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Food Security in the Drylands of South Asia and Sub-Saharan Africa: Research Challenges and Opportunities

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Abstract: Despite the significant agricultural research achievement that led to the green revolution, South Asia (SA) and Sub-Saharan Africa (SSA) remain the hotspots of food and nutrition insecurity in the world. One of the reasons behind this challenge is the failure of the green revolution to increase dramatically rainfed crop and livestock productivity in SA. The green revolution achievement has also generally eluded SSA despite the increased availability of high-yielding and risk-reducing cultivars and agricultural innovations. Many factors are attributable to the lack of productivity growth. This paper investigates the major factors that have contributed to the food insecurity in SA and SSA and forecasts the future of the food production and consumption and their effect on food and nutrition security to the year 2020. Our projections of food production and consumption show that child malnutrition in SA is decreasing much faster than the case in SSA, due to increase in per capita income, female education and female life expectancy. Fast reduction in child malnutrition is also possible in SSA if the countries invest significantly in improvement in agricultural production and in addressing the constraints that impede access to food. The demand for livestock products has been increasing dramatically mainly due to increasing income and urban population. The livestock sector also has a large potential to achieve food and nutrition security in the drylands. Unfortunately, past research and development investments in livestock have not reflected the potential and opportunities offered by the sector. Harnessing the potential of livestock would require developing suitable crop-livestock innovations to improve productivity. Even though returns to agricultural research investments have been high and have shown a great potential to increase food security in both SA and SSA, government and donor research funding has generally decreased in the SSA region where national capacity is weak and underdeveloped. There is an urgent need to increase availability of funds to address the research challenges and harness the opportunities in the two regions. Returns to the research investment will also have multiplier effect on reducing food and nutrition insecurity if the support services – such as extension services, market services, etc. are developed. Research also need to take seriously farmer innovations, which have shown great potential in developing technologies well adapted to the drylands.

Key words: Food security, drylands, child malnutrition, access to food, South Asia, Sub-Saharan Africa.

The dryland areas of the arid and semi-arid tropics are characterized by low and erratic rainfall and infertile soils, leading to high production risk and vulnerability of livelihoods to climatic variability. In addition to adverse biophysical conditions for agriculture, these areas are also less served in terms of investment in irrigation, roads, communication and market infrastructure, making agriculture predominantly rainfed and relatively less commercialized compared to more favorable regions with better infrastructure and market opportunities. As a result, these areas have largely been bypassed by the green revolution and did not benefit from productivity enhancing technological change. A reflection of higher levels of land degradation and low agricultural productivity in these areas is the widespread poverty that makes these areas the hotspots of hunger, food insecurity and environmental degradation (Ryan and Spencer, 2001; Shiferaw and Bantilan, 2004).

Based on data compiled from different sources, Ryan and Spencer (2001) find that, in 1996, about 38% (379 million people) of the total rural poor are found in arid and semi-arid regions, about 50% (500 million) in humid and sub-humid regions and the rest in temperate areas. The data also indicate that in most eco-regions, the poverty incidence is high in rainfed areas than in irrigated areas. Although the breadth of poverty is high in irrigated areas in Asia, the relative incidence and severity of poverty is often high in the rainfed and drought-prone dryland areas. This is supported by other more recent findings that show a higher poverty incidence in marginal areas at risk from poor soils, low rainfall, and adverse climate change (IFAD, 2001; Rao *et al.*, 2005).

A recent global hunger index (GHI) – which is defined as the insufficient availability of food, shortfalls in nutritional status of children and child mortality – ranked South Asia (SA) and Sub-Saharan Africa (SSA) as hotspots of hunger and malnutrition (Weisemann, 2006). Even though SA has shown significant progress in reducing the GHI from 40 points in 1981 to about 25 points in 2003,[1] hunger is still a major problem in the region, which is home to the largest share of poor people in the world (Alagh, 2001). It is estimated that 47% of the children under five-year age and 43% of the women are underweight in SA (Smith and Wiesmann, 2007). Additionally, about 52% of the population in SA experience food energy deficiency and 34% experience severe energy deficiency (Ibid). These findings underscore the severe food insecurity in the region and pose a big challenge to the region that is experiencing fast economic growth.

In SSA, where 41% of the 750 million people lived on less than US$ 1 a day in 2005, a third of the population was malnourished in 1999-2001 (Rosegrant *et al.*, 2005; World Bank, 2007) and about 52% of the population experience severe food energy deficiency (Smith and Weismann, 2007). This is the highest rate of energy deficiency in the world and highlights the severity of food insecurity in the region.

This study reviews the food security in SSA and SA with special focus on the drylands. The focus is particularly in the drylands since these areas experience the most severe food insecurity in the two regions. The arid and semi-arid lands

[1] GHI is an index ranging from 100 points, which indicates highest rank of hunger and malnutrition to zero which is the lowest ranking.

account for approximately 30% of the world total area and are inhabited by approximately 20% of the total world population (Sivakumar *et al.*, 2005). About 40% of the population in the arid and semi-arid lands is classified as chronically poor (Ryan and Spencer, 2001). India, which accounts for 16% of the area and 50% of the value of agricultural production in the semi-arid tropics has 300 million people depending on dryland agriculture (Kerr, 1996; Rosegrant *et al.*, 2002). Although the successful green revolution in the high potential irrigated areas in India has insulated the negative impacts of drought on food availability at the national level, 53.2% of the children under the age 5 suffer from under-nutrition (World Bank, 2006). In Africa, 36-42% of the land area is classified as drylands, receiving less than 1000 mm of rainfall in 180 days (Mortimore, 1998). Given the low investment in irrigation and other forms of agricultural investment and the heavy reliance of the rural population on agriculture, food security in the drylands in SSA is more severe than the case in humid areas.

The study first examines the trends in agricultural production and consumption and their implications on food security in the drylands of the two regions. The study also simulates food production to year 2020 and the corresponding impacts of the life expectancy and education of women, and access to safe water on food consumption. This is followed by a review of the major factors that affect food security in the two regions. The third section discusses the major research achievements that have shown potential to address food security in the two regions. This is followed by a review of the outstanding research questions that need to be addressed in the future to contribute to food security. The paper will then end with major conclusions and policy implications.

Context and Definition of Food Security

According to the World Food Summit of 1996, "Food security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". This is the official definition of food security, which entails measurement of access to food rather than availability. Many studies have used availability of food due to the difficulty of obtaining household level data showing access to food (Smith *et al.*, 2006). As argued by Amartiya Sen, national food availability while necessary is not a sufficient condition for individual access to sufficient, safe and nutritious food. Access depends on individual entitlements which in turn depend on production, distribution, exchange, or transfer rights and capabilities of a given household or individual. When own supply entitlements fail or decline, households may have the option of complementing their endowments by using markets and/or transfers from governments and other agencies for smooth consumption. Such inter-household transfers and reciprocity are particularly important coping strategies in areas where rural markets are imperfect and fail to serve this function. Food insecurity and starvation in this context can therefore be seen as a result of inability to establish entitlements to sufficient food through own production, markets or other transfer entitlements (Sen, 1981).

As noted earlier, food security in the drylands is a major problem due to the low agricultural potential and heavy dependence of the population on rainfed agriculture. Livelihoods in the drylands are dominated by crop-livestock mix, with the importance of livestock increasing from the relatively wet drylands to the fringes of deserts in the arid areas (Parthasarathy Rao *et al.*, 2005). For example, pastoralism is the common livelihood strategy in the drylands along the Sahelian region of Africa. The major crops grown in the drylands are sorghum, millets, groundnut, chickpea and pigeonpea. Other important crops in some dryland areas (particularly in SSA) include cowpea and cassava. Cattle are the major livestock kept by pastoralists.

In this section, we will explore the current conditions and projected trends for the production and consumption of dryland crops and implications for food security in SA and SSA. While dryland crops like sorghum and millets remain important staples in many dryland areas of Africa, their importance in the household's budget share has declined in South Asia (especially in India), where subsidized rice and wheat have gradually replaced these traditional crops for consumption even in the drier areas (Gulati and Kelley, 1999). The average budget shares for the rural poor for sorghum and millets in India have fallen from 13.6% in 1972/73 to 4.3% in 1993/94. The share of these coarse grains among the urban poor over the same period fell from 7.4% to 3.6% (Murthy, 1997; Ryan and Spencer, 2001).

While sorghum (with the exception of post-rainy season sorghum) is increasingly used for livestock feed, millets still remain important staple food crops in many parts of Asia. In SSA, both cereals are vital food security crops for the poor in the dryland areas. The overall consumption demand for dryland legumes, such as groundnut, cowpea, chickpea and pigeonpea, consumed in different forms seem to be increasing with increasing income growth and urbanization in both Africa and Asia. Livestock also play a vital role for food security in the drylands both in terms of household production of edible livestock products and as source of cash income, which can be used to complement household food security through exchange entitlements.

