Internal document for strategic planning

Challenges and Opportunities for Agricultural R&D in the Semi-Arid Tropics

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ICRISAT
Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

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Foreword

To proactively address challenges and new developments in its rapidly changing task environment, ICRISAT is mapping out a new Strategic Plan to 2020. This initiative is also being undertaken to pursue the recommendation of ICRISAT's sixth External Program and Management Review (EPMR) in 2009-2010.

Essentially, strategic planning enables us to:

- Sharpen our awareness of contemporary challenges and opportunities in our task environment.
- Envision ICRISAT's future and create pathways to influence it by assuming a strategic posture.
- Revisit our mission and chart a new research direction while maintaining our strong position in agricultural research for development in the semi-arid tropics (SAT) of Asia and sub-Saharan Africa.
- Involve our staff, partners and stakeholders in the process and map out higher standards of excellence and relevance.

To help us scan the contemporary environment of the SAT, we commissioned Tom Walker of Michigan State University to conduct a study which updated the comprehensive analysis of SAT trends written by Jim Ryan and Dunstan Spencer in 2001.

This internal document presents the results of Walker's study which primarily reviews the trends and main drivers of agriculture in the SAT and their potential implications to ICRISAT's strategic plan. It guided the deliberations of a series of facilitated in-house retreats in Asia, West and Central Africa (WCA) and Eastern and Southern Africa (ESA) involving all ICRISAT scientists and some Governing Board (GB) Members including an expert consultation workshop involving major partners of the Institute.

In the foregoing exercises, participants discussed a number of critical drivers and trends and their implications, major challenges and ICRISAT's roles and changes. These were spearheaded by a Strategic Planning Task Team I created which is chaired by the Deputy Director General-Research and composed of the members of the Management Group.

ICRISAT has a distinct advantage of undergoing strategic planning from a position of strength rather than a position of crisis. Strategic planning is the key to helping ICRISAT collectively and cooperatively chart its future and influence its destiny as a global R4D organization.

Ultimately, ICRISAT's strategic planning will help create a better future for the smallholder farmers and poor people of the semi-arid tropics.

William D. Dar
Director General

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Chapter 1

Overview

1.1 This internal document aims to synthesize substantive information to contribute to ICRISAT strategic planning in general and to the agenda of four working group meetings scheduled for early 2010. The new strategic plan builds on the ICRISAT Vision that was published in 2006

1.2 It would be pretentious to say that ICRISAT is at a crossroads in its institutional development, but it is a time of change, most of it for the better in terms of funding for international agricultural research. Compared to 2006, ICRISAT has received more solid support for its program from donors, particularly from the Bill & Melinda Gates Foundation (BMGF) and the Government of India. The BMGF takes a longer view than most donors, so the prospects that they could be funding ICRISAT research well into 2020, the target date for the time horizon of the new strategic plan, are bright.

1.3 In 2006, the long-term downward trend in real food prices was still very much in evidence. Surging food prices in 2007 and the price spike in 2008 seem to have reversed this trend. This reversal is the major driver in the changed external environment. Other drivers, such as global climatic change, have intensified and are already starting to have implications for funding and resource allocation at agricultural research institutions

1.4 This document selectively updates a comprehensive report by Ryan and Spencer (2001). The organization of the present work is patterned after Ryan and Spencer (2001) who broadly divided their report in two parts: (1) Dimensions of poverty and (2) Dynamics of agriculture in the semi-arid tropics (SAT). Unlike Ryan and Spencer, who organized their analysis from the lens of small, medium, and large SAT countries based on the proportion of land mass in the SAT in Asia, Latin America[1], and sub-Saharan Africa, I chose to focus on ICRISAT's three major regional divisions, Asia's SAT, West & Central Africa (WCA), and East & Southern Africa (ESA)[2]. Estimates for the three regions are weighted within each region by the SAT country's population, which was derived from the proportion of the SAT area in each country according to Table 49 in Ryan and Spencer (2001).

1.5 Based on discussions with ICRISAT research management, I did not explicitly consider the implications of the CGIAR's Change Initiative in general and the proposed Mega-Programs in particular (von Braun et al. 2008)while authoring this

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[1] Latin America is relevant to ICRISAT's mandate on sorghum, but it is not generally a crop produced by poor small farm households with the exception of location-specific pockets such as eastern El Salvador. Much of the poverty in Latin America's SAT is in Northeast Brazil which is widely recognized as a geographic poverty trap but which is wholly contained within Brazil. Like India, Brazil is characterized by a strong NARS but, unlike India, poverty in Northeast Brazil is driven by inequality of land holding in what is steadily becoming an urbanized economy. I do not see any substantial opportunities for ICRISAT's research to leverage poverty alleviation either via its crop or area mandate in the region; therefore, I did not include Latin America's SAT in the analysis.

[2] Asia's SAT includes a large part of India and small land areas of Myanmar, Thailand, Indonesia, Sri Lanka, and Vietnam. The SAT of West & Central Africa is made up of all of The Gambia and parts of Benin, Burkina Faso, Cameroon, Chad, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, and Togo. The SAT of East & Southern Africa is comprised of parts of Angola, Botswana, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe. Several small countries that appear in Ryan and Spencer's Table 49 were excluded from the analysis because the SAT is a very small agroecology in each country or because the prospects for ICRISAT to work in these countries in the medium-term future is limited. The composition of the countries in each of the three regions varies somewhat from tabulation to tabulation depending on data availability. For most analyses, data are complete for all countries in the region.

document. Nor are all relevant trends and drivers discussed in the report. Notable omissions include new science, food safety, supermarkets, and information technology. But many candidate trends and drivers are assessed, and the most relevant for ICRISAT's mission of contributing to poverty alleviation in the SAT are summarized in Section 4.

1.6 Reporting on past trends in the SAT and speculating on SAT futures is a relatively easy task; teasing out important and relevant insights for agricultural research is an infinitely more difficult undertaking. The error in exercises such as this one is to report too much and not tease out enough. This document also errs on the side of reporting too much. Section 4 is slimmer than it should be, but hopefully it provides sufficient raw material to motivate productive discussions and deliberations for strategic planning

Chapter 2

Population Growth and the Potential for Poverty Alleviation in Africa's and Asia's SAT to 2020

2.1 Introduction

2.1.1 Among the seven Millennium Development Goals, agricultural research is most directly related to and has the most leverage over the first one: Eradicating extreme poverty and hunger. Reducing poverty is embraced by the CGIAR among its interrelated triad of goals of increasing food security, reducing poverty, and enhancing environmental sustainability. Increasing food security and alleviating poverty go hand in hand. Frequently, short-term measures of food security are used as indicators of poverty when household income and consumer expenditure data are not available. Likewise, more durable measures of resource sustainability condition the potential for poverty alleviation

2.1.2 There are many dimensions of poverty, but, since 1992, with the publication of Martin Ravallion's monograph on poverty comparisons, poverty is increasingly identified in absolute terms with poverty lines based on the daily cost of providing a minimum recommended dietary allowance of energy to an adult. In standardized indices, the incidence of poverty refers to the percent of the population below a poverty line, the depth of poverty indexes the size of the gap between the poverty line and a poor person's consumption expenditure (or income when data on consumption expenditure are lacking), and the severity of poverty gives significantly more weight to incremental income received by the poorest rather than the poor who are closer to the poverty line. There is increasing interest in qualitative poverty measures and in quantifying and standardizing these measures (Kanbur and Shaffer 2007), but for purposes of strategic planning, absolute poverty founded mainly on nutritional status of caloric intake and compared internationally with adjustments to purchasing power parity is the most widely used basis for drawing inferences about poverty.[3] We follow conventional practice and rely on absolute poverty as our organizing construct to describe trends in the levels of poverty and in the potential to alleviate poverty, which is strongly linked to population growth.

2.2 Population growth

2.2.1 We present the medium variant of the 2008 Revision of the United Nations population data base to examine growth rates and numbers of people in the three regions of in the SAT (http://esa.un.org/unpp). The projected population growth rates are substantially higher in WCA and ESA in spite of the HIV and AIDS epidemic in much of sub-Saharan Africa (Figure 2.1.1). By 2020, the forecast population growth rates will dip below 1% in Asia's SAT and 2% in Africa's SAT. These rates are predicted to fall steadily from their peak exceeding or approaching 3% in the early 1980s for Africa's SAT and 2% for Asia's SAT. The rates are strongly positive throughout the period

[3] The UN Human Development Indices are highly correlated with per capita income and estimates of poverty across countries and over time.

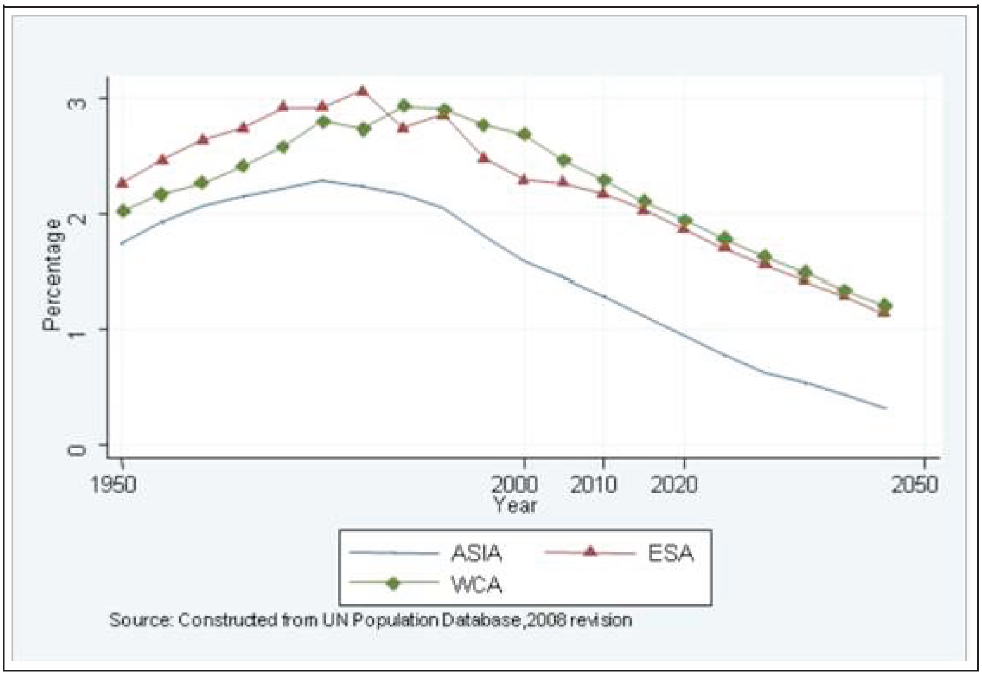

Figure 2.1.1. Projected annual population growth rates by SAT region to 2050.

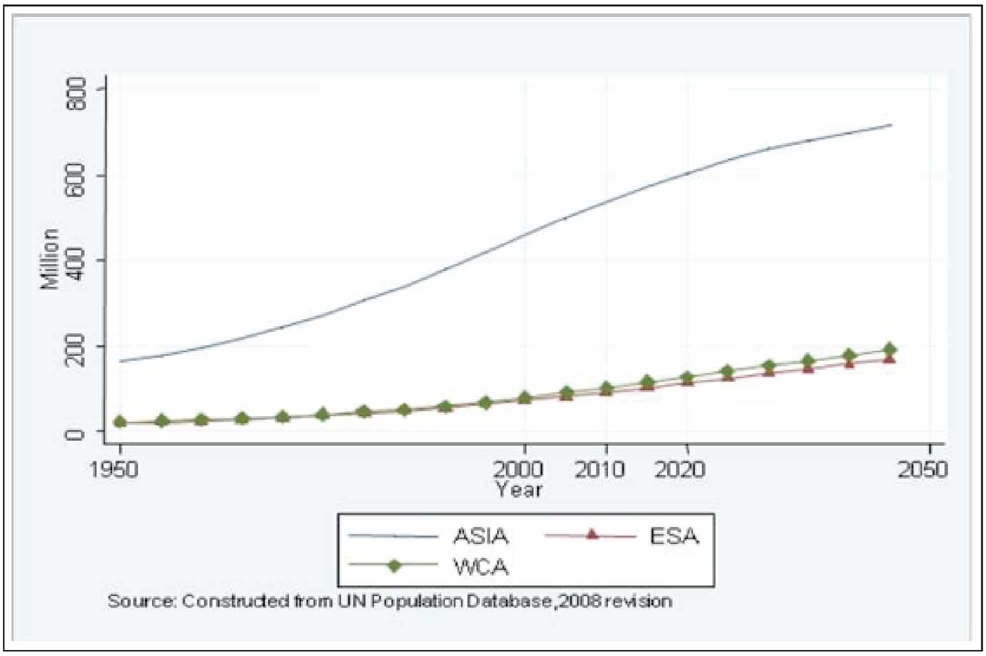

Figure 2.1.2. Projected total population by SAT region to 2050.

2.2.2 The forecast declining rates of growth generate a gradually increasing SAT population in the three regions to 2020 and on into 2050 (Figure 2.1.2). By 2020, the total population of the Asian and African SAT is projected to be about 850 million comprised of a 70% share for Asia and a 30% share evenly split between WCA and ESA. By 2045, Asia's projected share declines slightly to about 2/3rds and Africa's increases incrementally to 1/3rd. When ICRISAT was founded in 1972, the relative importance of the two continental populations was about 80% for Asia's SAT and 20% for Africa's SAT. The total SAT population in 1972 was only about 35% of the projected population in 2020.

2.2.3 The rural growth rates follow a similar downward trend in the three regions (Figure 2.1.3). Indeed, the projected rural population growth rates exhibit less interregional disparity than the total population and urban growth rates. The rate of rural growth in Asia's SAT reaches zero in 2025 when the rural population plateaus at 400 million and starts to decline (Figure 2.1.4). Negative rural population growth rates are projected to occur about 10 years later in Africa's SAT where population is forecast to level off at about 80 million rural people in ESA and 70 million rural inhabitants in WCA (Figure 1.1.4).

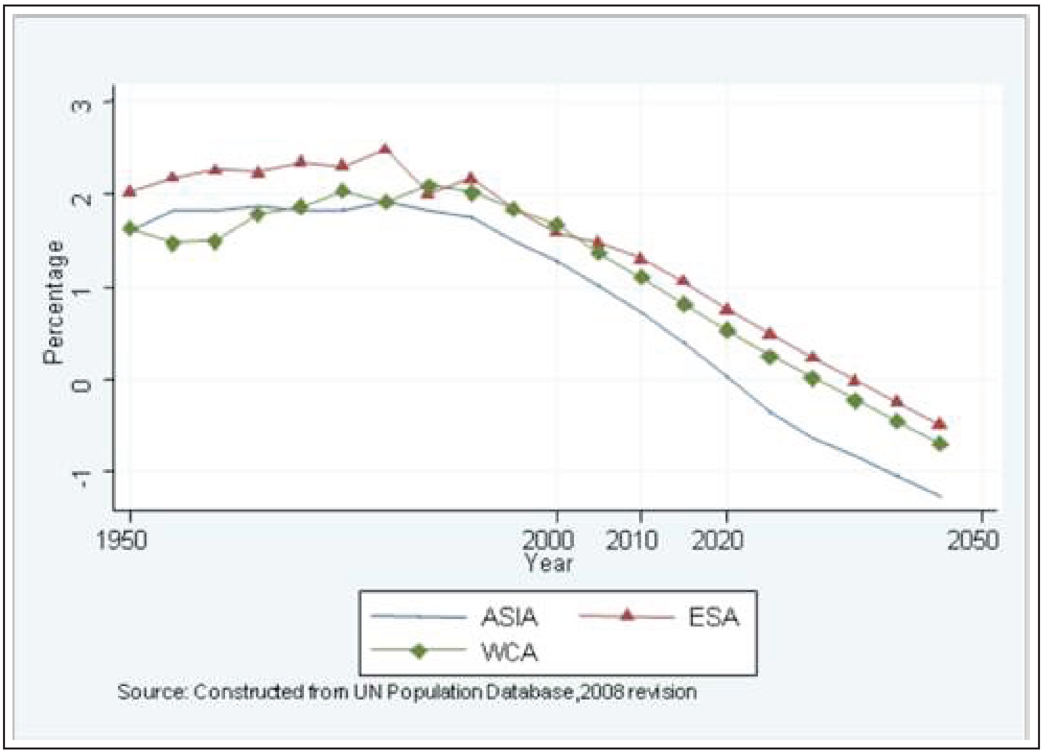

Figure 2.1.3. Projected rural growth rates by SAT region to 2050.

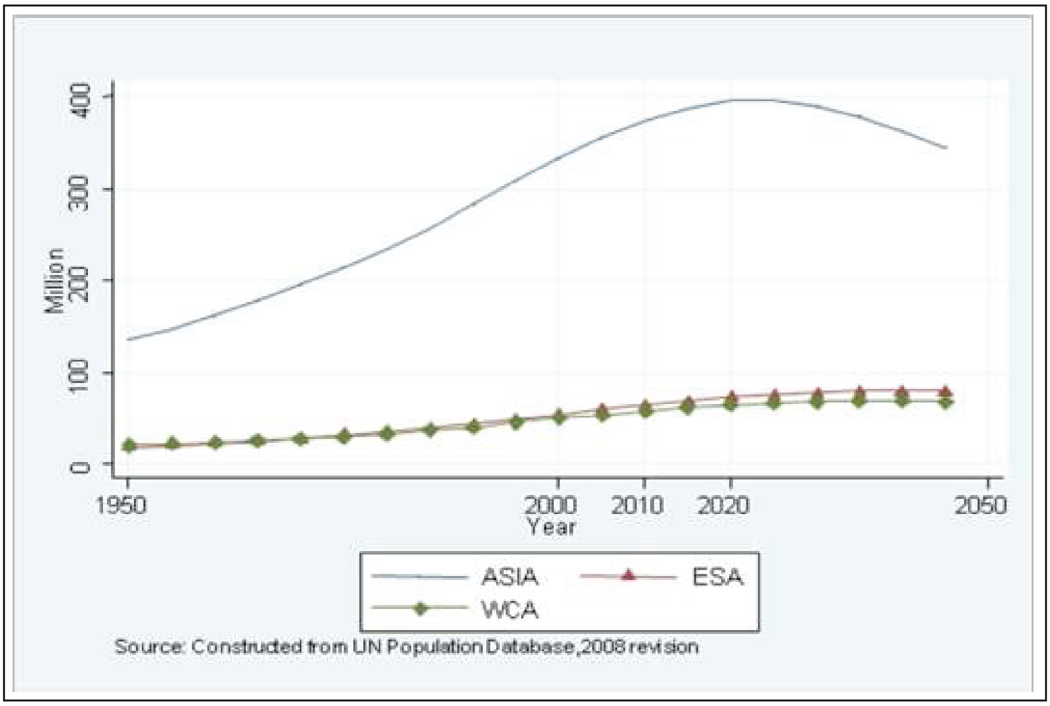

Figure 2.1.4. Projected rural population by SAT region to 2050.

2.2.4 Historically, the rates of growth in urban populations have been significantly higher in Africa's SAT than in India's SAT where the central and state governments have invested in several subsidized rural programs, such as public distribution of food for the poor and national employment guarantee schemes, that have reduced the rate of rural-urban migration (Figure 2.1.5). The very high rates of urban growth in ESA and WCA in the 1950s are mainly an artifact of a very small base population in cities and towns prior to Independence (Figure 2.1.5).

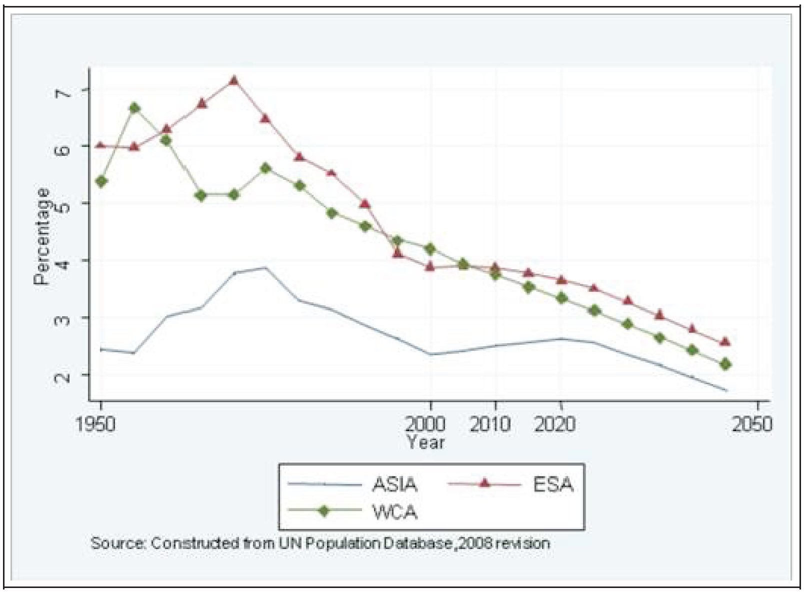

Figure 2.1.5. Projected urban growth rate by SAT region to 2050.

2.2.5 In Africa's SAT, growth rates in the urban population are a robust 3-4% from now until 2020. Niger, from a small base, and Uganda are projected to have the highest rates of urban growth (about 5.3%) of any country in this SAT data set.

High urban growth rates beget an ever-increasing urban population and are part and parcel of urbanization that is discussed in the next section (Figure 2.1.6).

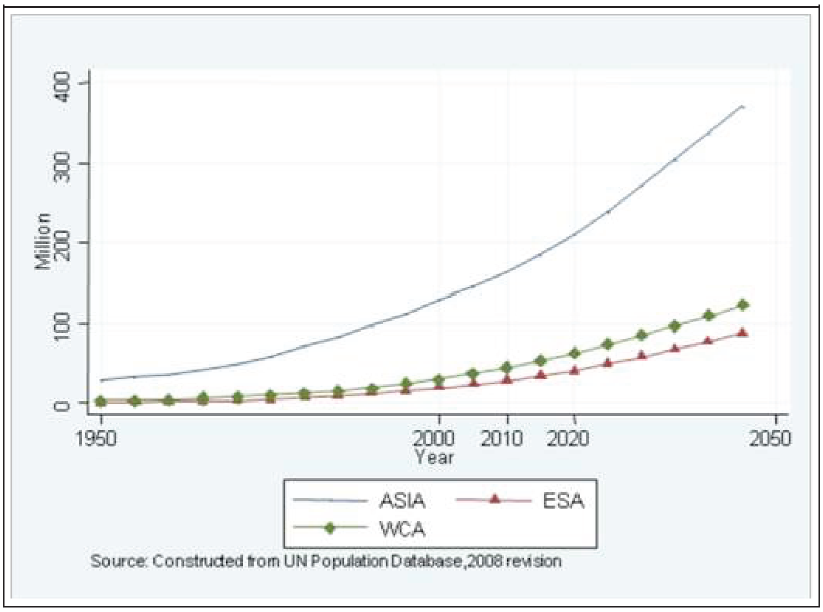

Figure 2.1.6. Projected urban population by SAT region to 2050.

2.2.6 An annual linear rate of population growth of 1.6% for the SAT as a whole implies that there will be about 115 million more mouths to feed between now and 2020; 46.5 million in Africa's SAT and 69 million in Asia's SAT. Achieving food security for this increase in population is a daunting challenge, but it also represents an opportunity.

2.2.7 **Population density**. Population density is gradually increasing in Africa's SAT (Figure 2.1.7), and rural population pressure is projected to intensify until 2035 or 2040. Higher population densities and greater land scarcity increase the demand for yield-augmenting technologies.

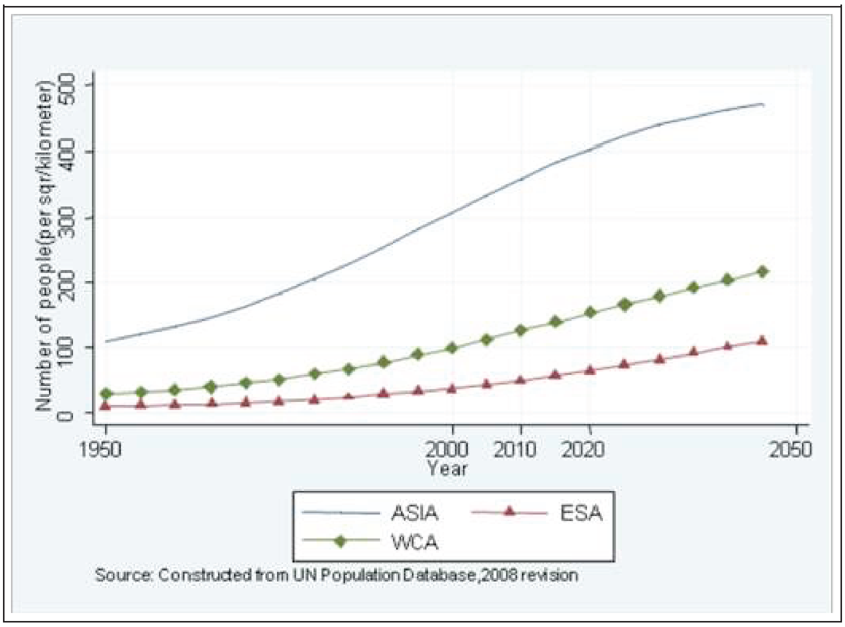

Figure 2.1.7. Projected population density by SAT region to 2050.

2.2.7.1 Still, it is important to point out the marked variation in population density among the 29 countries in Africa's SAT projected to 2020. Persons per km squared ranges from 3 to 209 with a simple mean of about 70 and a coefficient of variation of 84%. Generating technologies across such a wide range of population densities is a challenge. By 2020, twelve countries will still be relatively land abundant with a density of less than 50 persons per km squared. Weighting by projected SAT population in Africa in 2020 gives a substantially higher mean estimate of 110 persons per km squared, which was about the average population density prevailing in India's SAT at the founding of ICRISAT in 1972.

