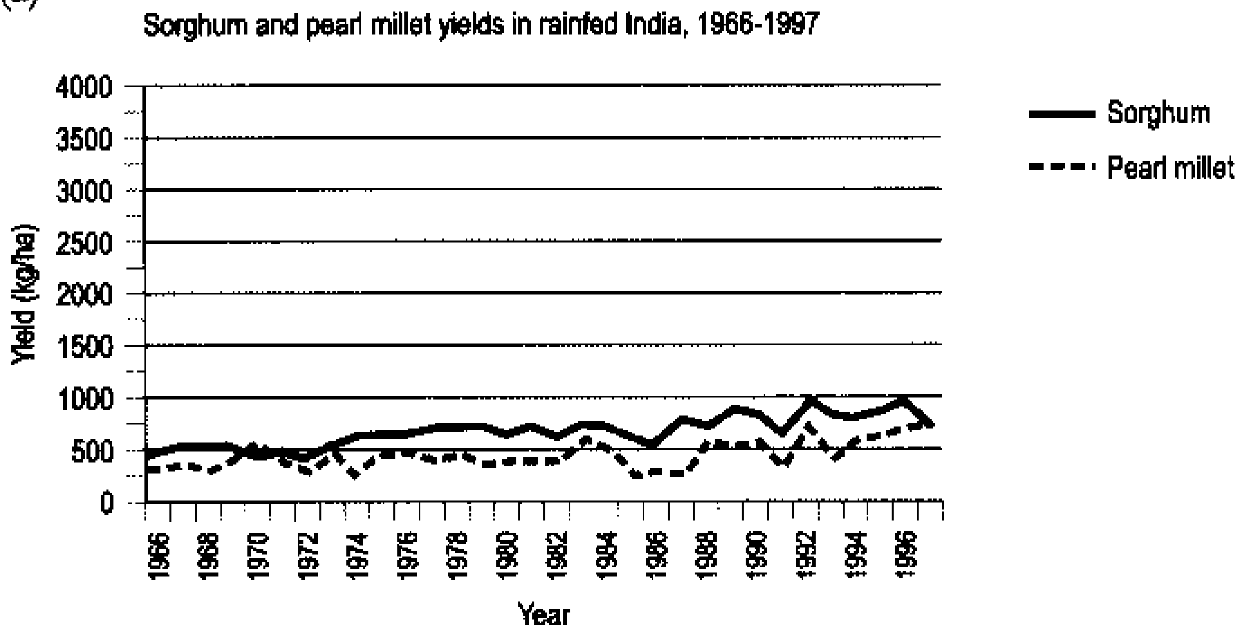
(b)


Rice and wheat yields in rainfed India, 1966-1997
Yield (kg/ha)
4000
3500
3000
2500
2000
1500
1000
500
0
Rice
Wheat
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
Year

(c)


Sorghum and pearl millet yields in irrigated India, 1966-1997
Yield (kg/ha)
4000
3500
3000
2500
2000
1500
1000
500
0
Sorghum
Pearl millet
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
Year

(d)



Source: ICRISAT District-Level Database.

Table 7.2 Descriptive Statistics of Crop Yields in Rainfed and Irrigated India, (1966-97)

	Rice	Wheat	Maize	Sorghum	Pearl millet
Rainfed areas					
Mean	**1,234.9**	**1,375.4**	**1,144.4**	**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	**1,990.2**	**2,396.1**	**1,377.5**	**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 (1966-97).

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

a) diversity,
b) sustainable agricultural intensification in a fragile ecosystem,
c) people and risk-reducing livelihoods, 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, in the extreme and hyper-arid zones, the little or erratic amount of rainfall, not to mention its total absence, fails to provide an economically viable basis for improving incomes and welfare. In this case, the pathways for development may be through the rural non-farm economy, that is, via diversification to other major sources of income including out-migration, provided there is access to markets, and the needed infrastructure and facilitating institutions exist. On the other hand, there is a vast expanse of dryland areas receiving as much as 200 to 1500 mm of highly seasonal and unpredictable annual rainfall such as in the semi-arid and sub-humid tropics. Here, the pathway for development is through the sustainable intensification of agriculture through favourable policies and public agricultural investments.