In this paper, we base our estimation of food security impacts on the patterns of consumption that we observe (and project) over time. We take into account the total portfolio of food consumption – both in terms of cereals, animal products, vegetables, fruits and other foods – when determining the total calorie availability. Combining the amount of calories available, on a per capita basis, with other important determinants of nutrition – such as availability of clean water, life expectancy of women, and female schooling – we project the levels of child malnutrition in the regions of interest, using an empirical relationship based on the work of Smith and Haddad (2000). Child malnutrition is used as an indicator of food security since children are among the most vulnerable groups suggesting that severity of child malnutrition serves as a strong indicator of the general food insecurity.

Child malnutrition is defined in terms of the degree to which a child falls 2 standard deviations below the level of normal weight-for-age, measured with respect to a normalized distribution. While this does not capture the total number of malnourished people in the region, we consider this segment of the population (zero to 5 years of age) to be particularly vulnerable to shortfalls in food availability, and that the level of nutritional stress among children has particularly important implications for future human development of that population cohort. In this way, we are able to establish an important link between the function and dynamics of agricultural markets and its implications for human welfare.

Food Security Trends and Outlooks in Dryland Areas

As a vehicle for projecting future trends of production and consumption growth of key dryland grains and legumes[2], we employ the IMPACT (**I**nternational **M**odel for **P**olicy analysis of **A**gricultural **C**ommodities and **T**rade) model of International Food Policy Research Institute (IFPRI), which has been used in a number of forward-looking studies on agricultural growth dynamics and its implications for policy interventions and human welfare. The IMPACT model has been applied to looking at scenario-based assessments of future food production and consumption trends, under both economic and environmentally-based drivers of change. The most comprehensive set of results from the IMPACT model were published in the book *Global Food Projections to 2020* (Rosegrant *et al.,* 2001), which gives a baseline scenario under which the best future assessment of production and consumption trends are given, for all IMPACT commodities. In addition to the baseline, alternative scenarios are also offered, based on differing levels of productivity-focused investments, lifestyle changes and other policy interventions. These scenarios describe changes that are both global as well as regional in nature – such as those which are specific to meeting the MDG goals in SSA (Rosegrant *et al.*, 2005). Policy analyses based on alternative scenarios that are more environmentally-focused were published in an IFPRI book titled *World Water and Food to 2025: Dealing with Scarcity* (Rosegrant *et al.*, 2002). The version of IMPACT that was used to generate the results for this study (IMPACT-WATER) will be used to discuss the scenarios examined in this paper.

Baseline model projections

Within the IMPACT-WATER model, there are several principal "drivers" that underlie the dynamics of agriculture production and consumption growth over time, within the modeling framework. The primary macro-economic drivers are those of income growth and population growth, which jointly determine the dynamics of per-capita income for each country, which is a major determinant in food commodity consumption behavior. The principal drivers for agricultural growth are those which determine the expansion or contraction of available land for agriculture, and the productivity growth of irrigated and rainfed crops over time, which reflects the

[2] In the IMPACT-based projections, we consider the following subset of dryland crops for analysis: Sorghum, millet, chickpea, pigeonpea and groundnuts.

improvement in agricultural technology and growth potential which can be realized over time. While all of these drivers are derived from observed data, there is some element of expert opinion embedded into some of the growth projections. They can also be subjected to scenario-based sensitivity analysis, to evaluate their importance in influencing key outcome indicators during the forward-looking projections. A number of key insights can be gained by designing alternative scenarios in a way which demonstrates the comparative efficacy of various policy interventions, in terms of their impact on key indicators of human well-being, as was done by Rosegrant *et al.* (2005).

Long-term trends for dryland crops

Figures 1 and 2 show the general trend for food demand in both SA and SSA, over time, using IMPACT-WATER projections to 2020. These trends in demand are accompanied by similar trends in overall production, that we will describe for the various grain and legume crops.

Overall the model projections (not shown because of space limitations) show that for both sorghum and millet, there's a steadily decreasing trend of area and production for SA, over a 20-year period, while in SSA we see a steadily increasing trend, which can also be observed in historical data. In terms of commodity demand for sorghum and millet, SSA has seen to have the greater total demand than SA although most of SSA's demand represents food demand. These trends fit very well with the historical utilizations.

The projections for both chickpea and pigeonpea area show a clear domination by SA, with a slightly downward trend that is consistent with the historical dynamics, and which is offset by steadily increasing productivity – leading to overall growth in production. SSA, by contrast, shows steady increases in chickpea area over the 20-year period, and express most of their demand in terms of food demand for pulses. SA also dominates SA in terms of both total and food demand for dryland

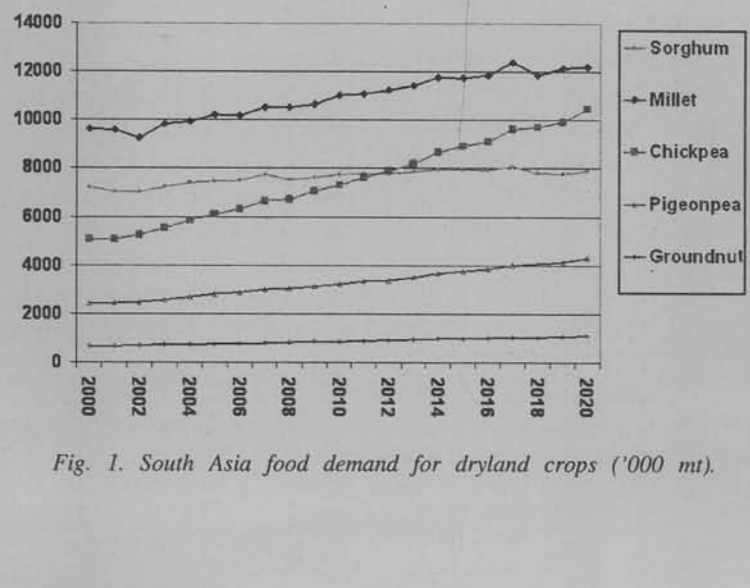


Fig. 1. South Asia food demand for dryland crops ('000 mt).

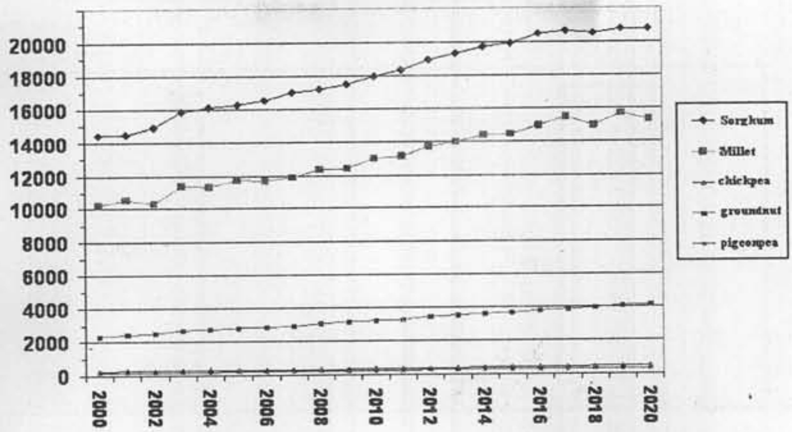


Fig. 2. Sub-Saharan Africa food demand for dryland crops ('000 mt).

pulses, and shows a rapid increase over time.

Groundnuts in SA, on the other hand, show fairly stagnant production trends, in contrast to SSA and other regions of Asia like China, which dominates African production, even though the total area is less. Most of SA demand for groundnut is in feed, whereas most of the demand in SSA is for food. The demand for groundnut oil is a major part of total demand, and is seen to be quite high in SA.

Projections of calorie availability and malnutrition

In light of the trends for production and consumption that we've described, above, we can now look at the implications that it has for calorie availability and malnutrition, over time. Figures 3 and 4

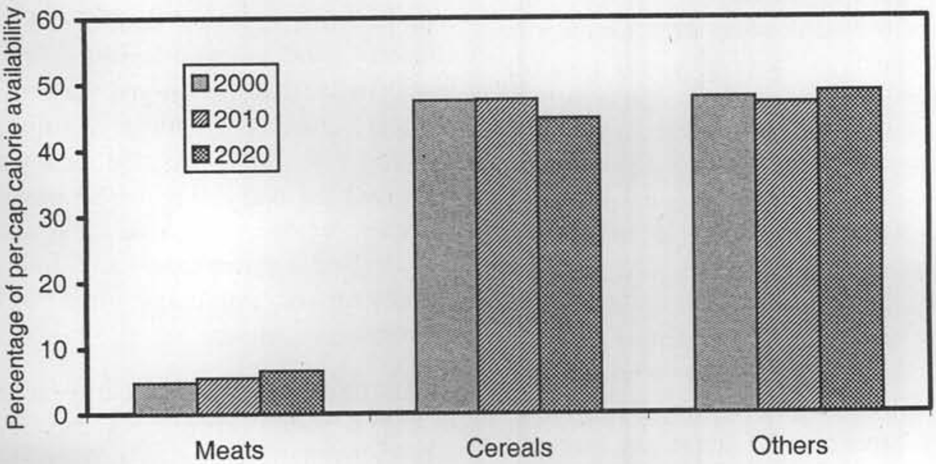


Fig. 3. Per capita calorie shares across food groups in South Asia (%).