2.2.8 **Changing population trajectories in the ICRISAT study villages**. Growth in population in the ICRISAT study villages from 1975 to 2001 broadly conforms to the aggregate rural population growth rates for India as a whole (Figure 2.1.8). Since 2001, the variation in growth rates has widened across the study villages. Four different recent population histories are charted in Figure 2.1.8. Shirapur has experienced considerable in-migration because of upward shifts in agricultural growth from investments in canal irrigation. Aurepalle, with a growing population, is near a newly constructed municipal airport that services one of the largest cities in India. Dokur is characterized by erratic and declining agricultural production because of diminishing water resources. High rates of temporary urban-rural migration, mainly by labor households, have substantially dampened population growth in the village. Kanzara shows declining population in a high potential rain-fed environment where the profitability of agriculture has eroded over time in spite of moderately high rates of technological change. Many households in that village have recently migrated to the nearest market town. Although the aggregate rural growth rate in India is forecast to be positive until 2020, the increasing study-village disparity in population growth rates suggests that a sizeable minority of villages in India's SAT will experience stagnating population levels or will even be losing population before 2020.

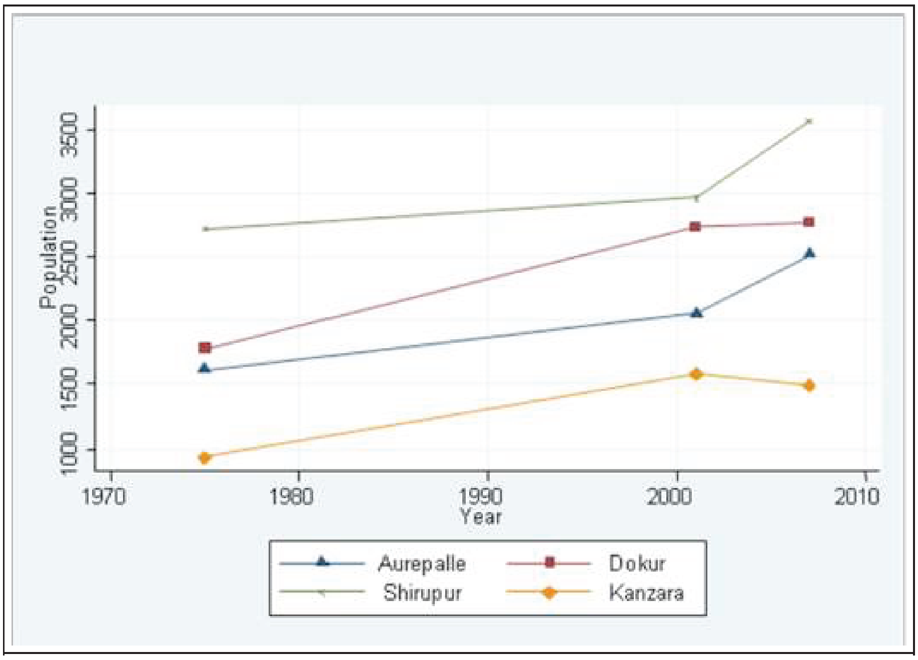

Figure 2.1.8. Population in four ICRISAT villages in 1975, 2001, and 2007.

2.3 The incidence and dynamics of absolute poverty in the SAT

2.3.1. In this section, we examine recent evidence on the levels and trends in absolute poverty in ICRISAT's three regions: India's SAT[4], West and Central Africa's SAT, and East and Southern Africa's SAT. The update on poverty levels, regional differences, and trends generates a few surprises, but the estimates in Table 2.2.1 and Figures 2.2.1 and 2.2.2 mostly confirm conventional wisdom.[5] The findings that reinforce a priori thinking include:

- The majority of the poor in the SAT still lives in India. About 10 of every 16 persons below their national poverty line in the SAT reside in India and an equal number of the remainder live either in WCA or ESA (Table 2.2.1).
- Rural poverty is pervasive in the SAT; the present ratio of the rural to the urban poor is about 3 : 1 (Table 2.2.1). The incidence of urban poverty is substantially less than rural poverty in each of the three SAT regions especially in WCA and ESA.
- The incidence of headcount index of poverty measured directly in national surveys or indirectly in international comparisons is substantially higher in Africa's SAT regions than in Asia's SAT (Table 2.2.1).
- The estimated poverty gap is also significantly higher in Africa's SAT than in India's SAT (Table 2.2.1). In other words, poverty is deeper in sub-Saharan Africa as the poor are further away from the dollar-a-day poverty line in WCA and ESA. The poor in India earned about \$0.87 per day in 2001; the poor in SSA earned about \$0.60 in the same year in 1993 purchasing-power parity dollars (Chen and Ravallion, 2004).
- India's SAT is characterized by a firm declining trend in both the incidence of poverty and the poverty gap (Figures 2.2.1 and 2.2.2). Although economic growth is increasing in some countries, such as Ghana, no marked improvement in the parameters of poverty is evident in sub-Saharan Africa as a whole.
- The population of the absolute poor is gradually trending downward in India as the decline in incidence has more than compensated for population growth. Absolute numbers of the poor are trending strongly upwards in sub-Saharan Africa.

2.3.2. Table 2.2.1 also contains two surprises. When we define the poverty line as \$2 per day, the interregional differences evaporate as each of the three regions is characterized by a headcount index that exceeds or approaches 80%.

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[4] We use India's SAT rather than Asia's SAT in the poverty analysis because over 90% of the poor in Asia's SAT live in India and because a credible poverty survey has never been carried out in Myanmar, the second largest SAT country in terms of area.

[5] It is important to point out several of the other assumptions and caveats that underlie the estimates in this section. Because of the infrequency of rural household income and consumption expenditure surveys, we are always viewing absolute poverty in the rearview mirror. The average year that the surveys took place across countries in the region was between 1994 in WCA and 1999 in India for the direct estimates and between 1999 in ESA and 2004 for the international estimates that are based on purchasing power parities. In the analysis of trends, the survey record is too spotty to do justice to trends for WCA and ESA separately, therefore, we rely on data for Sub-Saharan Africa as a whole which has had a relatively homogeneous record in terms of poverty performance.

Table 2.2.1. Poverty indices in the SAT by region in 2008.			
	India	**WCA**	**ESA**
National			
Rural headcount	30.2	42.8	54.3
Urban headcount	24.7	29.8	37.5
National headcount	28.6	38.6	49.9
International comparison			
$1/day (%)	34.3	54.0	42.8
Poverty gap 1	7.9	24.4	15.9
Poverty gap 2	35.0	47.7	40.0
$2/day (%)	80.4	82.5	78.1
Total poor (millions)	134	36	40
Rural poor (millions)	102	25	32
Urban poor (millions)	32	11	8

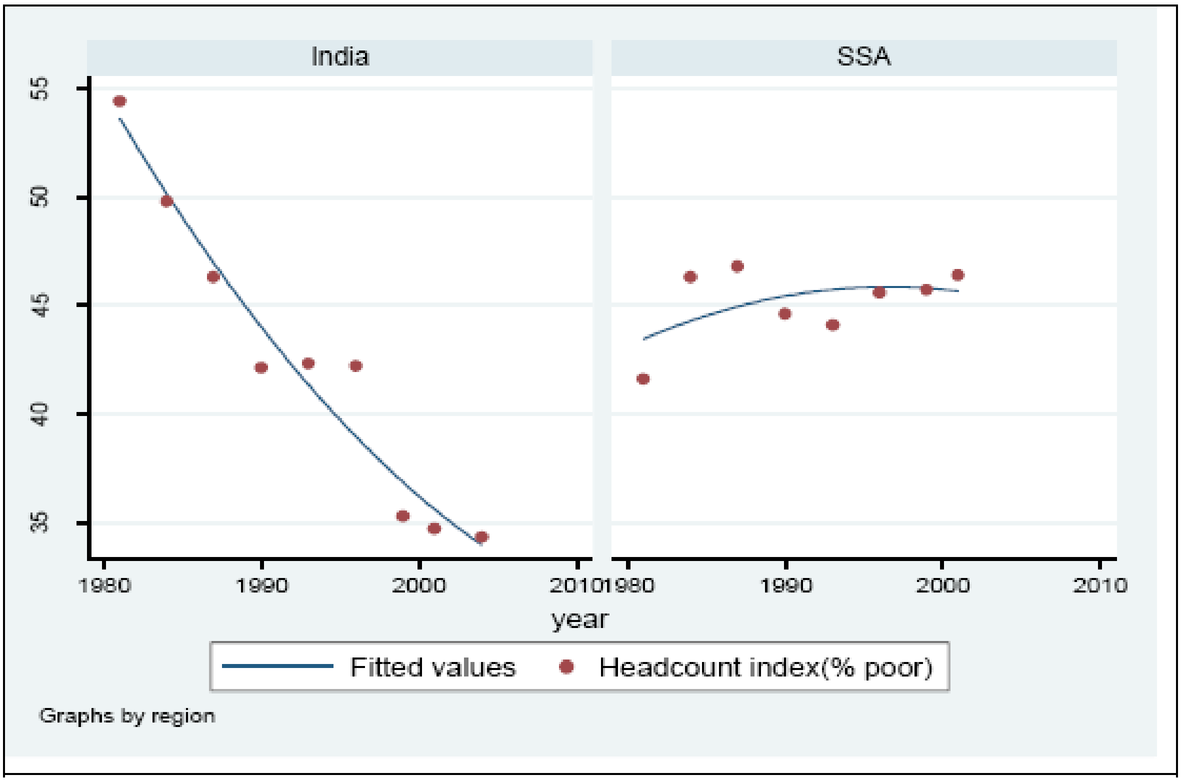

Figure 2.2.1. Estimated poverty incidence in India and Sub-Saharan Africa from 1981-2001.

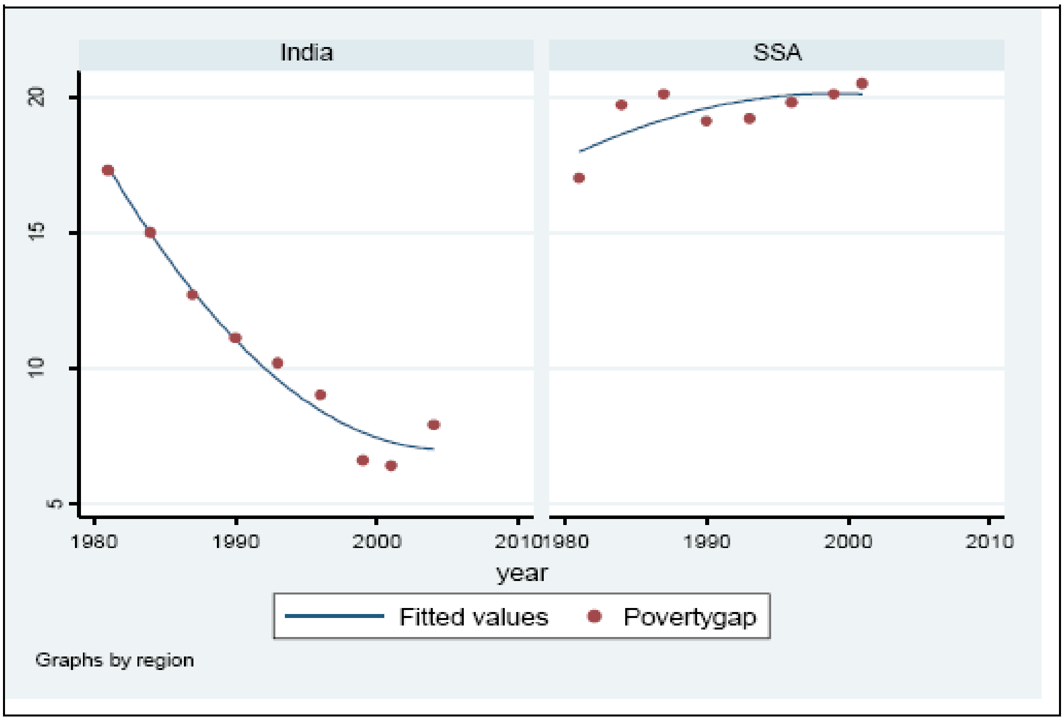

Figure 2.2.2. Estimated poverty gap in India and Sub-Saharan Africa from 1981-2001.

2.3.3. The ranking of the WCA and ESA regions on the incidence of poverty flip flops depending on whether national or international estimates are used. This strong reversal in ranking is most likely attributed to an over-valued exchange rate in Nigeria where agriculture is severely squeezed. Purchasing-power-parity comparisons placed that country first among all others in the prevalence of $1 a day poverty — 70% of the population was estimated to be below the poverty line in the 2008 World Bank Development Report on Agriculture. The poverty data are not sufficiently reliable to offer counsel on mean poverty differences between the two regions.

2.3.4. **Forecasting poverty incidence in 2020.** Combining the population projections with an expected trend in the incidence of poverty by SAT region gives an estimate of the number of poor by 2020. We focus on a trend scenario that is based on past trends reported in Figure 2.2.1 that shows declining poverty in India's SAT and stagnating poverty levels in Africa's SAT. The scenario is predicated on the assumption that in the past the future was like the past. From 1981 to 2002, $1-a-day poverty in international prices has declined steadily in India from 54.4% in 1981 to 34.7% in 2001 (Chen and Ravallion 2004). This decline results in a trend rate of change of -0.83% per annum. Starting with the poverty level reported in Table 2.2.1 and extrapolating change in poverty similar to the past results in an expected poverty incidence for India approaching 25% in 2020. The number of people in absolute poverty declines from about 185 million in 2010 to 150 million in 2020 as the rate of decline in poverty outstrips population growth. Assuming a constant headcount index for Africa's SAT, the number of poor increase from 95 million to over 115 million. Asia's share of the poor falls from 67% in 2010 to 58% in 2020.

2.3.5. **The fall in poverty in the ICRISAT Village-Level Studies in India**. Evidence from the Village-Level Studies (VLS) broadly confirms the downward trend in the incidence, depth, and severity of poverty in India's SAT (Badiani et al. 2007). In the late 1970s, when the studies started, poverty was widely shared across most households in the six study villages. Mean income per capita per year increased by 2.9-3.4% per annum in constant prices across the four size-holding strata in the sample between 1975-83 and 2001-04. Measured on consumption poverty, the mean headcount index declined from 76% to 22% over the roughly 20 years between the two periods.

2.3.6. Each village had a different story to tell on pathways out of poverty. Perhaps the most interesting narrative was that of Dokur where agricultural production fell between the two periods because of increasing water scarcity. Total farm income dropped from 94% of total income in the first period to 30% in the recent period. Growth in the wider economy and labor mobility combined with government welfare programs provided a means to more than compensate for the shortfalls in income from crop and livestock production and from farm labor (Nageswara Rao et al. 2009). In other villages, enhanced agricultural productivity and investments in irrigation contributed to substantial reductions in poverty.

2.4 Food prices and poverty

2.4.1. The reversal of the downward trend in food prices is the main external driver that has changed since ICRISAT's 2006 Strategic Vision. The spike in food prices in the summer of 2008 had a devastating effect on the poor especially those who consumed food grains as their staple food crops. International rice prices rose to over $1000 per ton and the cost of urea skyrocketed. The FAO index of food prices broke through a level of 150 for the first time.

2.4.2. Now, more than a year later, food prices have receded but, for the most part, have not returned to their earlier levels in real terms. The reversal of the downward trend in food prices should again put international agricultural research on the frontline in the battle against extreme hunger and poverty. In this sub-section, we address the cost of high food prices for the poor and try to identify a consensus on future food price trends.

2.4.3. **Poverty cost of the food price spike.** One of the most influential studies on the consequences of last year's rapid upturn in food prices was Zezza et al. (2009). They examined the effects of a moderate shock in the price of food staples of 10% across 11 developing countries with large data sets from the World Bank's Living Standard Measurement Survey (LSMS). Their results were predicated on the fact that for 10 of the 11 countries rural households were net buyers of food staples. Only about 1 rural household in 4 was a net seller of food staples across the 11 countries. So when food prices increased, three of four rural households suffered welfare losses, and the welfare of almost all urban households declined (Figure 2.3.1). Losses in welfare were proportional and inversely related to consumption expenditure as the economic position of poorer households deteriorated more than households with higher consumption expenditures. In the majority of the study countries, female-headed households bore more of the burden of the food-price increase than male-headed households (Figure 2.3.2). Vietnam was the only country where a sudden food-price shock led to a gain in rural welfare because the majority of households were net sellers of rice.

2.4.3.1. The recent spike in food prices was tragic for many poor people, but it was a good reminder of how successful agricultural research can impact poverty favorably, i.e., agricultural research would increase supplies, and this would put a downward pressure on food prices for net buyers (who are the large majority of rural households). The optimal scenario entails a delicate balance between gradually rising food prices over time that are attractive to producers, and the maintenance of relatively constant real prices that do not hurt consumers.

2.4.3.2. Productivity-increasing technologies, generated by agricultural research, also impact poverty favorably by stimulating growth in income to producers and earnings to laborers through wage effects. Of the three mechanisms, direct income to producers was the most important in the short term in reducing poverty, but, in the longer term, food-price effects have historically been the most important contributor to poverty reduction from yield-increasing technologies in India (Datt and Ravallion 1998).

2.4.4. **The emerging consensus on the future trend in food prices.** Crystal ball gazing on emerging trends in food prices has become a hot topic since the surging prices of 2007 and 2008.[6] Factors that influence demand are well-known: (1) population growth, (2) income growth, (3) urbanization, and (4) alternative end uses. As discussed in the next section, rural population growth is positive in the three ICRISAT regions, and income growth is likely to continue in India's SAT. Urbanization strongly decreases the demand for ICRISAT's cereals as food grains, so their prospects are limited by the pace of urbanization. Biofuels is a new alternative use that is only now being incorporated into models of food price projections (Alexandratos, 2009).

2.4.4.1. Supply constraints are also familiar to agricultural scientists: (1) increasing inertia in the growth of yields in major food grains especially rice and wheat, (2) stiffening competition for limited supplies of water for irrigation and the high costs of prospective investments in canal irrigation, (3) worsening but largely undocumented land degradation, and (4) stagnating application in the use of transgenic biotechnology on food crops in general and in sub-Saharan Africa in particular in field trials leading to released varieties. In spite of these and other constraints, area expansion and technological change enhancing yields has historically kept supply ahead of increasing demand resulting in declining prices for crops, a trend that was first identified in the 1870s (Binswanger-Mkhize and McCalla, 2008). Like oil companies that invest proportionally more after a bout of strong prices, farmers have tended to over-invest in response to high crop prices that has set the stage for another long round of declining real prices for food.

2.4.4.2. This boom and bust cycle of short-term price spikes leading to overinvestment followed by long periods of depressed prices is now

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[6] This section draws heavily on Binswanger-Mkhize and McCalla (2008) and on Fischer et al. (2009).

viewed as unlikely to recur in the future for several reasons that point to tighter global markets for staple food crops. Prospects for area expansion are limited to a few countries where land abundance still prevails. However, several of these countries are in the SAT. Most importantly, growth in cereal yields has been perceived to be slowing since the Green Revolution. Recent analysis is consistent with lighter absolute annual yield gains over time in rice and wheat, but not in maize where annual absolute yield increments accelerated from 1980 to 2007 (Fischer et al. 2009).

2.4.4.3. Since 1960, yields of major food grains have increased at a linear rate of 43 kg/ha per annum. Projecting this rate forward to 2050 and combining it with a medium variate of demand growth results in a large projected deficit that in turn leads to a 44% increase in real agricultural prices (Tweeten and Thompson, 2008).

2.4.4.4. In the IFPRI IMPACT model, the rate of yield increase is projected at a lower level of 37 kg/ha mainly because of increasing water scarcity (Rosegrant et al. 2008). This lower rate of yield growth translates into real price increases ranging from 60% for rice to 97% for maize in 2050.

2.4.4.5. Two aspects of the IFPRI projections warrant comment. Firstly, demand is estimated to slow down considerably in the second 25 years (between 2025 and 2050) from 1.4% in the first period to 0.4% in the second. Secondly, their projections are highly sensitive to assumptions on yield growth. Increasing public investment in agriculture by 13%, bumping yield growth by 0.4 percentage points, is sufficient to reinstate the downward trend in real food prices and to halve child malnutrition by 2050. But this optimism is equivalent to increasing yield growth by more than one-third and appears to be a strong assumption (Fisher et al. 2009).

2.4.4.6. Prospects for yield growth in rice, wheat, and maize are addressed in Fisher et al. (2009). Their analysis suggests that:

- Yield gaps between on-farm and attainable yields are closing at a slow rate in most contexts with the exception of maize in Africa where the gap is estimated at 200%;
- Higher potential yields translate into higher on-farm yields. In both wheat and rice, heterosis offers the best prospects for raising yield potential, and private-sector investment in both crops will become attractive when heterosis becomes more of a commercial reality paving the way for further yield increases;
- Genetic modification using transgenes is unlikely to contribute to raising yield potential;
- Transgenic varietal change is seen as an effective means to close the yield gap between on-farm and attainable yields especially in the area of breeding for resistance or tolerance to biotic stress;
- Putative drought tolerance genes are characterized by trade-offs in well-watered conditions or often do not work in the field; however, Monsanto plans to release maize hybrids carrying cold shock protein genes in backgrounds adapted to SSA on a royalty-free basis in a private-public partnership, and
- New molecular tools for selection will likely increase breeding efficiency but the marginal cost of yield gains will also rise.

2.4.4.7. In narrowing the gap between on-farm and attainable yields, Fisher et al. (2009) are not optimistic about the prospects for lower real prices of nitrogen (N). Historically, the price of urea tracks the price of natural gas. Increasing the efficiency of N use and biological nitrogen fixation are viewed as the best options to combat rising N prices but N-fixation in cereals is not seen as feasible by 2050. Both of these options have greater applicability in irrigated agriculture than in dryland farming. Global phosphorus production is projected to rise until 2034 when extraction peaks. World reserves of potash are ample to provide supplies beyond 2050.

2.4.4.8. Turning to demand from biofuels and biodiesel, the USDA projections to 2018 are consistent with a slackening in demand compared to the recent past (USDA 2009). They predict that 35% of the corn crop will be utilized as biofuels in 2018. Seasoned observers see biofuels as a bridge technology for the next two decades until superior energy-efficient alternatives come on stream. Utilization of crops as biofuels and biodiesel has also resulted in trade distortions that have led to higher prices of food crops. Almost all production of biofuels—even ethanol in Brazil as recently as 2007—and biodiesel require trade protection, subsidies, or both to be profitable.

2.4.4.9. Although an increasing trend in real food prices is a real possibility to 2020, the abatement of the downward trend in real food prices is a greater certainty. Because agriculture was so seriously neglected in the 1980s, 1990s, and early 2000s in official development assistance and in public-sector investment in developing countries, it is unlikely that supply increases will be forthcoming to change the current fundamentals and create the conditions for the renewal of a downward trend in real food prices from now to 2020.

2.5 The potential to reduce absolute poverty in the SAT from the perspective of ICRISAT's commodity mandate

2.5.1. In developed countries, agricultural research does not contribute much to the alleviation of absolute poverty. With economic growth and development, relative inequality of income and consumption expenditure looms larger in the definition of poverty lines. With structural transformation, most of the poor reside in urban areas. The share of total expenditure allocated to food rarely exceeds 20% for the poor. The rural poor, a small minority of the indigent, derive a small share of income from agriculture; significant breakthroughs in agricultural research do not impact materially on their lives in a pronounced manner. In the developed country context, agricultural research is a very blunt instrument to tackle poverty; hence, investments in agricultural research are seldom motivated by poverty considerations.

2.5.2. The poor in the developing countries are characterized by an opposite set of characteristics in terms of the definition of poverty lines, the size of food shares, the incidence of rural vs. urban poverty, and the role of agriculture in household income. With economic growth and development, the potential for agricultural research to contribute to poverty alleviation declines slowly over time. Below we examine some trends in the poverty alleviation potential of agricultural research centered on ICRISAT's crop mandate.

2.5.3. **The close link between poverty reduction potential and value of production.** We need to introduce the motivation for the use of value of production as a proxy variable for poverty alleviation potential. Several priority-setting exercises for agricultural research have shown that value of production of crop and livestock commodities are closely associated with poverty reduction potential (Byerlee 2000, Walker et al. 2006). For instance, a uniform 20% increase in productivity across the most important commodities in Mozambican agriculture results in decreases in the severity of poverty that are highly correlated with the relative importance of the commodity in value of production (Figure 2.4.1). The same remarks apply to the close correspondence between poverty alleviation potential and the value of production across agro-ecologies (Figure 2.4.2). These results are based on adding farm income equivalent to the above productivity effects to poor and non-poor households in a nationally representative 5,000 household rural income survey. This analysis is very partial, does not consider labor markets, nor does it incorporate local price effects of technological change as all households are viewed as producers if they produced the commodity in the survey. That the relative importance of value of production can be used as an indicator of poverty alleviation potential is not surprising, particularly in an undifferentiated farm sector mostly producing nontradeable goods for domestic production.

2.5.4. **Poverty reduction potential and ICRISAT's crop mandate in the Asian SAT.** Shortly after Independence, in 1950-51, ICRISAT's crops accounted for about 45% of the value of crop production in India's SAT (Figure 2.4.3). At that time, the share of sorghum was superior to the share of wheat in value of production for the country as a whole. Fifty five years later the share of ICRISAT crops in value of production has fallen to about 20% in India's SAT. By the early 2000s, the share of ICRISAT-mandate crops in gross cropped area in India's SAT had fallen to about 30%.