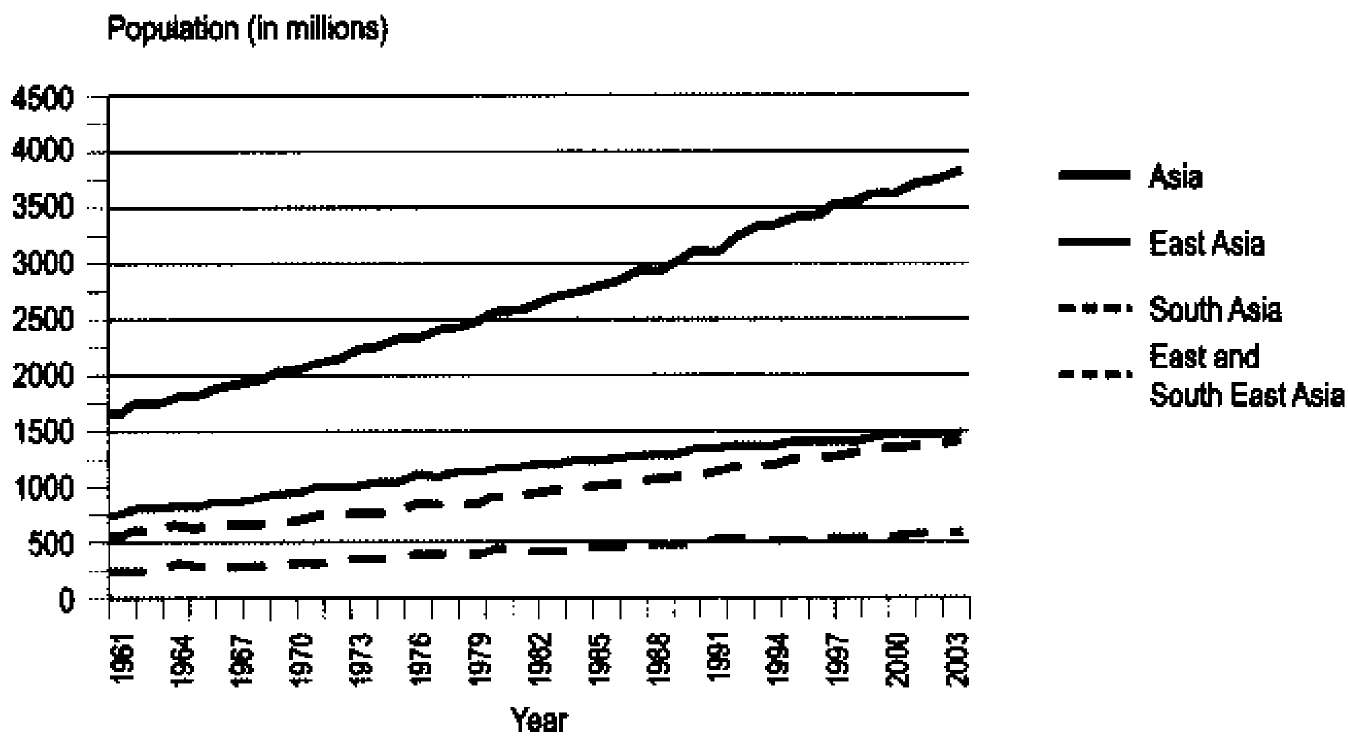
Sustainable intensification in a fragile ecosystem. Ensuring food security, reducing poverty and managing agricultural development for the rapidly growing populations of Asia increasingly depend on the sustainable intensification of land use, since much of the land suitable for agriculture has already been used. However, the 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 favourable agricultural areas of Asia.

People and risk-reducing livelihoods. Asia's population, which increased from 3438 million in 1995 to 3832 million in 2003, accounts for nearly three-fifths of the world's population. In the coming decades, the global population growth rate is expected to decline further and reach levels lower than the growth rate of 1.38 per cent attained in 1995-2003 (compared to 1.43 per cent for Asia). This trend whereby the Asian population grows faster than the world population, is expected to continue in the future. For convenience, we may categorise Asia, which is characterised by its vast size and diverse demographic character, into four major divisions — East Asia, South Central Asia, South-Eastern Asia and Western Asia. In 2003, Eastern Asia alone contained about 1512 million people, South Central Asia 1544 million, South Eastern Asia 543 million and Western Asia 201 million (Figure 7.4).

The population growth rates of China and India, the two most populous countries in Asia, during 1995-2000 are 0.90 per cent and 1.61 per cent respectively. Currently, the population of China is 1310 million whereas that of India is 1094 million.

