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Priority Setting for Public-Sector Agricultural Research in Mozambique with the National Agricultural Survey Data

by

T. Walker, R. Pitoro, A. Tomo, I. Sitoe, C. Salência, R. Mahanzule, C. Donovan, and F. Mazuze

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Priority Setting for Public-Sector Agricultural Research in Mozambique with the National Agricultural Survey Data

EXECUTIVE SUMMARY

Fourteen years after the return of peace in 1992, the Mozambique economy can no longer rely on borrowed technologies to fuel agricultural development in the smallholder sector that accounts for the bulk of the value of agricultural production. National agricultural research needs to step up and generate adaptive research solutions to more localized, but still economically relevant, production problems. Priority setting for Mozambique's recently consolidated and increasingly decentralized public-sector agricultural research institute (IIAM) is timely, not only because of these organizational changes, but also because of the increasing opportunity cost of under-performing agricultural research. In this priority-setting exercise, we assess research resource allocation across commodities and agroecologies from the perspectives of economic importance and poverty reduction. We use the rich national rural household survey data to inform priority setting.

The productivity of IIAM in the next 15 to 20 years is tied to the success of the cassava and maize programs. These two staple food crops represent about 50% of the value of production and 55% of the potential to alleviate income poverty in the smallholder sector. A 20% increase in productivity of either maize or cassava translates into a reduction in the severity of income poverty by as much as 19%, and leads to a poverty reduction that exceeds 5% in 34 of the 80 survey districts. The mean national reduction is 6% to 7% for each of these two staples. The estimated size of poverty reduction for maize and cassava is four to five times greater than groundnuts, the third most important commodity ranked for poverty reduction. Given their importance, the cassava and maize programs each warrant a minimum investment of seven to ten scientists.

The amount of research attention to give to the other 30 commodities with value of production exceeding $0.5 million per year is a more difficult decision. A simple cost-benefit analysis of a stylized example of technological change suggests that commodities with a value of production less than $3 million are risky candidates for research because of their small production base. This calculation reduces the list for research attention to about 20 commodities that are the focus of the rest of the analysis.

Information on prospects for borrowing technologies from countries in the region and on market demand is presented to contribute to decision-making on research resource allocation. Cassava, sweetpotato, groundnut, rice, sorghum, cashew, coconut, and cowpea are substantially more important in Mozambique than in the rest of southern Africa. Most of these commodities are produced in the coastal lowlands, which defines to a large extent Mozambique's uniqueness. Comparisons of price ratios over time suggest that demand for fruit, sorghum, pearl millet, cassava, sweetpotato, and coconut is weak, and that demand for vegetables and animal products is strong.

Targeting agricultural research to marginal regions of low production potential to tackle chronic poverty is one temptation that the management of agricultural research in Mozambique does not have to face. In analyzing the national rural survey data over two years, we documented geographic traps of chronic poverty: districts in the lowest mean income quintile in one year are also in the lowest mean household income quintile in the next

year. But many of these same districts are characterized by reasonable agricultural production potential in terms of soils, rainfall, and higher population densities. Hence, the trade-off between localized chronic poverty and production potential is not steep. In contrast, geographic relief traps, areas that have a higher incidence of food insecurity than other regions largely because of a greater likelihood of drought, can be a source of distraction for agricultural research. Their low production potential does not necessarily translate into lower household income relative to the rest of the country.

The bulk of this research report addresses the question of where commodity research should be cited across IIAM's ten agro-ecologies and four zonal research centers. As IIAM decentralizes its scientific human resources to its four zonal center locations, it should not lose sight of the primacy of the Northeast Zonal Research Center in both economic importance and the potential for poverty reduction. Our analysis suggests that the Northeast Zonal Research Center contributes about 40% to value of commodity production and to absolute poverty alleviation. The temptation is that too many resources are allocated to the South Zonal Research Center because the research infrastructure in the south is wider and deeper than in the center and north of the country. If the three other zonal research centers are to fulfill their promise, a few key facilities need to be rehabilitated and strengthened in the center and north. The scarcity of research infrastructure is most constraining in the coastal agroecologies, especially for rice.

We assembled a human-resources database that shows about 55 of IIAM's 120 scientists can be attributed to crop and livestock commodity research. The present research resource allocation at IIAM broadly reflects economic importance and poverty-reduction potential as the actual allocation of 55 scientists does not depart that much from our illustrative best-bet allocation based on the analysis of the national survey data. More emphasis could be given to the staple food crops maize and cassava and to potato, sesame, and goats. IIAM seems to be over-invested in rice and most of the other livestock species. Any over-investment in livestock is not that much of a problem because the livestock populations are still recovering in a country decimated by the civil war.

Because it was based on the national survey data with a rigorous sample design, this priority-setting exercise was less subjective than most. But it also suffers from several of the same limitations as the other conventional exercises. A review of priorities within commodities with organized stakeholder involvement at the zonal research centers is most likely the next priority for priority setting at IIAM. Moving to a project-based research and accounting system would facilitate priority setting.

This priority-setting exercise was the basis for a workshop attended by IIAM research administrators and scientists. That event generated a "consensus" allocation of scientists by zonal research center that is described in Table A1. Subsequent presentations were made to scientists at the Central and Northeast Zonal Research Centers. The results of this research report also assisted in laying the building blocks of an investment plan for IIAM that was recently submitted to the Government of Mozambique.

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LIST OF ACRONYMS

ASTI	Agricultural Science and Technology Indicators
CEF	Center of Forestry Research
CESE	Center for Socio-economic Studies
CFA	Center for Agricultural Training
CIMMYT	International Center for the Improvement of Maize and Wheat
CIP	International Potato Center
FAO	United Nations Food and Agriculture Organization
FEWS NET	Famine Early Warning System Network
IAF	National Household Consumption Survey
IARCS	International Agricultural Research Centers
ICRAF	World Forestry Center
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IIAM	Institute of Agricultural Research of Mozambique
IITA	International Institute of Tropical Agriculture
INIA	National Institute of Agronomic Research
INIVE	National Institute of Veterinary Research
IPA	Institute of Animal Production
KARI	Kenyan Agricultural Research Institute
KIT	Royal Tropical Institute (Netherlands)
MADER	Ministry of Agriculture and Rural Development (now MINAG)
MINAG/DEST	Ministry of Agriculture/ Department of Statistics
NARS	National Agricultural Research Systems
NGO	Non-governmental Organization
SADC	South African Development Community
SARRNET	Southern Africa Roots Crops Research Network
SAT	Semi-Arid Tropics
SSA	Sub-Saharan Africa
TIA	National Agricultural Survey
UEM	University of Eduardo Mondlane
USAID	U.S. Agency for International Development

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1. INTRODUCTION

In spite of the increasing importance of private-sector agricultural research in globalization, public-sector agricultural research will continue to play a dominant role in determining the pace of agricultural development for most developing countries, especially those in Sub-Saharan Africa (SSA). For example, recent results from a 27-country survey showed that in 2000 public-sector research still accounted for the bulk (98%) of total research expenditure in SSA (Beintema and Stads 2004). Even in South Africa, with arguably the most advanced agricultural research system in the continent, the private sector's share in research expenditure does not exceed 5% (Liebenberg, Beintema, and Kirsten 2004).

Getting priorities right is one way to improve the effectiveness of public-sector agricultural research. But informed priority setting is not a necessary and sufficient condition for effective public-sector agricultural research that is often constrained by weak salary incentives, low and seasonally unavailable operating budgets, dilapidated research infrastructure, and inadequate human capital (Eicher 2001). Eliminating these constraints requires long-term attention and so does the generation of a routine and cost-effective process for priority setting.

A formal priority-setting evaluation that systematically draws on secondary agricultural data is a good place to begin the process to identify "macro" priorities for public-sector agricultural research. Indeed, priority-setting evaluations, based on different methods and criteria, have been conducted for many national agricultural research programs in developing countries (Medina Castro 1993).

A meta-evaluation of priority-setting exercises across countries has not been undertaken, so we do not know if priority setting generated valuable information that changed decision-making on research resource allocation. But presumably, a priority-setting exercise is more informative when the lack of effective agricultural research is increasingly perceived as constraining the growth of the sector, when agricultural research is undergoing structural and organizational change, when reliable national survey data are available to inform on research resource allocation, and when macro-economic policies are favorable to economic stability and growth. Arguably, Mozambique satisfies these four conditions that point to the desirability of a priority-setting evaluation at this time.

Mozambique is a poor country that has not benefited from stable agricultural research for much of its recent history. Specifying the country context, especially the dynamics of agricultural research, is extremely important to getting the methodology right for priority setting. Our methodology focuses on economic value of production, the potential for technological change to reduce absolute poverty for rural producers, and the agroecologies that provide a framework for the operational decentralization of public-sector agricultural research. National rural household surveys are the raw material for our priority-setting analysis. Results are reported in the rest of the paper under the three broad methodological headings of economic congruence, absolute poverty, and agroecologies. These estimates provide a foundation for comparing the existing research resource allocation in public-sector agricultural research to highlight commodities that appear to warrant more or less priority. This comparative evidence was presented at a workshop on priority setting, and a consensus resource allocation obtained at that workshop is given in a summary (Appendix Table A1). Several lessons, guidelines, and recommendations are presented in the concluding section of the paper.

2. THE CONTEXT: CONSOLIDATION AND DECENTRALIZATION OF PUBLIC-SECTOR AGRICULTURAL RESEARCH

Prior to 1974, agricultural research in the colonial period in Mozambique was marked by the negligence of the smallholder sector (Bias and Donovan 2003). Since Independence, the effectiveness of agricultural research was eroded by political instability and civil war until peace prevailed in 1992.

In order to make up for lost time, Mozambican agriculture borrowed technologies both regionally and globally. Prime examples of technology borrowing include improved maize varieties from neighboring countries, particularly Zimbabwe, a widely adapted bean variety from Colombia, higher ginning-percentage cotton varieties from West Africa, vaccines from an Australia-funded project to combat Newcastle's disease in chickens, disease control in cashew via a spraying program that was successful in Tanzania, and a charcoal-production technology from Thailand.

Mozambican research has also identified a local variety that is tolerant to the effects of cassava brown streak virus, the major source of biotic stress in cassava. That variety is being multiplied extensively and its economic impact is conservatively estimated at $8 million annually (McSween et al. 2006). Mozambique has also tested and released varieties from elite material from the International Agricultural Research Centers (IARCS), most notably the short-duration maize variety Matuba from the International Institute for Tropical Agriculture (IITA) and the International Center for the Improvement of Maize and Wheat (CIMMYT), the rosette-resistant groundnut variety Nametil from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and orange-fleshed sweetpotato varieties from the International Potato Center (CIP).

The scope for technology borrowing or for identifying unmodified local solutions to Mozambican agricultural problems and opportunities is not exhausted. But progress is increasingly linked to adaptive research that opens up an extension gap between best-practice and average-farm productivity. Mozambique now finds itself approaching what Evenson (2002) calls technological-capacity level 2 in a five-stage hierarchy that defines the maturity of agricultural research in an economy. Agricultural research is not constraining in a technological-capacity level 1 country because of ample scope for borrowing technology from abroad. Fourteen years after the return of peace, public-sector agricultural research should be in a situation to deliver technologies that provide the fuel for agricultural development. Failure to do so limits the prospects for economic growth in the agricultural sector and for economic development (Pardey 2001).