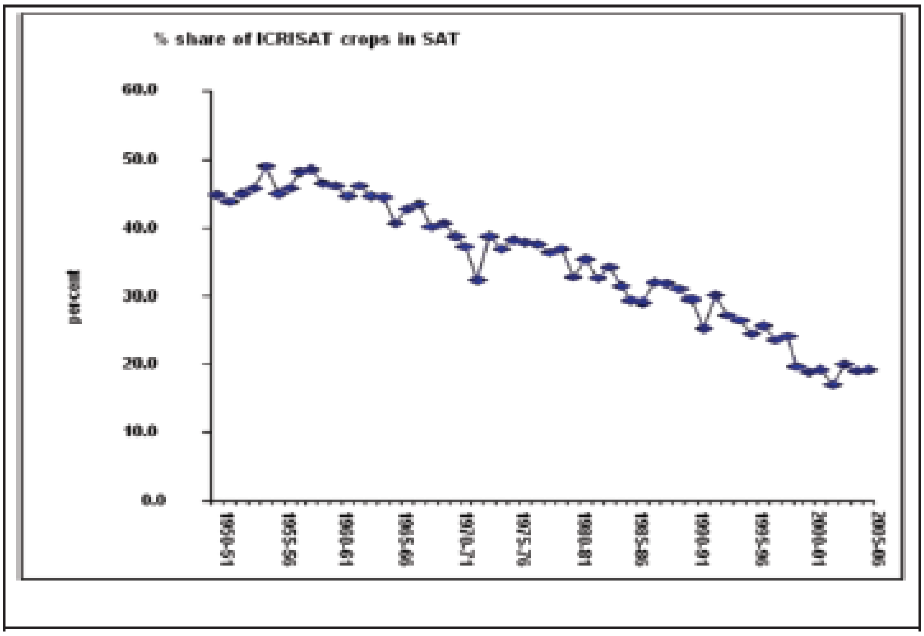

Figure 2.4.3. Share of ICRISAT's mandated crops in value of production in India's SAT (1950-51 to 2005-06)

2.5.4.1. Turning to the All-India data for all crops and livestock commodities, a similar trend prevails with different starting and ending points (Figure 2.4.4). The value share of mandate crops to all crops declined from about 18% in the late 1950s to about 6% in 2005-06. Comparable estimates for the mandate crops' share in the agricultural sector (crops plus livestock) are about 12% in the late 1950s to 4% in 2005-06. This decline in value share was equivalent to a fall from about 30% of gross cropped area in the mid-1960s when the ICRISAT-mandated commodities approached 50 million hectares to about 18% by 2005-06.

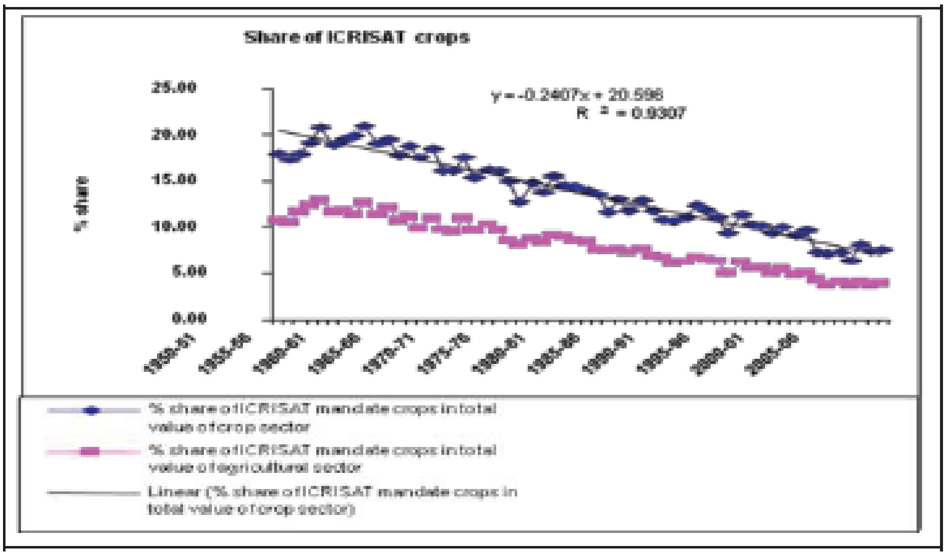

Figure 2.4.4. Shares of ICRISAT's crops in All-India value of agricultural production (1950-51 to 2005-06).

2.5.4.2. These secularly declining shares of the institute's crops in value of production do not imply that ICRISAT'S crop mandate is entering a stage of obsolescence or that ICRISAT scientists have worked themselves out of a job in India. The number of the rural poor in India's SAT is at an all-time high. But the contribution that ICRISAT makes to poverty alleviation is changing qualitatively. At the founding of the Institute in the early 1970s, the time was riper to make a larger contribution per poor person benefited in the form of gains in real income to net buyers of the mandate food crops and to net sellers of mandated cereals and grain legumes. Nowadays, an equivalent productivity contribution is more incremental and is more widely shared among poor net buyers allowing them to make small gains that move them nearer to a poverty threshold. Net sellers in good years, probably for the most part, are above the poverty line. A broad-based contribution is just as important as a concentrated one, but the idea that successful commodity research at ICRISAT is going to leverage poor people across a poverty line is increasingly false unless they are near the poverty threshold prior to the transfer of an ICRISAT-related innovation.

2.5.4.3. Showing a decline in the real value of production of the ICRISAT mandate crops would be a more damning trend. Growth in real value of production of ICRISAT's mandate crops including byproducts has slowed down, but it is still rising, approaching about 8 billion dollars a year in India in constant 1990-91 prices (Figure 2.4.5). Congruence—that is ICRISAT's expenditure in India as a proportion of value of mandate species production in India—without considering potential for spillovers to the rest of Asia and to sub-Saharan Africa (documented in Shiferaw et al. 2004) is about 0.25%. This figure is considerably below the national program's (ICAR's) congruence estimate that approaches 0.5%, which is low by international standards.

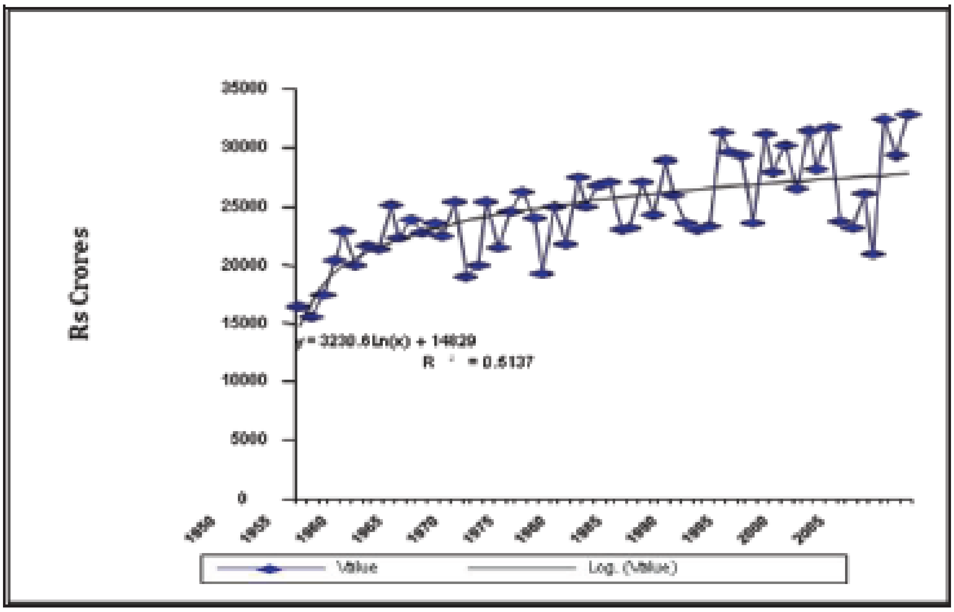

Figure 2.4.5. Value of production in constant prices of ICRISAT crops (1950 to 2005).

2.5.4.4. Returning to Figure 2.4.4, all the ICRISAT crops displayed a declining value share during the second half of the 20th century. Among 46 crop and livestock categories that were the basis for the All-India graph in Figure 2.4.4, twelve exhibited a decline in relative importance equivalent to an erosion of 1% per annum from 1964/65 to 2005/2006. Crops becoming less economically important are linseed, barley, sorghum, finger millet and other small millets, green gram, chickpea, pigeonpea, groundnut, other fibers (new), black pepper, miscellaneous crops, and pearl millet. In other words, all of ICRISAT mandate crops fell into the lower quartile of commodities that showed the most erosion in value share.

2.5.4.5. With changing preferences and differential rates of technological change, it was difficult to maintain a constant stake in value shares. Nevertheless, eight generalized crop categories were able to more than double their value share over the last 40 years: other oilseeds, mainly soybean, rapeseed and mustard, castor, other narcotics, potato, other horticulture, rubber, and floriculture. Additionally, dairy, poultry meat, and eggs registered a strong performance.

2.5.4.6. Table 2.4.1 provides disaggregated commodity information for the districts in India's SAT that are represented in Figure 2.4.3. India's SAT accounts for about 1/3rd of the value of these commodities. Fruits, rice, vegetables, wheat, and cotton are the big five in value of production. Groundnut, soybean, chickpea, sugarcane, and sorghum round out the top 10. By now, soybean is surely in the top five. Turning to the relative importance of the SAT in All-India crop production in the last column of Table 2.4.1, it is easily seen that the SAT is the primary home of the ICRISAT mandate crops with the exception of pearl millet, and that the SAT is a natural habitat for oilseed production. Updating Table 2.4.1 with the most recent data is a priority for the purposes of strategic planning.

Table 2.4.1. Value of production (in rupees lacs) of crops in India's SAT in 2003-04 based on district data and ordered by relative importance between the SAT and non-SAT.

Rank in total value of production in the SAT		Sum of SAT	19-state total	% value in SAT
20	Safflower	18655	19037	97.99
7	Soyabean	672666	741483	90.72
10	Sorghum	496482	554953	89.46
16	Sunflower	126213	153889	82.02
17	Castor	89501	109247	81.93
6	Groundnut	802155	1069248	75.02
5	Cotton (Lint)	910724	1305064	69.78
13	Pigeonpea	265792	390418	68.08
19	Finger millet	77405	120134	64.43
11	Maize	470441	759638	61.93
8	Chickpea	603801	1041706	57.96
18	Seasmum	84667	151109	56.03
21	Linseed	10922	23120	47.24
1	Fruits	1986544	5000043	39.73
12	Minor pulses	318073	838719	37.92
14	Pearl millet	194698	633040	30.76
9	Sugarcane (Gur)	565152	2149770	26.29
3	Vegetables	1045727	4234909	24.69
2	Rice	1727030	7486151	23.07
15	Rape & Mustard	171125	840511	20.36
4	Wheat	959185	5639759	17.01
22	Barley	7183	65071	11.04
19-state total		**11604141**	**33327020**	**34.82**

2.5.4.7. Partnering with other research institutions is one means of combating the relative erosion in value share in ICRISAT's mandate. In India's SAT, ICRISAT has forged partnerships with AVRDC, ILRI, and IWMI among others in a more inclusive approach to agricultural development of the SAT. Another way to tackle the problem of mandate erosion is to shift emphases in the mandated crop. Since 1999, sorghum breeding has focused on diverse traits consistent with expanding end uses (Reddy et al. 2006). The need for dual-purpose varieties has been a recurring theme in social science since the late 1980s. More recently, the large project HOPE centers on applied research and technology transfer in post-rainy season sorghum, which, compared to rainy-season sorghum, has suffered from relative neglect in resources destined for sorghum research in peninsular India.

2.5.4.8. New initiatives are another mechanism to address this issue. The case for new initiatives, such as assigning greater importance to oilseeds, is stronger if the Institute is willing to close down mandated areas that are declining in absolute importance. The strategic plan is an opportunity to evaluate the phasing in of new initiatives and the phasing out of old areas of work that are less economically desirable than they were in the past.

2.5.5. **Poverty reduction potential and ICRISAT's crop mandate in the SAT of WCA and ESA.** Data bases on value shares by commodity were not initially found for sub-Saharan Africa, therefore, we calculated the relative importance of the mandate species in total arable land, which should be associated with value share. In WCA, the summed area share for sorghum, pearl millet, and groundnut declined in the late 1970s and early 1980s, but recovered strongly during the mid and late 1980s (Figure 2.4.6). Some of the fall and subsequent rise was conditioned by the behavior of sorghum. Presently, the three ICRISAT crops occupy slightly over 40% of arable land in WCA's SAT.

2.5.5.1. Somewhat surprisingly, the same trend of constancy is evident in ESA's SAT where the mandate crops' aggregate area share has oscillated between 15-20% from 1961-2007 (Figure 2.4.7). Apparently, expanding area to maize has not made a significant dent in the relative importance of the ICRISAT crops at the regional level.

2.5.5.2. ICRISAT field-crop performance in the two regions is summarized in Figure 2.4.8 with two WCA scenarios, with and without Nigeria. Comparing these two scenarios confirms the constancy of the ICRISAT crop share over time and suggests that the Nigerian data were associated with the depression of the area-cultivated share in the late 1970s and early 1980s.

2.5.5.3. The maintenance of relative importance was achieved in spite of advancing maize- and cowpea-growing area in WCA (without Nigeria) and maize-growing area in ESA (Figures 2.4.9 and 2.4.10). The maintenance of relative importance for sorghum, pearl millet, and groundnut in WCA is surprising given increasing rice and wheat imports. Nevertheless, the present 40% level could easily continue to 2020. The capacity for agricultural research on the mandate crops to generate favorable outcomes on poverty has not diminished over time.

In that vein, the USDA, in their latest projections, predicts small increases in sorghum production in sub-Saharan Africa to 2018 (USDA 2018). It is also surprising that several of these crops have stayed the course in ESA where the expansion of maize area has been one of the dominant themes in regional supply response for several decades.

2.5.5.4. Times series of commodity-specific value of production are available for selected countries in Africa's SAT. Analysis of these data in Figure 2.4.11 supports the finding that the ICRISAT mandated commodities are characterized by diminishing relative importance in several selected countries, especially Mali and Malawi. In Mali, the decline in relative importance has been steeper than the decrease in India as the share of ICRISAT crops has fallen steadily from 40 to 20% between 1970 and 2005. However, the country-specific graphs in Figure 2.4.11 also display considerable variation in this estimated trend. In Burkina Faso, the ICRISAT mandate crops have contributed about half of the value of crop production throughout the period. Despite this variation, the countries share a common tendency: the decline in value was greater in the first half of the period than in the more recent past. Estimated shares seem to be stabilizing in most countries in Figure 2.4.11.

2.6 Poverty reduction potential and the dynamics of income sources in the SAT

It is easy to understand how crop improvement research can contribute to poverty alleviation when the bulk of rural households derive a large share of their income from crop production. But several production-related contexts dampen the capacity of agricultural research to influence poverty alleviation. Households that derive proportionally more income from crop agriculture may also be characterized by higher household income. Economic growth stimulates diversification of income sources with structural transformation. Broadly speaking, with agricultural and economic development, households who had relied heavily on crop production diversify across income sources, and then specialize in non-farm activities in a mature, developed economy.

The above two contexts could apply to India's SAT. In Africa's SAT, it is frequently argued that livestock production dominates crop production in terms of value share. Moreover, because of risk management, wealth accumulation, and cultural aspects of livestock production, farmers are much more interested in livestock production than in crop production (Ryan and Spencer 2001).

2.6.1. **Income sources in rural India in 2003.** Analysis of large-scale survey data from rural India for farm households, broadly defined and arrayed from the perspective of farm size in Table 2.5.1, generates findings that have an enduring quality. All household categories have at least a 15% share in crop agriculture, but shares in crop agriculture appear to be concentrated in the three largest farm-size categories that represent slightly more than 25% of the farm household population. Unlike the relative importance of livestock that is equally spread across all farm-size categories, crop shares are positively associated with per capita income. These data give the erroneous impression that crop-related innovations will not result in poverty alleviation because crop income is concentrated in the hands of the non-poor.

Table 2.5.1. Income sources in rural India in 2003 by farm category among farm households.*

Farm category	Households	Per capita income	Agriculture	Livestock	Wages & salaries	Non-farm business
	(%)	(Rs)		(% Share)		
Sub-marginal (0.002-0.5 ha)	40.0	8298	16.2	14.8	36.1	32.9
Marginal (0.5-1.0 ha)	23.3	8703	36.3	15.0	21.4	27.4
Small (1.0 -2.0 ha)	19.0	9796	49.6	15.7	15.4	19.3
Medium (2.0-4.0 ha)	11.5	13576	56.6	13.8	9.7	19.9
Large (>4.0 ha)	6.3	21325	67.0	12.2	4.4	16.4
All	100.0	10411	41.4	14.4	19.8	24.4

*** Based on an NSSO sample of over 50,000 households in more than 6,000 villages. A farm household is defined as one that engages in any agricultural activities.**

Source: Birthal et al. 2008, Table 4.1.

When the data in Table 2.5.1 are recast by income quintile (Table 2.5.2), the scope for crop improvement research to contribute to poverty alleviation broadens considerably. Agricultural shares are weakly and inversely correlated with per capita income. The four lowest income quintiles on average still derive 40-50% of their income from crop production in terms of gross value of production.[7]

Implicit in Table 2.5.2 is differentiation in the labor market and the non-farm business sub-sector. The highest income households often have a productive non-farm business and/or are employed in a permanent job. Therefore, the prospects for agricultural research to influence poverty are brighter than what is communicated by farm-size categories.

2.6.2. **Dynamic evidence from the ICRISAT Village Level Studies.** While the cross-sectional data in Table 2.5.2 underscores the promise of agricultural research to contribute to poverty alleviation, the time-series data in Figure 2.5.1 tell a different story. These data are intergenerational, spanning about 25 years. Figure 2.5.1 is elaborated from the perspective of the farm-size categories of the households at the founding of the ICRISAT VLS in 1975. Although the conceptual underpinnings for describing rural household income may be somewhat different in the two periods, the constructs are close enough to outline the broad trends that have taken place.

[7] These estimates for the relative importance of crop income may be overstated somewhat because the data are based on gross value of production. The estimates for agriculture, livestock, and non-farm business are overstated because out-of-pocket expenses have not been deducted from gross value of production to estimate net returns to own factors of production. By the same reasoning, wages and salaries are likely understated.

Table 2.5.2. Income sources in rural India in 1999 by income quartile among farm households*

Income quintile	Per capita income	Agriculture	Livestock	Wages & salaries	Non-farm business
	(Rs)		(% share)		
Lowest	2503	49.2	18.7	28.4	3.7
Second	4079	45.2	19.2	31.2	4.4
Third	6162	43.8	19.6	30.1	6.4
Fourth	9834	45.3	19.2	25.2	10.3
Highest	32324	38.4	10.7	13.5	37.4
All	10411	41.4	14.4	19.8	24.4

* Based on an NSSO sample of over 50,000 households in more than 6,000 villages. A farm household is defined as one that engages in any agricultural activities.

Source: Birthal et al. 2008, Table 4.1.

2.6.2.1. Of the four farm-size categories graphed in Figure 2.5.1, labor households are the only group where the relative importance of different income sources has not changed. About 60% of their income still comes from wage earnings and salaries. Occupationally, they have not diversified into other income sources with the same propensity of small, medium, and large farm households. Both medium and large farm households display greater diversity of sources in the second period compared to the first. For small farm households, the level of diversity is about the same, but the ranking of the sources has changed. Business and trade have replaced crop production as the second most important source. All four household categories relied more heavily on business and trade in the early 2000s than the same households did in the mid-1970s and early 1980s. By the same token, agricultural income sources from crop and livestock production have diminished in importance for each of the four farm-size groupings. Over time fewer households in the study villages state that their primary occupation is agriculture.

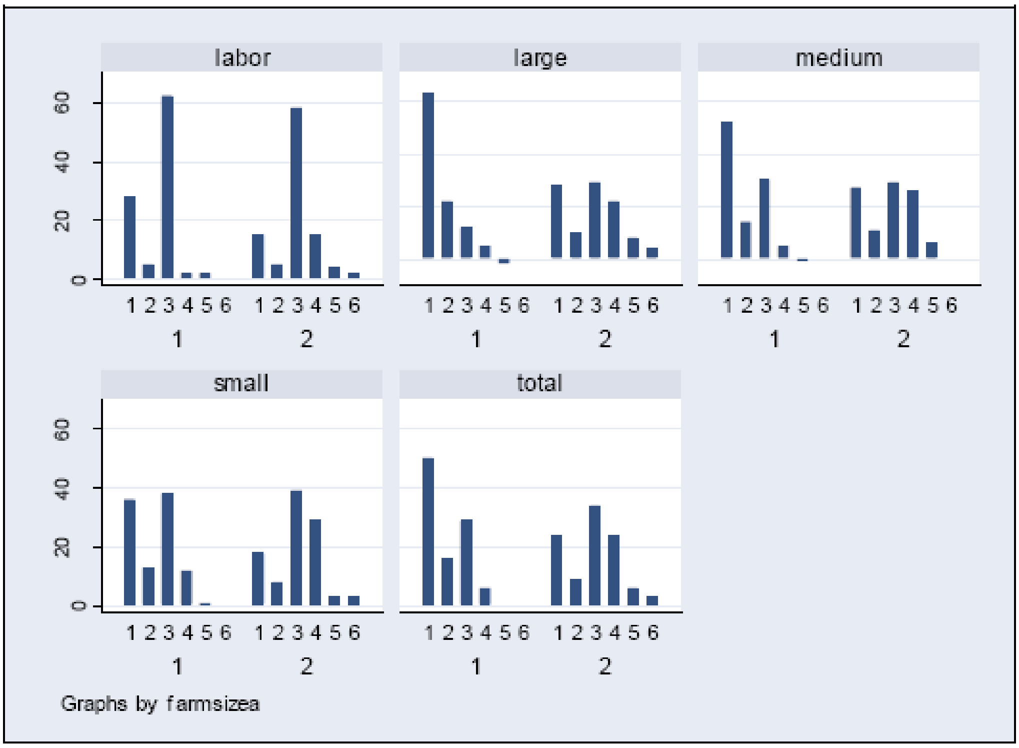

Figure 2.5.1. Relative importance of income sources for 318 VLS households in India's SAT between 1975-83 (1) and 2001-04 (2). Income sources:1=crop, 2=livestock, 3=labor, 4=trade, 5=transfer and 6=net migration. Source: Badiani et al. (2007).

2.6.2.2. The leveling in the importance of income sources is not surprising and reflects economic growth in a transforming economy. If we ranked the village households by quintiles based on per capita income, we would likely arrive at the same finding as the All-India cross-sectional data: crop agriculture still plays an important role in the income formation of many households in the poorest two quintiles. Over time the relative importance of crop income is declining, but a snapshot at any point in time reveals that crop income plays an important role in the well-being of the poor.

2.6.3. **Heterogeneous evidence from rural household surveys in Africa**. The heterogeneous nature of African agriculture is reflected in geographically dispersed income sources (Ndjeunga and Savadogo 2002). For example, a review of 25 studies, mainly from village sources, showed that non-farm income varied between 15 and 93% as a share of total household rural income (Reardon 1997).

2.6.3.1. National-level rural household surveys in Mozambique over several years reinforce some of these smaller survey findings but they also present another reality (Table 2.5.3). These surveys are a rich source of information as data on more than 40 sources are canvassed.

2.6.3.2. Mozambique is the poorest country where Michigan State University has participated with national governments in the conduct of rural household income surveys in ESA and WCA. Therefore, the

Mozambican evidence reflects the highest concentration in crop income, lowest concentration in livestock income, and the least diversity of income sources among the MSU-assisted surveys. The main findings in Table 2.5.3 are the following (Mather 2009):

Table 2.5.3. Shares of rural household shares by source in Mozambique, in 2002-03 and 2005-06.

Quintiles of total net HH income/AE	Crop Production		Retained Food crops		Food crop Sales		High value crops		Livestock sales		Unskilled farm labor		Farm income	
	2002	2005	2002	2005	2002	2005	2002	2005	2002	2005	2002	2005	2002	2005
1-low	82.5	71.8	73.8	61.6	4.5	6.7	3.7	3.8	3.8	3.3	1.4	5.6	87.1	80.7
2	80.8	70.3	72.6	58.7	4.3	6.8	3.9	4.9	2.5	2.6	1.6	4.5	84.9	77.3
3-mid	78.3	65.8	70.0	54.7	4.9	6.0	3.4	5.3	2.6	2.9	2.2	3.4	83.2	72.1
4	71.2	61.2	61.9	50.7	4.8	5.1	4.4	5.2	2.4	2.1	2.9	3.5	76.4	66.7
5-high	51.3	46.4	42.8	37.5	3.9	3.8	4.7	4.8	2.1	1.3	1.9	1.7	55.3	49.4
Average	72.8	63.1	64.2	52.6	4.5	5.7	4.0	4.8	2.7	2.4	2.0	3.7	77.4	69.3

Quintiles of total net HH income/AE	Unskilled nonfarm wage		Skilled nonfarm wage		SME natural resource		SME other – low		SME other – high		Remittance/ pension		Nonfarm income	
	2002	2005	2002	2005	2002	2005	2002	1005	2002	2005	2002	2005	2002	2005
1-low	0.6	0.7	0.1	0.9	3.3	3.3	2.8	4.9	1.9	2.7	3.3	5.5	12.0	18.0
2	1.3	2.0	0.5	1.3	3.6	5.1	2.9	5.6	3.0	3.4	3.8	5.2	15.1	22.5
3-mid	2.5	2.4	1.5	3.1	3.6	5.6	4.0	6.3	2.7	5.0	2.5	4.5	16.8	27.8
4	3.0	3.7	4.8	7.1	3.6	4.7	4.9	5.5	4.3	7.9	3.1	4.5	23.6	33.3
5-high	2.7	3.0	12.8	16.5	5.0	5.3	6.1	5.4	13.2	15.6	4.8	5.0	44.7	50.8
Average	2.0	2.5	4.0	5.8	3.8	4.8	4.1	5.5	5.0	6.9	3.5	4.9	22.4	30.5

HH = household; AE = adult equivalent.
Source: Mather, 2009, Table 13; Constructed from TIAA, 2005.