Figure 7.4 Population in Asia, 1961-2003

(a)



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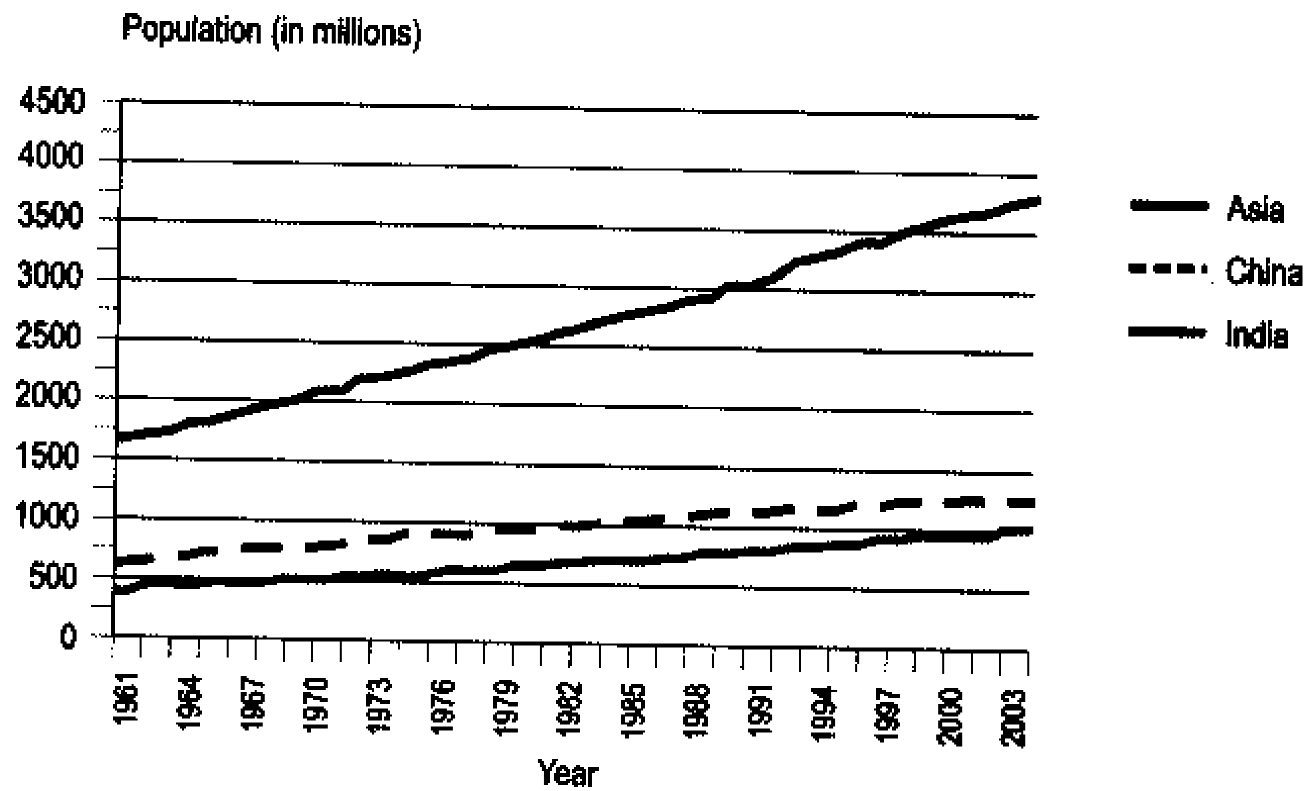


Source: FAOSTAT database (2006).

Data compiled (Table 7.3) 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. 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 higher in rainfed and less-favoured regions (Shiferaw and Bantilan 2004).

The pathways to agricultural transformation require an understanding of the poor in dryland areas. A large number of the dryland poor are 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 behaviour and investments in new innovations.

Table 7.3 Number of Rural Poor (in Millions) in Developing Countries Categorised 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 rural poor	995	242	629

Note: The poor are defined as those subsisting on US$ 1 or less per day.
Sources: Ryan and Spencer (2001) and FAOTAC database.

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 at the same time sustaining the productivity of the natural resource base.

CHALLENGES AND OPPORTUNITIES FACING DRYLAND AGRICULTURE

Despite the highly visible agricultural achievements during the last 40 years, dryland agriculture in Asia faces persistent challenges which have a bearing on 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 the region but also amplify the process of marginalisation in much of the rainfed regions. Moreover, as growth opportunities in irrigated areas are being exhausted, the need to improve the productivity of rainfed regions is becoming more compelling, on grounds of equity, efficiency and sustainability. Hence, development planners and policymakers are increasingly looking towards the hitherto less-favoured rainfed regions.

The emerging challenges facing dryland agriculture include persistent poverty, water scarcity, climate change, land degradation, nutrition and health threats and migration. 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 Asia. An estimated 1.85 billion people or 57 per cent 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 per cent) reside in the arid/semi-arid tropics and another 500 million (50 per cent) 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).

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 per cent while the SAT countries have shown an improvement of 35 per cent. 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 the six large SAT countries has improved to 48 per cent since 1975 compared to 32 per cent for the medium SAT group and only 5 per cent for the small group. Hence, 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.

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

Data from the National Sample Surveys of India indicate 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 per cent 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 utilisation of anti-poverty programs, highlighting the issue of constrained access.