Public-sector agricultural research at IIAM in Mozambique faces the same challenges that comparable institutions in SSA have dealt with (with a mixed record of success and failure) since Independence. In December 2000, a comprehensive report by the Royal Tropical Institute of the Netherlands (KIT 2000) identified the following major constraints on the output of agricultural research in Mozambique: (1) shortage of qualified management and scientific staff, (2) low and seasonally unavailable financial resources, (3) deficient infrastructure, (4) weak research management, (5) inadequate research planning, priority setting, and stakeholder participation, (6) donor interference, and (7) unimplemented restructuring proposals.

Since 2000 progress has been made to alleviate several of these generalized constraints. Human capital is increasing as scientific training is deepening from a low base compared to other countries in southern and eastern Africa. Low and seasonally untimely recurrent budgetary support and unattractive salary levels are increasingly recognized as major institutional constraints to enhancing the productivity of agricultural research. Strong linkages with international centers are another bright spot on the horizon for technology generation.

Agricultural research in Mozambique also faces challenges that other countries in SSA have not had to deal with. The infrastructure for agricultural research was devastated by war, which also decimated the cattle population. Infrastructure for input distribution is still rudimentary. Poor access to animal traction and improved inputs, particularly inorganic fertilizer, substantially diminish the likelihood of area expansion and intensification. The use of animal traction in the more populous Zambezia, Nampula, and Cabo Delgado provinces is effectively nil, which implies that farmers cannot take advantage of Mozambique's most prominent agricultural asset: its abundance of land. Schemes to bypass animal traction by jumping from hand-hoe agriculture to tractorization have failed throughout SSA (Pingali, Bigot, and Binswanger 1987). Therefore, the absence of animal traction in large swathes of central and northern Mozambique poses a severe constraint to realizing production potential. Finally, the location of the capital in Maputo with reasonably good living conditions and educational facilities is far from the agricultural heartland of the country. The attractiveness of living in Maputo impedes the decentralization of agricultural research.

The location of an experimental station is one of the key variables that determines the success of agricultural research. The Portuguese colonists endowed Mozambique with reasonably good infrastructure for agricultural research, but too many stations and laboratories were concentrated in the south with sparse rainfall and low population densities. To be fair, both Sussendenga in central Mozambique and Nampula in the north were blessed with research infrastructure at Independence, but access to research focused on Portuguese settlers, some of whom benefited from irrigation and almost all of whom produced commercial crops for export. The existing infrastructure for research at Independence did not address the needs of the present-day 3.2 million smallholders that constitute the backbone of Mozambique's agricultural sector.

Unlike many other developing countries in SSA, Mozambique has not benefited from a large infrastructure-included, donor-supported project to revitalize public-sector agricultural research to make it responsive to its smallholder mandate. Generalized donor support in the form of Proagri has helped to keep agricultural research from losing ground, but it has not been sufficient to impact program performance in a pronounced fashion. Small earmarked funds for agricultural research in and outside of Proagri have provided much needed recurrent resources to promote program stability.

In contrast to an agricultural sector that is beset by structural weaknesses, Mozambique is lauded by donors for its enlightened monetary and fiscal policies that have set the stage for growth rates that rival those of any other economy in SSA since the mid-1990s (World Bank 2005). Robust growth stems in part from the very low starting point in 1992. But several donors are quick to point out that the easy gains from resettlement following the war have now been realized. This observation is another variation on the theme that future growth is contingent on improved performance of agricultural research and extension that facilitates intensification.

Public-sector agricultural research is also changing. In an effort to increase the efficiency of agricultural and natural resource research directed at the alleviation of rural poverty, the government of Mozambique established the Institute of Agricultural Research of Mozambique (IIAM) in late 2004. IIAM was created by combining the staff, mandates, and resources of five separate institutions: the National Institute of Agronomic Research (INIA), the Institute of Animal Production (IPA), the National Institute of Veterinary Research (INIVE), the Center of Forestry Research (CEF), and the Center for Agricultural Training (CFA).

Capitalizing on supposed economies of scale was one reason for this institutional change; decentralizing and shifting research from the more sparsely populated and dryer south to the more densely inhabited and wetter center and north was another. Since the late 1990s, increasing emphasis is given to the conduct of research in four zonal research centers that each contain a main agricultural experimental station with several geographically dispersed auxiliary stations and laboratories.

Lastly, Mozambique is characterized by nationally representative agricultural surveys that were carried out in 1996, 2002, 2003, and 2005. These data have not yet been used to inform agricultural research in a systematic manner. Summing up, the time is ripe for a priority-setting evaluation for agricultural research in Mozambique because of the increasing opportunity cost of ineffective research, of a stable macro-economic environment, of the ongoing institutional dynamics of research reorganization and decentralization, and of the availability of reliable national survey data.

3. THE METHODOLOGY: COMMODITIES, AGROECOLOGIES, ECONOMIC CONGRUENCE, AND ABSOLUTE POVERTY

Priority setting focuses on emphases at the margins. The spirit of priority setting is a bit more here, a bit less there. In and of itself, a priority-setting evaluation cannot be used to define a research program because many important considerations are difficult to assess. However, priority setting establishes a basis for quantifying trade-offs and the opportunity cost of pursuing different resource allocations (Kelley, Ryan, and Patel 1995).

Priority setting for agricultural research is still guided by T.W. Schultz's observation that scientific creativity should not be hamstrung by research administrators who plan and monitor research within a narrowly defined context (Arndt and Ruttan 1977). In other words, priority setting should not be used to micro-manage research. Scientists should be given enough freedom to be entrepreneurial within some generalized guidelines established by research administrators. In that spirit, we focus our analysis on the aggregate commodity level. At times, we discuss, but not formally evaluate, opportunities or identify problems that warrant attention within the commodity. Evaluation of specific options is best done in stand-alone studies focusing on the expected consequences of well-defined technologies.

3.1. Commodities

Making commodity the unit of account in priority setting reflects the dominant paradigm for organizing agricultural research. Several disciplines can contribute to the commodity perspective that provides a natural focus for organization: the productivity of a plant or animal species. Most rate of return studies of technological success refer to commodity innovations (Alston et al. 2000). And most commodity success stories are about crop varieties. Historically, the rate of return to livestock research has been lower than crop research; consequently, genetic improvement does not loom as large in livestock as it does in crops. The importance of agricultural research in generating varietal change is one area of emphasis in our generalized priority-setting exercise.

Not all competing uses for research resources can be evaluated with a priority-setting exercise founded on a commodity perspective. Several areas of agricultural research, such as natural resources management and germplasm conservation, are difficult to value. Moreover, a commodity perspective does not shed light on priorities for service provision or socio-economics research. Several heuristic rules of thumb apply in these cases, but a unified quantitative treatment is not possible.

We have to reconcile ourselves that a considerable part of agricultural research falls "outside" a conventional priority-setting analysis. How large is large is a legitimate question. Inside the box are those elements that increase productivity. Outside the box are considerations that are only indirectly linked to increased productivity or that address other criteria such as biodiversity.

Service areas are difficult to evaluate in a conventional priority-setting exercise. Areas outside the box include training, soils, germplasm conservation, socio-economics, service laboratories, and forestry, for which estimates of species value of production are not available or have not been collected. In principle, several of these areas could be brought inside the box with scoring techniques (Kelley, Ryan, and Patel 1995) or with a fuller description of projects (Walker 1996). But scoring techniques are very arbitrary (Alston, Norton, and

Pardey 1995), and IIAM does not presently operate with projects as the units of account. We return to the allocation of scientists inside and outside the box later in this report.

3.2. Agroecologies

Adaptive agricultural research is all about designing technological options for specific geographic conditions that are often summarized with the concept of an agroecology. Nowadays, with geographic information systems, the definition of a recommendation domain is flexible depending on the problem and can cut across one or more agroecologies. Nevertheless, the notion of agroecology is useful to define potential recommendation domains for broad technologies addressing crop and animal species. An agroecological classification is the basis for the definition of the four decentralized zonal research centers.

The classification featuring ten agroecologies is mapped in Figure 1, and is derived from the work of the National Institute of Agronomic Research (INIA), one of the institutional precursors to IIAM. Agroecologies are used notionally to define broad, decentralized research responsibilities corresponding to the South, Central, Northeast, and Northwest Zonal Research Centers. They are defined largely on topography (especially altitude), rainfall, and soil criteria.

The location of INIA stations is also mapped in Figure 1 in 2002. At that time, four of the seven operating stations were in the south. The large coastal agroecologies in the center and north (R5 and R8) were devoid of operational research facilities. This geographic imbalance is being corrected, but, as Figure 1 shows, Mozambique is a very large country, and rehabilitating infrastructure to service the needs of all ten agroecologies requires a long-term commitment to agricultural research and calls for sequenced investment based on priority setting.

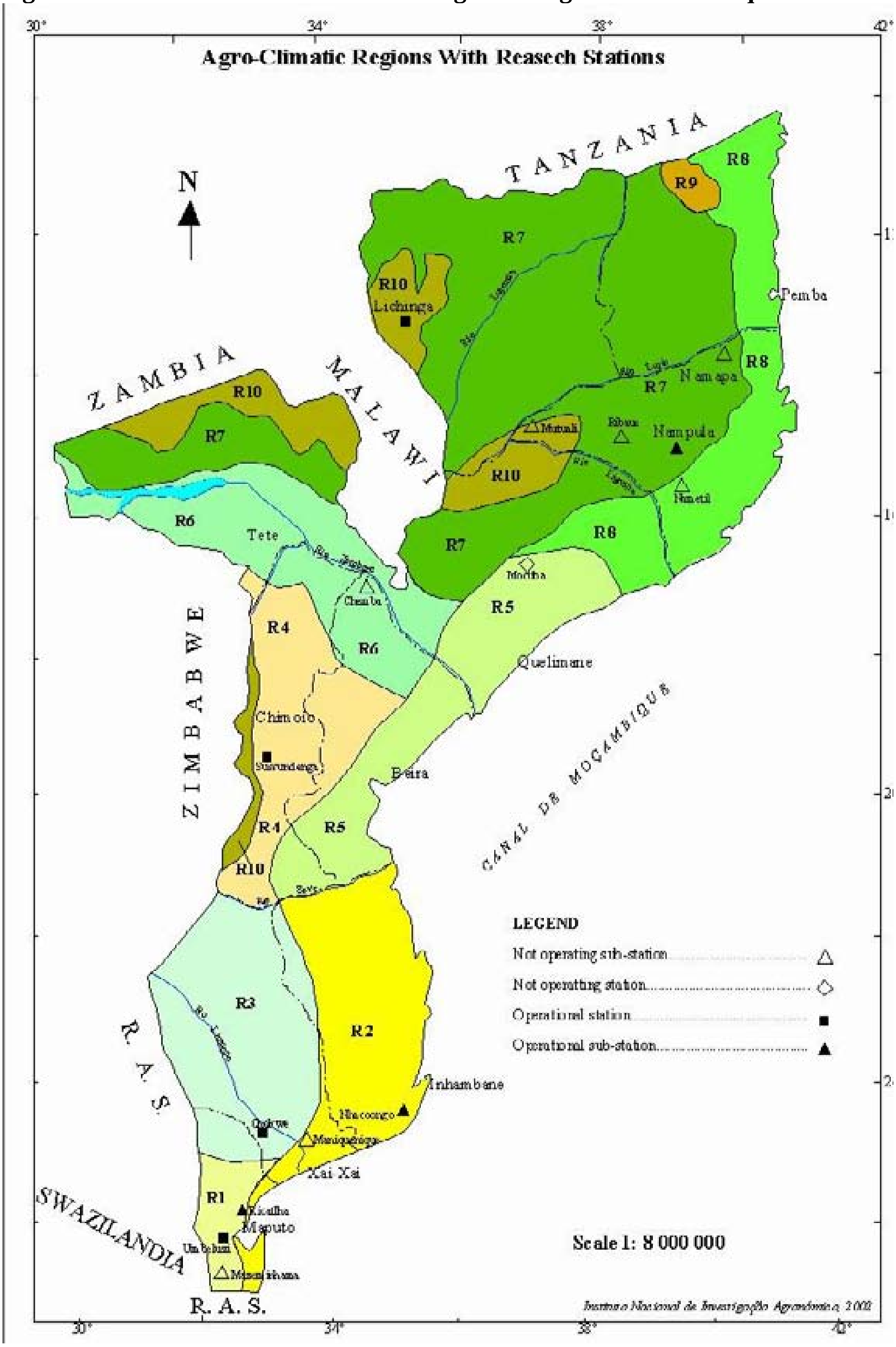
To complement the agroecological description of space, we also disaggregate the commodity data by district (Figure 2). The national rural household surveys, on which our priority-setting exercise is based, covered 80 of 128 districts in Mozambique. Statistically speaking, the district samples may not be large enough to draw valid inferences at the district level, but they provide valuable geographic points of departure and insight.