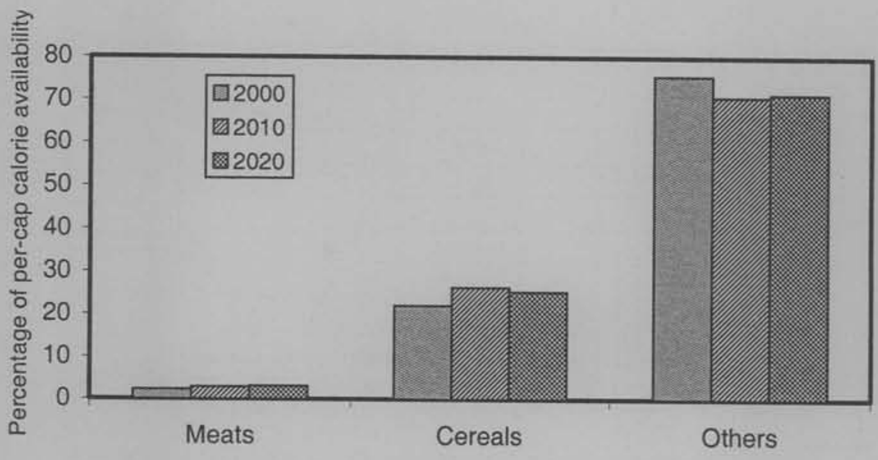


Fig. 4. Per capita calorie shares across food groups in Sub-Saharan Africa (%).

show that the proportion of calorie availability that is accounted for by cereals and 'other' crops (which includes legumes, root and tuber crops, and vegetables and fruits) are almost equal (about 47%), when compared to meat (less than 10%). In the case of SSA (Fig. 4), however, the proportion of calories which come from the category of 'other' crops is much larger than the other two food categories. This reflects the importance of key roots and tubers in the staple diets of consumers in SSA – such as cassava, sweet potatoes and yams. The increase in contribution of meats to calorie consumption also reflects the increasing dietary quality of foods in SA region. As it will be seen in the preceding section, SA contributed about 60% of the increase in demand for milk in developing countries and 10% of the change in demand for meat in the world. The picture for SSA, on the other hand, is quite different, with about 71% of calories coming from 'other' foods – primarily the important root and tuber crops like cassava, sweet potatoes and yams, which constitute an important part of staple diets on the sub-continent. Grain staples and meat contribute only about 22% and less than 5% of calorie, respectively.

With respect to dryland crops, we see from Fig. 5 that dryland grains and legumes make up a much larger share of available calories in SSA and SA. Given the higher utilization of dryland grains like sorghum and millet as food in SSA, the share of total calories is twice that of SA. This suggests that improvements in the productivity, distribution and marketing of dryland crops – holding consumption patterns constant – has the potential to improve food availability in SSA more than in other regions, and makes the success of dryland agriculture an important component of improving food security outcomes in Africa.

The projection of food security outcomes in Fig. 6 shows where SSA and SA are relative to the other regions. Even though the overall prevalence of child malnutrition is much higher in SA, it is projected to

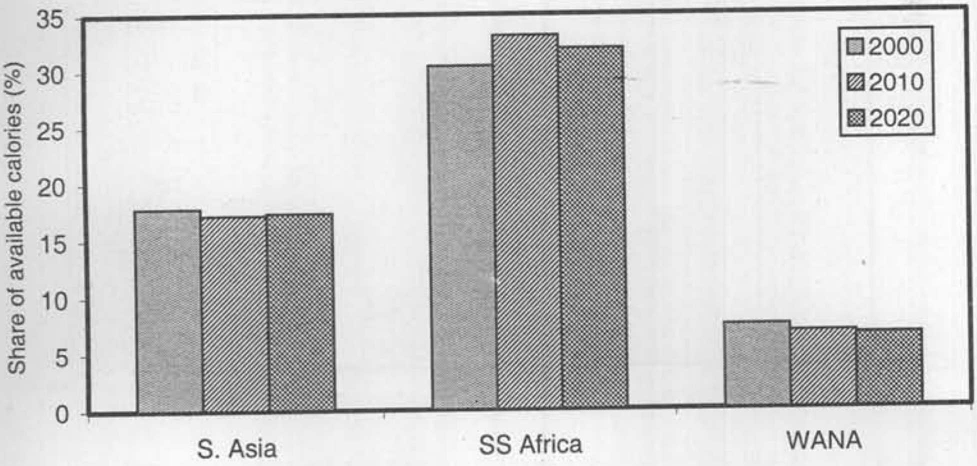


Fig. 5. Share of dryland crops in total available calories across regions (%).

decrease much more rapidly, over time, than in SSA. Much of this difference is due to the much more rapid increase of per-capita incomes in SA, and the corresponding projection of improvements in water access, life expectancy of females and rates of female schooling, as well. Under alternative scenarios of investments in social services, these amenities could be improved in SSA, and lead to improved nutrition outcomes (Rosegrant *et al.*, 2005) – but would have to happen in conjunction with increased agricultural productivity across a range of food crops, including dryland grains and legumes.

Discussion and implications

Our brief overview of a plausible future of dryland crop productivity and growth, based on baseline assumptions, has helped to demonstrate the potential role that dryland agriculture can play in influencing overall food availability in SA and SSA. These pathways of influence arise from the contribution that dryland crops make to the total food intake portfolio, either through direct consumption as food, or indirectly through the supply of necessary feed to livestock – whose meat and milk products will continue to be increasingly demanded across SA and SSA. The difference in role that products of dryland agriculture play in supporting the food economies of SA and SSA are reflected by the contrast in the shares of calorie intake, as well as the differences in the prominence of the various dryland crops in the overall agricultural landscape.

The importance of dryland pulses in SA is reflected by the dominance of countries like India, in the demand for chickpea and pigeonpea, which are relatively high-value food products. The lower-value dryland grains, such as millet and sorghum, assume a larger role in the food economies of SSA, and remain important commodities for human consumption, as do important dryland

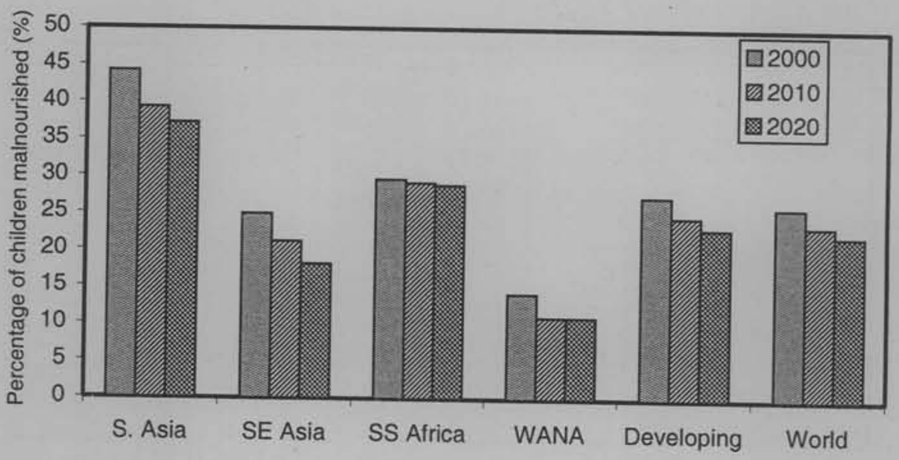


Fig. 6. Projections of malnourishment prevalence in children across regions (as share of children under 5 years of age).

legumes like groundnut. Under the baseline trajectory of growth, SSA also helps to satisfy the net import demand of SA countries for dryland pulses through increasing levels of production for export.

Other plausible futures for dryland agriculture that could be explored through scenario analysis are those which involve important shifts in economic drivers – such as income growth – as well as key environmental drivers like climate change. The resilience of dryland grains such as millet and sorghum to water-scarce and dry conditions, is important in providing a buffer against a shortage of staple foods, that would likely occur if more water-sensitive grains, such as rice and maize, were the sole source of cereal supply. The increasing concern over the implications of climate change- induced shifts in average temperature and precipitation levels for human well-being and food security in SA and SSA provides further justification for looking more closely at the role that policy interventions and technological innovations can play in strengthening dryland crop production systems, and supporting the food economies of SA and SSA, as they face various challenges brought about by global economic and environmental change.