- On average, crop production was the main source of income for all households in both cropping years, 2002-03 and 2005-06;
- The poorer households relied more heavily on crop production in the formation of income in both cropping years;
- The share of crop production declined between 2002 and 2005 mainly because 2005 was characterized by drought and because of a slow trend towards economic progress since the cessation of civil war in 1992;
- The bulk of income from crop production is in the form of food produced for home consumption. Only small amounts of food crops are sold;
- Participation in higher value cash crops such as cotton and tobacco is geographically limited and their sales do not contribute substantially to any of the household quintiles;
- Livestock sales are largely restricted to small ruminants and chickens as Mozambique, unlike other countries in Africa's SAT, is almost devoid of cattle in the bread-basket agricultural regions of the country;
- As expected, individuals in the higher income quartiles have jobs in the skilled nonfarm wage sector, which leads to differentiation of household income;
- Likewise, the higher income households participate more actively in small micro-enterprises (SME) that have the potential to generate higher levels of net income than the other income quartiles;
- Participation in activities such as charcoal-making (SME natural resource) and petty trading (SME other-low) are characterized by a relative importance that is uniformly distributed across the income quintiles;
- Remittances and pensions comprise only a small share of household income and they too are uniformly distributed across the income quintiles.

2.6.3.3. The above findings suggest that crop production does matter and, in relative terms, it is distributed in a highly pro-poor fashion. But like most of Africa's SAT, marketed surplus is low. Few households are net sellers of food. The average ratio of food crop retained : food crop sold is about 10:1 in Table 2.5.3. That same ratio in India's SAT ranges from about 3 : 2 for post-rainy season sorghum to 1 : 2 for wheat (Rao and Kumara Charyulu 2007). In general, about 40-60% of the food grains produced in the ICRISAT village studies in India are sold, and that proportion does not vary significantly by farm-size class.

2.6.3.4. The lack of market orientation for staple food crops for much of Africa's SAT limits the potential for technological change, which typically needs to be targeted for sub-regions with on-going or emerging commercialization. There are important exceptions to this generalized economic rule; these include biological control of exotic pests and pest- and disease-resistant cultivars that can be transferred in a non-market setting such as via NGOs and a public sector extension system. Another exception applies to cultivars imbued with tolerance to abiotic stress. However, intensification of production almost always requires a market orientation as a pre-existing condition.

2.7 Poverty reduction potential and the production environment of the SAT

2.7.1. In ICRISAT's last strategic vision document, the relationship between poverty and production potential was expressed as follows: *We may hypothesize that the relative incidence and depth of poverty is higher in marginal areas where the productivity of land is low, market access is limited and opportunities for nonfarm employment are scarce (ICRISAT 2006, p.15).* This conventional hypothesis, based on seemingly sound intuition, has been rejected in several well-defined circumstances. Research founded on the ICRISAT VLS in West Africa's SAT showed that household income was higher for farmers/herders in the Sahel than for settled farmers in the Sudanian Zone characterized by higher production potential (Reardon and Taylor 1997). Farm households in the Sudanian Zone were less mobile and, as a consequence, more vulnerable to drought. Absolute numbers of the poor matter more than the incidence of poverty; more poor may be found in higher potential than lower potential areas if people are allowed to decide for themselves (World Development Report 2008). Similarly, the incidence of poverty in arid Rajasthan is significantly lower than in bordering SAT districts that are characterized by higher production potential.

2.7.2. Research by IFPRI reviewed by Ryan and Spencer (2001) show that in India investments in roads, agricultural research, and human capital had a higher return in terms of poverty alleviation in the high potential rain-fed regions than in the irrigated and low-potential rain-fed environments (Fan et al. 1999). The findings in the IFPRI research are conditioned by the number of the poor in each broad agro-ecological zone and the effectiveness of investments in those zones. Because irrigation is prevalent to a varying extent in much of peninsular India, the distinction between high potential and marginal regions is not as sharp as it is in Africa's SAT.

2.7.3. We briefly examine two elements of the nexus between the potential for agricultural production and poverty alleviation in this sub-section: (1) the location of geographic poverty traps in SAT countries in Africa's SAT and (2) trade-offs among agricultural potential, poverty levels, and numbers of the poor in India's SAT.

2.7.4. **Are geographic poverty traps located in SAT regions in SAT countries?** The World Bank Development Report in 2009 focuses on the economic geography of development. They provide information on the richest and poorest regions within developing countries in terms of the incidence of poverty between 1995 and 2006. Poverty was usually lowest in the capital city and highest in a remote rural location. Areas that are heavily laden with poverty are often referred to as poverty traps.

2.7.4.1. Selecting all SAT countries from their list and matching the poorest areas to agro-ecologies reveals that the prevalence of so-called poverty traps in the semi-arid tropics is higher than expected (Table 2.6.1). The SAT was the prevailing agro-ecology for the poorest sub-region in 12 of 19 countries in SSA in Table 2.5.1. In more than half of these countries, the poorest sub-region contained a sizable number of the total poor in the country.

Table 2.6.1. Location of Geographic Poverty traps in Africa's and Asia's SAT.

Countries	Poorest area	Poverty incidence 1995-2006	Area's number of poor as per percentage of total country poor 1995-2006	Area's welfare measure as a % of counry's average welfare measure 1995-2006	SAT area
Benin	Mono	58.6	8.5	64	
Burkina Faso	Centre Sud	66.1	6.1	61	√
Cameroon	Extreme-Nord	56.3	24.9	67	√
Chad	Mayo-Dala	79	4.9	68	√
Ethiopia	Benishangul	71	1.1	72	
Gambia	Upper River	80	15.7	52	√
Ghana	Upper East	79.6	14.9	35	
Guinea	Labe	66.3	15.1	75	
India	Bihar	41.4	12.2	76	
Kenya	Eastern Province	57.6	18.5	65	√
Madagascar	Fianarantsoa	81.1	24.4	65	
Malawi	Northern Region	62.5	11.9	81	
Mali	Sikasso	76.4	21.7	78	√
Mozambique	Inhambance	82.6	8.6	70	√
Namibia	Ohangwena	85.8	16.9	38	√
Niger	Maradi	80.4	26.2	64	√
Nigeria	Jigwa	89.5	5.4	36	√
Tanzania	Rukwa	36.4	3.8	68	
Thailand	Nong Bua Lam	35.2	2.1	39	
Uganda	Northern	63.3	29.9	54	
Vietnam	Lai Chau	79.8	1.7	46	
Zambia	western	89	9.4	59	√
Mauritania	Guidimakha	71.6	10.8	60	√

Source: Constructed from the 2009 World Bank Development Report.

2.7.5. **Poverty incidence, the size of the poor, and percent irrigation in India's SAT.** Earlier analysis by Kelley and Parthasarathy Rao (1995) and updated in Ryan and Spencer (2001) showed no relationship between the proportion of marginal land in a region and the incidence of poverty. Agricultural production potential was identified in that analysis with the total value of output in 1993-1995. Recently, two NSS data sets have become available to describe poverty at the district level. These data should be interpreted with caution because the sample size is probably insufficient to generate a reliable estimate for poverty at the sub-sub national level.

2.7.5.1. The 1999-2000 data were analyzed by Rao et al. (2005) who found that crop output per capita, the population of agricultural labor, and the agricultural wage rate were key determinants explaining the variation in poverty incidence across the SAT districts. In a correlation analysis, the statistically significant negative correlates of poverty in the SAT were crop output per capita, crop output per hectare, livestock output per capita, literacy rate, the percentage of non-agricultural labor, and both the agricultural and non-agricultural wage rates. Statistically significant positive correlates with poverty were the incidence of scheduled caste population and the population of agricultural labor.

2.7.5.2. Here, with the same data set, we examine two simple relationships between irrigation level as a proxy for agricultural potential and poverty incidence and the number of the poor. The relatively poorer districts have a heavier load of poor people (Figure 2.6.1). The relationship is not one to one, but poverty incidence is broadly covariate with poverty numbers. This positive association also appears to hold across the other major agro-ecologies in India.

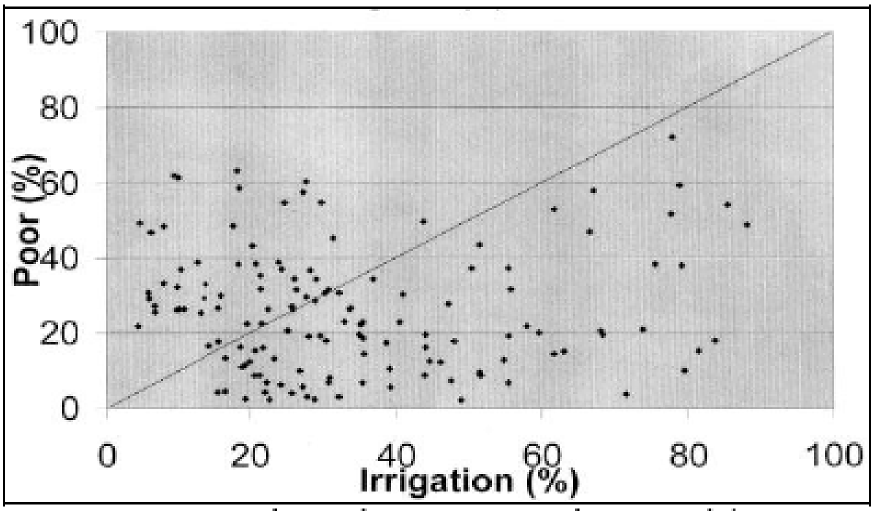

Figure 2.6.1. Poverty incidence and % irrigation across districts in India's SAT, 1999-2000.

2.7.5.3. In contrast, the incidence of irrigation seems to be a poor predictor of the incidence of poverty across the SAT districts in India (Figure 2.6.2). It is true, however, that districts with a level of irrigation below 15% are not characterized by a low level of poverty incidence below 20%. But, in general, the expected negative relationship in Figure 2.5.2 did not materialize. The lack of correspondence of percent poverty and percent irrigation also holds across the arid, humid, and temperate agro-ecologies of India.

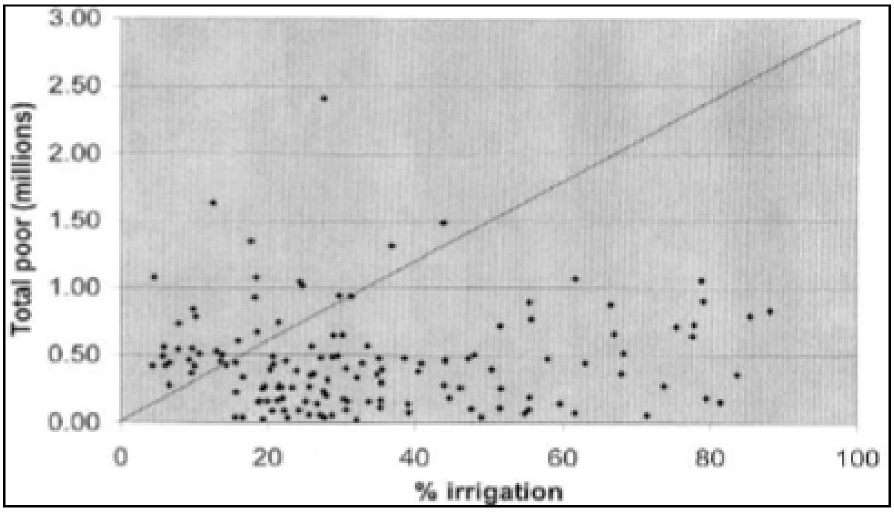

Figure 2.6.2. Scatter plot of number of people below the poverty line and % irrigation in India's SAT.

2.7.5.4. Lastly, the total number of the poor is strongly and positively associated with the incidence of poverty (Figure 2.6.3). Hence, within the SAT, poverty incidence also conveys information on the number of the poor. (This relationship may seem obvious to anyone who is not an economist).

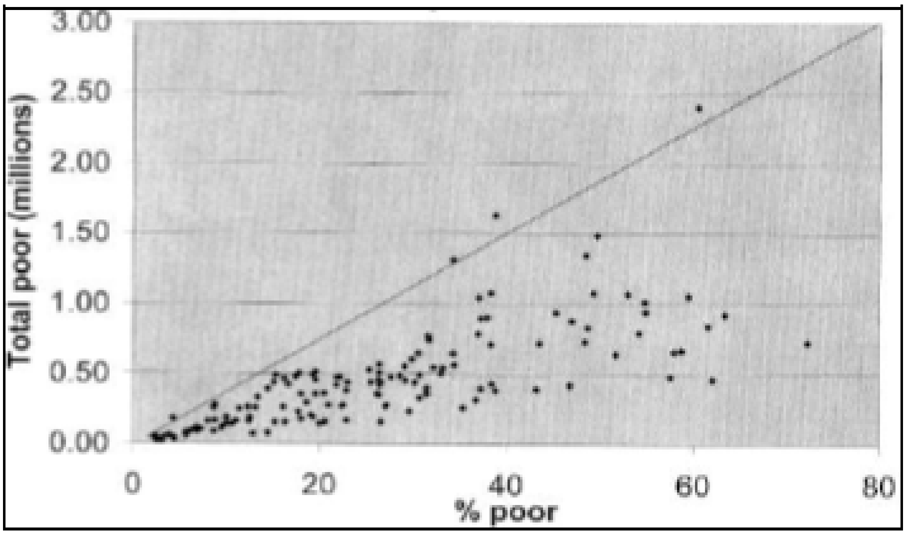

Figure 2.6.3. Scatter Plot of number of the poor and the incidence of poverty in India's SAT.

2.7.5.5. Summing up, trade-offs between poverty incidence and numbers of poor appear not to be that much of an issue in the SAT where several geographic poverty traps are found in sub-Saharan Africa. The lack of incidence-numbers trade-offs and the documentation of severe sub-national poverty in the SAT for several countries supports the conventional wisdom that the poor are found primarily in more marginal production regions assuming geographic poverty traps have low production potential compared to other sub-regions in the same country.

2.7.5.6. On the other hand in India's SAT, the above results suggest that there is not a linear and positive relationship between poverty incidence and the potential of the production environment. On a temporal scale, the quality of the economic environment for production should be improving in India's SAT with greater market integration and deeper infrastructure. But, on a spatial scale, the quality of the production environment is probably deteriorating to some extent even with more specialization that is described in Section 3.3. Chickpea has migrated south from Hissar and other districts of more favorable production potential in Uttar Pradesh and Haryana. Groundnut is increasingly prevalent in drought-prone Anantapur. Rainy season sorghum, traditionally produced in higher production potential sub-regions, is steadily declining in area. Shifts in the quality of the production environment over time await further documentation, but they should command some attention at the workshops in light of the IFPRI conventional results that underscore the greater effectiveness in investing in poverty alleviation in agriculture in sub-regions of higher production potential.

2.8 Child malnutrition and regional performance on the other MDGS

2.8.1. The prevalence of child malnutrition is the most widely used indicator of eradicating extreme poverty and hunger for the First Millennium Development Goal. Child malnutrition often figures as the key outcome variable to communicate results from long-term projections on food output, consumption and trade to scenarios of climate change in IFPRI's IMPACT model (Msangi et al. 2009 and Nelson et al. 2009). These projections and scenarios rely on an empirical relationship developed by Smith and Haddad (2000) who examined the determinants of the decline in malnutrition between 1975 and 1995. They attributed 43% of the decrease in prevalence to increased female schooling and 23% to enhanced caloric availability. Access to clean water also contributed to this positive outcome in relative terms.

2.8.2. Although the prevalence of child malnutrition has been falling, we have not seen much movement in the number of malnourished children whose population has been hovering around 140 million pre-schoolers for some time (Msangi et al. 2009). By 2020, that number is projected to remain about the same because the decline in South Asia is projected to only compensate for the increase in sub-Saharan Africa. In spite of these changes, prevalence is still expected to be significantly higher in South Asia at 35% than in sub-Saharan Africa at between 15% and 22%.

2.8.3. Consistent with the above discussion, the mean weighted prevalence of child malnutrition is about 15 percentage points higher in Asia's SAT (42%) than in WCA (27%) and ESA (25%). Child malnutrition is not unique to the SAT, but it is ubiquitous throughout the SAT. Its prevalence in Asia's SAT is especially appalling. In 1990, the SAT had the highest incidence of prevalence (49%) with about 49 million malnourished, more than any other agro-ecology (Ryan and Spencer 2001).

2.8.4. Child malnutrition is a stubborn foe. Malnutrition results in stunting that afflicts infants and young children aged 0-6 months. A global map of the incidence of stunting shows the highest rates in India's and Africa's SAT. Substantially improving the weight of infants is not an easy task. It requires much more targeted actions than simply increasing caloric supplies (P Bidinger, personal communication). Field testing and impact assessment of innovative pilot programs is a priority. Weaning food has to be tasty. Interventions should not impose more burdens on the mother's time. Finding a cost-effective role for agricultural research to address child stunting is not an easy task. On the plus side, ICRISAT has selectively invested in a small amount of diagnostic nutritional research in a timely fashion to guide its research (Ryan et al., 1984 and Chung 1998). The new strategic results framework also opens up a space to contribute to improved child nutrition in the form of a Mega-Program on agriculture, nutrition, and health.[8]

2.8.5. Updated estimates by SAT region are given in Table 2.7.1 for the most important indicators on the other MDGs. Significant progress has been made on primary school education in the three SAT regions. In health, Africa's SAT lags considerably behind India's SAT although progress has been attained in improving the odds of survival of young children.

[8]Making a frontal assault on child malnutrition in India's SAT would be a major new undertaking for ICRISAT which has invested resources on the problem of aflatoxin, a more focused health concern that is strongly linked to its mandate. But contributing to the solution of the aflatoxin problem, although highly desirable, is not going to make a dent in child malnutrition.

2.8.6. We have added three other indicators of human welfare to Table 2.7.1. Access to rural water is significantly higher in India's SAT than in Africa's SAT; however, availability of latrines in somewhat better in Africa's SAT. Considering that values for internet band width are typically in the tens of thousands for developed countries, all three SAT regions, particularly ESA, are starved for internet connectivity.

Table 2.7.1. Mean estimates of indicators of Millennium Development Goals by region.

Indicators	Region		
	Asia's SAT	WCA SAT	ESA SAT
% share of poorest quintile in national consumption or income	8	5.5	6.4
% of primary completion rate in 1991	68	27	46
% of primary completion rate in 2005	89	65	63
Gender parity ratio in primary and secondary school in 1991	70	72	83
Gender parity ratio in primary and secondary school in 2005	89	83	89
Under five mortality rate per 1000 in 1990	121	217	164
Under five mortality rate per 1000 in 20005	73	185	131
Maternal mortality ratio per 100,000 live births Modeled estimates in 2000	528	855	1012
Birth attended by skilled health staff % of total in 1990-05	34	34	57
Birth attended by skilled health staff % of total in 2000-6	44	38	44
HIV Prevalence% of population ages 15-49 in 20005	0.89	3.05	8
Rural with access to water(%)	83	40	45
Rural sanitation (%)	24	30	30
Internet band width (bits)	26	15	4

Source: World Development Report 2009. World Bank.

Chapter 3

Dynamics of Agriculture in the SAT

Although many of the relevant so-called drivers of and themes pertaining to agriculture are revisited, our focus is narrower than that of Ryan and Spencer (2001). We concentrate more on ICRISAT's research mandate from the perspective of the external environment.

3.1 Production data quality and analysis of trends for the ICRISAT mandate crops

3.1.1. Ryan and Spencer (2001) briefly analyzed the production trends of the ICRISAT mandate crops from 1979-94. Prior to updating their analysis, it is necessary to discuss the state of the FAOSTAT production data in sub-Saharan Africa. The quality of agricultural statistics is not usually considered an external driver in the strategic planning of agricultural research. It is assumed that data quality is sufficient for planning or that one can use what is available as long as it is in a consistent format. Unfortunately, for ICRISAT's strategic planning, the quality of production data varies markedly by region, ranging from better than adequate in much of the Asian SAT to worse than unreliable for some countries in the SAT of WCA. The disparity in the value of information is accentuated by the fact that agricultural data in Asia can be disaggregated to the sub-sub national level in contrast to SSA where very gross national-level data is used in strategic planning. Regional and country estimates of many variables in the Ryan and Spencer SAT Futures book are derived from percent area and not from percent population. Apportioning on area to estimate may be appropriate in some contexts, but is not in others.

3.1.2. Ministries of agriculture continue to be the weak institutional sisters in economic development in SSA even in countries, such as Uganda and Ghana, where considerable growth has occurred in the agricultural sector (Headey et al. 2009). Ministries of agriculture are poorly regarded by ministries of planning, and this low esteem is one of the important reasons why African governments under-invest in agriculture. Many examples can be given of better governance in Africa during the past 15 years with structural adjustment (Binswanger-Mhize, 2009), but few of these relate to improved performance in delivering important public goods from ministries of agriculture. Unfortunately, it is well nigh impossible to reform one sector even with significant donor support over many years. Across-the-board sectoral reform is needed especially in important human resource considerations such as pay scales and policies regarding firing and hiring. Therefore, it is likely that significant improvements in ministries of agriculture will only be restricted to a handful of countries in sub-Saharan Africa by 2020.

3.1.3. The above does not imply that stagnancy and inertia will prevail. There are some bright spots on the horizon regarding the quality of agricultural statistics. With donor support, more nationally representative rural household surveys are being conducted and will be carried out by 2020. These surveys generate valuable information on production. However, ministries of agriculture in some countries in SSA do not report these estimates to the central statistical authorities in the country. Or if they are reported, it is not guaranteed that they will be the basis for the FAOSTAT data particularly if the estimates show sharp downturns in production as they inevitably will in some years. Unlike in Asia, agricultural statistics in some countries of Africa are not insulated from manipulative behavior and political pressure. The estimates that are reported tend to show limited variability in a highly variable production environment. Summing up, the supply of reliable production information should increase but it may not be reported, and it may be difficult to obtain access to.

3.1.4. Turning to the ICRISAT mandate crops in WCA and ESA, examples of seemingly unreliable production data are easy to spot in FAOSTAT. Major offenders are Nigeria, Uganda (for sorghum), and Guinea (also for sorghum). The sorghum data in Nigeria show a constant linear trend in production between 2001 and 2006 (Figure 3.1.1). Based on these data, we do not know what has happened to sorghum production in recent years. The same (identical) trend in production applies to millet and groundnut between 2001 and 2006 (Figure 3.1.1). Nigeria now accounts for 80% of the sorghum, 70% of the pearl millet, 80% of the groundnut grown in WCA up from 50% of sorghum, 50% of pearl millet, and 10% of groundnut in 1980. In the early 1980s, Nigeria reported sorghum yields that exceeded 1.5 t/ha. These increases compensated for the same level of relative declines in area so production was maintained. Declines in area and rising yields and increases in area and falling yields figure prominently across several food crops over time in the FAOSTAT data set for sub-Saharan Africa.

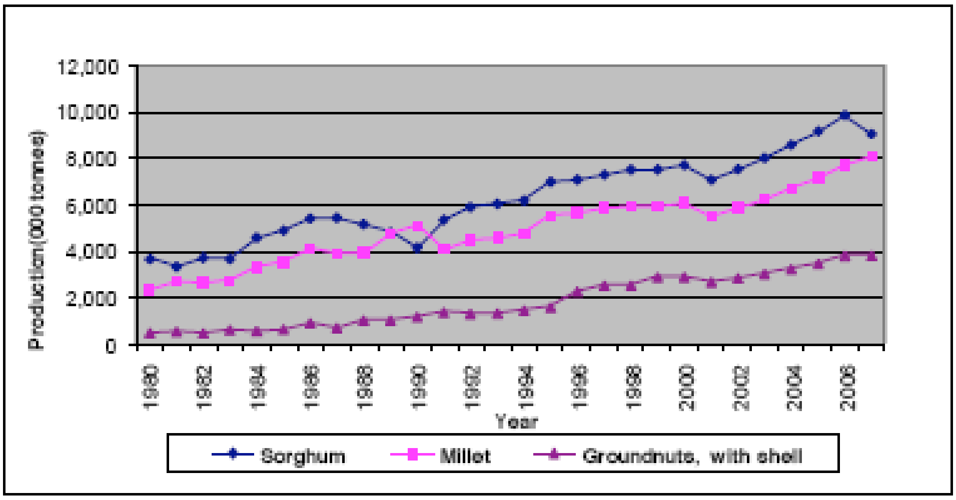

Figure 3.1.1. Production trends in sorghum, pearl millet and groundnut in Nigeria from 1980-2007 illustrating unreliable data.

3.1.5. Reliable production data display considerable variation over time in highly variable production environments such as the SAT. The estimated coefficient variation of production in Table 3.1.1 attest as much to the quality of the data as to the potential of the production environment. The higher the coefficient of variation of de-trended production, the more reliable the data. Groundnuts in Senegal are identified as reliable data and are characterized by about the same level of variability as pearl millet in India. Data on pearl millet production in Mali and Burkina Faso also appear to be reliable and are broadly covariate (Figure 3.1.2). The up and down movement in those data are a marked contrast to the ‘smooth’ production data for Guinea, which is partially a result of plotting small levels of production on the same graph with larger ones. Good quality data across countries in a region should show covariate outcomes such as the severe drought year 1992 in the data set on sorghum yield from ESA in Figure 3.1.3. Uganda is the outlier in that data set, which points to the quality of the sorghum productivity data in South Africa.

Table 3.1.1. Coefficient of Variation of production of ICRISAT mandated crops in selected countries from 1980 to 2006.

Country	Crop	CV (%)[a]
Nigeria	Sorghum	6.7
Nigeria	Groundnuts	9.0
Nigeria	Pearl millet	6.8
Guinea	Pearl millet	8.5
Guinea	Groundnuts	8.4
Senegal	Groundnuts	25.4
Ethiopia	Sorghum	37.2
South Africa	Sorghum	39.1
Niger	Sorghum	23.1
Burkina Faso	Pearl millet	17.9
India	Sorghum	14.7
India	Pearl millet	21.1
India	Groundnuts	22.2
India	Pigeon Pea	11.4
India	Chick Pea	17.8

[a] Constructed from FAO STAT 2009 and estimated as the average ratio of the first differences to the previous year t-1.