In each agroecology, the sampled districts account for at least 50% of the total number of districts that pertain to a particular agroecology. The district data in Figure 2 are useful in responding to more general questions on the relationship between geography and agricultural research. For example, the question of emphasis to give to marginal regions vis-a-vis higher potential environments looms large in agricultural research. The agroecological ordering of the data in Figure 1 is mainly used to describe the overlap between commodity production and geography in deciding where to site research programs across the zonal research centers.

3.3. Economic Congruence

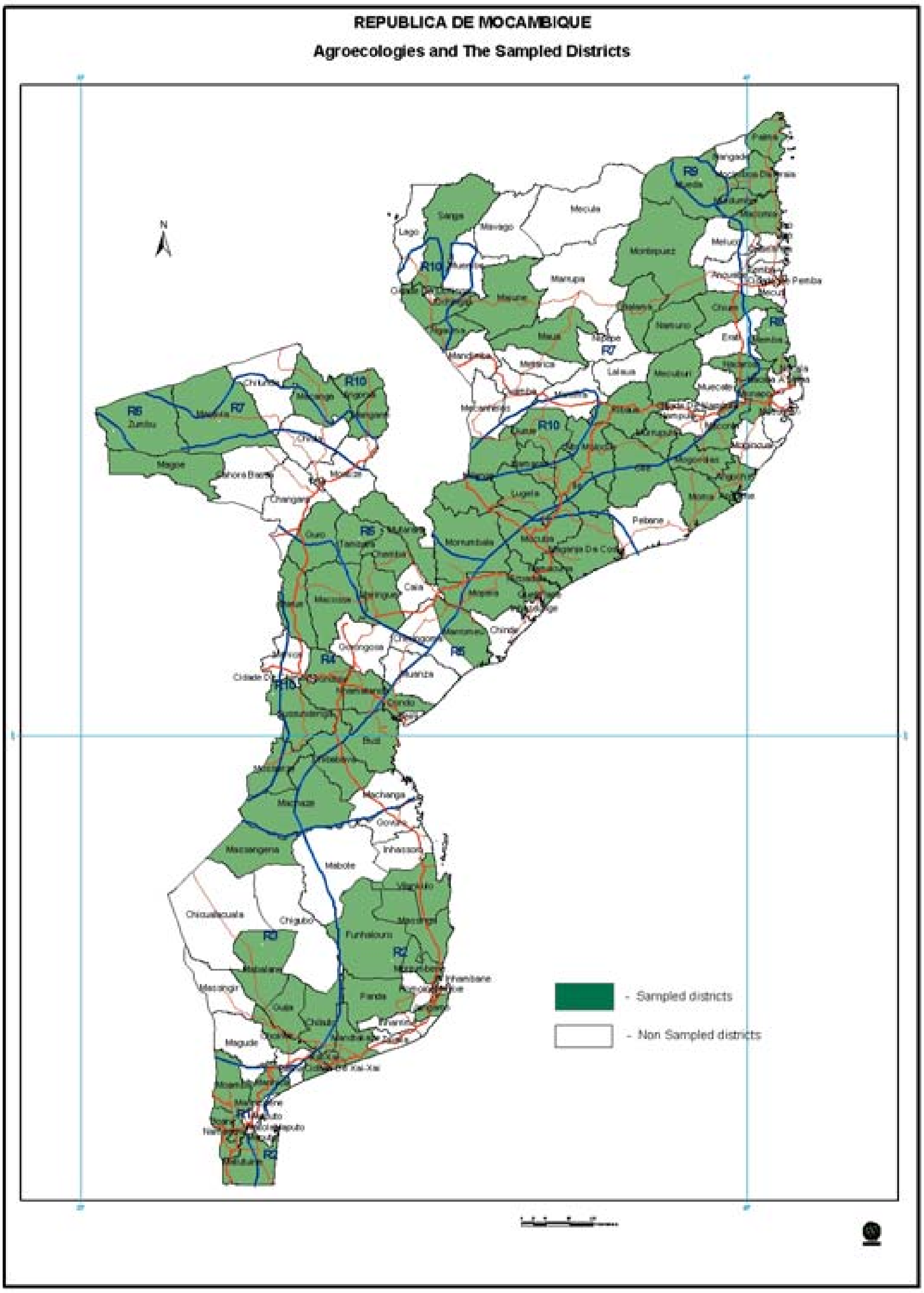
An array of approaches and methods have been used to generate information for priority setting in agricultural research (Schumway 1977). All entail strengths and weaknesses; there is no best approach for all contexts. The recent consolidation and decentralization of public-sector agricultural research in Mozambique calls for a simple approach to provide generalized

Figure 1. Distribution of the Ten INIA Agro Ecologies in Mozambique



Source: Ministry of Agriculture and Fisheries 1996

Figure 2. Sampled Districts in the TIA 2002 and 2003



Source: Constructed from MADER 2002

information to guide research resource allocation. We focus on what we believe are the two most important criteria for priority setting in agricultural research at this stage in Mozambique's economic development: economic importance and the potential to reduce absolute poverty.

Because agricultural research is critical for economic growth, examining the economic importance of commodities is a "natural" starting point for the initial evaluation of research resource allocation. In economic jargon, this starting point checks for congruence or parity of value of production and research expenditures across commodities. Broadly interpreted, economic congruence implies that the importance of a commodity in agricultural research should be proportional to the importance of the commodity in the national economy. Importance is expressed in monetary terms: agricultural research expenditure and the value of agricultural production.

Congruence is defined in (1):

$$(1) \quad \frac{e_c}{\sum_{c=1}^{m} e_c} \cong \frac{p_c q_c}{\sum_{c=1}^{m} p_c q_c} = s_c$$

where e_c is the research expenditure on commodity c, $p_c q_c$ is the value of production of the commodity c (price x quantity), and s_c is the proportion or share, reflecting relative importance, of commodity c in value of agricultural output. In practice, scientist years are often used as a proxy measure for expenditure because data are usually not available on expenditure by commodity in an agricultural research institution. Although still difficult to elicit, the allocation of scientific time by commodity is the most visible part of expenditure on agricultural research. Scientist years by commodity are (presumably) highly associated with total expenditure by commodity. Moreover, the results of the priority-setting analysis, based on scientist years, can be expressed in a way that is conducive for decision-making on research resource allocation. At the margin, large discrepancies in the ratios in equation (1) underscore the need to analyze a shift of one or more scientists from commodities with significantly higher ratios of scientists than ratios of value of production to commodities with significantly higher ratios of value of production than ratios of scientific input.

The operative phrase is "underscore the need to analyze." By itself, our parity approach cannot be expected to provide definitive information on research resource allocation. It only contributes a framework for highlighting areas for further analysis. Significant departures from congruence warrant justification in terms of key considerations that are not reflected in economic importance. Commodities differ in prospects for technological change, in the availability of alternative providers of research, and in their potential impact on other criteria, such as absolute poverty and food security. These three considerations do not exhaust the weaknesses of a congruence analysis. For example, commodities vary in their timing of research investments to achieve a level of benefits. Congruence analysis favors the status quo, i.e., research investment may be critical to the establishment of a rarely introduced commodity.

Overcoming these weaknesses with a more complex procedure rarely pays dividends.
For example, scientists tend to be equally optimistic about the technological prospects for their commodities. Introductions rarely succeed with or without research.

Explicitly investigating the reasons for major departures from congruence can be a healthy exercise providing the basis for analysis of "key considerations" to determine if such justifications make sense. Extending the congruence analysis provides information for examining three "key considerations:" the minimal size of production for technological change to generate economic impact, the relative commodity importance in Mozambique vis-a-vis the region, and price trends in commodity demand. Congruence analysis also furnishes prescriptive guidelines on the staff strength of IIAM derived from the total value of agricultural production. This information is used later in the comparative analysis of the current research resource allocation of scientists at IIAM.

3.4. Absolute Poverty

Contrary to economic congruence, applications that incorporate information on poverty to inform decision-making on priority setting in agricultural research are scarce (Byerlee 2000). Indeed, the major reference in the field does not mention any studies that used absolute poverty as a criterion for research resource allocation (Alston, Norton, and Pardey 1995).

Including absolute poverty as a criterion for priority setting in agricultural research makes good sense (Walker and Collion 1997). Alleviating absolute poverty is at the center of almost all agendas for economic development as manifested by the collective millennium development goals and by individual country poverty plans, such as Mozambique's PARPA. Furthermore, analysis of the growth experience in developing countries thoroughly confirms that when the economy expands, absolute poverty falls (Deininger and Squire 1996; Dollar and Kraay 2000). Likewise, a shrinking economy is accompanied by a rise in absolute poverty. Technological change from agricultural research is one of the primary engines of economic growth. Therefore, we have every reason to believe that economic growth from technological change will result in a reduction in absolute poverty via direct and indirect effects on producer income and consumer expenditure.

In contrast, a statistically significant linkage between economic growth and relative inequality has not been documented across countries or over time within countries (Walker 2000). Hence, we have no reason to believe that success in agricultural research will reduce inequality across Mozambique, and relative inequality within agroecologies and districts does not figure as a criterion.

The effect of agricultural research on absolute poverty appears to be substantial in historical (ex-post) studies over time. For example, Thirtle, Lin, and Piesse (2002) find that a 1.0% increase in yield is accompanied by a 0.7% fall in the number of poor in SSA. Other equally auspicious results are provided in a recent synthesis on agricultural research and poverty (Byerlee and Alex 2003). A counterpoint to these impressive results is provided by Alwang and Siegel (2003), who simulate the effect of a 50% increase in research budget on absolute poverty in Malawi. Their "what if" (ex-ante) study shows that, with the exception of maize, increased budget allocations to other commodities barely make a dent in a baseline poverty headcount of 41.6%. They conclude that many things have to change to bootstrap large numbers of the poor over the poverty line.

Where the truth lies on the size of effects of agricultural research on poverty is not our immediate concern. Our application is similar to Alwang's and Siegel's (2003) and is based on household income data as the raw material for poverty analysis. The importance of our simple, simulated results is not to say by how much successful agricultural research and extension reduce the severity of poverty. Importance is attached to the *relative magnitude* of effects across commodities, agroecologies, and districts.