Factors Affecting Food Security in Drylands

There are many factors that affect food security and it is not our intention to exhaustively discuss all of them. We discuss the major factors affecting food security, namely income poverty, conflicts and insecurity, education and status of women and food availability. Since our focus is on dylands, we discuss the effect of drought on food security, but due to space limitations, we do not discuss the other abiotic factors that also influence food security.

Income poverty

The United Nations defines poverty as "...a condition characterized by severe deprivation of basic human needs, including

Table 3. Comparison of progress made by South Asia and Sub-Saharan Africa in some determinants of and outcomes of food security

	South Asia	Sub-Saharan Africa
Determinants		
Poverty (%)	29.9	46.4
Per capita national income (GDP/capita) (US$)	2897	1856
Per capita dietary energy supply (kilocalories/day)	2356	2136
Net primary enrollment (%)	79	62.0
Outcomes		
Underweight children under five (%)	47.0	31.0
Underweight women (%)	43.0	11.5
Low birth weight children (%)	30.0	14.0
Food energy deficiency (%)	52.0	59.0
Severe energy deficiency (%)	34.0	52.0
% of food energy derived from staples (%)	63	65

Source: Smith and Wiesmann (2007).

food, safe drinking water, sanitation facilities, health, shelter, education and information." (UN, 1995). This is a broad definition and does not cover some other aspects. For example, lack of security and democracy are among the indicators of poverty (Varshney, 1999). Due to the difficulty of measuring poverty using its broad definition, many studies and data reports have used income poverty to represent poverty. For example a dollar a day is a well-known and widely used measure of absolute poverty. Income poverty is strongly associated with food insecurity since income is a means that enables people to have access to food. A study by Wiesmann (2006) showed that poor countries tended to have higher GHI. However, there were exception to this trend in both SSA and SA. For example, Botswana and Namibia show high rate of food insecurity despite their relatively higher gross national income (GNI) per capita. The major reason behind this is the high income inequality and high rate of HIV/ AIDS infection in these countries (Ibid; Loevinsohn and Gillespie, 2003; Gillespie, and Kadiyala. 2004). India and Bangladesh also showed higher GHI than predicted from GNI due to the low status of women and their low child nutritional knowledge (Ibid). These results underscore the role that women play in ensuring food security and the need for food security policies to involve many sectors and strategies that are not directly related to food production. The results also indicate the weakness of using national average income as a predictor of food security. For example Table 3 shows that, while about 30% of the population in SA and 46% of the population in SSA was classified as poor, some outcome indicators (underweight children under five and women and low birth weight) showed that SSA was better than SA.

National food supply

We have already discussed the trend of food production and its impact on food security. This section looks at a broader context of the food supply and its impact on food security. Food availability has always been used as an indicator of food security. As discussed earlier, access rather than availability is the key to food security. A study by Smith and Haddad (2000) showed that national food supply contributed only 25% of the reduction in prevalence of child malnutrition in developing countries between 1970 and 1995. Even though this small contribution could be due to an equally small increase in the dietary energy supply – which increased by 22% from 2,092 kilocalories per capita in 1970 to 2,559 per capita in 1995 – the findings show that there are other important factors that determine food security in developing countries. These factors are those which constrain access to the food supply and to technologies that increase agricultural production. Hence the important question is how to address these constraints. One of such constraints is the access of poor farmers to agricultural technologies that increase agricultural productivity. This is a key solution to meeting the increasing human population since the population pressure on land decreases the per capita arable land (Boserup, 1965; Ortiz and Hartman, 2003). Agricultural research has contributed to increasing food supply in the SA region following the green revolution (Smith and Haddad, 2000), averting the Malthusian catastrophe in SA. However, green revolution did not increase significantly crop production in the rainfed marginal areas of SA (Chakravarti, 1973; Janaiah *et al.*, 2006). Adoption of improved crop varieties and livestock breeds is the pre-condition for increasing yields and overall production of staple crops and livestock products.

While agricultural research has shown very significant impact on the agricultural production in both SA and SSA (Pingali and Rosegrant, 2001; Gabre-Madhin and Haggblade, 2003; Janaiah *et al.*, 2006), the effect on production and productivity has been limited to the green revolution crops grown in the irrigated and high potential areas. This can be seen from the higher productivity growth for crop like rice and wheat in both SSA and SA compared to dryland crops like sorghum and millets (Figs. 7 and 8). The long term yield trends show that the yield of rice has increased from about 1.0 t ha^{-1} and 1.4 t ha^{-1} in the early 1960s to about 1.5 t ha^{-1} and over 3.0 t ha^{-1} in 2004 in SSA and SA, respectively. Similar trends can be seen for wheat. However, despite the high productivity growth in other parts of the world where growing conditions are conducive and improved varieties are widely adopted, the long term trends for sorghum and millets remain largely unchanged especially for SSA. This is mainly due to the low adoption of agricultural production technologies in the region. Increase in production in SSA has been mainly driven by expansion in area.

The lack of significant transformation in the crop yields for the dryland crops is a reflection of the complex abiotic and biotic constraints prevailing in the drylands and the rainfed nature of production. Given the fast growing populations that are increasingly dependent on agriculture for their livelihoods, increasing agricultural productivity through accelerated adoption of high-yielding and stress tolerant varieties and livestock breeds remains to be the only viable and perhaps sustainable solution to reducing

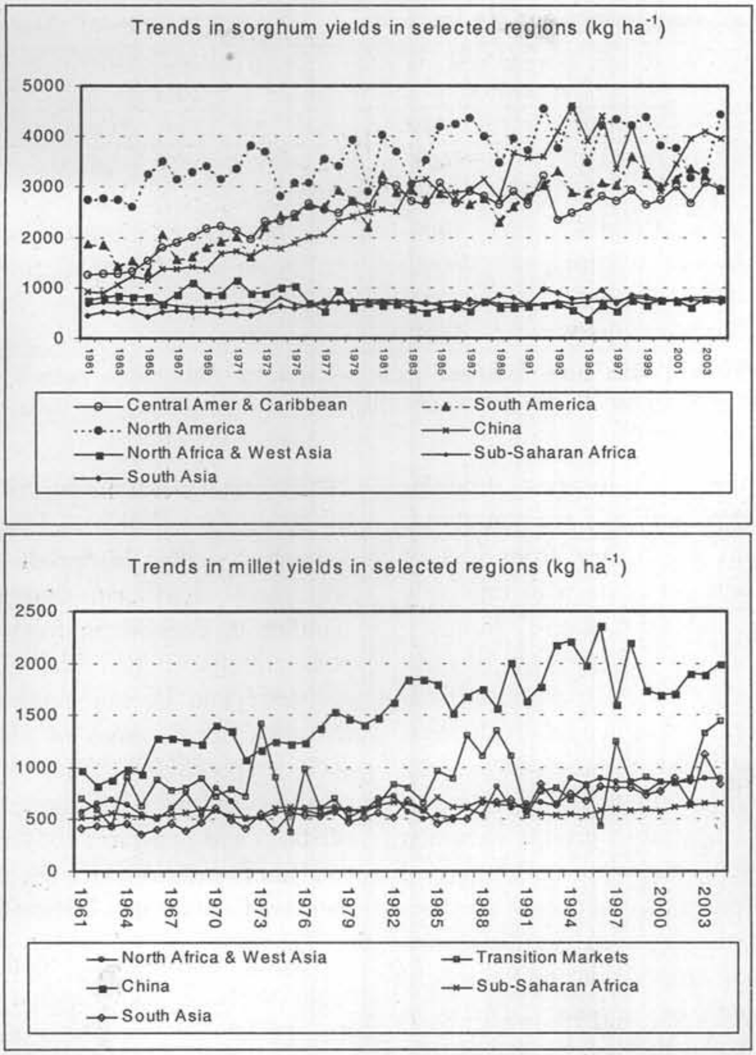


Fig. 7. Trends in crop yields for dryland non green revolution crops.

poverty and food insecurity in the semi-arid areas. As we show below, revitalizing and improving the productivity of agriculture in the drylands would require complementary investments in risk reducing and productivity-enhancing inputs, irrigation, market access and other institutional infrastructure to enhance farmer access to available technologies.