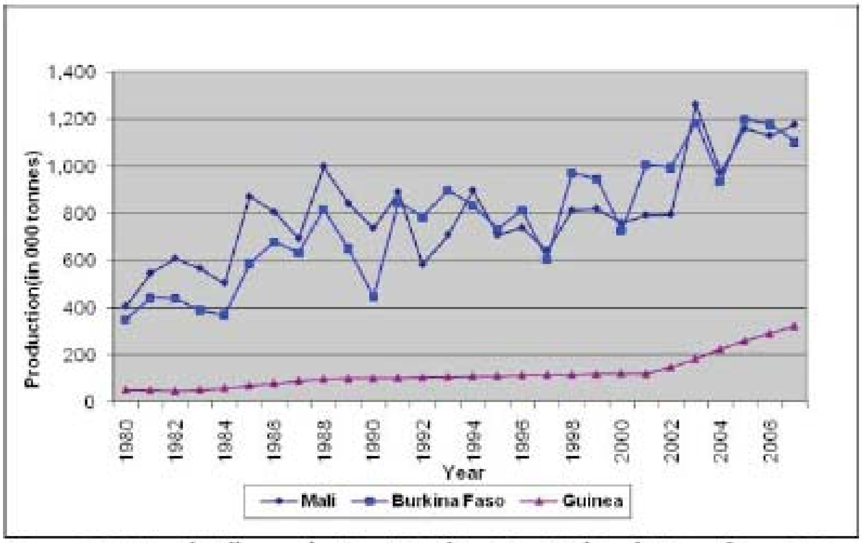

Figure 3.1.2. Pearl millet production in Burkina Faso, Mali and Guinea from 1980-2007 illustrating unreliable data in Guinea and more reliable data in Burkina Faso and Mali.

3.1.6. The unreliability of the FAOSTAT production data for Nigeria is not unique to the ICRISAT mandate crops. Crop production in the 1990s expanded by more than 10% annually across important foods such as cassava, yams, cowpeas, and even sweet potato. In squaring up food balance by commodity, a sizeable share of production is designated as waste in Nigeria. About 10 million tons of cassava, 8 million tons of yams, 1.5 million tons of sorghum, and 1.2 million tons of millet were designated as waste in 2001-03. These amounts correspond to about 20-30% of production. For the extreme case of yams, the quantity designated as waste in the early 2000s exceeded output in the early 1980s by 50%.

3.1.7. Based on FAOSTAT, Nigeria can claim to be the biggest producer of most food crops in sub-Saharan Africa. Since 1980 Nigeria has had the highest rate of agricultural growth in sub-Saharan Africa at about 3% per annum since 1970 (van der Mensbrugghe et al. 2009), yet Nigeria also had the highest incidence of people below the international poverty line of $1 a day or $2 a day of any country in the 2008 World Development Report.

3.1.8. The above negativism needs to be tempered by the reality that Nigeria is a very important country in the SAT and looms large in ICRISAT's mandate crops. There have been successes in terms of adoption of sorghum cultivars for brewing and more recently in longer duration, midge-resistant sorghum varieties (CT Hash, personal communication). Sorghum, pearl millet, and groundnut may be gaining ground in terms of area expansion in response to increasing population pressure. And poverty is still pervasive in Nigeria.

3.1.9. Like several other CGIAR centers, ICRISAT has struggled over the years with the most effective ways to partner with Nigeria, which is perceived as a large NARS in a uniquely complicated country where crops are severely afflicted by Dutch disease that impedes agricultural growth. The working group in WCA should discuss how ICRISAT can leverage more positive outcomes on Nigeria's poor and how Nigerian scientists can contribute to positive spillovers in other priority countries in WCA. At a minimum, ICRISAT needs to have more clarity about what is happening in Nigeria in terms of aspects of production for sorghum, groundnut, and pearl millet. The working group in ESA should also discuss SAT countries in their region that warrant more or less attention in the longer term until 2020.

3.1.10. Other implications apply to research priorities for economists. A sub-national data set on the SAT is a priority for both WCA and ESA. Completing a sub-national data set could proceed in the following sequence. First, population data from past censuses could be canvassed by a sub-national unit so that numbers of people in the SAT could be more accurately estimated. Second, data on area and production on crops and livestock activities could be assembled for the most recent year. Third, comparable data, if they exist, could also be assembled for earlier years. Fourth, representative rural survey data should be inventoried for each country to determine what is available, how it could be accessed, and what is its relevance for future research for ICRISAT scientists.

3.1.11. Up to now, we have been talking about data assembly and improving data access for a range of uses. The last item pertains to research by a good economist (probably a very good economist). For countries with reliable data on harvest and seasonal crop prices—I am assuming that price data are more available and reliable than any other production related-data and they usually are—time-series production data can be constructed from relatively simple models using the price data and estimated trends conditioned by other variables such as population growth and access to border trade. If the price data are available and reliable, it should be possible to construct an alternative time series that sheds light on trends and variability in production. For most of ICRISAT's mandate-crop contexts in WCA and perhaps to a lesser extent in ECA, data on prices should be informative about magnitudes of production. Comparing the FAOSTAT and the alternative time-series should allow for the identification of the most important discrepancies.

3.2 Analysis of recent trends in production of ICRISAT mandated crops

In ICRISAT's general strategic planning meeting held in Nairobi, regional trends in production were presented for the mandate crops. Some of the more important findings, both expected and unexpected, are highlighted Table 3.2.1.

Table 3.2.1. Growth rates of the ICRISAT mandated crops in selected regions for two periods, 1980-94 and 1995-2007.

Crop	Region	Growth rates: Production		Area		Yield		Regional share
		1980-94	1995-2007	1980-94	1995-2007	1980-94	1995-2007	2007
Sorghum	ESA	-1.62	2.09	-0.8	1.67	-0.79	0.44	7.6
	WCA	4.02	3	5.28	1.54	-1.24	1.43	25.4
	India-Rabi	0.52	-2.9	-1.33	-1.46	1.82	-1.5	_
	India-Kharif	-0.87	-4.23	-3.46	-3.87	2.65	-0.35	_
Millet	WCA	4.21	3.16	5.19	1	-0.94	2.14	46
	East Asia	-5.52	-5.22	-7	-5.34	1.61	0.16	6.8
	India	1.5	2.49	-1.06	-0.19	2.55	2.61	29.8
Groundnut in shell	WCA	3.68	4.08	2.01	1.51	1.66	2.53	20.5
	East Asia	5.59	3.64	2.51	2.65	2.97	0.98	37.6
	India	2.77	-1.92	1.36	-1.91	1.42	-0.05	18.9
Chick Pea	North America	NA	38.19	NA	39.26	NA	-0.56	3.1
	South-East Asia	-3.6	13.04	-1.64	5.36	-1.83	7.01	2.4
	India**	0.25	-0.72	-1.12	-0.87	1.37	0.14	64.1
Pigeon Pea	ESA	5.06	3.87	5.25	2.24	-0.16	1.56	9.4
	South-East Asia	9.38	15.84	8.33	10.88	0.83	4.47	15.8
	India	1.03	0.2	1.81	0.23	-0.75	-0.01	73.2

**Data for India refers to Pearl millet data sourced from the Directorate of Economics and Statistics for the years 1980-2006

3.2.1. **Sorghum.** With or (remarkably) without the Nigerian data, countries in WCA experienced strong growth in sorghum production in the most recent period from 1995-2007 that showed better balance than the earlier one in terms of more even contributions from area expansion and yield augmentation. Steadily increasing area and yield in Burkina Faso is one of the dominant forces shaping this favorable trend in production. The absence of a declining trend in area in any country is also a favorable development. The USDA projections until 2018 reinforce this positive finding of a non-declining trend in area as sorghum production in sub-Saharan Africa is expected to register small gains.

In ESA, which accounts for 7-8% of global production, the only bright spots in what otherwise seems to be stagnating production area and yield are high productivity in Rwanda and expanding area in Ethiopia (the center of origin and country that has received limited attention historically from ICRISAT).

In India's SAT, the production of rainy season sorghum continued its secular decline in production as increasing yield did not compensate for a steep decrease in area. As will be discussed later in this paper, this continuation was expected and has had important implications for research resource allocation at ICRISAT. The steepness in the decline in area of post-rainy season sorghum at 3.3% is surprising and does give one pause. If the ICRISAT VLS are any indication, increased irrigation in western Maharashtra played a role in the diminished importance of this crop highly valued for its quality food grain and crop residues.

3.2.2. **Millet.** Three regions/countries are signaled in Table 3.2.1: East Asia, WCA, and India. Foxtail millet in northern China is rapidly going out of production. The Chinese are experts on innovating alternative uses of food crops, but apparently they have not found a competitive end use for millet in a rapidly modernizing economy. On a more major scale, sweet potato is suffering a similar fate as millions of hectares of this root crop are allocated to more versatile crops in a highly competitive market.

Pearl millet production continued to expand in Niger, Mali, Burkina Faso, and Chad. The best-balanced performance seems to be turned in by Mali and Burkina Faso. Estimated yield growth increased by 3% annually compared to the previous period. It remains to be seen whether this was mainly the result of good weather, a changing geographic environment for the crop, or technological change.

In India, pearl millet did well in the recent period; area did not significantly contract. Yield growth was robust indicative of a thriving seed sector that has been nurtured by ICRISAT.

3.2.3. **Groundnut.** East Asia is again highlighted for groundnut production in Table 3.2.1. Growth was not as robust as the previous period as high growth was mainly confined to China and Vietnam under irrigation. Soon the East Asia region will account for 40% of global production.

In India, the positive trend in the earlier period was reversed. Production declined by about 2% per annum. Globalization resulting in lower trade barriers leading to rapidly expanding imports of palm oil is an important underlying reason for contracting production. Lower profitability relegates groundnut to more marginal, droughty production regions.

Groundnut production in Senegal continued its long-term decline in area. Decreased production in Senegal was more than off-set by increased area and production in several smaller producing countries including Ghana and Mali. Without Nigeria, groundnut production increased at a healthy clip of about 2.9% in the recent period. With Nigeria, the growth estimate of production increased to 9.7% from 1980-94 to 5.5% in 1995-2007. These two later estimates are viewed as unrealistic as groundnut exports are unduly taxed in WCA. To the detriment of producers, export taxes in WCA have resisted the forces of globalization. Countries in West Africa also have a difficult time complying with stringent international regulations on aflatoxin content (Waliyar et al. 2009).

3.2.4. **Pigeonpea**. Production was stagnant in India during the recent period. Strong expansion of area in 1980-94 was dampened as pigeonpea probably was a casualty to the expansion of Bt cotton. Nonetheless, pigeonpea is still a strong competitor for cultivated areas in the rainy season in the Akola villages. Strong growth in ECA continued. The latter period was marked by a robust performance in Southeast Asia mainly Myanmar, which was associated with contributions from ICRISAT.

3.2.5. **Chickpea.** Lack of growth of chickpea in India during the recent period is surprising as there is strong demand for the crop. A move to a new production environment should be associated with opportunities for technological change. Vibrant growth from a very small base was observed in North America.

3.3 Geographic specialization in production of the ICRISAT mandate crops in India

3.3.1. With market access and economic growth at a low level in much of Africa's SAT, we would only expect to see the seeds of emerging specialization in spatial production in WCA and ESA. Because national data are only available for Africa's SAT, an assessment of trends in specialization in production will not add much to our earlier discussion of production trends in Section 3.2 that was based on country-level data. In contrast, India has been characterized by moderate to high economic growth with secularly increasing market integration over several decades. Moreover, district data are available from the mid-1960 to the early 2000s to analyze trends in production specialization that have implications for agricultural research.

3.3.2. With an eye on those implications, several scenarios are possible. The implications are brought out by contrasting best and worst case scenarios. The best case scenario is that demand for the food crop is strong, and the crop shifts rapidly to regions of high production potential. In this scenario, which is exemplified by potato production in the United States in the first half of the 20th century, the gap closed between potential yield and productivity in farmers' fields as farmers' attainable yield in their fields approached researchers' attainable yield on experimental stations. Few crops have the economic and agronomic luck to partake of this best-case scenario, which is punctuated by periods of unprecedented yield growth. The conditions in farmer fields are similar to those in experimental stations and there are few GxE interactions to worry about because the crop's recommendation domain consists of well-defined, very compact production environments.

3.3.3. The worst-case scenario embodies situations where demand for the crop is weak, which gives rise to declining production in diffused geographic regions. Production specialization does not occur as the crop is orphaned on more marginal environments throughout sub-regions. The declining efficiency of agricultural research in this scenario is attributed to diminishing aggregate demand, a deteriorating resource base, and the stagnating specialization in geographic production. Demand for technology is limited because market demand for the crop is weak. Output is mainly consumed as food by producers who assign a subsistence orientation to a commodity that is not versatile and has limited end uses.

3.3.4. None of ICRISAT's mandate crops fit the best- or worst-case scenarios described above, but most are characterized by increasing spatial specialization in production over time (Table 3.3.1). Specialization is identified with a rising share of the leading 15 districts in gross cropped area. For example, the top 15 districts in the late 1960s accounted for only 27% of pigeonpea production. By 1999-2001, about half of national production was grown in the top 15 (which may or may not be the same districts). In general, production specialization is synonymous with commercial production in response to firm aggregate demand. Marketed surplus rises, and the food crop is increasingly viewed as a cash crop.

Table 3.3.1. Specialization in production of the ICRISAT mandate crops in India from 1967-69 compared to 1991-2001.*

Crop	1967-69 area	Share (%)	1999-2001 area	Share (%)
Rainy-season sorghum	3.1	28	2.1	44
Post-rainy season sorghum	4.5	69	4.5	86
Pearl Millet	5.6	45	5.3	55
Chickpea	2.5	33	2.0	34
Pigeon pea	0.7	27	1.5	43
Groundnut	3.1	43	3.9	59

* For 15 districts with the highest mean gross cropped area in each period.

3.3.5. The ICRISAT mandate crops fit four generalized patterns on dimensions of production specialization. Production specialization in rainy season sorghum is real, but it is not associated with rising commercial demand. The top 15 districts in gross cropped area are producing relatively more of the crop because farmers in other districts have abandoned the crop as a food grain. Over time production has stayed in the same districts where it figured as a staple food crop in the rainy season, but area has declined in almost all those districts.

3.3.6. The second case corresponds to static or slightly increasing demand with population growth and increasing specialization of production in the same sub-regions that accounted for the bulk of production prior to the green revolution. Both post-rainy season sorghum, which is still grown primarily in Maharashtra and Karnataka, and pearl millet, which is still concentrated in Rajasthan, fit this case. Post-rainy season sorghum was characterized by the highest rate of geographic specialization of production in both periods of the mandate crops. Thirteen of the top 15 districts in the first period were also in the top 15 in the second period (Figure 3.3.1). Only in Khamman and Nalgonda did post-rainy season sorghum production decline sharply. Fourteen of the 15 top districts are located in Maharashtra and Karnataka—just like the first period—and now in 2009 these heartland districts probably account for about 90% of production in the post-rainy season. This concentration is approaching 'niche' production but that description is still not warranted because the largest district, Sholapur, contained only about 13% of gross cropped area in the recent period. The next three districts have sizeable area shares, each with about 10%. Both post-rainy season sorghum and rainy season pearl millet have regional 'staying power' because no other commodities can compete in these marginal production conditions. Technological change may not have improved millet production in Rajasthan or post-rainy season sorghum production in Maharashtra, but it also has not facilitated the improvement of substitutes to displace these crops from their sub-regions of comparative advantage.

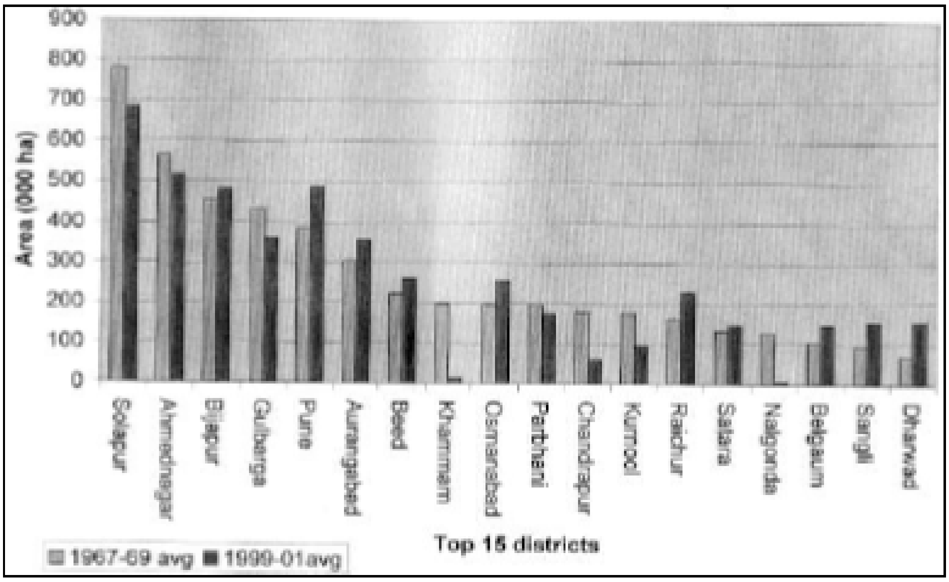

Figure 3.3.1. District-level shifts in important post-rainy season sorghum-producing districts in India.

3.3.7. The third pattern is driven by strong domestic demand and increasing spatial concentration in sub-regions that earlier contributed heavily to national production. This description applies to both pigeonpea and groundnuts. Pigeonpea has migrated south and west somewhat to sub-regions where medium-duration genotypes prevail; however, about 50% of the top producing districts are still the same. Gulbarga in Karnataka has emerged as the dominant producing district, but its area share only approached 10% in 1999-2001. Like Gulbarga, Anantapur has driven production specialization in groundnut production. With stiff competition from imports of palm oil, the trend toward production specialization may have slowed in groundnuts as farmers switched to alternative crops in several areas of the top 15 districts. Groundnut always was regarded as a cash crop. The increasing market orientation of pigeonpea should be congruent with increased demand for yield-increasing technology.

3.3.8. The last scenario is probably the most interesting and pertains to chickpea. In response to the green revolution in wheat, the crop has moved south mainly to Madhya Pradesh, which now contains 10 of the 15 districts with the largest area share in the recent period. Production is also increasing in Andhra Pradesh and Karnataka. In the earlier period, the northern states of Haryana, Uttar Pradesh, and Punjab accounted for the lion's share of production. Only four districts remained the same among the top 15 between the two periods (Figure 3.3.2). Shifting to a new production environment, albeit more marginal than the old one, opened up new opportunities for agricultural research which has responded to the challenge with shorter duration *kabuli* and *desi* varieties to escape end-of-season drought. This success story is a good example of agricultural research performing well in a marginal but new production environment for the crop. When the crop moved south into peninsular India, agricultural research benefitted from a concomitant move to a greater cash-crop orientation in response to strong demand. The prospects for technological change are bright for a crop moving to a new production environment with a market orientation.

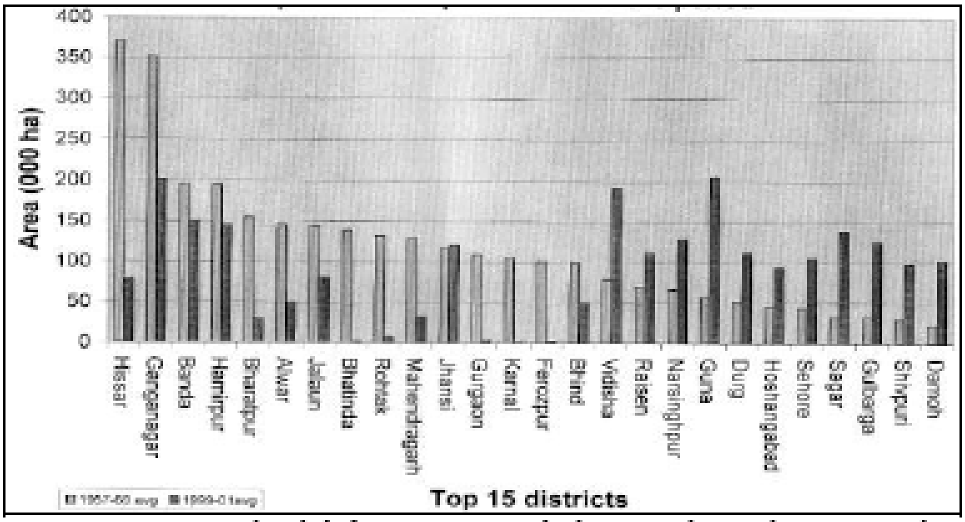

Figure 3.3.2. District-level shifts in important chickpea-producing districts in India.

3.3.9. What does this brief recounting of geographic history mean for ICRISAT's next strategic plan? Although data are lacking, more spatial specialization in production should be accompanied by greater market orientation especially for pigeonpea and chickpea. On the demand side, this is a favorable trend that augurs well for increasing demand for yield-increasing technology. On the supply side, specialization in more tightly clustered sub-regions should enhance the efficacy of agricultural research in diagnosing problems and in responding with solutions that are tailored to sub-regional production conditions.

3.3.10. Gains in production specialization may be eroded if the production environment deteriorates in quality over time. Anecdotal evidence suggests that this may be the case with groundnut, which is increasingly produced in Anantapur. This temporal hypothesis is a variation on the spatial theme of the marginality of the production environment that resonates most at ICRISAT when the location of the Sahelian Center is discussed.

3.3.11. Testing the conjecture on quality of the production environment over time was based on weighting poverty incidence and average rainfall by district-level value of production data for each of the mandated commodities in two time periods, 1980-82 and 2003-04. No differences were found on poverty incidence between the two periods, that is, we cannot say that people are poorer where the crops are now produced than where they were produced, but there was one large difference in rainfall. In the early 1980s, pearl millet was produced in districts with a weighted annual rainfall that approached 680 mm; by the early 2000s, the crop had moved to districts with an average rainfall of about 385 mm (Table 3.3.2). Much of this movement was undetected in the above discussion and took place within Rajasthan as the crop was increasingly produced in the drier districts in the western part of the state. So for pearl millet the anecdotal evidence on a declining production potential rings true, but it does not appear to hold for the other crops with the possible exception of groundnut where weighted annual rainfall decreased by about 4%.

Table 3.3.2. Weighted average rainfall by crop by period on shares of value of production, 1980-82 compared to 2003-04.					
Period	Sorghum (kharif)	Pearl millet	Chick pea	Pigeon pea	Groundnut
1980-82	926.2	679.6	896.1	1024.6	816.7
2003-04	900.5	384.9	1006.6	1003.6	783.4
Change (%)	-2.8	-43.4	12.3	-2.0	-4.1

3.3.12. The findings in Table 3.3.2 are easily misconstrued. They do not mean that the districts where pearl millet is now produced are becoming drier over time. They mean that the location of production has shifted to droughty districts.

3.4 Livestock Production in the SAT

3.4.1. The SAT is a natural environment for the development of mixed crop-livestock systems. Since the founding of the Sahelian Center, ICRISAT has recognized the importance of livestock in its SAT mandate and has partnered with ILRI. ICRISAT has conducted research on ways to improve crop-livestock interactions as evidenced by greater emphasis on dual-purpose types and on fodder quality in its cereal programs.

3.4.2. Ryan and Spencer (2001) reviewed projections for livestock product demand and noted more optimism in IFPRI assessments that spoke to a livestock revolution than the FAO analyses. IFPRI assumed that the past aggregate growth rate for meat demand of 2.8% per annum would continue to 2020; FAO foresaw a slowing of the growth rate to 1.9%. Both assessments indicated high growth for poultry, pork, milk, and milk products.

3.4.3. Livestock in the SAT were comprehensively reviewed by ICRISAT economists in 2005 (Parthasarathy Rao et al. 2005). Based on data in that review, weighted average growth rates across the three SAT regions are given in Table 3.4.1. Livestock products have about the same relative importance in the three SAT regions, but their production performance was markedly different. Strong demand for livestock products translated into robust growth in production in Asia's SAT. In WCA and ESA, growth in livestock production did not exceed growth rates in crop production. Lack of income growth combined with supply constraints, especially livestock diseases, explain a large share of this mediocre performance.

Table 3.4.1. Comparing annual growth rates in crop and livestock production by SAT region from 1981-2001.			
SAT Region	Share of livestock in agricultural GDP (%)	Crop growth (%)	Livestock growth (%)
Asia	23	2.9	4.0
WCA	21	5.7	2.1
ESA	34	2.0	2.1
Constructed from Parthasarathy Rao et al. (2005).			

The following are some of the salient points in Parthasarathy Rao et al. (2005) who used SAT countries as an organizing construct for their analysis:

- Grazing systems are still more important than mixed systems in provisioning meat and milk production in SSA but grazing systems are turning into mixed systems;
- Unlike crop production, growth in livestock production has the potential to reduce income inequality and enhance equity in India's SAT;

- As a share in agricultural GDP, livestock is increasing in importance in South Asia and East Africa but is declining in southern Africa and West Africa;
- The SAT countries are the home of at least 1/3rd of the world's cattle, buffalos, and goats;
- Among livestock types, poultry and goats are characterized by the highest growth rates in livestock population during the decades of the 1980s and 1990s;
- In India's SAT, the bulk of crop residues are fed to livestock and supply about half of total dry matter intake for bovines, but in West Africa, 2/3rds of cereal residues are used as material for domestic construction or fuel, with only 1/3rd fed to livestock;
- Technologies designed to supplement the nutritive value of crop residues have not been adopted because of capital costs, labor constraints, and lack of evidence on economic benefits to farmers;
- The prevalence of cultivated fodder crops is still low in the SAT and is constrained by one main growing season;
- The importance of using cereals as feed grains is increasing in several SAT countries mostly in Malawi and Nigeria in response to population pressure;
- Except for India, all SAT countries are net importers of milk mainly in the form of dry-skimmed milk or whole-milk powder; and
- Urbanization is one of the principal drivers of poultry production in India.