Data from ICRISAT's Village Level Studies (VLS) conducted since 1975 provide 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 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 neighbour'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 neighbours in pursuit of scarce groundwater. As a result, there is a lowering in water tables and a reduction in yield from wells.

Given this scenario, water-constrained dryland agriculture must include 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, e.g., 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 2000).

Climate change will increase the number of people at risk of hunger. It has been noted, however, that "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, p 287). 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 (Committee on World Food Security 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 in arid, semi-arid and dry sub-humid areas, the biological or economic productivity and complexity 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: (1)

soil erosion caused by wind and/or water; (2) deterioration of the physical, chemical and biological or economic properties of soil; and (3) 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, salinisation, soil compaction, agrochemical pollution, desertification 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.

Nutrition and health threats. Micronutrient malnutrition or "hidden hunger" has become more conspicuous in the dryland regions. More than 840 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) reductions in labour productivity, educational attainments in children, school enrolments and attendance; and 3) increases in mortality and morbidity rates, and health-care costs.

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. UNAIDS reports that in 2003, 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! By the end of 2005, as many as 5.2 million Indians were living with HIV. The country has been projected to overtake South Africa as the nation with the largest HIV-infected population in the world (UNAIDS and WHO 2003). 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 labour. This poses new challenges for agricultural R&D.

Migration. Among the many factors causing uncertainty is the migration of people engaged in dryland agriculture. Migration of workers from less favoured areas to more favourable 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 labour play an important role in balancing the regional supply and demand for casual labour. While informal migrant labour markets continue to increase, their efficiency could be improved and many more poor could benefit from an institutionalised 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 labour markets and ensure that wage rates are fair, and exploitative practices such as bonded labour are done away with.

Opportunities in Dryland Agriculture

Agricultural diversification. 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, e.g., 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 optimise the use of water. As a result, cropping pattern shifts are taking place and coarse cereals are being replaced by soybean, pigeonpea and lentil, and in some places maize. Significant dietary changes are also occurring across all income baskets.

Growing importance of livestock. Population growth, urbanisation 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. 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 per cent of the global milk, 54 per cent of cattle meat and 100 per cent 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 utilisation of land, labour and capital over space and time. Since the poor in dryland regions hold a major share of livestock, the 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 favoured 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).

Trade liberalisation and commercial orientation of agriculture. Dryland agriculture needs to keep pace with the changing world trade regime which is characterised by globalisation, interdependence, international competitiveness and commercialisation of agriculture, and the changing food habits of people in favour of livestock products, fruits and vegetables. It is crucial that dryland farmers have a clear market orientation to make decisions about crops that 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 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 liberalisation 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 liberalisation and globalisation of trade in agricultural commodities, most developing countries are finding it difficult to adjust to the new scenario. However, there is resentment in developing countries that the agreement carried many asymmetries in favour of developed countries.

Secondly, some developed countries resort to various methods of protection while implementing the agreement. There are apprehensions that a flood of subsidised imports may harm the interests of small farmers in developing countries in general, and dryland farmers in particular (Gulati and Kelly 1999). So, there is a clamour 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 globalisation, technology, policy and institutional innovations can be harnessed to reduce poverty and resource degradation rather than lead to further marginalisation 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 globalisation, modernisation, climate change, disintegrating community organizations and inadequate and ineffective public sector interventions.

Institutional innovations. 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 International Crops Research Institute for the Semi-arid Tropics (ICRISAT) played a nurturing role to the fledgling industry and provided breeding material, often through informal networks. During the early 1990s, as private seed industry grew, 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 recognised 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.

IMPLICATIONS FOR POLICY AND RESEARCH PRIORITIES FOR DRYLAND AGRICULTURE

As discussed earlier, food security and productivity growth in agriculture in Asia are increasingly dependent on the improved utilisation 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.

Policy Recommendations

Any policy initiative supporting dryland agriculture starts from an implicit recognition of the policy bias in favour 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 characterise 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 emphasise the importance of an effective public and private sector in reaching the rural poor. Earlier results (Fan et al. 2000) show that marginal returns to 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.

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

Like fertilisers, irrigation water and electricity are two other inputs that are heavily subsidised. 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 the 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. 2003). For instance, the heavily subsidised Public Distribution System (PDS) and rice and wheat markets in India have eroded the competitiveness of coarse cereals and altered market price ratios.

Substituting the 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 marginalised, 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. 2003). 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 subsidised 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. 2003) that can meet all the credit requirements of dryland farmers during this period, even if they default after one or more years.

Institute measures to cope with globalisation and marginalisation. Market reforms that encourage integration and liberalisation 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 smallholder farmers (Bantilan et al. 2003).