Drought and household food security

Drought is one of the major abiotic factors that reduce agricultural productivity and food supply at the household level in the drylands. Drought is an inherent and recurrent risk factor for dryland farmers. Occurrence of droughts can have devastating effects on livelihoods, in some cases causing

Table 1. Effect of drought on yields (kg ha^{-1}) for selected crops in semi-arid Kenya

Crop	Normal year (2002/03)		Drought year (2004/05)		% yield reduction
	N	Yield	N	Yield	
Maize	401	577	1123	368	36
Beans	305	239	424	106	55
Pigeonpea dry grain	218	409	142	129	68
Green/fresh pigeonpea	210	366	40	265	28
Greengram	188	228	252	171	25
Cowpea	159	431	203	85	80

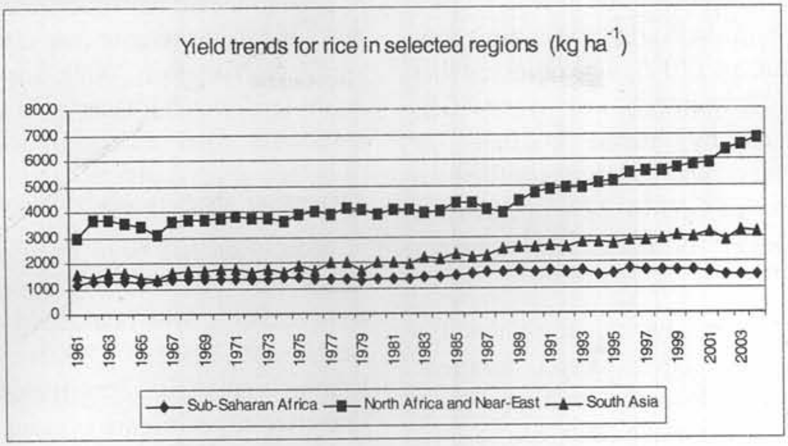
Source: Panel ICRISAT data from cultivated plots managed by 250 sample farmers.
(N = number of plots grown to the crop from 250 sample farmers, hence the variation from crop to crop).

famines. In some areas, recurrent droughts lead to chronic poverty as farm households lack the means to recover from loss of productive assets. In areas with relatively less frequent and less severe droughts, smallholder farmers in transient poverty and food security often recuperate from drought-induced shocks in a relatively short period of time. Even in these cases, some external assistance is often needed especially for the most vulnerable groups in terms of providing seeds and other inputs needed to revitalize production practices. The effect of drought in the drylands can be shown by the decline in crop yields and household incomes adopted by dryland farmers in Eastern Kenya. An ICRISAT panel survey of 250 households over the years shows that compared to the 'normal' year of 2002/03 crop yields during 2004/05 declined by 25% to 80% (Table 1). Given the already low crop yields, this productivity decline was very significant and forced many families to depend on food assistance or non-agricultural activities. The drought induced yield decline reducing crop and livestock net incomes of about 50% and 40% respectively (Table 2). This was compensated by increasing participation in off-farm and non-farm activities (including food aid transfers) which led to a substantial increase in non-farm income and transfers.

While the increased food aid transfers seem to have compensated for the loss in agricultural incomes, this may not necessarily imply quick recovery for the most vulnerable and poor families who may have lost productive assets and could not

Table 2. Effect of drought on household net income from different sources

Income source	Normal year (2002/03)	Drought year (2004/05)	% change
	Kenyan Shillings		
Crop	16,970	8,374	-51
Livestock	13,746	8,461	-38
Other sources	50,240	97,228	+94
Total	80,956	114,064	+41



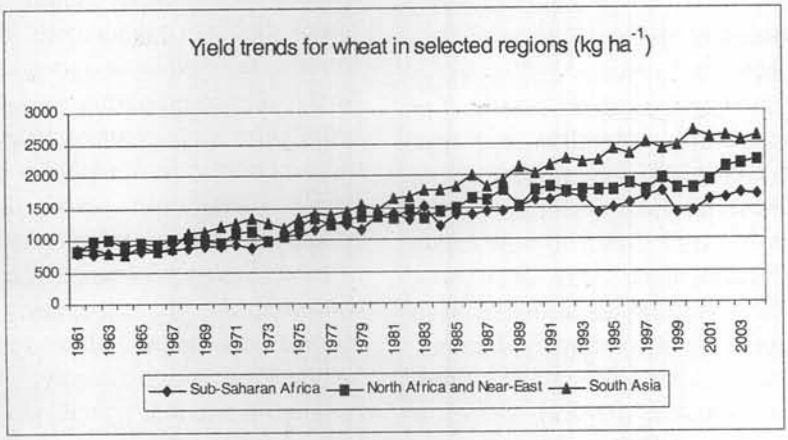


Fig. 8. Trends in crop yields for green revolution crops.

afford to save own seed for planting. Farmers deal with this problem through supplemental irrigation (when possible), diversification of cropping patterns, and deliberate selection of risk reducing varieties and management practices. Increased availability of such options is critical in protecting livelihoods and maintaining food security in the drylands. For many poor and risk-averse farmers, the overarching concern for ensuring subsistence through own production of staples can be a disincentive for adoption of new varieties and agricultural technologies.

Violent conflicts

Messer and Cohen (2004) note that conflicts are cause and effect of food insecurity. Insecurity limits farming activities leading to the reduction in production of food. Studies have shown a strong correlation between food insecurity and conflicts. In 2006, 64% of the 39 serious food emergencies were due to armed conflicts that lasted for more than five years (Commission of the European commission, 2006). Weismann, (2006) also observed that nine of the 12 countries with worst GHI, were affected by armed conflicts or recovering from war. Armed conflicts in general increased GHI by 22% in countries with comparable economic development indicators (Ibid).

One interesting question is whether the limited water and other natural resources in drylands also lead to conflicts. There is a strong relationship between armed conflicts and drylands (UNCCD, 1994; Westing *et al.*, 2001). Competition of water and land resources between farmers and pastoralists has led to many civil wars in SSA and other regions of the world. For example, the Maasai pastoralists in Kenya and Tanzania and the Karimojong pastoralists in Uganda (Muhereza and Otim, 2002); the Fulani and FulBe communities in west Africa (Turner, 2004; Maganga, 2002; Nicholson, 2005) and others pastoral communities have clashed frequently with sedentary farmers. The conflicts are more severe and more violent when nomadic herders move to farmers who have different ethnicity and cultural identity (Turner, 2004; Muhereza and Otim, 2002; Munzoul, 2006). Resource degradation and the increasing population density among the pastoral communities have forced them to migrate to areas with abundant water and pasture resources outside their areas. This has also led to conflicts that are not only due to resource conflicts but also with cultural and ethnic identity (Maganga, 2002). Like the case for other forms of conflicts, the farmer pastoralist conflicts have led to food insecurity in the drylands. This calls for a better understanding the nature of these conflicts and for ways to accommodate both customary institutions and formal institutions that can manage the conflicts (Maganga, 2002). Such mechanism could lead to minimization of conflicts and enhancing food security.

Education and status of women

Education has been cited as the major factor that can improve significantly the food security in a household. A study by Smith and Haddad (2000) showed that women's education contributed 43% to the reduction of prevalence of child malnutrition in developing countries between 1970-95 reduces significantly child malnutrition. These findings underscore the role that women in developing countries play in producing and preparing food. Women with better knowledge of nutrition are more likely to take better care of children and the entire family. Education can also increase household income, which improves access to food. Status of women relative to men, measured as life expectancy of women relative to men, also reduces child malnutrition significantly, highlighting further the role that women play in securing food security in developing countries (Smith and Haddad, 2000). This suggests the importance of approaching the food security problem using a variety of methods and approaches.

HIV/AIDS

HIV/AIDS and food insecurity are becoming increasingly linked in a vicious cycle. People with food insecurity are more susceptible to HIV/AIDS exposure and infection and HIV/AIDS increases susceptibility to food security due to its impact on the family labor and treatment costs that take resources away from food production and other economic activities that enhance food security (Loevinsohn and Gillespie, 2003). The GHI is 3.9 points higher in countries with HIV/AIDS prevalence greater than 10% than it is in countries with lower prevalence rates (Weismann, 2006). These results confirm the rich evidence of the negative impact of HIV/AIDS on food security[3].

Major Research Achievements in Addressing Food Security in Drylands

Crop, livestock and agroforestry research has produced technologies suitable for the drylands of SA and SSA. These technologies have helped farmers to increase agricultural productivity in the fragile dryland environment. Farmers in the drylands have also developed a number of practices suitable for improved agricultural productivity and resource management (Reij and Waters-Bayer, 2001). Below, we review the salient research achievements and farmer innovations in the drylands and then discuss the outstanding challenges that future research needs to address.

Crop variety improvement

The green revolution is one of the most significant outcomes of crop research that led to improvement of food security in SA. Availability of high yielding crop varieties of wheat and rice was the major research achievement that boosted the impact of green revolution on food security in SA. As noted above, however, the green revolution did not have a major impact in the marginal rainfed agriculture in SA and its impact in SSA has also been limited (Janaiah *et al*., 2006; Dorward *et al*., 2004). Beyond the green revolution, breeding programs by public and private organizations has generally increased crop yield, helping farmers to achieve food security. For example, 80% of the area under sorghum and 60% of the area under pearl millet in India are planted with hybrid varieties (CGIAR, 2004).