Absolute poverty analysis is thoroughly discussed in Ravallion (1993). An application based on the TIA data is given in Walker et al. (2004) for the Mozambican context. The choice of poverty indicator and the selection of poverty lines are described in detail in that application that is based on the Ministry of Plan and Finance (2004). We use the squared poverty gap as an indicator of absolute poverty because it is more sensitive to poverty-related outcomes and because it incorporates information on how poor the poor are relative to each other.

The squared poverty gap is defined as:

(2) $$g_{ij}^2 = \left(\frac{i_{ij} - l_j}{l_j} \right)^2$$

where g_{ij}^2 is the squared poverty gap for household i in rural region j, i_{ij} is the income per capita per day (in meticais) for household i in rural region j, and l_j is the poverty line in meticais per person per day in rural region j. As described in (3), the minimum value for the squared poverty gap is zero for all households with a per capita daily income that exceeds or is equal to the poverty line. Equation (3) sums up the salient feature of absolute poverty analysis: households above the poverty line do not matter and are given a weight of zero.

(3) $$g_{ij}^2 = 0 \text{ if } i_{ij} \geq l_j$$

For households below the poverty line, the weight a household receives is proportional to the difference between their per capita daily income and the poverty line (see (4) below). The lowest income household receives a weight approaching one and the highest income household below but nearest the poverty line receives a weight that is close to zero. Effectively, the weight assigned to the poorest rural household – one with almost no documented sources of income – could be almost 100 times greater than the "highest-income poor" household.

(4) $$0 < g_{ij}^2 < 1 \text{ if } i_{ij} < l_j$$

The weighted mean value of the squared poverty gap was 0.37. This high value is attributed to a low incidence of households above the poverty line and a uniform distribution of households below the line.

Our calculations of how technological change will affect absolute poverty are summed up by equations (5), (6), and (7). We see to what extent a 20% expansion in production of a commodity reduces absolute poverty. Twenty percent in (5) is the size of change one would expect from the adoption of a high-yielding variety (Evenson and Gollen 2002). A 20% net change may seem high, but in absolute terms it is relatively small at current productivity levels of agriculture in Mozambique. For example, it is equivalent to adding 160 kgs to a mean yield level of 800 kgs per hectare. A recent example from the diffusion of varieties tolerant to cassava brown streak in coastal Nampula was equivalent to a 24% increase in value of production (McSween et al. 2006). Less than a 20% net change in value of production begs the question of whether farmers will adopt the improved technology.

Algebraically, this assumed change for household i in poverty-line region j is equal to 20% of the value of production of commodity c of household i in district d.

$$(5)\quad \Delta i_{ij} = 0.2\, p_{cd} q_{ci}$$

$$(6)\quad g'^{2}_{ij} = \left(\frac{(i_{ij} + \Delta i_{ij}) - l_j}{l_j} \right)^2$$

$$(7)\quad r_{ic} = \left(\frac{g_{ij} - g'_{ic}}{g_{ij}} \right) x100$$

The difference between actual and simulated squared poverty gap divided by the actual index and expressed as a percent gives an estimate of the poverty-reducing effect of a 20% increase in production of commodity c for household i. When we sum (7) across all households, we receive a mean estimate of expected commodity importance on absolute poverty in (8).

$$(8)\quad \overline{r}_c = \frac{\sum_{i=1}^{n} r_{ic}}{n}$$

Dividing the mean commodity estimate by the total for all commodities gives a “normalized” estimate of the commodity’s potential to contribute to poverty alleviation relative to all other commodities. These relative estimates in (9) are symmetric to the shares for value of production described in equation (1). In both cases, they sum to 1.00.

$$(9)\quad s_c = \frac{\overline{r}_c}{\sum_{c=1}^{m} \overline{r}_c}$$

Before discussing other criteria, the calculations in equations (1) to (9) warrant clarification. Sampling weights based on the 1997 population census are incorporated into these calculations. About 1.5% of the households in the 2002 national agricultural rural survey did not have positive income; these households were assumed to be characterized by transitory poverty and were excluded from the poverty analysis. The simple poverty simulations were conducted iteratively for one commodity at a time, always using the same starting baseline of the squared poverty gap estimated in the TIA 2002.

Similar to economic congruence, the scope for agricultural research to favorably impact absolute poverty is beset by several collateral issues. The most widely discussed linkage between poverty and agricultural research is the efficiency of agricultural research to improve productivity in areas of marginal production potential. The issue of geographic poverty traps is a variation on the marginal vis-a-vis high potential regions theme. Is poverty endemic to certain regions in Mozambique? If the response to this question is affirmative, we would be more easily persuaded to target agricultural research investments to poverty-endemic areas, particularly if those areas are endowed with production potential.

The nexus between household income and food insecurity over time is another aspect in the documentation of geographic poverty traps. Specifically, are households that are food insecure in one year characterized by higher or lower income than other households in other years? This question is timely because the tradeoff between relief and development is sharp in SSA. More funds for relief mean less for development. Moreover, relief activities can entail a high opportunity cost by skewing agricultural research into technically difficult areas, such as the search for varietal drought resistance and tolerance to low soil fertility. Encountering food insecurity going hand-in-hand with low income year after year enhances the priority for research to ease the hardship of poor, food-insecure farm households. On the other hand, the food insecure may live in riskier production environments, but they may not possess chronically lower income (Reardon, Matlon, and Delgado 1988). Targeting agricultural research on “relief traps” may be a costly way to tackle poverty.

Commercialization and market orientation are increasingly recognized as drivers of technological change. But greater market orientation is often thought to mean that benefits would accrue proportionally more to richer farmers than to poorer ones. Historically, the indirect effect of reduced prices is by far the largest impact of technological change in food crops on the rural poor, most of whom are net consumers. We are not able to model this important indirect effect, but we can quantify the relationship between marketed surplus and income poverty based on the data that are described in the next section.

4. THE DATA: THE NATIONAL RURAL HOUSEHOLD SURVEYS IN 2002 AND 2003

Since the mid-1990s, Mozambique has a rich history of investing in national rural household surveys that focus on agricultural production and household income. These surveys are referred to as TIAs in Portuguese (Trabalho de Inquérito Agrícola). Four TIAs were conducted in the past 11 years. We use data from the TIA 2002 and the TIA 2003. The 1996 TIA generates comparable data to the TIAs in 2002 and 2003, but the questionnaire, sample design, and district coverage varied with that of the latter years. The 1996 estimates provide a valuable recent historical benchmark for diverse aspects of production, and we refer to these results where we feel they are informative (Boughton et al. 2006). Data from the most recent TIA 2005 will be available for analysis later this year when the results of this paper can be quickly updated once rural household income is estimated.

The TIA 2002 was coordinated and carried out by the Ministry of Agriculture from July to October 2002 for the agricultural year 2001-2002 covering October 2001 to September 2002 (MADER 2002). The sampling frame was based on the Census of Agriculture and Livestock 2000 (CAP) and the population census of 1997. In total, 4,908 small and medium-sized farms were interviewed in 559 primary sampling units. These data on small and medium-sized households were complemented by group interviews at the community level, by a survey of over 400 large farming enterprises, and by measurements of 2,500 fields of the same small and medium farm households.

The TIA 2002 was the most ambitious attempt to elicit comprehensive information on rural household income in a single-interview survey for all of Mozambique's ten provinces. Questions were explicitly asked on more than 100 potential sources of farm and non-farm income. The TIA 2002 was heavily supervised: three to four enumerators per supervisor. It also featured several technological innovations, such as the use of field data entry and field measurement based on satellite information in some provinces. For these reasons, we are confident that the data are reliable and that widespread underreporting of income – a general weakness in single-interview rural income surveys – was limited mostly to consumption of farm-produced fruits, vegetables, and livestock which were not valued.

Results from income surveys are bedeviled by the typicality of the agricultural year. Ideally, we want to conduct the survey during a "normal" agricultural year. The cropping year 2001-2002 was characterized by drought in some provinces and districts, and farmers were still recovering from the severe floods experienced in 2000. On the other hand, Mozambican farmers benefited from unusually strong border trade in maize as several neighboring countries experienced shortfalls. Overall, we feel that the 2000-2001 agricultural year could be called "normal" although normalcy in high-risk, Mozambican agriculture defies definition.

Income is defined as returns to household owned resources. This concept is equivalent to value of production minus paid-out costs. As much as possible, consumption from own farm production was valued.

We made two major corrections to the survey data. Cassava production was underreported. We imputed production for those farmers who said they grew the crop, but did not report output from farmers who cultivated cassava and reported production. We also adjusted reported field areas downwards because declared areas were significantly larger (about 15%) than measured areas.

Although the TIA data are a good source for generating reliable estimates of commodity economic importance in Mozambique, they are not ideal. First, the value of agricultural production fluctuates from year to year depending on the weather. For that reason, we use data from both 2002 and 2003 surveys. Second, commodity coverage is complete for sales, but is incomplete for production consumed on-farm. The value of home consumption of milk, eggs, fruits, and vegetables was not elicited in the TIA 2002; hence, the economic importance of cattle, chickens, fruits, and vegetables is underestimated relative to other commodities. Moreover, the TIA 2003 was not designed to measure household income from non-farm sources with the detail of the TIA 2002, and no quantitative information on fruit and vegetable sales was collected in the TIA 2003. To calculate the total value of production for the sector in 2003 we use the 2002 estimates for fruit and vegetable sales. Last, aside from charcoal production, no information was collected on the value of forestry products.

5. RESULTS: CONGRUENCE

Any commodity with a value of production greater than $0.5 million in either 2002 or 2003 is listed in Table 1. Thirty-two commodities, including a grouping of other species, exceeded this threshold in 2002 and 2003.

5.1. The Dominance of Cassava and Maize

The economic dominance of cassava and maize is the main message of Table 1. Both of these commodities account for about 50% of agricultural value of production in the small- and medium-farm sectors.

In terms of food security, maize and cassava retain their dominant role as the staple food crops. The TIA 2003 asked about the most staple food for the rural household. About 49% of respondents stated that maize was their staple food crop. Cassava was a close second represented by 40% of households, and rice was a distant third at 8%. Sorghum was in fourth place at 3%; millet and sweetpotato accounted for the remaining responses (less than 1% each).

The TIA data also suggested a strong contrast between maize and cassava on one hand and rice on the other. About 98% of the households who stated that either maize or cassava was their staple crop produced that crop. Only about 50% of the rice-consuming staple households could make that claim. Eighty percent of the rice-consuming, non-growing households were located in the three southern provinces of Inhambane, Gaza, and Maputo. They accounted for 18% of the total rural population in the south. The food security of these households is linked to the import price of rice more than any other parameter. The widely recognized dominance of maize and cassava in several dimensions, including food security, is one of the main themes of this paper and highlights the importance of having effective research programs on these two commodities.

5.2. Variation in Value of Production between 2002 and 2003

The variation in value of production for the majority of the economically important commodities is quite small for most commodities (Table 1). Much of the discrepancy in value of production between the two years is attributed to cassava, which we discuss later in this section.

Cassava was not the only commodity to gain economic ground in 2003. Tobacco is of rising economic importance in the Mozambican economy, particularly with the demise of production in Zimbabwe. Sesame is another commodity of secularly increasing economic importance. It is one of the recently introduced crops that is making an economic impact in Mozambique.