Facilitate migration. Seasonal, semi-permanent, or permanent migration is a predominant coping strategy adopted by the poor to escape poverty. Informal markets for migrant labour (in SAT villages of India) play an important role in balancing the regional supply and demand for casual labour. The efficiency of informal migrant labour markets could be further improved if an institutionalised system of collection and dissemination of information on supply, demand, and wage rates is provided in select dryland regions (Bantilan et al. 2003). Wage rates for female workers are substantially lower (50 per cent) than that of male workers. Policies to address this gender inequality and imbalance are needed.

Implications for Research Priorities in Asian Dryland Agriculture

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 favoured regions (Fan et al. 2000) suggest the need to prioritise these hitherto overlooked areas in terms of technology, institutions and policy. Evidence from the 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 R&D priorities in dryland areas.

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 the expansion of biotechnology, intellectual property rights (IPR), free trade regime and, commercialisation of agriculture have to be advanced.

A summary of priority areas for research in dryland agriculture is given in Box 1.

Box 1 Research Priorities in Dryland Agriculture

Policy studies: Dryland crops have poor market policy support. Increased priority for subsidies to 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, and 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 maximise 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 different stakeholders from various sectors are linked together to generate advanced breeding lines, pest-resistant varieties, trait-specific germplasm, screening techniques for biotic and abiotic stresses and seed systems. 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 GM crops), low productivity caused by poor varieties, and inadequate local seed systems are major constraints to agricultural development. Hence, a need to provide sustainable solutions to these pressing problems is a real challenge.

Food security: Sluggish 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 limited access to markets is a major challenge.

Globalisation and WTO: Open markets and globalisation are posing unfair competition. Lack of proper policy support further marginalises poor dryland farmers who are not sufficiently protected from the impact of globalisation, continuing subsidies of developed countries, and threats of WTO.

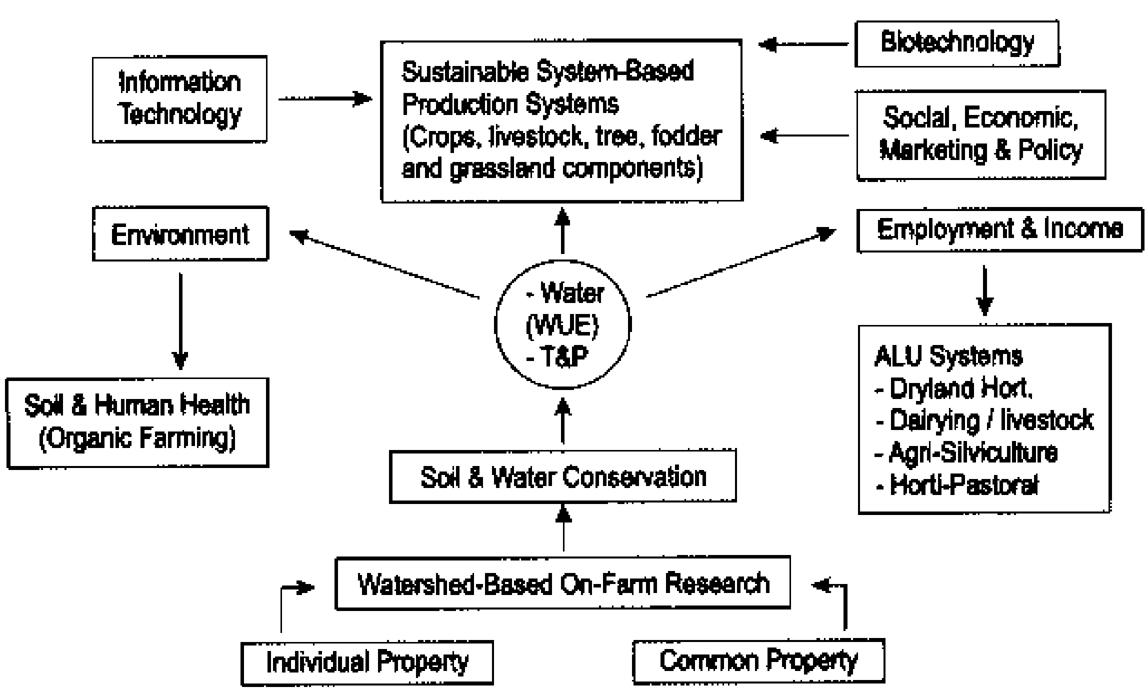
Networks and collaborations: Resources need to be leveraged through innovative partnerships and better linkages with regional programs through networks. Powerful global networks, collaborations and partnerships with ARIs, NARS, NGOs, private sector, donors, and other stakeholders are required. So is worldwide capacity building with NARS through training and networking activities.