The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with national agricultural research institutes in semi-arid tropics has developed more than 130 sorghum, 76 pearl millet, 42 chickpea, 26 pigeonpea and 45 groundnut varieties suitable for the dryland areas of SSA and SA (Shiferaw *et al*., 2004). These are varieties selected for various traits like high yield, resistance to biotic stresses (disease and pests) and resistance or drought escape, along with farmer and market preferred economically valuable traits. In relation to drought, one of the main research approaches has been reducing the growing period (earliness) in order to respond to the short and erratic rainfall in the drylands. Several early maturing pigeonpea, chickpea and groundnut varieties with desirable economic traits have been developed, giving farmers an opportunity to exploit the available moisture. This is particularly the case for chickpea and pigeonpea varieties that can be grown in the post-rainy season after harvesting the main cereal crops (e.g. rice and wheat fallows).

These varieties are released in several countries across SSA and SA although variety uptake remains limited and has not reached the potential. Along with partners,

3 See Gillespie and Kadiyala, 2005 for a review of the relationship between HIV/AIDS and food security.

ICRISAT also developed the first hybrid pigeonpea, which increases yield by 30% and more resistant to drought than the traditional varieties (CGIAR, 2004). Hybrid lines that exploit the potential of heterosis to improve crop yields by up to 30% have also been developed for sorghum and pearl millet.

Soil fertility and watershed management

Improved water management has helped to reduce degradation of resources and this has led to their improved productivity. Studies have shown that improved watershed management can reduce rainwater loss by an average of 55%, reduce soil erosion by about 67.5% and can increase water recharge by more than 40% (CGIAR, 2004). The major watershed management practices that have contributed to improved productivity and food security are agroforestry, soil and water conservation structures and biodiversity conservation. New approaches to integrated watershed management tested in SA also bring together technological innovations for crop, soil fertility, water management and biodiversity management options within a defined landscape along with institutional innovations for strengthening collective action and market linkages (Twomlow *et al.*, 2008). This approach is now becoming the major strategy for development of semi-arid drylands in India, and offers good potential for adaptation in SSA. Strategies for enhancing the uptake of improved inputs especially inorganic fertilizers are also important for enhancing productivity. One such strategy tested in Africa is the micro-dosing innovation for inorganic fertilizers, which allows farmers to use small quantities of fertilizer applied around the plant to enhance the efficiency of fertilizer use (Twomlow *et al.*, 2007). This approach which reduced input costs without compromising crop yields to farmers has improved fertilizer adoption in the drylands, especially when it is combined with improved soil and water management to reduce the drought risk. In some dryland areas, application of micro-nutrients like boron, zinc and sulfur in addition to macro-nutrients like nitrogen and phosphorus may enhance the efficiency and responsiveness to fertilizer applications.

In SSA, traditional watershed management and soil fertility practices have also increased the resilience of the dryland ecosystems. For example, farmers in Burkina Faso also developed the *zai* technology, which is planting pit that breaks the hard pan and harvest runoff water. Improved *zai* are used to rehabilitate severely degraded lateritic soils by breaking up the surface hardpan and allowing infiltration of soil moisture. This technique works better in dryland areas that are between 300 to 800 mm annual rainfall (Kaboré and Reij, 2004). *Zai* have been widely adopted in densely populated areas in the central plateau where lateritic soils are common. The improved *zai* technology has also spread to Niger and is used in Zambia (as part of conservation agriculture) (Haggblade and Tembo, 2003). It is estimated that up to 160,000 farmers in Burkina Faso and Niger (20,000 to 80,000 in each country) have adopted this technology (Franzel *et al.*, 2004). Using this technology, farmers have been able to obtain millet and sorghum yields of 400 to 1200 kg per hectare on formerly unusable land (Ibid.). According to one recent study conducted in Niger, farmers' rate of return from investments in *zai* range from 30% to over 100% (Abdoulaye and Ibro, 2006).

Despite their adaptability and good performance in tackling soil erosion and desertification, traditional practices have however not been promoted significantly by the extension services (Stocking, 2003).

Agroforestry management

Agroforestry practices have also contributed to sustainable intensification of agriculture and better food security in drylands. One of the key roles that agroforestry practices play in the drylands is soil fertility improvement. Fertilizer application is a risky investment even in humid zones of SA and SSA. The risk of fertilizer application is even more pronounced in arid and semi-arid areas (Bationo *et al.*, 2007). Hence research in the drylands has explored the use of agroforestry as part of the integrated nutrient management strategies, in which chemical fertilizers are used judiciously with agroforestry, organic residues soil and water conservation practices. Agroforestry has shown a large potential of rehabilitating abandoned farmlands and enhancing soil fertility in drylands. Sanchez *et al.* (1997) observed that successful agroforestry systems increase nutrient inputs, and decrease nutrient losses. For example, nitrogen-fixing leguminous tree fallows accumulate 100 to 200 kg Nitrogen per hectare (Sanchez, 2002). Deep-rooted trees capture deep nitrate and the leguminous trees and shrubs fix atmospheric nitrogen, contributing to the nutrient replenishments. Agroforestry trees can also be used as barriers of runoff in the drylands which have scanty vegetation. Well adapted trees such as Acacia have been used in the Sahelian region to improve crop and pasture productivity and making the arid lands ecologically stable. Contrary to the concept that population pressure promotes deforestation and severe soil erosion, studies have shown that in areas with high market access, farmers adopt agroforestry and other practices to control soil erosion (Tiffen *et al.*, 1994; Sanchez *et al.*, 1997).

Farmers have contributed significantly in developing agroforestry practices that are well adapted to the drylands. For example, among the most important traditional agroforestry practices in the Indian drylands include sand-dune stabilization, shelterbelt plantations, tree planting techniques in difficult land forms, silvopastoral and agrisilvicultural systems and introduction and improvement of fruit trees (Shankarnarayan *et al.*, 1987). The transhumant *Bhotiya* communities in the central Himalaya in India have also conserved biodiversity of plants and animals using traditional practices. This has enhanced sustainability of their production systems (Farooquee *et al.*, 2004).

In the drylands of SSA, agroforestry practices have shown potential to increase crop livestock productivity. For example a farmer managed natural regeneration of cut trees in Niger has led to significant improvement in the vegetation and crop and livestock productivity (Kalinganire *et al.*, 2005). According to satellite pictures, tree natural regeneration has covered 11.84 million hectares in Niger (New York Times, 2007). This dramatic regeneration has occurred in spite of the rapid growth in population, which more than doubled from 5 million people in 1975 to 12 million in 2005 (Adam *et al.*, 2006).

The Niger community managed natural regeneration case also serves a good example of the potential that local communities and their institutions can contribute to sustainable resource management and food security. At community or watershed level, customary and local institutions have been used to enact and enforce natural resource management regulations. Studies have shown that customary and local institutions are more effective in managing local common natural resources than central governments (e.g. see Agrawal and Gibson, 1999; Ostrom, 1990). For example a recent study in Uganda showed the compliance with locally enacted natural resource management regulations was higher than is the case with regulations enacted from higher authorities (Nkonya *et al.*, 2007). This point to the need of strengthening the local institutions as part of efforts to improve natural resource management which in turn improves food security

Enhancing food security through livestock production

Livestock sector in the drylands provides a big potential for improving food security significantly. The importance of livestock increases as the amount of rainfall diminishes towards the desert margin. Pastoralism is the major livelihood in the Sahelian region. Livestock play an increasingly greater role as sources of livelihood, security against risks, transportation and many other tangible and non-tangible benefits. Recent studies have also shown that crop-livestock interaction offers a low cost system that can sustainably increase agricultural productivity than the specialized sectors (pastoral, industrial livestock systems or crop systems) (Defoer *et al.*, 2000; Ryan and Spencer, 2001). This is due to the significant role that livestock play in producing and transporting manure and agricultural products. For example, a recent study showed that livestock-crop-agroforestry interaction enhanced the crop and livestock productivity and reduced production risks in the drylands (Winslow *et al.*, 2004).

Nutritional studies in SA and SSA have also shown that poor households who own livestock have better diets than those who do not keep livestock (Grillenberger, 2006). School children who are given milk and meat products have better cognitive development than those who feed mainly on cereal and tuber crops (Ahmed and del Ninno, 2002; Siekmann *et al.*, 2003). These research findings underscore the importance of livestock in the food and nutritional security of poor people in the drylands. The results also highlight the importance of diversified sources of income and food in ensuring food security among the poor.