Table 1. Commodities with Value of Production Greater than $ 0.5 Million in 2002 and 2003

RANK	Crop	Crop Value (million $) TIA 2002	TIA 2003	Percent Crop Value TIA 2002	TIA 2003	Production (´1000 tons/ ´1000 heads) TIA 2002	TIA 2003	Mean Price ($US/kg or unit) TIA 2002	TIA 2003
1	Cassava[1]	128.00	244.00	26.44	40.99	3,450.00	4,180.00	0.04	0.06
2	Maize	113.00	101.40	23.41	17.03	1,110.00	1,180.00	0.10	0.09
3	Sweetpotato[1]	30.80	38.10	6.38	6.40	456.00	561.00	0.07	0.07
4	Groundnut	26.59	21.30	5.52	3.58	102.10	87.40	0.26	0.24
5	Chicken[2]	18.80	14.72	3.89	2.47	8,165.74	7,320.17	0.93	1.07
6	Rice	18.30	20.80	3.80	3.49	93.40	117.00	0.20	0.18
7	Tobacco	16.90	22.30	3.49	3.75	42.60	51.10	0.39	0.44
8	Sorghum	15.20	17.80	3.14	2.99	138.00	191.00	0.11	0.09
9	Cashew[3]	13.20	9.51	2.74	1.60	61.00	20.60	0.22	0.46
10	Cotton	12.70	11.50	2.57	1.93	102.00	75.10	0.13	0.15
11	Goats[2]	12.30	9.55	2.54	1.60	1,305.40	1100.06	6.37	9.63
12	Cattle[2]	9.80	15.36	2.03	2.58	60.78	88.85	161.24	161.38
13	Coconut[3]	8.60	4.95	1.78	0.83	271.00	13.40	0.03	0.37
14	Cowpea	8.18	8.20	1.69	1.38	53.70	63.20	0.15	0.13
15	Butter beans	8.15	15.10	1.69	2.54	35.70	38.90	0.23	0.39
16	Tomato[4]	5.20	5.20	1.08	0.87	N/A	N/A	N/A	N/A
17	Sugar cane[4]	5.20	5.20	1.08	0.87	N/A	N/A	N/A	N/A
18	Pigs[2]	4.50	3.83	0.93	0.64	586.04	398.35	7.68	9.61
19	Bananas[4]	4.48	4.48	0.93	0.75	N/A	N/A	N/A	N/A
20	Bambaranut	3.70	2.00	0.77	0.34	22.50	18.20	0.16	0.11
21	Pigeonpea	3.16	2.80	0.70	0.47	31.80	48.50	0.11	0.06
22	Sesame	3.00	3.00	0.62	0.50	13.90	13.60	0.22	0.22
23	Potato	2.75	2.75	0.57	0.46	15.20	N/A	0.17	N/A
24	Cabbage[4]	1.30	1.30	0.27	0.22	-	-	-	-
25	Onion[4]	0.90	0.90	0.18	0.15	N/A	N/A	N/A	N/A
26	Lettuce[4]	0.87	0.87	0.17	0.15	N/A	N/A	N/A	N/A
27	Mango[4]	0.81	0.81	0.17	0.14	N/A	N/A	N/A	N/A
28	Tangerine[4]	0.79	0.79	0.16	0.13	N/A	N/A	N/A	N/A
29	Millet	0.78	1.60	0.16	0.27	12.20	21.60	0.07	0.07
30	Sheep[2]	0.67	0.67	0.14	0.11	45.07	-	14.87	-
31	Orange[4]	0.63	0.63	0.13	0.11	N/A	N/A	N/A	N/A
32	Others[5]	5.40	3.90	0.81	0.66	-	-	-	-
Total		**484.66**	**595.32**	**100**	**100**				

Source: Computed from the TIA 2002 and 2003

[1] For cassava and sweetpotato production, we capped the yield data at 20 t/ha and consumption at 2 kg/person/day for cassava and 1 kg/person/day for sweetpotato to compensate for data problems caused by multiple harvests.

[2] For livestock, we refer to total number of animals sold.

[3] For cashew and coconut, the value in 2003 was imputed from the unit value in 2002 and the number of trees in 2003.

[4] In 2002, only information on sales was available for fruits and vegetables. For these cases, the value of production is the same as sales value. We use the same values in 2002 as in 2003 to calculate percent crop value for 2003.

[5] Total for all crops and livestock species below $0.5 million.

The increase in value of production for beef and butter beans (*phaseolus*) is harder to explain. Much of the increase in beef output came from higher sales in Gaza which experienced drought in 2002. A sharp rise in bean prices was associated with the increase in value of production for beans. Both these changes appear to be fluctuations in value of production and may also be part of an upward trend, particularly in the case of cattle.

Coconut and cashew represent the mirror image of tobacco and sesame. Production of these tree crops is decreasing over time for multiple reasons that manifest themselves in a declining number of productive trees (Boughton et al. 2006).

For cassava, both output and price increased substantially between 2002 and 2003. Some of the increase in output stems from a change in questionnaire design. A question about daily harvests was added in 2003; only information on weekly and monthly harvests was canvassed in 2002. Nevertheless, the estimate of 4.2 million tons in 2003 still is considerably less than FAO's published estimate of about 6 million tons for cassava production in Mozambique in their production database.

In spite of the uncertainty about the cassava value of production estimates, it is apparent that, based on economic importance, both cassava and maize warrant a major sustained research effort in Mozambique. Given economies of scale in research, a major effort implies a commitment of at least seven to ten scientists per year working full-time on each commodity.

5.3. The Other 30 Commodities of Economic Importance

Aside from cultivar or breed testing, the same cannot be said about the 30 or so "other" commodities listed in Table 1. The amount invested in agricultural research for these commodities depends on context. Are there large opportunities for expansion of production that can be facilitated by research? Are there binding biological constraints that can be broken by applied and adaptive research? The "other" commodities with over $0.5 million in Table 1 warrant testing of improved cultivars and breeds, i.e., the scope for technology borrowing should be fully exploited, but probably none could economically justify a major breeding effort without a sound ex-ante assessment of specific technological prospects.

To shed some light on the size of production that it takes to justify a small but systematic crop improvement effort, we conduct a simple scenario analysis of rate of return to investment from different levels of value of production. Varietal change is extremely important to Mozambique because improved crop varieties have widespread adaptability across widely varying ratios of land, labor, and capital (Pingali and Binswanger 1984). The spirit of this analysis is reflected in earlier work by Brennan (1992) and applications by Bohn, Byerlee, and Maredia (1998), and Walker and Fuglie (1999). Our assumptions on the values for the relevant variables are given in Box 1.

Box 1. Assumptions of a Commodity Improvement Scenario to Determine Return on Investment by Value of Production

Variable	Assumption
Project duration	30 years
Cost: Variety testing	10 years at $100,000 per annum
Timing of variety release	6th year and the 11th year
Net benefit per ha adopted	20% of value of production
Adoption and diffusion	
Ceiling level of adoption	30% for each released variety
Diffusion profile	Logistic: speed of diffusion = 0.5 start = -3.00

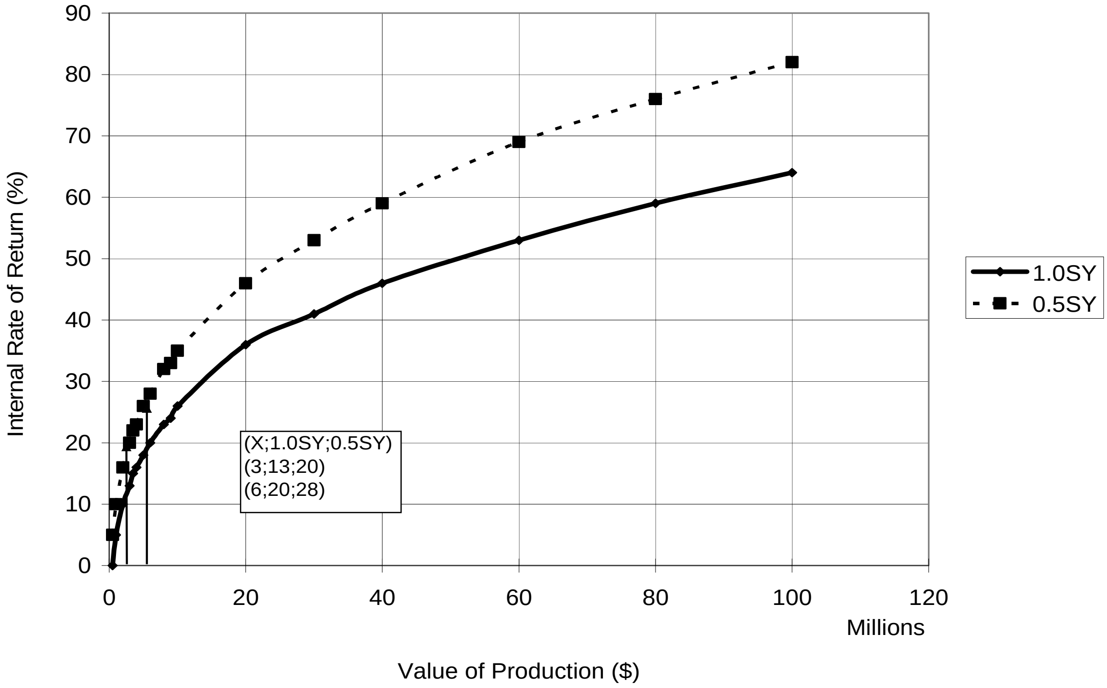
Our scenario examines the return to investing in a systematic project to test and subsequently release improved varieties. The investment is equivalent to one scientist working full-time in the project that costs $100,000 per year (Pardey et al. 1999). We assume that the project is successful: two varieties are released five years apart. Each variety results in a net increase in production by 20%. The uptake of each variety follows the common logistic diffusion pattern (Rogers 1995). Eventually, each variety accounts for 30% of area.

This scenario is optimistic because we assume success and because we do not include any costs of extension. The assumption of a 20% increase in production equivalent to a 4% annual yield gain is also optimistic, but is possible to reach this level of selection productivity in a testing program where little systematic work has been carried out. A stable multi-locational testing program on a relatively "under-researched" commodity could generate this scenario that is structured as a crop improvement project but could just as easily be a livestock production project.

The results are summarized in Figure 3. Assuming a minimum rate of return of 20%, our initial commodity value of production needs to achieve a threshold of $6 million (the lower broken line in Figure 3). Applying these same assumptions to a large commodity, such as maize, results in an internal rate of return exceeding 50%, showing that size matters. If we assume that the program can be achieved with 0.5 scientists, a value of production of $3 million satisfies our minimum criterion of a 20% rate of return on investment (the broken line in Figure 3).

Returning to Table 1, about one-third of the commodities fall below the $3 million value of production threshold. The simple scenario analysis does not say that research should not be conducted on these commodities. It says that research undertaken on these commodities is risky because the production base is small. Within this group, research on some is riskier than research on others. For example, potato and sesame are close to the $3 million threshold and are both characterized by strong demand. Both commodities have readily identifiable problems and opportunities that can be addressed by agricultural research. In contrast, pearl

Figure 3. Economic Importance and the Rate of Return to Agricultural Research



Source: Authors' computations

millet's low level of production per household and its negligible commercialization, suggesting declining demand, make it an unlikely prospect for successful agricultural research.