DEVELOPMENT PATHWAYS: ICRISAT PERSPECTIVES FOR DRYLAND AGRICULTURE

The discussion in this section uses the context of ICRISAT's experience in the dryland region of South Asia where poverty, food insecurity, child malnutrition and gender inequalities are widespread. Three paradigms are presented: a) Grey to green revolution; b) Science with a human face; and c) Institutional innovations. The framework (Figure 7.5) is used to discuss critical entry points for development (Bantilan et al. 2003).

The framework focuses on the effective and economic utilisation 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 emphasise the 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 of land and water resources to 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.

Figure 7.5 Entry Points for Development in Dryland Agriculture



Grey to Green Revolution

The benefits of the Green Revolution did not percolate to the dry and marginal rural farmlands. These areas, characterised 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 nutrients stresses, 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 optimising 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 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 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 science innovations, dryland agriculture can be a vehicle for economic, social and eco-friendly change in rural societies.

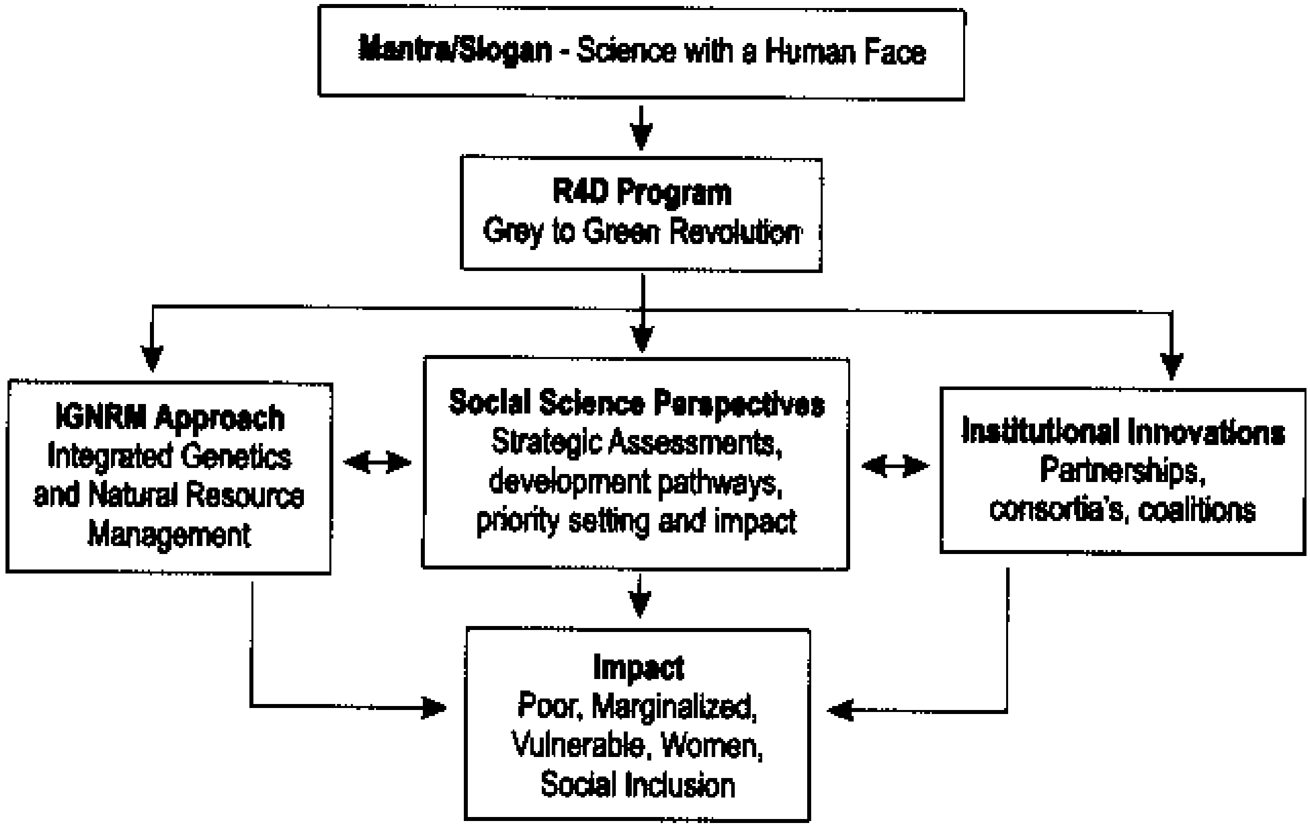
Science with a Human Face

This is ICRISAT's mantra for development in the drylands. ICRISAT's goal is to harness the power of technology for development, food security, poverty alleviation and environmental protection targeted at poor rural families in general, and at women and children in particular. This is called doing "Science with a human face": research not for its own sake, but targeted at specific goals and implemented through genuine partnerships. Its mandate areas are marginal lands such as the fringes of the Sahara where starvation and malnutrition are recurrent. Research themes at ICRISAT — Institutions, Markets, Policy & Impacts, Biotechnology, Crop Improvement and Management and Agroecosystem Development — are geared towards achieving the second Green Revolution in less inhospitable rural agro-ecosystems.