Livestock productivity in the drylands in developing countries is still low but its potential to increase is enormous given the large livestock population and the low population density in the dry areas and the increasing demand for livestock products. The demand for livestock products in the world has been increasing with population and income. Delgado *et al.*, (1999) estimated that the demand for milk in developing countries will increase

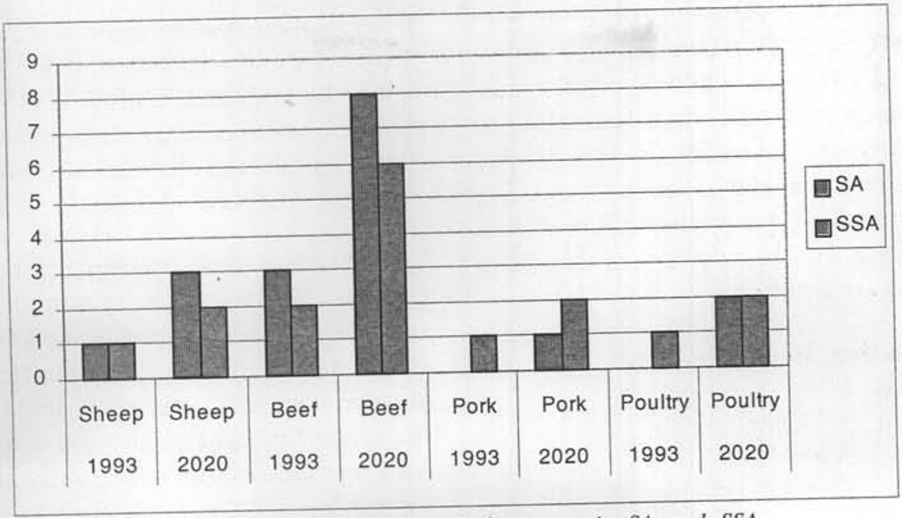


Fig. 9. Projections of demand for meats in SA and SSA.

annually by 3.3% from 168 tons in 1993 to 391 tons in 2020. SA will account for 60% of the increase and SSA will account for only 17% of the increase in demand. This shows the large potential that local demand for the livestock products and highlights the importance of paying more attention to the livestock sector in efforts to ensure food and nutritional security. Figure 9 also shows large increase in demand for meats and poultry in SA and SSA. The world meat demand will increase by 111% from 89 tons in 1993 to 188 tons in 2020 (Delgado *et al.*, 1999). SA and SSA will respectively contribute 10% and 7% of the increase in demand for meats[4].

Population and stocking rates of small and large ruminants in SA and SSA have been increasing in the past three decades in response to the increasing local and international demand (ILRI, 2000). This has put pressure on the low potential resources in the drylands. However, the ecosystem and farmers have shown their resilience and capacity to adapt to the changing livestock and human population and has minimized the overgrazing (Ellis and Galvin, 1994; Tiffen, 2003). Farmers in the drylands have also shown remarkable resilience and adaptability to changing ecosystems and socio-economic environment.

Despite the potential of livestock to reduce poverty and achieve food and nutritional security and to contribute to sustainable agricultural production, investment in livestock research in the national and international institutions has remained low. For example, in 1972 to 2000, the Consultative Group on International Agricultural Research (CGIAR) invested only 17% of its total investment of $ 5.6 to livestock research (CGIAR, 2000). The relatively low investment in livestock research at national level is similar for most countries in SA

4 This is computed from the change in demand for sheep, beef, pork and poultry in SA and SSA. Other sources of meats (e.g. buffalo, goats, game meats etc) are not considered.

and SSA, where the main focus has been on crop research (Beintema and Stads, 2006; Pal and Byerlee, 2006). Given the importance of the livestock sector in the drylands and its potential to reduce poverty and malnutrition and given the increasing demand for livestock products, there is need to increase significantly the investment in livestock research.

Outstanding Research Needs in Drylands

New varieties

Research has shown that crop productivity has increased yields of sorghum, millet and pulses grown in the drylands countries (Ryan and Spencer, 2001). This means improvement of dryland crops is an essential investment that can improve food security in drylands countries. Given the complex biophysical conditions and abiotic and biotic stress factors that continue to limit agricultural production in the drylands, future crop improvement programs need to address these limiting constraints. Addressing these constraints would not only improve crop and livestock productivity, but also reduce the risks and vulnerabilities faced by dryland farmers. When we look at the major constraints to productivity growth, future research needs to address the chronic problem of recurrent droughts and climatic variability for all dryland crops. Under the plausible scenario of future climate change, climate risk management in terms of more recurrent droughts and changed pest and disease prevalence may even become more important in the future. Another important abiotic stress is poor soil fertility caused by soil erosion, soil mining and desertification in some areas of the dryland tropics. Developing varieties that respond best under poor soil fertility and low input conditions or tolerate or escape the drought stress are critical for sustainability and economic viability of dryland agriculture.

The major pest problem of sorghum remains to be striga (parasitic weed) infestation (*Striga hermontica* in Africa and *Striga Asiatica* in South Asia). There are also economically important insect pests like shoot fly, stem borers, and midge that reduce yields. In terms of important diseases for sorghum, future work need to address the problem of grain mold caused by various species of fungi, anthracnose, and leaf blight. In relation to millets, more emphasis need to be given to striga infestation, and the disease, downy mildew for pearl millet and blast for finger millets. Insect pests are not major problems for millets, except shoot fly in finger millets. In the case of dryland pulses (pigeonpea and chickpea), future research need to address the major diseases like fusarium wilt caused by various soil-borne fungi and aschocyta blight. The major pests include pod borers, pod fly and others mainly for pigeonpeas. For cowpea, mosaic virus and bacterial blight are economically important diseases, while the main pests include striga, thrips, pod sucking bugs, aphids and maracua. In the case of groundnuts, the major disease problems are aflatoxin (caused by a fungus *Aspergilus flavus*), rosette, and foliar diseases. Aflatoxins are particularly important as stringent phytosanitary and food safety standards in many importing countries of the OECD require nuts that are almost free from Aflatoxin infestation. Both breeding and crop management practices are needed to address this challenge which has prevented African smallholder farmers from harnessing available market opportunities. ICRISAT and other national and international research institutes have already identified resistance sources for some of the biotic stresses, making the future research in this area more promising. Crop varieties that embody traits for better disease and pest tolerance, combined with integrated approaches for pest and disease management, will provide economical and low cost options for dryland farmers.

Another important factor for cereals is targeting traits for alternative uses (food, feed, fodder, breweries, biofuel) or even varieties that meet multiple uses (e.g. food and fodder). This will stimulate demand for these crops and open new opportunities for commercialization of smallholder dryland agriculture. Availability of hybrids that embody these important economic traits will further increase yields, reduce the cost of production and enhance the returns to land and family labor in dryland agriculture. The development of hybrids, however, need to be carefully synchronized with the development of output markets and the emergence of private sector seed companies and input agro-dealers. Unlike varieties, hybrid seed need to be replenished at every planting season, hence requiring a well functioning seed supply and marketing system. Hybrids also perform better under high input conditions (e.g., fertilizer and some supplemental irrigation). In the case of dryland legumes, incorporating market preferred traits in terms of grain color, size, taste, etc., are important factors in terms of accelerating the commercialization of these crops. Along with improving productivity and reducing risks, improving food quality and safety standards for all dryland crops also require explicit attention to make smallholder farming competitive in regional and international markets.

Seed and technology delivery systems: Unfortunately, adoption of the improved crops has been a major problem in dryland countries due to the poorly developed agricultural markets in the drylands. So what has been a major research challenge is the need to understand what should be done to increase adoption of improved drylands crop varieties and well adapted livestock breeds. Many studies have been done to identify the important factors that are required to increase adoption of agricultural technologies among poor farmers. While, more adoption studies are required to better understand the factors that affect adoption in the changing market and socio-cultural environment, one recurrent finding has been lack of access to improved and profitable varieties. This follows from failures in seed markets and lack of credit to acquire improved technologies. The imperfections in seed markets arise from the classic problems of asymmetric information that make it difficult for seed buyers to distinguish the grain from quality seeds and the culture of saving seed for self or open pollinated varieties. The viability of the seed market also depends on the performance and functioning of output markets. In the absence of remunerative output market opportunities, smallholder farmers often prefer to use own saved seed rather than buying fresh material of superior genetic purity. Along with investments to develop new and more profitable innovations, there is an urgent need to expand research and development investments to identify and strengthen viable seed supply systems. This is critical in improving the availability and accessibility of new cultivars and technologies to smallholder dryland farmers.