Only seven commodities in Table 1 are characterized by a value of production between 3 and $6 million. Of these, sugar cane is protected by trade policy and is the dominant commodity in the large-farm plantation sector. Presumably, incentives are sufficient to fund research on sugar cane from the private sector relieving the public sector of this responsibility. Of the other commodities in the $3 million to $6 million bracket, bambaranut is probably the most controversial candidate for agricultural research. The paucity of regional and global research on bambaranut limits prospects for technological change.

The first 15 entries in Table 1 belong to the upper echelon of materially important commodities above $6 million in value of production. The two food staples, cassava and maize, were discussed above. The other 13 commodities in this group do not warrant as much public-sector research effort as cassava and maize, but they would expect to receive resources unless there are strong reasons not to invest. For example, tobacco research should be supported by the industry as it is in neighboring countries, such as Malawi. Although tobacco production is a smallholder commodity, the industry is dynamic and should be capable of supplying its own research for contract farmers who receive credit from multi-national companies.

Cotton, cashew, and coconut are also export commodities, but they could be termed as anything but dynamic. As described above, cashew and coconut are characterized by declining production and both commodities lack a cohesive organization that could generate sustainable private-sector research. Cotton in Mozambique is beset by the lowest prices in the region, and the structure of production is not now conducive for private-sector research.

The balance between public- and private-sector research for cotton, cashew, and coconut needs to be revisited periodically. For example, cashew may have reversed its decline with greater emphasis on efficient processing. But at this time, there is almost no evidence that public-sector research crowds out private-sector research on any of these three crops. Presently, IIAM supports research on cotton and cashew, but not on coconut, that recently has benefited from a French project searching for resistance/tolerance to lethal yellowing, a disease that threatens to wipe out coconut production in Mozambique.

5.4. Prospects for Technology Borrowing in the Region

Some of the most important commodities in Mozambique (Table 1) are extensively grown in southern Africa; others are relatively rare in terms of regional economic significance. Commodities highlighted in Table 2 are proportionally more important in Mozambique than those in the rest of the region. Their percent shares are at least twice as high in Mozambique than in the neighboring eight countries that comprise the rest of the region.

Table 2. Economically Important Commodities in the Agricultural Sector in Mozambique and Southern Africa (% value of production)

Rank	Mozambique (Commodity)	Mozambique (%)	Southern Africa[1] (%)
1	**Cassava**	**26.43**	**4.91**
2	Maize	23.41	12.89
3	**Sweetpotato**	**6.38**	**<1**
4	**Groundnut**	**5.51**	**2.06**
5	Chicken	3.89	11.35
6	**Rice**	**3.81**	**<1**
7	Tobacco	3.50	2.03
8	**Sorghum**	**3.15**	**<1**
9	**Cashew**	**2.73**	**<1**
10	Cotton	2.57	1.77
11	**Goats**	**2.55**	**1.06**
12	Cattle	2.03	22.74
13	**Coconuts**	**1.78**	**<1**
14	**Cowpeas**	**1.70**	**<1**
15	Beans	1.70	1.06
16	Tomato	1.08	<1
17	Sugar cane	1.08	4.48
18	Pigs	0.93	<1
19	Grapes	0	4.26
20	Sheep	<1	3.21
21	Potato	<1	2.69
22	Wheat	0	1.87
23	Apples	0	1.65
24	Orange	<1	1.50
25	Sunflower	<1	1.49
26	Vegetables (fresh)	<1	1.41
27	Others (<1% val. Pro.)	6.72	15.35

Source: Constructed from Table 1 and IFPRI 2006

[1] Eight countries, excluding Mozambique

Understanding regional importance is itself important because agricultural research generates technologies that are location-specific. Adaptation can be narrow or broad, but adaptation rarely is so broad as to apply to a large region of many countries. More research within the region augments the odds of successful borrowing of technologies from neighbors. In plant breeding, countries within the region share roughly the same latitude and day length during the different seasons of the year. Shared economic importance means more investment in research and more potential solutions tailored to common climatic and edaphic circumstances. Moreover, recent efforts to harmonize seed protocols among the Southern African Development Community (SADC) facilitates the borrowing of varietal technologies.

The highlighted commodities have a harder road to hoe than the others in Table 2. In other words, we expect proportionally less progress in the highlighted commodities because Mozambican scientists have proportionally less research to draw on in the search for solutions tailored to Mozambican conditions.

The qualitative nature of the research is also likely to be different. The highlighted commodities require more strategic and applied research, whereas research progress in the other commodities is more likely to be associated with adaptive research building on past regional research.

The highlighting of 9 of the 15 most important commodities bears witness to the "uniqueness" of production conditions in Mozambique, which has more lowland coastal area than any other country of the region. For these nine commodities, it is unlikely that neighboring countries have invested in significant research. Fortunately, IIAM's research on cassava and sweetpotato benefit from active partnership with the International Agricultural Research Centers (IARCs). In particular, IITA has a regional cassava-breeding program based in Tanzania (which is not considered in the southern African region in Table 2). The International Potato Center (CIP), via the IITA-run SARRNET, had an aggressive multiplication and distribution program for orange-fleshed sweetpotato and now has a country presence in Mozambique. The Rockefeller Foundation also provides recurrent budgetary support for the national cassava program.

Rice, sorghum, cashew, goats, coconut, and cowpea appear to confront more daunting prospects for technology borrowing, although several regional, continental, and global initiatives exist to partially compensate for location-specific circumstances. A case can be made that, for each of these commodities, the recommendation domains in Mozambique are atypical of those in the rest of the world. For example, Zambezia province is the largest producer of rice in the country. Rain-fed, lowland production is the most common rice production ecology. A high incidence of floods and droughts combined with poor water management contribute to risky production in a largely subsistence setting. About 90% of production is consumed on-farm.

Sorghum is another case where the production conditions in Mozambique vary from those in the rest of the world. Nampula is the largest producer. Sorghum is produced in a very "wet" environment (for sorghum) that can exceed 1,200 mm of rain. Sorghum is not an important crop in the dryer southern provinces.

In contrast, livestock research, except for goat improvement, should be able to draw on regional technologies. The importance of livestock is substantially higher in the region than in Mozambique. Cattle contribute about 20% to 25% to the value of regional agricultural production; their share to Mozambique's value of production is only 2% to 3%. Only goats appear to depart from this salient, stylized fact. They are more important in Mozambique than in the rest of the southern African region.

5.5. Total Value of Agricultural Output and Research Intensity Ratios

The total value of agricultural production for the small and medium-holder sector approaches $530 million averaged across the two years in 2002-2003 prices in Table 1. Accounting for deficiencies in home consumption and the tendency in single interview surveys to underestimate production because of memory bias would likely mean that a reasonable estimate could be closer to the 2003 total than the 2002 total. A total of $600 million for agricultural output is consistent with an average estimate of about $187.50 per household.

Establishing an estimate for agricultural output provides a basis for a normative estimate of how large the national agricultural research program should be in terms of total number of scientists in the denominator of the first term in equation (1). Beintema and Stads (2004) recently published data on intensity ratios – expenditure on public-sector agricultural research as a percent of total agricultural value of production – for 27 sample countries in SSA. Beintema and Stads (2004) sum up their findings on intensity ratios as follows:

> *In 2000, Africa invested $0.70 for every $100 of agricultural output (in international dollars) – lower than the 1981 of $0.95. Ratios ranged from 0.20 percent or lower in The Gambia, Niger, and Sudan to over 3.00 percent in Botswana, Mauritius, and South Africa. In 1995, the latest year for which global data are available, SSA's average agricultural research intensity ratio was slightly higher, at 0.79 percent – greater than the average ratio for the developing world (0.62 percent) but lower than the global average (1.04). (p.4)*

The recommended intensity ratio, which is usually surpassed by developed countries and more middle-income developing countries, such as South Africa, Mauritius, and Botswana in southern Africa, is 2%. The 2% rule translates into an expenditure of about $12 million on agricultural research in 2002-2003 prices.

In the mid- to late 1990s, before the advent of generalized donor support for the agricultural sector in the form of Proagri, the investment in public-sector agricultural research in nominal dollars was about $2.5 million (KIT 2000). With somewhat more inflated dollars and the effective initiation of Proagri in 1999, total expenditure on the five research agencies that now constitute IIAM is estimated at $3 million to $4 million annually between 2001-2005. This amount includes earmarked funds for partnerships with the IARCs, and refers to what is actually spent, not to what is budgeted, which may deviate from actual spending for several reasons, mainly seasonal shortages in liquidity in donor funding.

IIAM is not the only institutional actor in agricultural research in Mozambique. Relying almost exclusively on donor funding, some research is carried out at the agricultural faculty of the University of Eduardo Mondlane (UEM). NGOs with a mandate in extension also test some technologies in an ad hoc manner. Agricultural technical schools may also conduct a limited amount of research. Assuming a very generous estimate of $1 million per year for the total of research expenditures for all these other actors gives a total annual research expenditure of about $4.5 million equivalent to a research intensity of about 0.75 that approaches the all-Africa average of 0.79. In this case, it is not good to be average. The average agricultural research intensity in Mozambique is significantly below the 2% desirable level.

5.6. Market Demand and Economic Congruence

Market demand is an important driver of technological change, particularly in the commodities of lesser economic importance. Market price data of some of the main commodities are available in Mozambique since the early 1990s, but the product coverage is not as comprehensive as the 32-commodity list in Table 1. For that reason, we use consumption-expenditure data from the national statistical agency (INE) to trace the outline of how prices are changing by commodity over time. National-level consumption-expenditure surveys were conducted in 1997 and 2003; purchase prices of many products are available for comparison over two points in time. A selected list of rural prices of the most transacted products of commodities in Table 1 is given in Table 3, together with the number of transactions recorded in the 2003 survey.

The ratio of nominal prices in Table 3 displays considerable variation by commodity. Several commodities are characterized by price ratios less than 1.00, suggesting declining real prices over time. Coconut prices have been depressed internationally by surging palm oil

Table 3. Price Ratios between 2003 and 1997 for Selected Commodities

Commodity	Purchases (Number of Transactions)	Price Ratio (03:97)
Coconut	3,371	0.50
Cassava flour	400	0.60
Mango	257	0.72
Papaya	180	0.83
Banana	505	0.90
Bread	5,635	0.99
Fresh cassava	1,492	1.00
Sweetpotato	691	1.14
Sorghum flour	159	1.25
Eggs	164	1.30
Sorghum grain	93	1.36
Maize grain	594	1.49
Rice	3,596	1.53
Lettuce	755	1.58
Tomato	7,054	1.62
Fresh fish	1,850	1.63
Cowpea	1,022	1.64
Brown granulated sugar	1,034	1.69
Live chickens	284	1.72
Beans	1,115	1.84
Groundnut	4,275	2.03
Cauliflower	2,115	2.13
Potatoes	187	2.26
Maize meal	2,700	2.29
Onion	4,384	2.49
Beef	117	2.78
Dried fish	3,073	3.49
White granulated sugar	415	4.58

Source: Constructed from data from the IAF National Consumption Surveys 1997 and 2003 production, mainly in Malaysia. Similar to the scenario in many other developing countries, fresh cassava, sweetpotato, and cassava flour appear to be constrained by stagnating market demand.

The high number of bread purchases indicates that largely imported wheat-based, bakery products are penetrating into rural areas. Mozambique produces a negligible amount of wheat and does not invest in wheat research. Highland area, suitable for wheat cultivation, is scarce in Mozambique and constant or declining real prices of bread over time from food-aid imports do not make the case for positive returns from research on wheat. Resisting the temptation to invest in wheat research sets Mozambique apart from many other SSA countries that have allocated excessive resources to wheat relative to its production base and to the countries' comparative advantage (Bohn, Byerlee, and Maredia 1998).