3.4.4. Two aspects of these interconnected findings warrant more comment. (1) Demand for milk and poultry products is robust but supply is unlikely to come from the SAT of WCA or ESA and (2) Most of the SAT is lowland. The highlands have a strong comparative advantage in dairy production. Intensification of rural poultry production is a daunting challenge, and not much progress has been made in the countries where it has been tried. Poultry production is characterized by economies of scale and requires vertical integration. Exploiting poultry production as a pathway out of poverty is likely to be restricted to agricultural laborers who have migrated to nearby urban areas. Consumption of eggs and broilers is also likely to confer nutritional benefits on the urban poor. The comparative advantage of Africa's SAT in livestock is derived from the production of meat from cattle, goats and sheep.

3.4.5. The relative importance of cereal residues in the ICRISAT mandate crops has changed over time in peninsular India, but those changes are better known for their non-linearities and are not consistent with a linear trend. Cereal residues in sorghum by-products were becoming more important in the mid-1980s after which their relative importance declined (Figure 3.4.1). Increasing tractorization leading to a steady reduction in the bullock population is the most likely cause of this decline. The data on sorghum in both Karnataka and Maharashtra do not convey much information from the 1990s, but there are signs in Figure 3.4.1 that crop byproducts are again looming larger in the early 2000s in Maharashtra. The value of crop residues from pearl millet has rivaled the value of the grain throughout the period of coverage in Figure 3.4.1 in Rajasthan. During drought years, such as 2002, byproduct value has exceeded grain value, which reflects the limited local market for fodder because of high transport cost. The relative value of groundnut haulms is considerably less than the relative value of cereal residues in the most important producing states.

3.4.6. Overall, the data in Figure 3.4.1 suggest that the relative importance of byproducts has not changed in a linear fashion since 1981. These data confirm the wisdom in emphasizing dual-purpose types in the ICRISAT mandated-cereals. In the mid- and late-1980s, the strong upward trend in the relative importance of residues in local fodder markets, such as Sholapur's, was thought to open up a space for the cultivation of fodder types in India's SAT, but the sharp decline in bullock numbers was not anticipated. Cultivation of fodder crops is restricted to more heavily irrigated areas with higher cropping intensities.

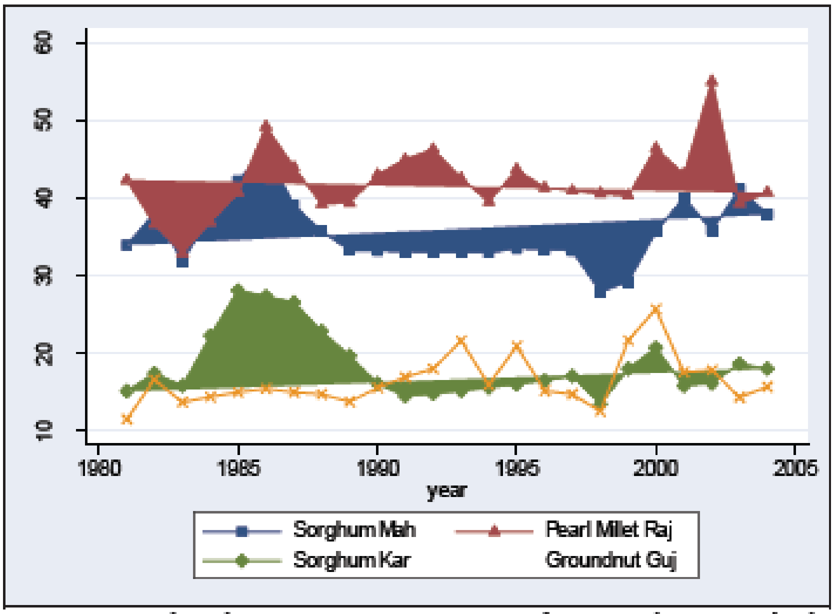

Figure 3.4.1. The relative economic importance of crop residues in total value of production from 1981 to 2004 by crop and state.

3.5 Urbanization and Agglomeration

3.5.1. Urbanization is one of the most important drivers in shaping the medium and long term prospects for the effectiveness of agricultural research at ICRISAT. With urbanization, agricultural research is widely perceived as having diminished leverage on poverty outcomes because of the differential rates of poverty between rural and urban areas. High rates of urbanization in Latin America attributed to economic growth combined with severe inequality of land holding have dampened donor interest in tackling poverty, which is increasingly viewed as an urban phenomenon.[9] Therefore, urbanization is viewed as a threat to the funding of international agricultural research because in a rapidly urbanizing economy, agriculture's contribution to growth and to poverty alleviation is perceived to be diminishing in relative importance.

3.5.2. As the World Bank Development Report 2009 makes abundantly clear, urbanization is a natural outcome of agricultural development and economic growth, provided the pull factors in migration outweigh the push factors. Threshold levels of agglomeration and population density are required to increase the demand for productivity-enhancing agricultural research.

[9] And donors have not made a commitment to urban agriculture. The Systems-Wide Initiative on Urban Agriculture is about to close because of a lack of donor interest.

3.5.3. The share of urban dwellers in the SAT population shows a strong upward trend in Figure 3.5.1 for the three regions. By 2020, about half of the population in SAT WCA will be urban. The other two regions will still be predominantly rural with a 65% share of total population. The projected trends in Figure 3.5.1 mask sizeable variation among the countries in Africa's SAT. Countries that will be urbanized at a level exceeding 50% in 2020 are Angola, Botswana, Sudan, The Gambia, Ghana, Nigeria, and Togo. The other 22 SAT countries in Africa will be characterized by a rural majority in 2020.

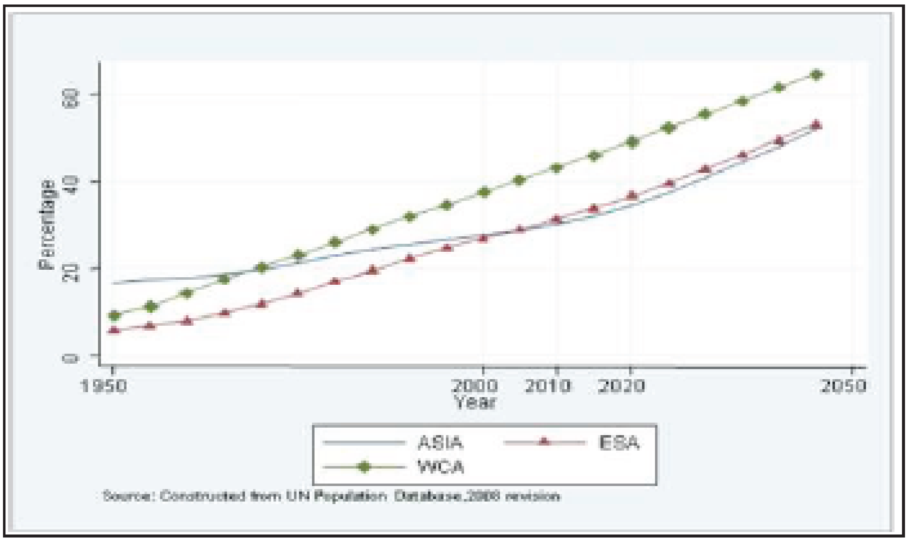

Figure 3.5.1. Projected levels of urbanization in the SAT by year by region.

3.5.4. The relative importance of urbanization in some of these countries, such as the low 20% level in 2020 for Niger, may be surprising; however, estimates of urbanization are not comparable across countries. Economic geographers have standardized measures of urbanization or settlement compactness. One of these is called the agglomeration index, which is based on minimum thresholds of population density, time to a sizable urban center, and efficiency of transport (World Bank Development Report 2009). This index varies from 1 to 100. The range is bound by Papua New Guinea at 3.5 and Hong Kong at99.8. The index has only been estimated for 2000. We compare it to percent urbanization for that year in Figure 3.5.2. More than just urbanization, this index suggests potential for market and economic development.

3.5.5. Weighted by SAT population in each region, the mean agglomeration index is substantially higher in Asia's SAT at 52 than comparable readings for WCA at 35 and ESA at 25. In other words, in terms of uniform measurement, urbanization is significantly greater in Asia's than in Africa's SAT although the conventional use of percent urbanization measures imply otherwise or no interregional differences. Mean weighted urbanization was 28% in Asia's SAT, 35% in WCA, and 25% in ESA. Hence, effective urbanization was about 100% underestimated in Asia's SAT.

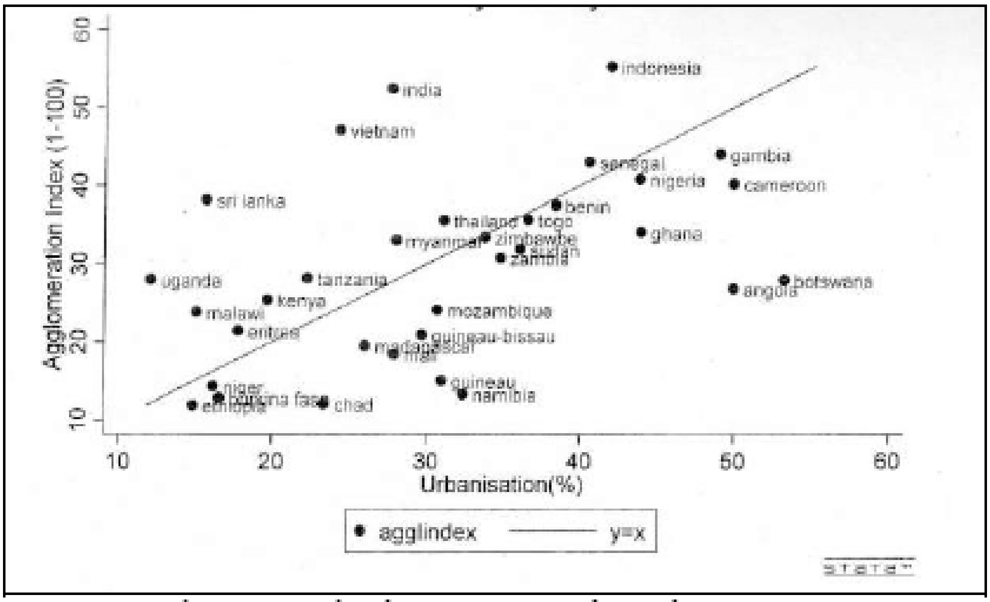

Figure 3.5.2. Urbanization and agglomeration across the SAT by country in 2000.

3.5.6. Most of the country disparities between the two measures in Figure 3.5.2 pertain to Asia's SAT. But, there are discrepancies in countries in Africa's SAT too. Angola shows up as significantly more rural on the agglomeration index; Uganda is more urban. In general, Africa's SAT is more rural than is commonly thought and Asia's SAT is more urban. No country in Africa's SAT is characterized by an agglomeration index greater than 50; Nigeria at 41 has the highest value.

3.6 Urbanization and the typologies of agricultural development.

3.6.1. The authors of the 2008 World Bank Development Report (WDR) on agriculture divided the developing world into three groups of countries (1) agriculture-based, (2) transforming, and (3) urbanized countries (Figure 3.6.1). Agriculture-based countries are characterized by a share of agriculture in gross domestic product greater than 20% and a proportion of rural to total poverty more than 0.5. In these countries, the fate of economic development hinges on outcomes in the agricultural sector. The staple food crop sector is large and is characterized by limited external trade. Gains in crop productivity translate into benefits for net-food purchasers, many of whom are in the rural sector. As described in Section 2.3, more than half of rural households are net food buyers of staple commodities. Productivity gains in tradeables, either exports or import substitutes, accrue directly to producing households and to labor households involved in production. Agriculture is an engine of growth.

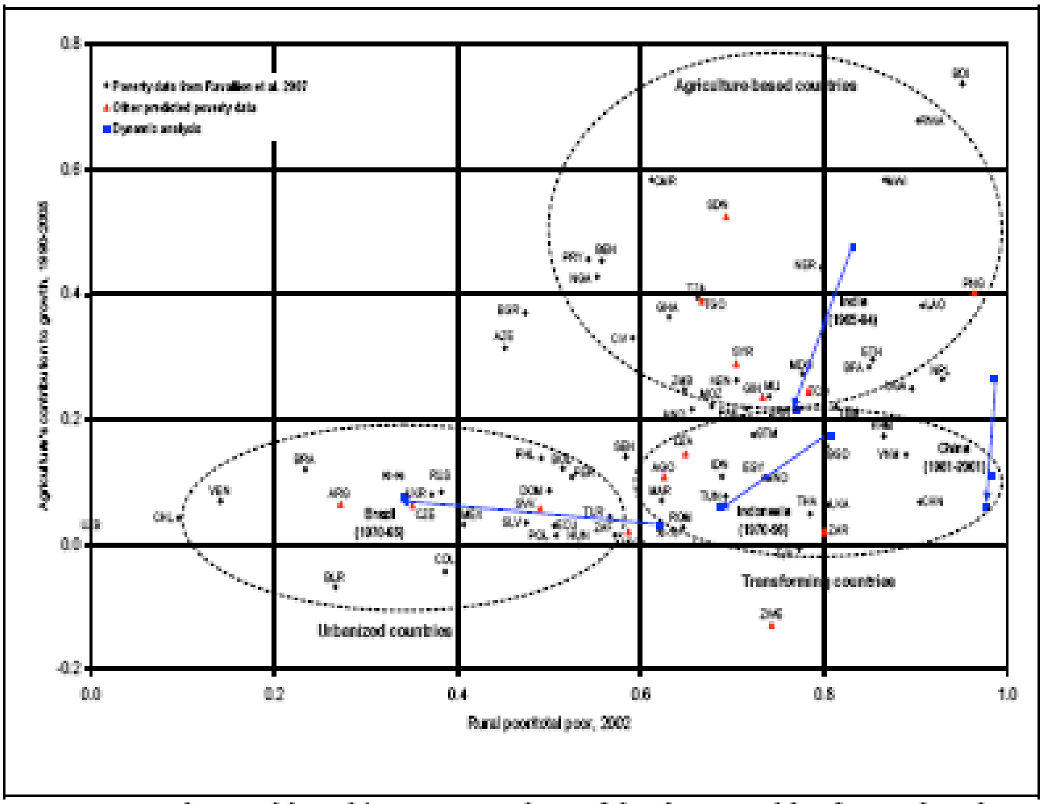

Figure 3.6.1. The World Bank's recent typology of the three worlds of agricultural development. Source: WDR 2008, p. 31.

3.6.2. Transforming countries comprise the most populous group containing about 2 billion people. In spite of advances, poverty remains largely rural, but the agricultural sector contributes less than 20% to GDP. Recent growth has placed pressure on natural resources, particularly water and soils. The nonagricultural sector accounts for the bulk of economic growth and impediments to migration constrain structural transformation of the economy. Increasing the yield of staple food crops is still critical for growth and poverty alleviation, but rising income shifts food expenditure away from staples and toward processed foods. Growth is driven over time by expanding demand for livestock products and labor-intensive high value crops.

3.6.3. On average, agriculture only contributes a 6% share to GDP in urbanized countries where the majority of poor reside in cities and towns. Increasing productivity via agricultural research can still be a powerful engine for growth and poverty reduction in urbanized countries, but the size of these effects depends much more on context than in agriculture-based or transition countries. For example, the export surge in fruits and vegetables in Chile was characterized by substantial poverty impacts on the rural poor. In contrast, the soybean boom in Brazil was capital intensive and mostly required higher skilled laborers in a land abundant setting.

3.6.4. The WDR 2008 typology is described in some detail because it is very congruent with ICRISAT's mandate and warrants more than a mention in the forthcoming strategic plan. About 90% of sub-Saharan Africa conforms to agricultural-based countries; hence, for all intents and purposes, we can say that the WCA and ESA SAT are agriculturally based. Much of India was agriculturally based as late as 1993-94 (Figure 3.6.1), but, today, most of the states in India's SAT would be classified as transforming economies because the bulk of their poverty is rural but agriculture's contribution to the economy is low.

3.7 Urbanization and changing food preferences. Urbanization is not a threat to ICRISAT's mandate in the generalized World Bank typology of agricultural development, but changing food preferences with urbanization are another matter. Because of changing food preferences away from coarse cereals to rice, wheat, (and imported maize meal in some parts of southern Africa) with urbanization, ICRISAT's potential for alleviating poverty is diminished by urbanization in its sorghum and millet crop mandate if the priority end use is food. Of all the IARC-mandated food crops, sorghum, millet, and sweet potato are probably more affected by urbanization than any of the other commodities.

3.7.1. **Urbanization and changing food preferences to wheat and rice in Africa's SAT.** The penetration of wheat and rice imports into cities and the countryside in the interior regions of Africa's SAT erodes ICRISAT's potential to alleviate poverty through agricultural research. The provinces below the Sabe River in Mozambique are prime examples, especially Maputo, where staple food-crop producers in the Central and Northern provinces cannot compete with cheap rice imports from the Punjab and Haryana in India because of long-distance transport over land. These geographic areas represent so-called dead zones for domestic sorghum and millet production in West Africa and even for maize in Southern Africa. Imported wheat is increasingly present in the countryside in many African countries.

3.7.1.1. The trend of increasing rice and wheat imports is likely to continue into 2020. Based on recent USDA projections to 2018 (USDA 2009), imports of rice are expected to rise from 6.4 million tons in 2007 to 8.7 million tons in 2018 corresponding to a 3.3% annual growth rate in sub-Saharan Africa. Although SSA is projected to be the largest rice importer in the world, the projections for wheat are direr. Exports are expected to approximately double from a base of 8.5 million tons in 2007 to about 15.7 million tons. A very robust growth rate of 6.5 percent per annum is forecast.

3.7.1.2. The recent historical growth rates of rice and wheat imports into African SAT countries are considerably higher than the latest USDA projections (Figure 3.7.1a and Figure 3.7.1b). Since the mid 1970s, rice and wheat imports have increased eightfold. Starting in the mid 1990s and on into the early 2000s the trend in imports shifted upwards in both crops. Although increasing women's labor market participation resulting in a premium on time, and urbanization, are the principal drivers of rising imports (Kennedy and Reardon 1994), the temporary halting of this trend is one of the few silver linings of the recent rise in food prices. A change to higher levels of food prices is beneficial to ICRISAT not only because it should mobilize more resources for agricultural research but also because stronger prices give the institute more spaces to operate and more windows of opportunity to affect the poor in sub-Saharan Africa.

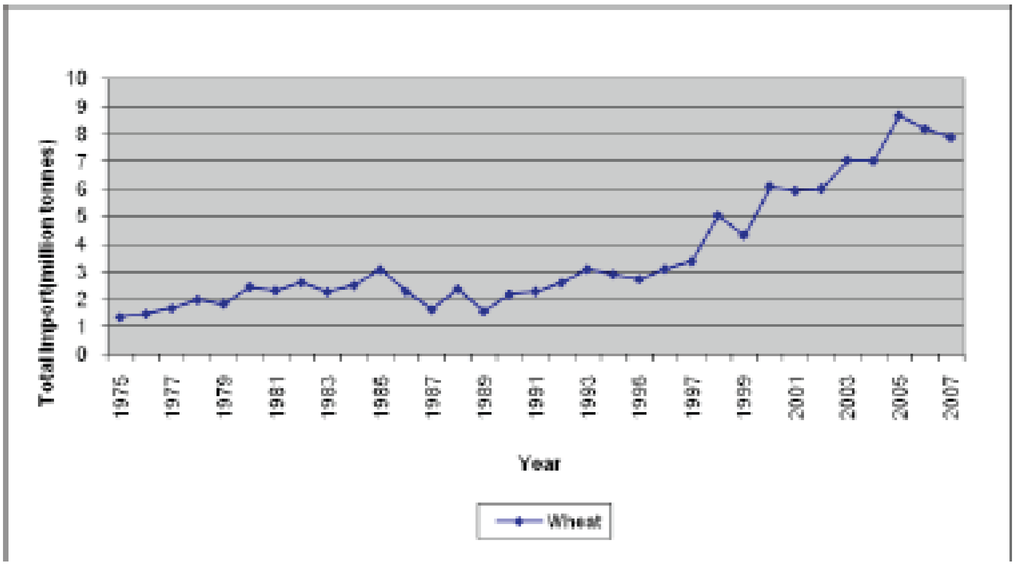

Figure 3.7.1a. Trends in wheat imports in Sub-Saharan Africa, 1975-2007.

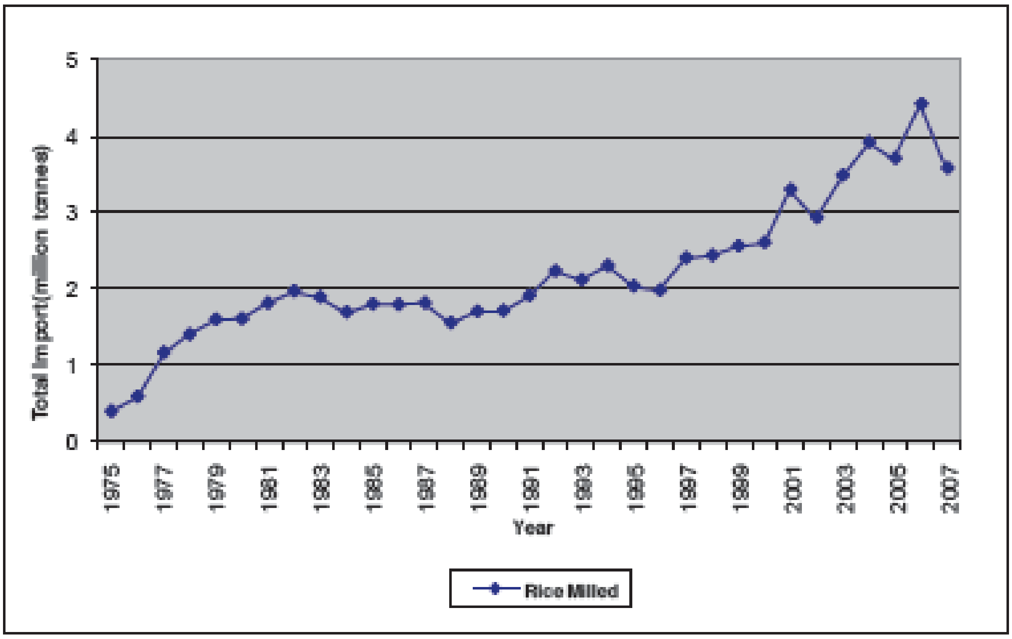

Figure 3.7.1b. Trends in rice imports in Sub-Saharan Africa, 1975-2007.

3.7.1.3. High per capita intensity in imported rice is most notably a West Africa phenomenon in the SAT. Benin, Togo, Cameroon, Guinea, Burkina Faso, Gambia, and Niger were characterized by per capita import availabilities exceeding 10 kg/person ranging from Benin with over 80 kg/per capita to Niger with 13 kg/capita in 2005.

3.7.1.4. Imported wheat import intensities are more evenly distributed between WCA and ESA. Countries in Africa's SAT with more than 10 kg of imported availability per capita included Eritrea, Senegal, Namibia, Nigeria, Kenya, Cameroon, Togo, Ghana, Uganda, Tanzania, and Ethiopia in 2005.

3.7.1.5. The competitiveness of coarse cereals as food grains with increasing urbanization is important to ICRISAT's strategy in West Africa. Few empirical studies have been carried out to determine the degree that increases in coarse cereal production result in increased urban consumption and the extent that processing improves the prospects for competitiveness. The available literature is summarized in Ndjeunga et al. 2004 who find evidence for inelastic demand, limited sensitivity of coarse cereal consumption to rice and wheat prices, and brightened prospects for competitiveness with processing that are species specific. Most of the empirical work in West Africa was conducted in the 1990s and needs to be updated. Comparable research (Murty 1983 and 1997), cited in the next sub-section for India, shows that the estimated size of consumption parameters have changed over time with transparent implications for coarse cereals intake in both urban and rural areas. Failure to invest in this type of consumption research can result in unwelcome surprises in 2020 and beyond.

3.7.2. **Urbanization and food consumption in India's SAT.** Urbanization has played less of a role in changing food grain preferences in India's SAT where public distribution programs in rural areas have accelerated the shift to wheat and rice as staple food crops. In terms of food demand, rainy-season sorghum production has suffered the most from changing preferences for the so-called superior cereals. The magnitude of decreasing demand has become more apparent since the early 1990s when increasing productivity slowed and production fell as fast as area (Figure 3.7.3). During the past 30 years, rainy-season sorghum production has fallen in every important producing-district in peninsular India but Osmanabad (Figure 3.7.4). The data arrayed on the x axis of Figure 3.7.4 shows that the districts that used to produce small or moderate amounts of rainy season sorghum in the late 1960s had all but abandoned the crop by the early 2000s.

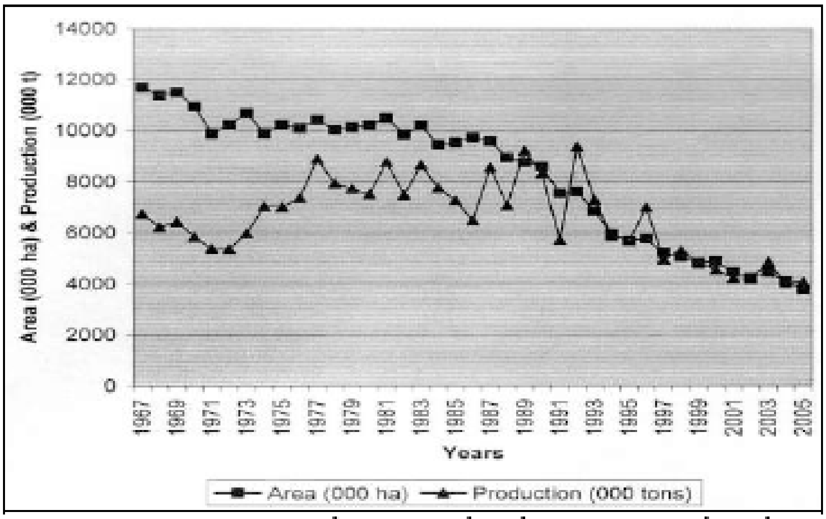

Figure 3.7.3. Rainy season sorghum area and production in peninsular India, 1967-2005.