Improving crop-livestock systems

Our review shows that crop-livestock livelihoods are common in the drylands and offer great opportunities for achieving food security and sustainable agricultural production. However, research in improving the productivity and market opportunities for dryland livestock keepers and agro-pastoralists has been low, despite the sector's key role as source livelihood and its potential to reduce poverty and food and nutritional insecurity. Future research and development may give high priority to investigate how to improve (in terms of meat and other products) for local livestock breeds that are highly adapted to the drylands. Improving dry season fodder, watering points, veterinary services and market linkages to facilitate live animal off-take from the dryland areas are very crucial to enhance the contribution of livestock for dryland families. Increased marketing opportunities and availability of essential infrastructure also reduce banking on live animals and help reduce pressure on fragile rangelands that often leads to resource degradation and desertification. A number of technologies have been developed for the intensive exotic livestock breeds. However, technologies for the most common extensive feeding systems and the local livestock breeds are few and in some cases not well adapted to the drylands. For example, a recent review showed that none of the forages for reducing land degradation appeared to meet the needs of the semi-arid areas of West Africa (Peters *et al.*, 2001). Few forage and agroforestry technologies suitable for the drylands have been developed. For example research on the *Acacia senegalensis* has shown promising potential to both improve soil fertility and consequently crop and livestock productivity in the drylands of west Africa (Kalinganire *et al.*, 2005). Enhanced crop-livestock integration and controlled grazing on crop residue has also improved soil fertility due to deposition of excreta (Schlecht *et al.*, 2006). A lot remains to be done to fully exploit the potential that crop-livestock systems offer in the drylands.

Soil fertility and water management

Agricultural production in the drylands is risky due to the low and erratic rainfall and the poor sandy soils or soils with hard pans (Bourma and Scott, 2006). Degradation of the productive capacity of land through various processes accelerated by proximate and underlying causes is a major threat to sustainability of livelihoods in the drylands (Robins and Williams, 2005). To improve the conditions for agricultural production, investments are needed in soil fertility and water management to improve soil fertility, increase soil moisture and allow for supplemental irrigation in critical stages of growth (Keller *et al.*, 2000, Oweis *et al.*, 1999). Integrated watershed management that addresses crop, soil, water and tree management problems at a landscape level has been demonstrated to be a promising approach in the semi-arid areas of SA (Joshi *et al.*, 2004). Successful pilot and case studies show that this approach can address the problem of market and institutional failures through local collective action to internalize local externalities. Such integrated land and water management often leads to better soil conditions and increased utilization of available surface and groundwater resource for dryland farmers, allowing them reduce drought risks and improve food security and sustainability of agricultural production. Farmer investment in fertility enhancing inputs like fertilizer is lowest in rainfed dryland areas. Enhanced utilization of available water will also make adoption of inorganic fertilizer more attractive to farmers. The important question is what works where and why? A lot needs to be done to understand the reason behind the low adoption of improved soil and water conservation that have been introduced, especially in SSA, and how the landscape and community-based watershed management approach can be adapted to African conditions. In most countries, agricultural technologies that are promoted by the extension services have to be approved by a formal regulatory body. For natural resource management interventions that tend to have high location specificity, the challenge remains to be the process of identifying farmer-preferred and economically attractive innovations and conducting verification trials. The participatory and action research approaches have improved the formal research interaction with farmers but a lot remains to be done to scale up such approaches which tend to be concentrated in few villages with limited statistical validity (Barahona and Levy, 2002). Social distance between farmers and scientists and other challenges involved in the participatory action research also face this new research approach (Bentley, 1994) and they need to be addressed in order to fully accommodate the farmer innovations in the research and extension approaches.

Improving education

Education of women has been shown to decrease significantly child malnutrition in developing countries. The important research question is to better understand the barriers that limit women access to education. These impediments, which include cultural, religious and poverty in general, have been affected by the significant changes in information technology and other national and global socio-economic changes. The impacts of these changes differ across countries and socio-cultural communities. The new changes call for better understanding the best and most up-to-date methods to break the barriers to women education.

Improving markets and institutions

Our review has also shown the importance of informal and formal institutions in improving access to essential productivity enhancing inputs, output markets and management of natural resources[5]. The marginal dryland areas are often less served in terms of road networks and communication infrastructure, making markets in these areas highly imperfect and incomplete. Improved market access creates incentives for smallholder farmers and livestock keepers to benefit from market-led technological opportunities and stimulate uptake of productivity-enhancing commercial inputs. Market access also reduces dependence on subsistence agriculture for food security and stimulate diversification into other income strategies that further enhance food and nutritional security. While infrastructural investments are critical for future development of the drylands, there is a need to explore alternative institutional innovations (e.g., farmer organizations) to develop market linkages and strengthen rural agro-enterprises that create employment and incomes for the poor (Poulton *et al.*, 2006). Cross-border partnerships in trade and market development would also open new opportunities for dryland resource users, especially for exploiting livestock for income growth and food security.

Even though a lot of work has been done to understand the customary and local institutions, more work is needed to better understand the best approaches to harmonize formal and informal institutions found in the local communities. For example a study in Mali observed that local conflict resolution mechanisms are more reinforced by involving all the protagonists in the damage assessment and subsequent negotiations while also involving mediators who are respected by all parties (Beeler, 2006). This legal pluralism (Meinzen-Dick and Pradhan, 2002) remains a big challenge especially in socially heterogeneous communities (Poteete and Ostrom, 2004).

Related to this is the country and regional efforts to minimize cross-border and civil conflicts that have negatively affected food security. Even though conflicts in SSA have shown a downward trend in the past seven years (Harbom and Wallensteen, 2007) and have remained fairly stable in Asia after a temporary spike in 1992-1994 (UCDP, 2007), a lot remains to be done to eliminate conflicts. Research in peace and international relations need to inform policy makers the major determinants of these conflicts and best methods to prevent them.

Conclusions and Policy Implications

Food security is a fairly complex concept which depends on availability of sufficient food of desirable quality and access of individual consumers to meet their subsistence needs. Food security therefore depends on availability, quality, access, and utilization of food to meet the biological needs for a healthy life. Food security in the drylands is affected by interplay of all these factors. The tropical drylands of Sub-Saharan Africa and South Asia are often described as the hotspots of food insecurity, chronic poverty, and environmental degradation mainly due to adverse biophysical conditions and poor infrastructure for markets and agricultural development.

Many dryland farmers practicing rainfed crop-livestock agriculture are yet to benefit from the dramatic gains in productivity growth attained in the more favorable green revolution areas in SA. Despite the increased availability of high-yielding and risk-reducing cultivars and agricultural innovations, the on-farm productivity of major staples and crops grown in the drylands has largely stagnated and did not record appreciable growth over the last four decades. Many factors are attributable to lack of productivity growth – limited adoption of available cultivars, poor soil fertility and limited use of inorganic fertilizers, and

[5] In this paper, formal institutions include the central and local government laws. They also include international laws and regulations. Informal institutions include customary laws and norms, religious laws, project, donor or program law, group or association law, and local norms (Meinzen-Dick and Pradhan, 2002).

insufficient irrigation and dependence on unpredictable rains. In some cases, the available varieties reduced the risk of crop failure or increased stability of supply without necessarily increasing crop yields. While the progress made in agricultural research is significant, more work is needed to address the chronic challenges of low productivity in dryland agriculture and to make available innovations accessible to the intended users (smallholder farmers). There is a need to develop new high-yielding cultivars that embody desirable traits for drought, pest and disease resistance as well as preferred by farmers and markets. This would need to be complemented by agricultural strategies for diversification of production systems to facilitate commercialization and foster sustainability of smallholder agriculture in the drylands.

The projection of dryland food production and consumption shows that coarse grains and legumes make up a significant share of dietary energy for both SA and SSA regions. However, the increase in utilization of coarse grains in SA is mainly due to the increasing demand as feed rather than food. In SSA, the increase in consumption of coarse grain is mainly due to the increasing demand as food. This suggests that improvement in productivity and distribution and marketing of dryland crops have the potential to improve directly food security in the SSA drylands and indirectly – through livestock products and income – in SA.

The increasing concern over the implications of climate change-induced shifts in average temperature and precipitation levels for human well-being and food security in SA and SSA provides further justification for looking more closely at the role that policy interventions and technological innovations can play in strengthening dryland crop production systems, and supporting the food economies of SA and SSA, as they face various challenges brought about by global economic and environmental change.

Our projections of food production and consumption show that child malnutrition in SA is decreasing much faster than the case in SSA, due to increase in per capita income, female education and female life expectancy. Fast reduction in child malnutrition is also possible in SSA if the countries invest significantly in improvement in agricultural production and in addressing the constraints that impede access to food.

The review of the factors that determine food security show that food security cannot be achieved simply by increasing the production of food. This is illustrated by India which still has high rate of child malnutrition even though the country achieved food self-sufficiency following the green revolution and serves as one of the leading exporters of key commodities (Pal and Byerlee, 2006; Weismann, 2006). While availability is the critical first step, factors that determine access to food are important in ensuring food security. In many cases, access depends on ability to self produce a desired quantity of food; but access can also be ensured or complemented through markets, safety nets and benefit transfer programs. This shows the importance of income diversification strategies for ensuring food security in the drylands. In the long-term, sustainable livelihood security in the drylands depend on expanded investment in education, health and development infrastructure, including

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