The low price ratios and the limited number of transactions on mango, papaya, and banana are consistent with weak domestic demand for these fruit crops. Unless well-defined export opportunities are exploited, research on fruit crops is unlikely to show a high rate of return. In contrast, the domestic market for vegetables is vibrant and demand for tomatoes, onions, cauliflower, potatoes, and lettuce seems strong. All of these commodities have price ratios that exceed 1.50, and tomatoes and onions figure prominently among the most contracted commodities.

As expected, almost all of the animal-based products have favorable price ratios over 1.50. The only commodity with a price ratio severely distorted by economic policy is white granulated sugar which is also the only commodity produced in the large-farm plantation sector.

Summing up, the results in Table 3 suggest that market demand is likely to loom large as a limitation to research attractiveness in coconut, cassava, sweetpotato, and the fruit crops. Sorghum and millet – not present in Table 3 with a very small number of transactions – also suffer from demand problems. Grain legumes, livestock products, and vegetables, including potatoes, are characterized by strong demand.

6. RESULTS: ABSOLUTE POVERTY

6.1. Commodities

As expected, a 20% increase in production from a scenario of successful agricultural research has a widely varying impact on absolute poverty reduction across the 30 economically most important commodities. In maize and cassava, a 20% increase in production leads to a 6% decline in the squared poverty gap; in contrast, in several of the minor commodities in Table 1, the impact of this simulated increase is less than 0.2% nationally.

For a particular commodity, impact on absolute poverty depends on three factors: (1) how poor producers are, (2) how important the commodity is relative to other sources of agricultural income, and (3) how important agricultural income is relative to other sources of income. Of these three factors, the second is by far the most important, as increasing 20% of a small amount of production for a minor commodity does not lead to a significant fall in income poverty even for very poor households. Therefore, we expect that the normalized (totaling to 100%) shares in equations (1) and (9) to be significantly and positively correlated: relative economic importance also indicates the relative potential for poverty reduction in a developing economy as poor as Mozambique.

That expectation is borne out in Table 4. With a few exceptions, the estimates in the economic importance and poverty reduction columns track each other closely from the top to the bottom of the table. Graphing these estimates in Figure 4 shows the strong association between these two criteria and reconfirms the importance of cassava and maize, this time from the perspective of poverty reduction.

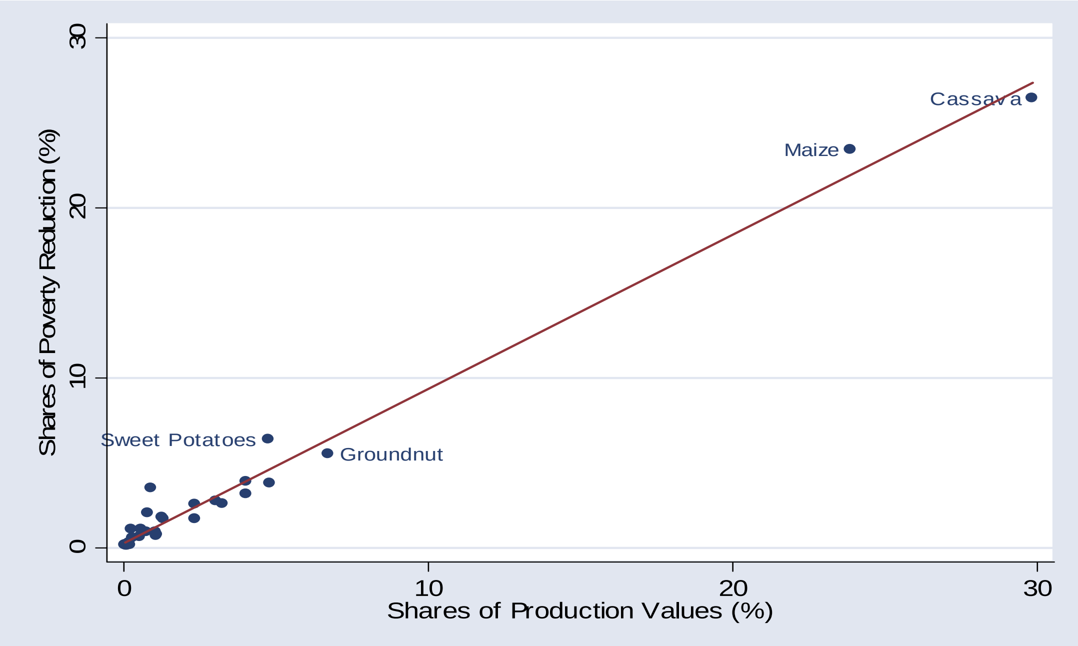
Table 4. Economic Importance and Potential for Poverty Reduction with Technological Change

Rank	Commodity	Production[i] Value (%)	Poverty[ii] Reduction (%)	Poverty Intensity
1	Cassava	26.69	29.75	1.11
2	Maize	23.63	26.86	1.14
3	Sweetpotatoes	6.44	4.78	0.74
4	Groundnut	5.57	6.05	1.09
5	Chicken	3.93	3.77	0.96
6	Rice	3.84	3.80	0.99
7	Tobacco	3.52	1.20	0.34
8	Sorghum	3.17	3.88	1.22
9	Cashews	2.77	2.43	0.88
10	Cotton	2.59	2.74	1.06
11	Goats	2.56	2.49	0.97
12	Cattle	2.04	0.87	0.42
13	Coconuts	1.80	1.18	0.65
14	Cowpea	1.71	2.06	1.21
15	Butter beans	1.71	1.52	0.89
16	Tomatoes	1.09	0.24	0.22
17	Sugar cane	1.09	0.55	0.51
18	Pigs	0.94	1.11	1.18
19	Bananas	0.94	0.69	0.74
20	Bambaranut	0.78	0.89	1.14
21	Pigeonpea	0.71	0.84	1.18
22	Sesame	0.63	0.42	0.67
23	Potatoes	0.57	0.33	0.58
24	Cabbage	0.28	0.20	0.70
25	Onion	0.18	0.09	0.51
26	Lettuce	0.17	0.06	0.36
27	Mango	0.17	0.17	0.98
28	Tangerine	0.16	0.04	0.23
29	Millet	0.16	0.27	1.66
30	Sheep	0.14	0.08	0.59

[i] Normalized to sum to 100
[ii] Percent poverty reduction divided by percent production value

Returning to the column on poverty intensity in Table 4, we see several commodities do not conform to our general statement about the strong association between their relative value of production and their scope for poverty reduction. Tobacco and tomatoes are produced by richer rural households. Tobacco farmers enjoy access to inputs and credit via company-assisted production. More than 50% of tomato production takes place in the irrigated and heavily subsidized Chókwe district in the southern province of Gaza. These commodities score significantly higher on the criterion of relative economic importance than on the relative potential for poverty alleviation. At the other extreme, pigeonpea and pearl millet are grown mostly in marginal upland conditions. Their estimated shares on poverty alleviation are significantly higher than their shares on economic importance.

Figure 4. Production Value and the Scope for Poverty Reduction by Commodity



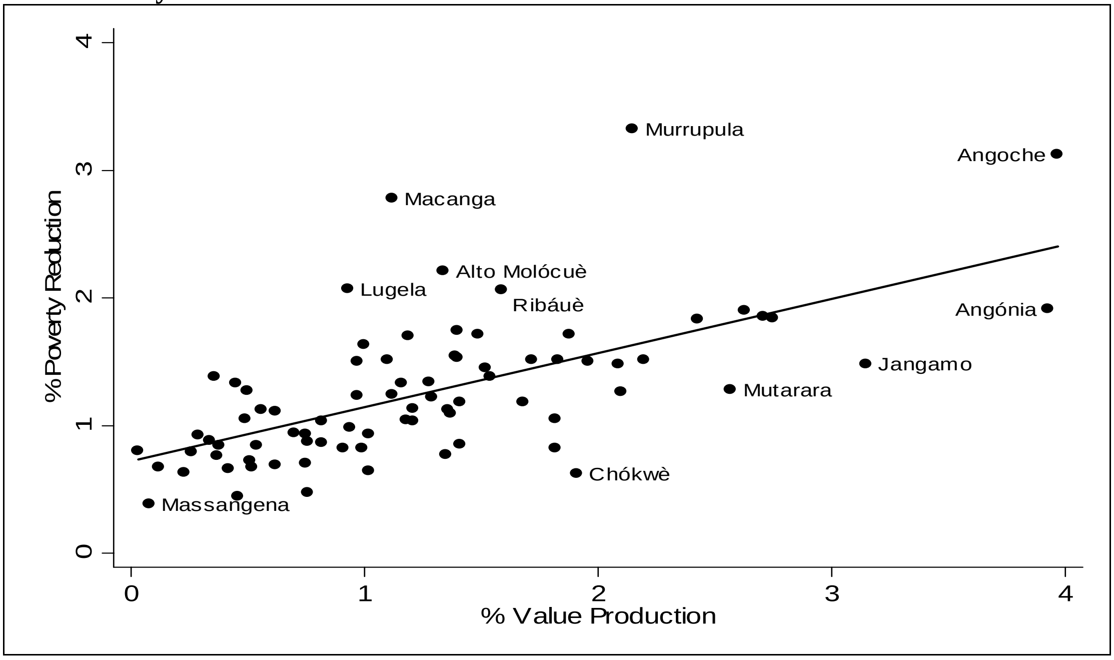
Source: Calculated from TIA 2002

The commodity ratings for poverty intensity vary by a factor of eight, i.e., a one-unit increase in monetary income for millet growers is accompanied by eight times as much poverty-reduction impact as a comparable increase to tomato growers. These differences seem large, but they are not sufficient to propel pearl millet and pigeonpea to the top of the poverty reduction column in Table 4. The differences in production base are several orders of magnitude larger than the differences in poverty intensity.

6.2. Districts

The district results on the poverty-reduction potential of technological change mimic the behavior of our commodity results. Poverty reduction estimates from an across the board 20% productivity increase range from only 3.5% in Massangena in Gaza, to more than 30% in Murrupula in Nampula. The normalized values that sum to 100 in Figure 5 plainly show these differences, and reconfirm the positive association between the relative values of poverty reduction and value of production criteria. Those districts below the regression line of best fit score better on value of production than on poverty reduction. In contrast, districts such as Lugela, Alto Molócue, Ribáue, Macanga, Murrupula, and Angoche, “excel” on poverty reduction relative to value of production. Most of these districts are in the north and central parts of Mozambique. Although falling below the regression line, agriculturally important Angonia district, bordering Malawi, makes an above average contribution to poverty reduction of about 2%. The disparity between value of production and potential for poverty reduction is greatest in Chokwe district, the location of an intensive irrigation scheme that has been heavily subsidized by government and donor initiatives.

Figure 5. Relative Economic Importance in Agriculture and the Potential for Poverty Reduction by District



Source: Constructed from TIA 2002 and 2003

The district results also underscore the importance of cassava and maize in rural poverty reduction. Eighty districts and 30 commodities give 2,400 possible district x commodity candidates in our poverty alleviation scenario based on a 20% productivity increase. We rank these district x commodity results in Table 5, according to their contribution to poverty reduction.