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 the profitable utilisation of germplasm and the development of novel products. Advances in genomics and bio-informatics will help realise 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 vigour 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.

Figure 7.6 features the three essential pillars towards achieving "Science with a Human Face," namely IGNRM, social science perspectives and institutional innovations.

Figure 7.6 ICRISAT's Research for Development Model



Integrated Genetic and Natural Resource Management (IGNRM). Participatory and interdisciplinary research towards IGNRM at ICRISAT 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 five dryland crops —sorghum, pearl millet, groundnut, chickpea and pigeonpea — which are particularly important in the diets of the poor. Over 570 improved crop varieties have been released by national programmes across Asia and Africa. The gene bank at ICRISAT is one of the largest in the CGIAR system, housing a collection of about 113,500 accessions and wild relatives of the staple food crops.

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 stabilising 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.

Social science perspectives. ICRISAT pioneered an effort to develop a longitudinal panel database, which could be used for tracking development pathways and testing several theories and policy impacts. The Village Level Studies (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 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 globalisation and national policies that influence input and output prices and the profitability of agriculture. Many policy interventions are needed in favour 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. Described briefly below are three examples.

a) *Agri-Science Park (ASP).* The Agri-Science Park is the means by which developed technologies are commercialised to help farmers in the SAT through partnerships. The Agri-Science Park consists of an Agri-Biotech Park (ABP), Agri-Business Incubator (ABI), a Hybrids Parents Research Consortia and the SAT Eco-Venture. The consortium undertakes collaborative research with private, public and government entities. Consortia member partners have access to research products before non-members.

b) *Biopesticides Research Consortium (BRC).* A dialogue with the private sector biopesticide industry in India has resulted in the endorsement of the Biopesticides Research Consortium (BRC). The BRC is meant to develop, promote and commercialise the use of biopesticides by farmers.

c) *Watersheds Development Consortium.* ICRISAT's research attacks water scarcity on two fronts (Wani et al. 2003). The first utilises natural resource management research to improve rainwater utilisation 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.

CONCLUSION

Though the Green Revolution transformed many regions in Asia, 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 marginalise agriculture and livelihoods in the drylands of Asia. 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 synergies among technologies, marketing systems, input supplies, credit, policies and institutions. Broad-based sustainable growth and development in Asia's drylands is the key to addressing rural poverty in this region.

NOTES

* This chapter is based on an earlier paper entitled, "Dynamics, Challenges and Priorities for Dryland Agriculture" (2005) by the same authors. Correspondence: *w.dar@cgiar.org*.

1 The drylands embrace hyper-arid, arid, semi-arid and dry sub-humid areas. These lands are characterised by low and erratic precipitation which is reflected in relatively low and notably unpredictable levels of crop and livestock production. 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, hyper-arid 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 per cent, and periodic droughts are common (Zurayk and Haidar 2002).

2 According to water resource availability, arable lands are also identified as irrigated, rainfed, moist and dry. Rainfed refers to arable areas that are grown to crops without the benefit of irrigation.

REFERENCES

Asian Development Bank (ADB). *Rainfed Agriculture in Asia and Pacific.* Manila, Philippines: ADB, 1989, 644 pp.

Bantilan, M.C.S. and G.V. Anupama. "Vulnerability and Coping Mechanisms". Working Paper 10. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2000, 13 pp.

Bantilan M.C.S., K.P.C. Rao, S.S. Acharya, Mruthyunjaya and R. Padmaja. "Vision for Rainfed Agriculture in South Asia". Policy Brief no. 3. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2003, 4 pp.

Committee on World Food Security. Special Event on Impact of Climate Change, Pests and Diseases on Food Security and Poverty Reduction. 31st Session held on 23-26 May 2005.

Dixon, J., A. Gulliver and D. Gibbon. *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World.* Rome and Washington DC: Food and Agriculture Organization and the World Bank, 2001, 409 pp.

Fan, S., P. Hazell and S. Thorat. "Government Spending, Growth, and Poverty in Rural India". *American Journal of Agricultural Economics* 82, no.4 (November 2000): 1038-51.

Food and Agriculture Organization (FAO). *1995-2006. FAOSTAT database* Rome, Italy: FAO, 2006.

———. *Key Aspects of Strategies for the Sustainable Development of Drylands.* Rome, Italy: FAO, 1993, 60 pp.