3.7.2.1. Trends in the aggregate and district-level data in Figure 3.7.3 and 3.7.4 are reconfirmed by the most recent data on net cropped area from the ICRISAT study villages. In 2006-07, only 3 of about 250 hectares cultivated by respondent households in the Mahbubnagar villages in Andhra Pradesh were planted to rainy-season sorghum or pearl millet. Of about 425 hectares planted in the Akola villages in Maharashtra in 2006-07, only about 30 hectares were sown to rainy-season sorghum sole crops or intercrops, which accounted for about 20-30% of gross cropped area in the mid- to late-1970s (Jodha 1977). In contrast, post-rainy season sorghum was still the dominant food staple produced in the Sholapur villages in western Maharashtra accounting for about 150 of 500 hectares under cultivation by respondent households.

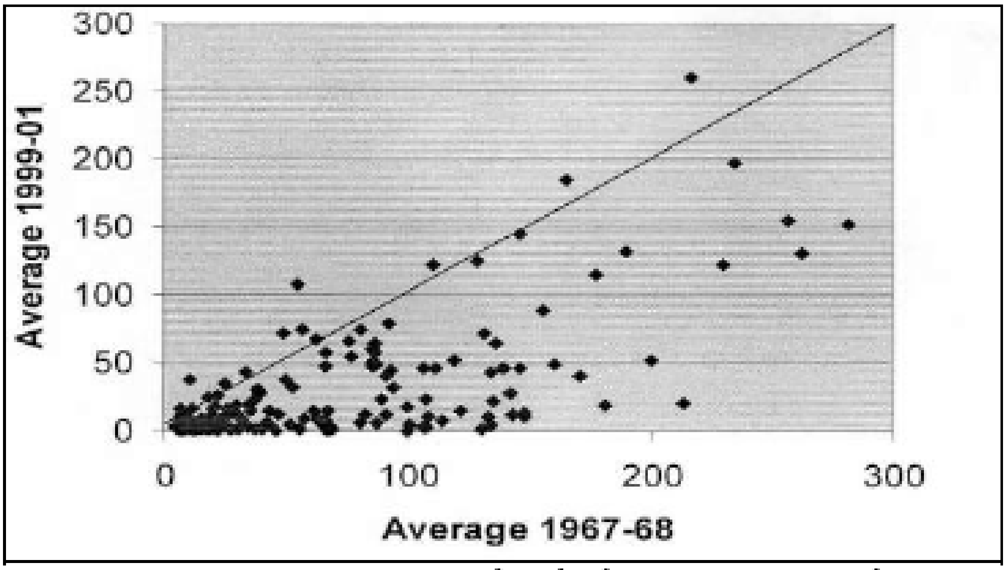

Figure 3.7.4. Area in rainy season sorghum by district in 1967-68 and 1999-2001.

3.7.2.2. The demise of rainy-season sorghum as a food crop went unnoticed for some time. In the early 1990s signs of diminishing demand for rainy-season sorghum as a food grain were not yet visible in the Village Level Studies (Chung 1998). In the Andhra Pradesh villages, where rice is the staple food crop, rainy season production of the ICRISAT cereals contributed about 20% of caloric intake and that contribution had not changed over 15 years between the late 1970s and the early 1990s (Table 3.7.1). The contribution of sorghum was also holding steady at about 60% of caloric intake in the Maharashtra villages over the same time period.

3.7.2.3. A steep decline in demand for rainy-season sorghum as a food grain was not anticipated in the early 1980s from KN Murty's comprehensive demand analysis on the ICRISAT mandate crops vis-à-vis other food commodities from the integrated perspective of a linear expenditure framework (Murty 1983). At the time of ICRISAT's founding in the early 1970s, the rural poor spent about 8% of their total consumption expenditure on sorghum across all of India. Pearl millet's average budget share was 2.2%. Poor urban consumers (those in the two lowest quintiles) spent slightly less, about 7%, on sorghum than their rural counterparts and about 2% of their total consumption expenditure on pearl millet in 1973-74. Twenty years later in 1993-1994, the only states where the budget shares exceeded these All-India averages were Maharashtra and Karnataka for sorghum at 9.2% and 9.0% for the rural poor, Gujarat and Rajasthan for pearl millet at 5.9% and 5.3% for the rural poor, Karnataka for sorghum at 5.4% for the urban poor, and Gujarat for pearl millet for the urban poor at 2.4% (Murty 1997). By the early 1990s, urban consumption of sorghum and millet was insignificant.

Table 3.7.1. A comparision of household energy intakes (Kcals adult equivalent^{-1} day^{-1}) in 1977-78 and 1992-93, by location and food crops in the ICRISAT Study Villages.

Food group	Andhra Pradesh		Maharashra	
ICRISAT crops	1977-78	1992-93	1977-78	1992-93
Sorghum	211	269	816	1028
Pearl millet	119	41	0	16
Finger millet	36	9	0	0
Groundnut	51	93	192	140
Pigeon pea	37	31	92	67
Chickpea	10	5	66	22
Total	**464**	**448**	**1166**	**1273**
Non-ICRISAT crops				
Rice	1625	1696	14	75
Wheat	8	9	188	266
Maize	0	0	101	47
Non-mandate legumes	8	10	41	38
Milk-Milk products	32	74	61	53
Meat/Fish/Eggs	24	10	2	5
Other vegetables	20	26	16	20
Fruit	0	5	6	9
Sugar/Spices	18	63	280	166
Other oilseeds	10	7	8	69
Green leaf vegetables	1	1	1	5
Processed cereal foods	1	8	1	13
All mandate cereals	366	319	816	1039
All mandate legumes	98	129	350	229
% share ICRISAT	**20.9**	**19.0**	**61.9**	**62.2**
All	**2217**	**2355**	**1884**	**2040**

1. Source ICRISAT VLS dietary survey 1977-78
2. Source ICRISAT-IFPRI alternative indicators village survey, 1992-93.

3.7.2.4. Based on NSS data from the early 1950s to the early 1970s, the rural-poor expenditure elasticities, reflecting the proportional increase in consumption expenditure on a specific commodity with a proportional increase in total consumption expenditure, were slightly above 1.0 for both sorghum and pearl millet and were on a par with the so-called superior cereals, rice and wheat. Even the estimated expenditure elasticities for the urban poor were fairly high at 0.6 for sorghum and 0.8 for pearl millet (Murty 1983).

3.7.2.5. Murty's analysis in 1983 did raise one red flag. The estimated elasticities for the marginally rural poor in the third expenditure quintile were substantially lower at 0.4 for sorghum and millet than for rice and wheat at about 1.0.

3.7.2.6. Between 1972 and 1994, the estimated expenditure elasticities declined steeply for the rural poor to 0.66 for pearl millet and 0.24 for sorghum. For the urban poor, an increase in total expenditure of 1.0% engendered a decline in consumption expenditure on both crops, a -0.35% change in sorghum and -0.10% in pearl millet. In contrast to these sharp changes for sorghum and millet, average estimated elasticities did not change markedly for other commodities including wheat and rice.

3.7.2.7. Sorghum and millet consumption also became less responsive to prices over time. In the first period from the early 1950s to the early 1970s, a 1% decline in the price of either pearl millet or sorghum was accompanied by over a 2% increase in consumption for the rural poor. By the later period, a 1% decrease in pearl millet price led to a 0.9% increase in pearl millet consumption; an equivalent change in sorghum price led to an even lower, a 0.3%, increase in consumption. In other words, the response in consumption to changes in sorghum and millet prices have changed over time: increasing supplies will result in substantially lower prices but not in markedly increased consumption.

3.7.2.8. Since the 1990s, ICRISAT researchers have paid more attention to alternative uses for sorghum and millet. Poultry feed is the principal alternative use to food for both crops. Sweet sorghum destined for biofuels has recently emerged as a promising alternative use. Scientists in the National Research Centre for Sorghum estimate that the minimum area for rainy season sorghum as a food crop will stabilize at about two million hectares (National Research Centre for Sorghum 2007). This minimum area estimate is driven by the perceived need to cultivate rainy season sorghum for fodder.

3.7.2.9. ICRISAT economists and other crop improvement researchers need to identify a tipping point in time when the use of rainy-season sorghum and pearl millet as a food grain is less than their utilization in alternative uses. Before that point is reached, a study should be conducted on the poverty alleviation potential of using rainy season sorghum and pearl millet as feed grain.

3.8 Gender

3.8.1. Although the term 'the feminization of agriculture' is increasingly used in development circles, it is hard to quantify. Feminization of agriculture usually implies differential rates of migration between men and women. Men migrate to the towns and cities in search of work. Women are left behind to tend the farm. Labor availability in agriculture declines and changes qualitatively.

3.8.2. Two quantitative aspects of gender are addressed here: the relative importance of women to men in the economically active agricultural population, and the incidence of women-headed rural households.

3.8.3. Globally, the men's and women's labor participation rate in agriculture has been falling since the 1990s. FAO data show that labor participation rates have declined less in the poorer developing countries where the majority of women still work in agriculture.

3.8.4. Based on FAOSTAT data, the relative importance of women in the agricultural workforce has not changed appreciably in many countries, but, in others, women loom larger in the economically active population working in agriculture. Experience in the SAT varies considerably by region. In India's SAT, the proportion of women to men working in agriculture has not changed in the recent past (Figure 3.8.1). Male workers outnumber female workers by about 2:1. The relative importance of women is substantially higher in WCA and has been increasing steadily over time. Chad, Nigeria, and Senegal have contributed heavily to this trend. More women than men work in agriculture in ESA, but women's share of economically active agricultural workers has remained steady since 1990. Among the SAT countries in ESA, women's share has been rising quite sharply in Malawi and to a lesser extent in Angola.

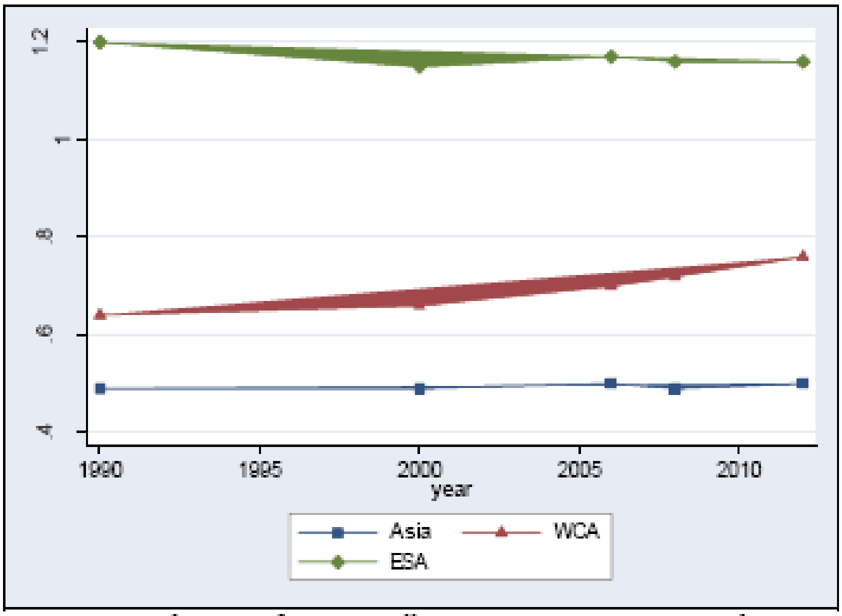

Figure 3.8.1. The ratio of economically active women:men in agriculture in the SAT by region for selected years. Constructed from FAOSTAT 2009.

3.8.5. Among all SAT countries, the relative importance of women in the agricultural labor force is by far the highest in Mozambique with 1.87 economically active women to every economically active man. A 15-year civil war and male migration for employment in South Africa largely explains the dominance of women workers in the agricultural labor force. The data on labor force participation in agriculture also reveal the influence of Islam in the countries of the SAT. Islamic countries are still characterized by substantially lower labor market participation rates.

3.8.6. The incidence of female-headed households is another datum that describes the feminization of agriculture. Large-scale sample surveys associated with the World Bank shed light on the extent of women-headed households. In rural India, about 10% of the households are headed by women almost all of whom are widows who are the most disadvantaged members of rural society. Rural India is characterized by a plethora of central and state government social schemes, but none of these seem to explicitly address the plight of widows who do not have access to a safety net. The incidence of widow-headed households has not changed in the recent past.

3.8.7. In several SAT countries of Africa, where large rural surveys have been carried out, the frequency of women-headed households ranged from a low of about 6-7% in Burkina Faso to 27% in Ghana. Four of six surveyed countries were characterized by an estimated incidence between 19-24%.

3.8.8. These countries were also surveyed more than once so it was possible to assess changes in age and family size of female-headed households over two points in time. A quick review of the data suggests mixed findings that were country-specific. The conjecture that female-headed households are becoming younger or have more dependents could not be confirmed with the World Bank survey data.

3.8.9. The national rural household data in Mozambique clearly show that female-headed households (about 25% of the rural total) are significantly poorer than male-headed households (Walker et al. 2002). Holding all other things equal, switching from a male-headed to a female-headed, non-widow household is accompanied by a 14% loss in household income and a 9% downturn in per capita income. But not all things are equal. Women-headed households have less of everything else. Widows are the worst off. Switching from a male-headed household to a widow-headed household results in a 30% decline in income. Women who are non-widows and who head households are characterized by significantly higher income than widow-headed households.10

3.8.10. The Mozambican results also show that adding a male adult to the household leads to an income increase of 11% net of other changes. Addition of a female adult augments household income by 7%. Therefore, women are disadvantaged from the narrow perspective of household income both as household heads and as workers compared to men.

3.8.11. Inclusiveness in diagnostic research and technology testing are essential for incorporating a gender perspective into agricultural research. Varietal options that were not exclusively driven by market criteria have found favor with women-headed households and were the basis for one of CIP's outstanding success stories in ESA (Rueda et al. 1996). The potato cultivar that women most liked survived the genocide in Rwanda and is still grown in the Great Lakes Region.

3.8.12. In the strategic planning deliberations, ICRISAT may want to assign greater priority to countries that have a higher participation of women in the agricultural work force and a greater proportion of women-headed households, particularly when they live in regions of relatively high production potential. In Mozambique, for example, this felicitous correspondence does not occur. Women-headed households are most prevalent (in relative terms) in the three provinces most marginal for crop production in the country.

3.9 Migration

3.9.1. Migration is implicit in urbanization and in the feminization of agriculture. Migration has been of interest to students of agricultural development for decades (Byerlee 1974), but data on migration and related-analytical studies are sparse. The recent 2009 World Bank Development Report on economic geography attempts to synthesize the information that is available on migration from different perspectives.

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[10] Widows did considerably better in 2005 in a later panel analysis (Mather 2009). Reasons for improvement are not clear although the government did institute a program to provide relief to widows in southern Mozambique.

3.9.2. Largely because of porous borders, the rate of labor migration in developing regions is highest in sub-Saharan Africa; however, the pace of migration has diminished since the 1960s. Migrants represented just over 3.5 percent of the population in sub-Saharan Africa in 1960 but only 2.3 percent by 2000. The incidence of migration was still highest in southern Africa, and West Africa was the only region characterized by a non-declining rate. Across-border migration has slowed the most in Central and in East Africa.

3.9.3. Rural-to-rural migration is a neglected phenomenon and is the movement associated with the largest share of internal migration in the 20th Century although rural-urban migration grew rapidly in the 1980s and 1990s. Rural-rural migration from lagging to leading regions is epitomized by migration from Western Kenya to the Central Highlands and from Bihar to the Punjab. With combine harvesting, seasonal rural-rural migration has abated in India. Nowadays, most migration from Bihar to Punjab takes the form of permanent hired laborers who work several years on farms before migrating to towns and cities in the Punjab (PS Birthal, personal communication). Rural-rural migration also seems to be more important in the SAT of WCA as farmers migrate from drier to wetter zones.

3.9.4. In India, the dominance of rural-rural migration has given way to rural-urban migration and more permanent circular migration. In Dokur, one of the ICRISAT study villages, about 35% of the village population seasonally migrate to find work that has been classified in nine different employment categories with context-specific characteristics represented by distance, destination, gender, and wage rate. The specific context is often caste-related (Nageswara Rao et al. 2009).

3.9.5. Although unskilled laborers migrate, educational attainment is the key variable that identifies migrants who are better educated than comparable workers in regions where they came from and in geographic areas they are going to. In the six ICRISAT study villages, migrants are predominantly young males with higher levels of education on average at all levels than the rest of the sample. Differences in the levels and composition of household income and assets seem inconsequential (Badiani 2007).

3.9.6. Perhaps the most relevant migration-related issue for agricultural research centers on the fate of remittances. Are remittances used to grease the wheels of technological change? Few if any studies address the fate of remittances, but those that do mainly generate negative findings for agricultural investment. Remittances are spent on consumption or on children's education or on capital-intensive, small-scale enterprises. If migration is from lagging to leading regions, it follows that remittances will not be spent on crop agriculture if the environment in the lagging region is perceived as marginal. For that reason, we could never find any evidence that rural households in drought prone Gaza province, a large source of male migration to the mines in South Africa, re-invested remittances in crop or livestock technologies in Mozambique. Preliminary results from resurveys of the ICRISAT Village Level Studies in Niger suggest the same conclusion: limited investment of remittances was made in agriculture in the drier zone (van Dyck 2007). But about 15-20% of remittances were invested in agriculture in the two wetter zones in the Boboye and Gaya regions. More work is needed in this area to understand the incidence and characteristics of contexts where and when remittances facilitate technological change.

3.10 HIV and AIDS

3.10.1. HIV and AIDS have exacted an enormous toll on human welfare particularly in sub-Saharan Africa. One would be hard pressed to design a more pernicious disease: mortality occurs mainly in prime-age adults aged 20-40 as lifetime income is lost, economic prospects of the current generation of survivors can be sharply curtailed in caring for the ill and children who could otherwise become orphans, and the children themselves become substantially more vulnerable to the scourge of poverty.

3.10.2. The deleterious impact of HIV and AIDS on human resources and on the production environment was highlighted in Ryan and Spencer (2001) who described multiple possible consequences from HIV and AIDS: (1) a decline in labor availability, (2) a subsequent shift to labor extensive crops that are less prone to drought, (3) a fall in crop income and production, (4) a decrease in cash cropping, (5) a loss in remittances, and (6) an increase in female-headed households. At the institutional level, Ryan and Spencer foresaw the threat of substituting resources destined for agricultural research to medical research. They emphasized that HIV and AIDS underscored the need to raise agricultural productivity by concentrating on developing and transferring labor- and capital-saving technologies in addition to drought-resistant cultivars that stabilize yields. More incisive targeting of female-headed households in technology development and transfer was also recommended.

3.10.3. Later, in an ICRISAT policy brief on new priorities for agricultural research in Africa, Freeman et al. (2002) noted that more research was needed to clarify the diverse nature of impacts and farmers' responses. They underscored the priority to design interventions that addressed labor shortages and nutritional constraints. In the ICRISAT Vision and Strategy to 2015, three areas of research intervention were described relevant to HIV and AIDS: (1) the use of the VLS to better understand the micro-dimensions of the disease, (2) the search for methods and approaches that contribute to disaster relief including HIV and AIDS, and (3) the deployment of successful groundnut research on aflatoxin that could lead to enhanced nutrition of victims and survivors. More recently, in 2008, an ICRISAT publication describing ICRISAT's regional strategy and programs in Eastern and Southern Africa noted that agricultural research "can help in identifying more effective strategies for protecting the livelihoods of the vulnerable and affected households in rural areas (p. 3)."

3.10.4. The above summary description begs the question, to what extent does HIV and AIDS warrant a qualitative change in the design of a strategy for agriculture research at ICRISAT, particularly for ESA where the prevalence of the disease is substantially higher than in the WCA and Asian regions.? A differential agricultural research response would be more effective if several of the following conditions hold:

- Prevalence of HIV and AIDS is easy to predict across agro-ecologies within countries;
- Macro-level impacts on agricultural output are well-documented and so-called AIDS famines have become a reality;

- Micro-level impacts on agriculture are adequately characterized and can be generalized;
- Improved food intake and nutrition reduces the risk of HIV infection;
- Higher food intake and improved nutrition extends the lives of the infected;
- Poverty is associated with higher incidence and prevalence; and
- Public-sector research in general and in the CGIAR Centers in particular have a comparative advantage and a good track record of success in generating labor-saving pre- and post-harvest technologies

3.10.5. A recent review of the challenges and opportunities for African agriculture and food security contained a thorough review of the implications of HIV and AIDS for agricultural development (Binswanger-Mkhize, 2009). The issues are complicated but, in general, available research suggests that none of the first six bulleted conditions hold. Spatial prevalence is highly variable across and within countries. Understanding of the proximate and underlying causes of such geographic variation is meager. So-called AIDS famines have not materialized, and knowledge of macro-level impacts is inadequate. Micro-level impacts are not readily visible from cross-sectional data even from large-scale nationally representative surveys, such as the TIAs, in Mozambique. Documenting impact requires panel data that have generated some important results in terms of consequences and adaptation strategies in a few well-defined settings. The evidence is, at best, mixed on the benefits from improved nutrition in mitigating infection and in prolonging life although it is well-known that energy requirements should increase for infected adults and children.

3.10.6. Contrary to other infectious diseases, HIV prevalence is not markedly higher among adults living in poorer households in SSA. In-depth analysis of representative surveys across eight countries with HIV testing in SSA concludes that "wealthier adults remain at least as likely as poorer individuals to be infected with HIV, if not more (Misra et al. 2007, p. S25 as quoted in Binswanger-Mkhize, 2009)."

3.10.7. Lastly, public-sector agricultural research does not have a good track record in generating labor-saving, pre-harvest, and post-harvest technologies that are the comparative advantage of small-scale artisans and the private sector (Walker et al. 2006). Summing up, defining a specific role for agricultural research in mitigating the impact of the disease is complicated by the uncertain spatial prevalence of HIVS and AIDS, the lack of persuasive evidence that improved nutrition leads to positive outcomes in treatment and prevention, perhaps aside from supplemental food given as part of an antiretroviral regime, and the absence of documentation that catalogs transparent and widely recognized impacts on agriculture.

3.10.8. For the above reasons, the HIV and AIDS epidemic does not require a changed research agenda for ICRISAT even through preventing and mitigating this disease looms large as one of the Millennium Development Goals. Increasing total food production would seem to be the right course to pursue until research persuasively shows that a qualitatively different and selective response in agricultural research leads to improved outcomes in prevention, treatment, and care and support. If ICRISAT in the medium-term future obtains funding for VLS panel data collection in ESA, then the Institute should be in a better position to document longer term consequences and adaptation strategies with its case study approach.

3.10.9. Total resources for HIV and AIDS in developing countries increased from about US$300 million in 1996 to US$8 billion in 2005 (World Bank, 2006). Unlike other drivers in the external environment, these justifiably heavy expenditures on the prevention and mitigation of HIV and AIDS have not translated into resources for agricultural research, most likely for several of the reasons described above. Until new research findings from the health sector identify a more incisive role for agricultural research, the separation of funding for HIV and AIDS treatment, prevention, and care and support, on the one hand, and for agricultural research, on the other, is likely to continue into the future.

3.11 Global Climatic Change

3.11.1. Increasing carbon dioxide concentration is reflected in a recent analysis of air bubbles trapped in Antarctic ice. Over the past 800,000 years carbon dioxide concentration has fluctuated between 170 and 300 parts per million. Because of human activities, carbon dioxide concentration is at an all-time high approaching 400 parts per million. Without mitigation, carbon dioxide concentration is projected to double in 2100 (World Bank Development Report 2010). Mitigation is projected to cost $400 billion annually in 2030, and the cost of adaptation is assessed at an additional $75 billion for a 2-degree Centigrade-trajectory reduction in global warming. A leading computerized political model of collective action and prediction of policy decisions across a wide range of human activity suggests that cooperation will not be forthcoming for this size of commitment for a low-emissions scenario to obtain; therefore, global warming will most likely be with us for a long time.

3.11.2. Global climate change appears to be manifested by a significantly higher incidence of flooding everywhere but especially in sub-Saharan Africa since 1971-75 (World Bank Development Report 2010). In the most recent period 2001-05, over 800 floods occurred worldwide; about 180 took place in Africa. The frequency of drought and earthquake events has not increased over the same time period. In that vein, preliminary results from a base data analysis of long term daily rainfall data with water balance models in a few hundred stations (with records longer than 50 years) in West and Central Africa show:

> a significant decline in rainfall over the 1951-2000 period (due to higher than long-term normal rainfall in 1950-60s and lower than long-term normal rainfall in 1970-80s), a significant increase in rainfall over the 1981-2009 period, and no significant trend in start of the growing season, end of the growing season, or length of the growing season in the long term (Pierre Sibiry Traore, personal communication, 2009).

3.11.3. This base data analysis is a good example of how research that was partially motivated by global warming should generate spill-over benefits for the lines of work that ICRISAT was already pursuing. ICRISAT seems to be well-positioned to seamlessly incorporate global warming into its research portfolio. ICRISAT leads an ASARECA regional project on climatic change. Deliberation among ICRISAT physical, biological, and social scientists resulted in several ex ante analyses that generated the following generalized findings and testable hypotheses (Cooper et al. 2009):

- Climate change will reduce the length of the growing period across the SAT, but that this could in large part be mitigated by improved water management innovations and the re-targeting and re-deployment of existing germplasm;
- Predicted temperature increases, through their effect of increasing the rate of crop development, have greater negative impacts on crop production than relatively small (+/- 10%) changes in rainfall.
- The impact of temperature increases alone on the yields under current low input agricultural practice is likely to be relatively small as other factors will continue to provide the overriding constraints to crop growth and yield. Significant reductions in rainfall amounts however would modify this conclusion.
- The adoption of existing recommendations for improved crop, soil and water management practices, even with climatic change, will result in substantially higher yields than farmers are currently obtaining in their low input systems.
- The development and adoption of better 'temperature-adapted' varieties, together with improved management practices, could result in the almost complete mitigation of the negative impact of temperature increases.

3.11.4. ICRISAT has a good record in risk analysis and assessment as exemplified by its recent work on rainfall insurance that was cited as a priority in the mid 1980s. Since the late 1970s and early 1980s, researchers have engaged in longer-term base data analysis and have deployed crop growth models, such as DSSAT, that are now being used to predict the effects of climatic change. (Because of budgetary constraints, this research area has suffered from a lack of critical mass for some time). ICRISAT has taken the long view in its Village Level Studies and in its assembly and analysis of district data in South Asia. These latter data are highly suitable for the analysis of dimensions of climatic change on agricultural and economic development.

3.11.5. Drought and heat tolerance loom large as priority traits in the institute's agenda for crop improvement that increasingly seeks genetic solutions to problems of abiotic stress. ICRISAT seems to have most of its bases covered to effectively address climatic change. Like other research areas, the issue of critical mass is important as strong links to climatic change themes reinforce the need for selective strengthening of specific areas in the research agenda. These linkages and those areas should be discussed in the regional strategic planning workshops. The commonsense approach is to fortify areas that are motivated by the challenge of climatic change without unduly distorting the "without climatic change" research agenda. A doubling or tripling of funds for agricultural research to address climatic-change could warrant a different qualitative response in research resource allocation. But we are not in that world yet.

3.11.6. ICRISAT's response to climatic change should also be placed in the context of other crops and other agro-ecologies in the evaluation of the potential of the threat and the scope for mitigation and adaptation. For example, potatoes only set tubers when the minimum night temperature falls below 19 ^{0} C. In the late 1990s, crop growth models of potato and climatic change showed that regional production was most vulnerable on the Indo-Gangetic Plain, one of the largest producing sub-regions in the world. At best, substantial shortfalls in production were predicted. Information about such an imminent threat to production of ICRISAT mandate crops in one or more sub-regions does not seem to be available at this time. Reliable and punctual information is needed to be able to craft a response in terms of priorities. ICRISAT seems to have a robust crop portfolio to cope with global warming.

3.11.7. With regard to mitigation, the SAT is not noted for fragile peat soils whose management is critical for carbon sequestration. Moreover, the prospects for adoption of minimum tillage technologies that sequester carbon are not bright in the medium term in the SAT. The competition for crop residues for livestock feed is too great to allow them to be economically incorporated into minimum tillage systems that will likely involve herbicide the use of which is increasing in India's SAT but is negligible in Africa's SAT on food grains and legumes. Lastly, sharp competition for soil moisture between annuals and perennials prohibits the widespread use of hedge alley cropping systems. Tree planting in small woodlots should be the norm.

3.11.8. In spite of the above difficulties, there obviously is scope for C sequestration in the SAT. Research from USAID's soil-management CRSP in West Africa's SAT suggests that field measurement of the potential for and actual amount of C sequestration is still in its early days. Measurement will be a topic for investigation when pilot schemes have been established for a compliance market of carbon off-sets. One of the first of these experiences is starting with several thousand coffee growers in Kenya (World Bank Development Report 2010). Increasing the reliability of the measurement of C sequestered and the rigorous monitoring of contracts are two areas that require research attention. It would be premature for ICRISAT to make a substantial commitment to such research now; the institute needs to maintain a watching brief on the experiences and prospects of these pilot experiences.

3.11.9. Research on farmer adaptation is a complex research issue and is currently a hot topic among donors. Requests to study farmer adaptation have mushroomed. Farmers should not have to be interviewed every year about how they are adapting to climatic change. Their actions, which are already recorded in survey data, should speak louder than their words. ICRISAT social scientists are wisely using space to proxy for time. Farmer adaptation is a topic that needs to be revisited once every 10 to 15 years. Given donor interest, this area could quickly become a time sink for one or more social scientists. A time-bound exit strategy is needed for research on farmer adaptation.

3.12 Land and Water

3.12.1. The recent trends in irrigation and fertilizer use in Africa's SAT are sobering (Table 3.12.1). In WCA, irrigation on cultivated land increased from 1.1% in 1989-91 to 1.3% in 2001-03. In ESA, the level of irrigation declined marginally from 5.9%. Ryan and Spencer (2001) foresaw a slowing in the rate of irrigation in sub-Saharan Africa from 2.1% in 1961-1997 to a projected rate of 0.8% from the mid 1990s to 2030. The slower projected rate now looks increasingly unattainable. The World Bank Development Report on Agricultural Development in 2008 is more optimistic but their optimism is only based on three case study experiences. Underperforming, larger surface irrigation schemes in the smaller countries in SSA can easily absorb the lion's share of the budget of a ministry of agriculture.

Table 3.12.1. Irrigation and fertilizer use in the SAT in 1992(1) and 2002(2) by region.				
Region	Irrigation 1 (%)	Irrigation 2 (%)	Fertilizer 1 (kg/ha)	Fertilizer 2 (kg/ha)
Asia's SAT	27.2	32.2	74.1	105.1
WCA	1.1	1.3	10.2	7.1
ESA	5.9	5.4	19.8	12.8

3.12.2. Ryan and Spencer (2001) also noted that fertilizer use was declining in some African countries because of structural adjustment programs. On average, fertilizer consumption per hectare fell in both regions of Africa's SAT (Table 3.12.1).

3.12.3. The drop in meager levels of fertilizer use is more worrying than the stagnancy in irrigation, although the bulk of fertilizer is destined for export or high value crops. The drop in consumption could spell less availability and is partially explained by a lack of effective market demand for food crops. The data in Table 3.12.1 are not that recent; however, they probably still reflect the reality in the region. Since 2000 the real price of urea has increased and then soared to over $800 per ton in 2008 when the price of DAP per ton hit $1200 and Muriate of Potash reached $900. Urea and DAP have quickly settled back to their pre-spike levels, but potash levels have stayed high throughout much of this year. Much of the drop in fertilizer use in WCA is attributed to Nigeria, which has somehow managed to chalk up a high rate of agricultural growth while shedding fertilizer.

3.12.4. The extent and depth of land degradation is uncertain in Africa's SAT where more measurement at a wider scale of remote sensing and more in-depth case studies are needed, particularly in areas of transition in terms of population density (TerrAfrica 2009). More assessment and diagnostic research are required to quantify the dimensions of land degradation so that more reliable predictions can be made on what types of land and water management techniques are likely to work when and where.11

3.12.5. What is undeniable is the imperative to ameliorate and reverse nutrient depletion. I think that ICRISAT needs to stay the course on micro-dosing and in-situ water conservation in SSA in a few carefully targeted environments where the prospects look the brightest. Partnering with IFDC could help.

3.12.6. In Asia's SAT, a thorough evaluation of the micro-nutrient work on boron, sulfur, and zinc is needed. Water scarcity was signaled by Ryan and Spencer as the most important NRM problem in India's SAT. ICRISAT could partner more aggressively with IWMI in tackling this problem. There is a brilliant ray of hope of the horizon in the form of results from IWMI's long-term research in Gujarat and that state's investment in re-electrification (Shah et al. 2008). The government launched the *Jyotigram* (lighted village) scheme, which invested US$ 290 million to separate agricultural electricity feeders from non-agricultural ones, and established a tight regimen for farm power rationing. This is a technology fix with rationing that seems to have

[11]Several success stories have been recorded in soil conservation mainly in in-situ land and water management but they represent only a very small percent of cultivated area (TerrAfrica 2009).

worked, and it could have profound implications for water management in peninsular India.

3.12.7. Work on water scarcity should be sufficiently research-based so that component products can be readily identified and attributed to research whose influence can be documented when policy changes. Generating international public-goods in terms of new components is still squarely in the IARCS domain in terms of comparative advantage. Developing integrated new systems is not. Users, mostly farm households, incorporate new components into their existing farming systems.

3.12.8. ICRISAT has a rich history in watershed research, development, and technology transfer. A recent, preliminary meta-analysis of over 600 village-level watershed evaluations finds an attractive rate of return to watershed development in dryland agriculture in India's SAT with almost all village sites showing a positive rate of return on investment. Those results are too good to be true, and ICRISAT has partnered with IWMI in coming up with good procedures for evaluation in this specific context. Thorough evaluations of watershed development projects in dryland agriculture in India's SAT have found little impact (Kerr 2002).

3.12.9. Because of its high location specificity, watershed development should be decentralized and participatory. Location specificity also means that it is difficult to generate international public goods from watershed research unless ICRISAT invests heavily in strategic research. Moreover, at this time, research investments in this area are problematic because a *Jyotigram* scheme has the potential to significantly alter the course of dryland watershed research and development that is based on conjunctive use of surface and groundwater.

3.13 Limited NARS Capacity

3.13.1. The story on the capacity of NARS to partner with ICRISAT to make an effective contribution to poverty alleviation in the SAT contains some familiar lines (Beintema and Stads, 2006). In Africa's SAT, growth in real public-sector expenditure on agricultural research has stagnated from 1971 to 2000, but growth in number of researchers is strongly trending upwards. More researchers and stagnating expenditures mean that operating budgets per researcher have fallen by about 50% in most countries. Few NARS rely heavily on recurrent funding from their own government; performance is linked to donor funding. When donor funding, usually from the World Bank, is obtained, public-sector research becomes operational if not downright effective. When donor funding ends as it did with INRAN in Niger in the late 1990s, public-sector research goes on life support at worst and limps along at best. These boom and bust cycles of donor support complicate partnerships particularly when countries do not have access to donor support. The CG centers can work well with smaller and weaker NARS, but the NARS require a threshold level of capacity; otherwise, the CG center, for all intents and purposes, assumes the role of the NARS, which may be warranted in a few specific circumstances, but which is not healthy for institution building in the longer term.

3.13.2. A few countries have made a policy commitment to funding public-sector agricultural research. Botswana has even raised the salary of its civil servants.

3.13.3. The problem is not one of low intensity of agricultural research as a percent of agricultural GDP. Developing countries in sub-Saharan Africa and in Asia and the Pacific have roughly the same intensity ratios that are mostly in the range of 0.35 to 0.75. The difference is that the agricultural sector in Asia and the Pacific is growing rapidly, which means that public sector research needs to be vibrant to keep pace. (Expanding public sector research is one of the reasons why the agricultural sector is growing.) For example, expenditures on public-sector research in both India and China grew at a 5-7% clip in real terms, which exceeded growth in almost all countries in SSA (Beintema and Stads 2008). Yet their agricultural research intensities are still low by international standards. It is hard to escape the conclusion that the capacity to perform routine research year after year is significantly higher in Asia than in sub-Saharan Africa per dollar of expenditure.

3.13.4. The list of alternative suppliers is not long. In 2000, which is the most recent year of data analyzed from the Agricultural Science and Technology Indicators (ASTI) Initiative, the private sector only contributed about 2% to total agricultural research expenditure in SSA. The bulk of that investment focused on hybrid maize, which should continue to increasingly receive support from the private sector. However, it is highly unlikely that the share of private sector research expenditure will exceed 10% by 2020. Presently, the share of private sector research in developing countries in Asia and the Pacific is about 10%..

3.13.5. Universities are an option and selected universities have benefited from Rockefeller support in recent years. But finding plant breeders in universities to run multi-location trials over time is not an easy task in crop improvement research.

3.13.6. In countries where the national program is dysfunctional, partnering in a temporary mode with other organizations in civil society, such as NGOs, may be a stop-gap measure. There also seems to be a re-awakening of interest in regional programs to combat the problem of inefficiencies of agricultural research in small countries with levels of production that may not warrant investing in a full-time equivalent scientist. Another bright spot on the horizon is the commitment made by the Bill & Melinda Gates Foundation to the training of plant breeders and other agricultural scientists in sub-Saharan Africa. ICRISAT needs to ensure that its mandated crops are well-represented in these training opportunities.

3.13.7. At the end of the day, ICRISAT scientists have the seeds for responding to the problem of dysfunctional NARS based on what has worked and has not worked over time in their networks and partnerships, particularly in large-scale collaborations such as Tropical Legumes I and II. Spending some time on this problem in the workshops, especially in WCA, could be rewarding and could result in a policy statement in the upcoming strategic plan.

3.14 Trade and Liberalization

3.14.1. International trade has enhanced the effectiveness of ICRISAT's agricultural research on pigeonpea in East Africa and in Myanmar. Groundnut appears to be the only mandate crop that could still significantly benefit from further liberalization of international trade. Africa has become a net importer of confectionary groundnuts, a traditional export crop (Birthal et al. forthcoming).

3.14.2. A large World Bank case-study effort recently analyzed trade distortions in 21 African countries. Similar to other traditional export crops, the synthesis of the case studies found that the rate of government taxation of exports on groundnut was declining, but it was still large (Anderson and Masters, 2009). The nominal rate of assistance was estimated at 40%. In other words, if the government did not intervene in the output market, farmers would receive a 40% higher price for their produce. The privatization of groundnut processing in the groundnut basin in Senegal was viewed as useful in reducing the size of this distortion. Millet and sorghum were also examined in the World Bank study, but there was no evidence for price discrimination against these crops from protectionist policies. Indeed, sorghum was viewed as slightly favored by government trade policies.

3.14.3. Returning to groundnuts, another study that focused on the South-South and North-South trade relationships found that import restrictions in China and India cost West African countries about $128 million annually in foregone export revenues (Beghin and Aksoy, 2003). Since that work was carried out, India has continued to liberalize trade; therefore, the size of that estimate may be considerably smaller than what is reported in the study. This research also found that subsidies to US peanut growers resulted in trade losses equivalent to less than 1% of the volume of international trade.

3.14.4. Overall, the liberalization of international trade should be regarded by ICRISAT as an increasing opportunity although its exploitation requires compliance with strict standards of food safety. However, unreasonable food safety standards can also figure as non-tariff barriers to trade. Groundnut trade in West Africa could warrant some attention in the context of levels of remaining distortion policy, liberalization, and the technological capacity to increase supply response.

Chapter 4

Implications for ICRISAT's Strategic Plan

The final section of the November draft of this report focused on implications for the agenda of the four strategic planning meetings that ICRISAT held in January and February of 2010. In this revision, I review trends and drivers that are relevant for the elaboration of the strategic plan, opportunities that warrant attention in the strategic plan, and research priorities for future strategic planning. To introduce this summary, it is insightful to briefly review a strategic planning perspective in the next sub-section.

4.1 A Strategic planning perspective

4.1.1. Like most ICRISAT scientists, I have been involved in several strategic planning exercises in the CGIAR. I never found them very informative because few hard decisions were taken about vision, mandate and substantive areas of research. The 'business-as-usual' approach was to project the past into the future, building on past strengths and existing mandates. There is nothing inherently wrong about building on past strengths, but the subsequent plans were not successful in communicating what emphases had changed from the past. This outcome is not unexpected because degrees of freedom are quite limited for an IARC in the CGIAR and agricultural research is commonly viewed as "slow magic." Nevertheless, the strategic plan should be about what ICRISAT wants to do and also about what it is not going to do or what it is going to deemphasize to place the institute in a better position to do what it wants to do. One or more blue-sky initiatives should figure in the strategic plan.

4.1.2. The strategic plan should effectively communicate generalized research priorities. It should reaffirm the institute's competitiveness in generating international public goods in well-defined research areas. The exigencies of funding should not figure prominently in shaping the strategic plan; nor should technical feasibility, which can be addressed in a more detailed business plan based on priority setting. The key defining criteria for strategic planning are desirability in terms of poverty alleviation, food security, and environmental sustainability, and ICRISAT's comparative advantage vis-à-vis alternative suppliers.

4.1.3. Although technical feasibility should not play a prominent role in the plan, it is important to have in the back of one's mind the track record of past research in terms of practical impact. Just because there is a high demand for research and ICRISAT has a comparative advantage in doing it does not mean that it should be done if past results have shown negligible impact and if the future continues to look like the past.

4.2 Challenges, Opportunities, Trends, and Drivers

4.2.1. The empirical evidence in Sections 2 and 3 of this report suggests that 'business as usual' is still an appropriate focus for much of ICRISAT's work. In particular, many countries in Africa's SAT would still be classified as agrarian economies in 2020. Rural poverty is pervasive. Agriculture contributes more than 20% to gross national product. Most farm households are net buyers of food. Private sector research, if it exists, is mainly restricted to maize hybrids. In these conditions, increasing the productivity of food crops has the potential to contribute significantly to poverty alleviation.

4.2.2. The main challenge for ICRISAT in this world of the 2008 WDR classification is to make 'the business' more effective in meeting poverty, food security, and sustainability goals. A carefully thought out business plan that builds on ICRISAT's Strategic Plan and reflects a commitment to incisive priority setting with an emphasis on critical mass should go a long way towards ensuring that these goals are met in a cost-effective manner. The business plan should also be informative about changes in tactics in dealing with lagging impact areas such as negligible varietal change in pearl millet in the Sahel and the limited uptake of ICRISAT-related cultivars in groundnut, which suffers from propagation problems attributed to a low multiplication ratio. In this case, the way ICRISAT does business may change, but the business of ICRISAT stays the same.

4.2.3. But I also make the case that not all of ICRISAT's business fits the 'business as usual' adage. The trends in section 2.4 underscore the need to deal with the eroding relevancy of ICRISAT's crop mandate in Asia's SAT. In particular, the window of opportunity for poverty reduction with crop improvement of ICRISAT-mandated cereals with an end use as food crops seems to be closing in India's SAT. By 2020, it is likely that the major consumption centers will be restricted to large production niches in western Maharashtra and northern Karnataka for sorghum and Rajasthan for pearl millet. Strategic planning needs to address the threat that the relevance of ICRISAT's mandate in India's SAT might be eroding. If no modifications are made, the trends documented in Figures 2.4.3 and 2.4.4 will continue their inexorable downward trajectory asymptotically approaching a low-level equilibrium.

4.2.4. In 2010, an economist can easily make back-of-the envelope calculations to show that crop improvement research on millet and sorghum is still attractive in peninsular India. However, the expected continuing decline in the value of rainy-season sorghum production in constant prices effectively shrinks the potential of ICRISAT's research to leverage improved poverty outcomes. Shifts in desirable emphases should be clear in the strategic plan.

4.2.5. Several of the trends and drivers analyzed in this report convey good news for ICRISAT. For example, the break in the long-term trend in declining real prices for food has opened up an economic space to reverse the decline in real funding for agricultural research. Largely because of the slowing in the rate of productivity growth that in turn reflects the neglect of agriculture in general and agricultural research in particular, it is unlikely that the trend of declining real food prices will re-establish itself prior to 2020.

4.2.6. Although global climatic change cannot be interpreted as positive news, ICRISAT, based on its past and present research, is poised to respond to this challenge. This is one area where ICRISAT should be able to make a seamless transition to enhance understanding of its area mandate in the sense of substituting spatial for temporal dimensions to inform on mitigation and risk adjustment strategies.

4.2.7. As is argued in Section 3, some drivers are very real, such as the HIV and AIDS epidemic in ESA, but their implications for agricultural research are far from transparent. Few if any of the hypothesized conditions for transparent implications were satisfied in the HIV and AIDS sub-section.

4.2.8. Others potential drivers, such as migration and the feminization of agriculture, are not characterized by sufficient empirical evidence for trend detection apart from women's secularly increasing participation in agriculture in West Africa. I also could not find very hard evidence to support the widely perceived conjecture that sectoral policies severely discriminate against ICRISAT crops. Groundnut in West Africa appears to be the exception.

4.2.9. Based on the discussions in Sections 2 and 3 of this paper, prime candidates for drivers in Asia's SAT are the transforming Indian economy that has steadily resulted in the erosion of the relative importance of ICRISAT's mandate, increasing water scarcity, and global climatic change. For WCA, my candidates would include rising imports of rice and wheat, increasing land degradation, and periodically dysfunctional NARS. For ESA, the main drivers would center on increasing imports of rice and wheat, increasing soil nutrient depletion, and global climatic change. Note that some of these so-called drivers, such as increasing cereal imports, are complex outcomes of intermediate causal factors like the increasing opportunity cost of women's time.

4.2.10. The analysis and discussion of trends and drivers also generated several surprises. I did not realize that pearl millet was increasingly produced in arid Rajasthan. Nor was I aware that a policy change in the form of re-electrification in rural Gujarat was sufficient to totally change the cost-benefit calculus on the conjunctive use of surface and groundwater in peninsular India. I was surprised that the SAT was over-represented in terms of so-called geographic poverty traps mainly in countries in sub-Saharan Africa.

4.2.11. Opportunities for expansion of ICRISAT's crop mandate do not appear to be attractive enough to warrant further evaluation. The demand for cereal fodder is still strong in India's SAT, but fodder : grain price ratios have not changed much in the past two decades largely because tractors have replaced animal traction at a surprisingly robust pace.

4.2.12. Oilseeds are the commodity grouping that are most congruent with India's SAT, and, with the exception of mustard, it is likely that that congruence is increasing over time. However, the overlap between oilseed production and Africa's SAT has not been rigorously assessed. ICRISAT's transformation as an oilseeds research institute would make economic sense if the prospects were bright that several of the oilseed species of major economic importance, such as castor, could find a home in farmers' fields in Africa's SAT. The increasing dominance of soybean would seem to curtail the potential of more minor oilseed species.

4.2.13. The demise of rainy season sorghum as a food grain has been accompanied by renewed interest in alternative uses and processing. Some uses such as sorghum as a feed grain make economic sense. Using sweet sorghum for biofuels is also promising. However, public-sector research in processing in general and in the CGIAR in particular on alternative food uses is characterized by a poor record on practical impact. For example, both CG Centers with a root and tuber crop mandate have invested in this post harvest research for many years and have generated few success stories. Many niche uses are too small to be described as having international public goods character. Moreover, the crop's competitiveness in major uses require the lowering of the average cost of production that is tied to technological progress which the IARCs, in large part, are already doing. In this regard, the identification of key traits in crop improvement that are end-use specific and the feasibility of their manipulation to attain threshold targets are important conditioners.

4.2.14. A preferred strategy to investing scarce research resources directly in alternative uses 'to save the crop' would be to engage in greater partnerships in areas of rising economic importance in the semi-arid tropics. The outcomes of such partnerships need to be assessed with rigor. The Plan should identify partnerships that need to be maintained, new partnerships that require nurturing, and discontinued partnerships that warrant renewal.

4.2.15. Partnerships are not the only institutional consideration that should loom large in the forthcoming Strategic Plan. In both WCA and ESA, the country portfolio warrants scrutiny. Which countries should command more attention from now to 2020? What is the strategy in working with large NARS such as Nigeria in WCA and Ethiopia in ESA relative to small NARS that may be increasingly dysfunctional? What production regions are likely to be most affected by imports of rice and wheat? How can the geographic location of ICRISAT research in terms of partners and research stations be optimized in each region?

4.2.16. In closing, I was not able to analyze all the potential possible drivers and related issues suggested by ICRSIAT scientists. If one or more concerns are not discussed in the paper, it is mainly because I did not think that the issue was important to pursue. For example, one scientist suggested that ICRISAT evaluate the possibility of incorporating orphan crops in Africa's SAT in its mandate. Crops are orphaned because few farmers adopt them. Agricultural research on orphan crops has a very poor track record in terms of practical impact both in and outside the CGIAR. Investing in research on orphan crops quickly exceeds two percent of their value of production annually and, in relative terms, they become more heavily researched than major field crops in a very short period of time. Introductions into new areas from very minor crops almost always fail, and the people who make money on new introductions are the initial seed growers.

4.3 Research for strategic planning

4.3.1. At several points in this report, the desirability of engaging in research that directly feeds into this and future strategic plans was highlighted. The rationale for research recommendations mainly responds to the uneven coverage in data quantity and quality between India's SAT and Africa's SAT. The abundance of reliable data at the sub-sub-national level in India creates a rich background tapestry from which a strategic plan can be fleshed out. The renewal of ICRISAT's Village-Level Studies and the existence of large representative household surveys from the National Sample Survey Organization (NSS) and from other statistical sources enhance the potential for probing trends, drivers, challenges, and opportunities.

4.3.2. In contrast, data relevant for strategic planning in Africa's SAT are only available at the national level. Estimates of the population in Africa's SAT are not direct but are imputed from areal estimates of the SAT vis-à-vis all other agro-ecologies in a specific country. The production data series for ICRISAT's mandate crops vary markedly in terms of their reliability in Africa's SAT. Priorities for strategic research that informs strategic planning for Africa's SAT are discussed in this report and include the following:

- Direct estimates of the SAT population from census data at the sub-national and, if available, sub-sub national levels;

- Validation of country-level data on crop-specific production levels reported in FAOSTAT with estimates from nationally representative household surveys;

- The derivation of estimates of production variability of the ICRISAT mandate crops from price analysis of time-series information where such data are believed to be reliable;

- An assessment of consumption of rice, wheat, maize, sorghum, and pearl millet in rural and urban households focusing on the extent that consumption patterns and parameters are changing over time;

- An evaluation of the poverty reduction potential of sorghum and pearl millet as feed grains vis-à-vis their role as food grains in India's SAT.

4.3.3. Without a commitment to the above strategic research agenda, rural households in Africa's SAT will always appear as shrouded in mystery compared to those in India's SAT. From now to 2020, more data sets will become available to shed light on the welfare and livelihoods of households in Africa's SAT. The challenge for ICRISAT researchers is to piece the relevant findings together to tell a credible narrative of the extent of and causal factors conditioning progress in attaining the triad of CG objectives in Africa's SAT.

4.3.4. The spirit of this base-data socio-economic analysis is similar to a long-term climatic analysis that ICRISAT research is known for. The purpose is to enhance systematic understanding in the SAT so that the Institute's defining characteristic becomes something more than a notional concept.

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