———. "Drylands and the MFCAL Approach in Cultivating our Futures." Background papers prepared for The FAO/Netherlands Conference on the Multifunctional Character of Agriculture and Land (MFCAL), 12-17 Sept. 1999, Maastricht, The Netherlands. Rome, Italy: FAO, 1999.

———. *Land Degradation Assessment in Drylands.* LADA project. World Soil Resources Reports no. 97. Rome, Italy: FAO. 2002, 48 pp.

———. *Carbon Sequestration in Dryland Soils.* World Soils Resources Reports no. 102. Rome, Italy: FAO, 2004, 129 pp.

GT-SAT Futures. "Development Pathways and Livelihood Options: Addressing Poverty, Water Scarcity and Marginalization in the Asian SAT". Concept note. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2002, 28 pp.

Government of India (GOI). *Agricultural Statistics at a Glance.* Directorate of Economics and Statistics (DES). Ministry of Agriculture & Cooperation. New Delhi, India: GOI, 2004.

Gulati, A. and T. Kelley. *Trade Liberalization and Indian Agriculture. Cropping Pattern Changes and Efficiency Gains in Semi-arid Tropics.* New York :Oxford University Press, 1999, 296 pp.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). *1966–1997. ICRISAT District Level Database.* Andhra Pradesh, India: ICRISAT, 1997.

International Fund for Agriculture Development. *Rural Poverty Report 2001 – The Challenge of Ending Rural Poverty.* New York: Oxford University Press, 2001, 266 pp.

McIntire, J., D. Bourzat, and P. Pingali. *Crop-livestock Interaction in Sub-Saharan Africa.* Washington, DC, USA: The World Bank, 1992, 27 pp.

Parthasarathy, Rao P., P.K. Joshi, Shravan Kumar, and D. Kar. "Revitalizing Agriculture Sector in Andhra Pradesh: Role of Agricultural Diversification and Agro-processing". Global Theme on Markets, Policy and Impacts, Progress Report no. 134. ICRISAT, Patancheru 502 324. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2005, 142 pp.

Rao, K.P.C. "Development of Dryland Agriculture: Policy Issues". In *Fifty Years of Dryland Agricultural Research in India*, edited by H.P. Singh, Y.S. Ramakrishna, K.L. Sharma, and B. Venkateshwarlu, pp 565-72. Hyderabad, India: Central Research Institute for Dryland Agriculture, 1999.

Rao, K.P.C., M.C.S. Bantilan, Katar Singh, S. Subrahmanyam, Priya Deshingkar, P. Parthasarathy Rao, and B. Shiferaw. "Overcoming Poverty in Rural India: Focus on Rainfed Semi-arid Tropics. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2005, 92 pp.

Rao, K.P.C., V.K. Chopde, Y. Mohan Rao, and D. Kumaracharyulu. "Salient Features of Village Economies in the Semi-Arid Tropics (SAT) of India". Progress Report 130. Global Theme on Markets, Policy and Impacts. ICRISAT, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2006, 57 pp.

Rosegrant M., Cai Ximing, S. Cline, and N. Nakagawa. *The Role of Rainfed Agriculture in the Future of Global Food Production.* Rome, Italy: IFPRI, 2002, 106 pp.

Ryan, J.G. and D.C. Spencer. "Future Challenges and Opportunities for Agricultural R&D in the Semi-arid Tropics". Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 2001, 83 pp.

Shiferaw, B. and M.C.S Bantilan. "Agriculture, Rural Poverty and Natural Resource Management in Less Favored Environments: Revisiting Challenges and Conceptual Issues". *Food, Agriculture & Environment* 2, no. 1 (2004): 328-39.

United Nations Programme on HIV/AIDS and the World Health Organization. "AIDS Epidemic Update: December 2003". Special Report on HIV Prevention. Geneva, Switzerland, 2003, 39 pp.

Vörösmarty, C.J., P. Green, J. Salisbury, and R.B. Lammers. "Global Water Resources: Vulnerability from Climate Change and Population Growth". *Science*, 289 (2000): 284-88.

Wani, S.P., H.P. Singh, T.K. Sreedevi, P. Pathak, T.J. Rego, B. Shiferaw, and Shailaja Rama Iyer. "Farmer-participatory Integrated Watershed Management: Adarsha Watershed, Kothapally India, An Innovative and Upscalable Approach. A Case Study". In *Research Towards Integrated Natural Resources Management: Examples of Research Problems, Approaches and Partnerships in Action in the CGIAR*, edited by R.R. Harwood and A.H. Kassam, pp. 123-47. Washington, D.C.: Interim Science Council, Consultative Group on International Agricultural Research, 2003.

Zurayk, R. and M. Haidar. "The Dryland Predicament: Natural Capital, Global Forces". *Development Outreach* 3 (2002): 35-39.