Table 5 contains two notable findings. First, the size of these commodity-specific results of technological change is large at the district level, with several commodities by district combinations exceeding 10%. Second, cassava and maize dominate the ranking. The first 47 entries feature either maize or cassava. Sweetpotato in Mutarara district in Tete appears in 48th position; cotton in Monapo district in Nampula ranks in 51st place. Of the top 50 contributions to poverty alleviation in Table 5, only one is from a commodity other than cassava and maize.

6.3. Chronic Poverty and Geographic Poverty Traps

The adoption of improved technologies is usually lower in regions of marginal production potential than in regions of high production potential. From this observation, it follows that agricultural research is a blunt instrument to tackle chronic poverty in marginal regions. The degree to which geographic poverty traps in marginal regions erode the effectiveness of agricultural research to make a dent in absolute poverty depends on two empirical facts. First, we need to show that household income replicates itself over time across space: on average, lower income households in a district or region in one year are also lower income

Table 5. The Potential for Localized Poverty Reduction by Commodity and District

Rank	Province	District	Commodity	Poverty[1] Reduction (%)
1	Nampula	Morrupula	Cassava	18.78
2	Nampula	Angoche	Cassava	17.68
3	Tete	Macanga	Maize	12.40
4	Zambézia	Lugela	Cassava	11.69
5	Tete	Zumbo	Maize	11.15
6	Zambézia	Mocuba	Cassava	10.98
7	Zambézia	Alto Molócue	Cassava	10.04
8	Zambézia	Gilé	Cassava	9.54
9	Tete	Marávia	Maize	9.40
10	Sofala	Nhamatanda	Maize	8.61
11	Niassa	N´gauma	Maize	8.44
12	Inhambane	Massinga	Cassava	8.32
13	Inhambane	Jangamo	Cassava	7.87
14	Niassa	Majune	Maize	7.81
15	Niassa	Lichiga	Maize	7.65
16	Sofala	Marromeu	Cassava	7.43
17	Niassa	Sanga	Maize	7.36
18	Nampula	Moma	Cassava	7.22
19	Tete	Tsangano	Maize	6.83
20	Inhambane	Funhalouro	Cassava	6.45
…				
48	Tete	Mutarara	Sweetpotatoes	3.89
…				
51	Nampula	Monapo	Cotton	3.60

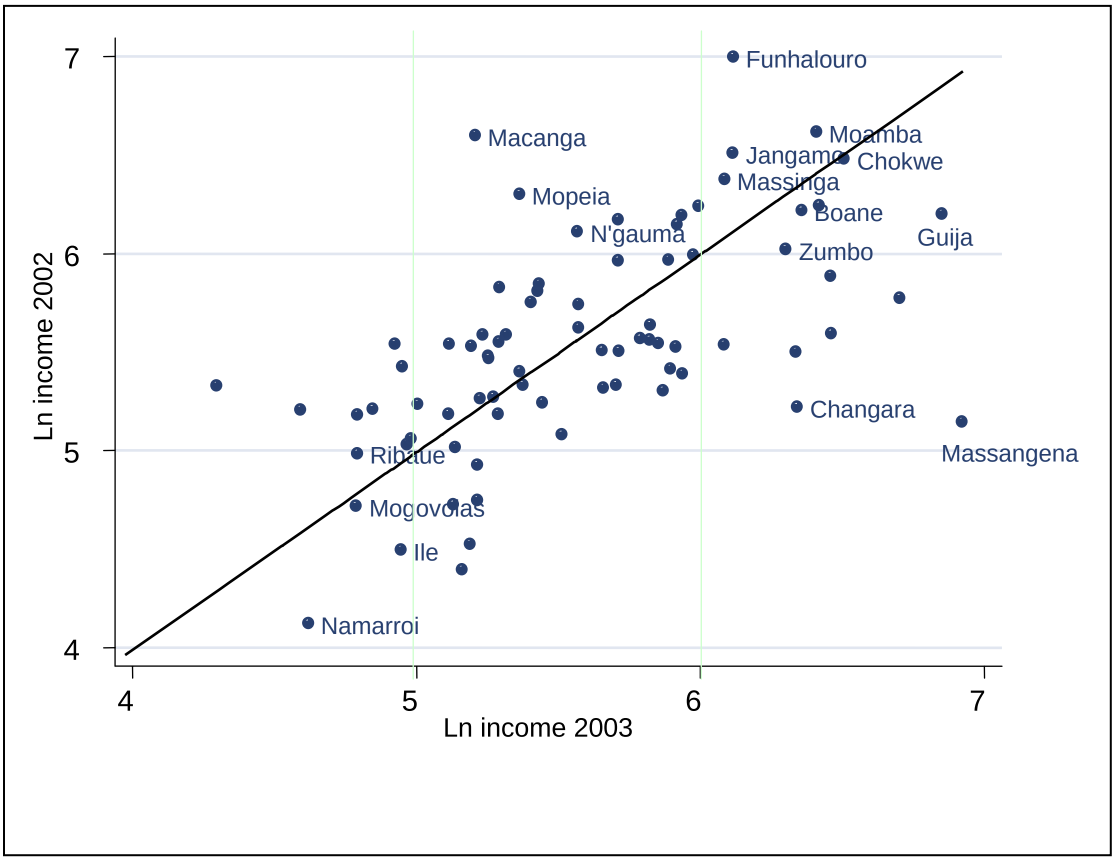
Source: Computed from TIA 2002
[1] Assuming a 20% increase in productivity

households in the next year. That is, we need to document the existence of geographic poverty traps. Second, we need to demonstrate that poverty traps are characterized by low production potential.

The persuasiveness of geographic poverty traps has received some scrutiny in Mozambique. Based on the national consumption-expenditure surveys of 1997 and 2003, differences among districts do not account for much of the variation in household poverty. Poorer households live next to richer households (Simler and Nhate 2005; Elbers et al. 2003). Within an area as small as a *posto administrativo*, one can usually find households with both higher and lower consumption expenditure per capita. We test a related but different hypothesis: Are the higher-income districts in one year likely to be the higher income districts in the next year? Finding positive co-variation over time points to the existence of geographic poverty traps.

Household income estimates from the TIA surveys in 2002 and 2003 support the hypothesis of positive covariance over time at the district level (Walker et al. 2004; Pitoro 2006). Higher income districts in one year are likely to be higher income in the next year as the observations fall within a broad band of the 45-degree line in Figure 6. This pattern of chronic poverty replicating itself over space has several notable outliers showing transitory poverty. For example, household income in both Changara in Tete and Massangena in Gaza was significantly higher in 2003 than in 2002.

Figure 6. Household Income in 2002 and 2003 TIA Districts Expressed in Logarithms (ln)



Source: Constructed from TIA 2002 and 2003

Mean income in only 17 of the 80 districts moved by more than one quintile between 2002 and 2003, suggesting similar rainfall years or a similar pattern in income discrepancies over time (Table 6). Seven districts belonged to the low-income quintile in both years: these are the candidates for geographic poverty traps. The low-income districts are located in Nampula and Zambezia provinces that should be the breadbasket for Mozambique (Table 7). In contrast, with the exception of Zumbo on the Zambian border, the high-income districts are found in the rainfall-scanty, southern provinces. Many observers of Mozambican agriculture would probably say that low-income Meconta, Monapo, and Ribaue are associated with more production potential in terms of soil and rainfall endowments and population density than any of the high-income districts listed on the left side of Table 7.

Summing up, the TIA data for 2002 and 2003 support the existence of geographic poverty traps in several districts with relatively high production potential. Agricultural research should be able to favorably affect the welfare of these poorer regions without sustaining efficiency losses from the (supposed) low production potential of geographic poverty traps.

Table 6. Income Dynamics Across Districts between 2002 and 2003

Change in Quintiles between 2002 and 2003	Frequency	Percent
-3	1	1.25
-2	8	10.00
-1	19	23.75
0	**25**	**31.25**
1	19	23.75
2	7	8.75
3	1	1.25
Total	**80**	**100.00**

Source: Computed from TIA 2002 and 2003

Table 7. Persistently High and Low Income Districts Both in 2002 and 2003

High Income		Low Income	
Province	**District**	**Province**	**District**
Tete	Zumbo	Nampula	Meconta
Inhambane	Funhalouro	Nampula	Mogovolas
Inhambane	Jangamo	Nampula	Monapo
Inhambane	Massinga	Nampula	Ribáuè
Gaza	Chókwè	Zambézia	Ile
Gaza	Guijá	Zambézia	Maganja da Costa
Maputo	Boane	Zambézia	Namarroi
Maputo	Matutuíne		
Maputo	Moamba		

Source: Computed from TIA 2002 and 2003

6.4. Transitory Poverty and Geographic Relief Traps

The need to respond to emergency relief threatens the stability of agricultural research in SSA. Relief consumes an increasingly large share of foreign aid budgets, and responsible governments are under considerable pressure to find more permanent solutions to food insecurity problems caused by fluctuations in growing-season rainfall. Agricultural research is viewed as contributing solutions to the problem of risk-prone regions. Research priorities can easily be skewed to mitigate the recurring stresses of such regions, particularly when project funding is available to contribute to emergency relief efforts.

Agriculture in Mozambique personifies risky production. Perhaps the floods of 2000 were the most famous weather-related rainfall event. Widespread, regional drought in 1992 was equally infamous. Every year various sources of risk exact a toll on production. For example, 44% to 87% of producers in the TIA 2002 stated that they lost some of their crop to one or another source of risk (Table 8).

The data in Table 8 provide some preliminary information on yield reducers to prioritize agricultural research. Sorghum is sensitive to bird damage. Pigeonpea yield depends on the insect pests, principally pod borer. Susceptible potato varieties are vulnerable to disease, mainly late blight. Rice requires water control. Butter beans do not like too much rain.

Table 8. Sources of Risk by Commodity

Commodity	Total No. of Observations	Affected Commodities (%)	Source of Risk (%)							
			Drought	Excessive Rain	Floods	Diseases	Insects	Animals/ Rats/ Birds	Rots	Others
Maize	3,128	74.7	72.6	5.2	1.7	2.8	1.8	11.1	1.1	3.8
Rice	1,001	76.2	65.2	4.6	3.3	1.4	1.2	19.3	0.6	4.4
Sorghum	1,263	70.8	64.2	1.5	0.4	1.3	1.9	25.9	0.9	3.9
Millet	466	86.6	78.3	1.9	0.4	0.6	1.5	15.9	0.4	0.9
Groundnuts	2,340	78.4	67.3	3.0	0.9	4.1	2.9	16.1	2.8	2.9
Butter beans	329	61.0	53.2	12.8	0.9	6.7	9.1	8.8	3.3	5.2
Cowpea	2,294	83.5	66.0	2.4	0.7	6.3	9.5	10.9	2.5	1.7
Bambaranut	1,140	79.9	70.9	3.9	0.4	2.5	2.5	10.0	6.8	3.1
Pigeonpea	544	59.8	48.3	2.2	1.1	3.5	11.4	21.9	3.9	7.7
Potatoes	52	44.1	26.9	13.5	1.9	21.2	1.9	7.7	13.5	13.5

Source: Computed from TIA 2002

But across the board, the most important source of risk is drought. The incidence of rainy season precipitation is almost never ideal for crop growth and harvesting. With the exception of potato growers, more than 50% of the producers of each commodity said that drought had caused production losses in 2002. In response to the same question, the majority of respondents cited drought as a significant cause of productivity loss in 2003 for all commodities except for pigeonpea (41%) and potatoes (which was not considered as a main food crop in 2003).

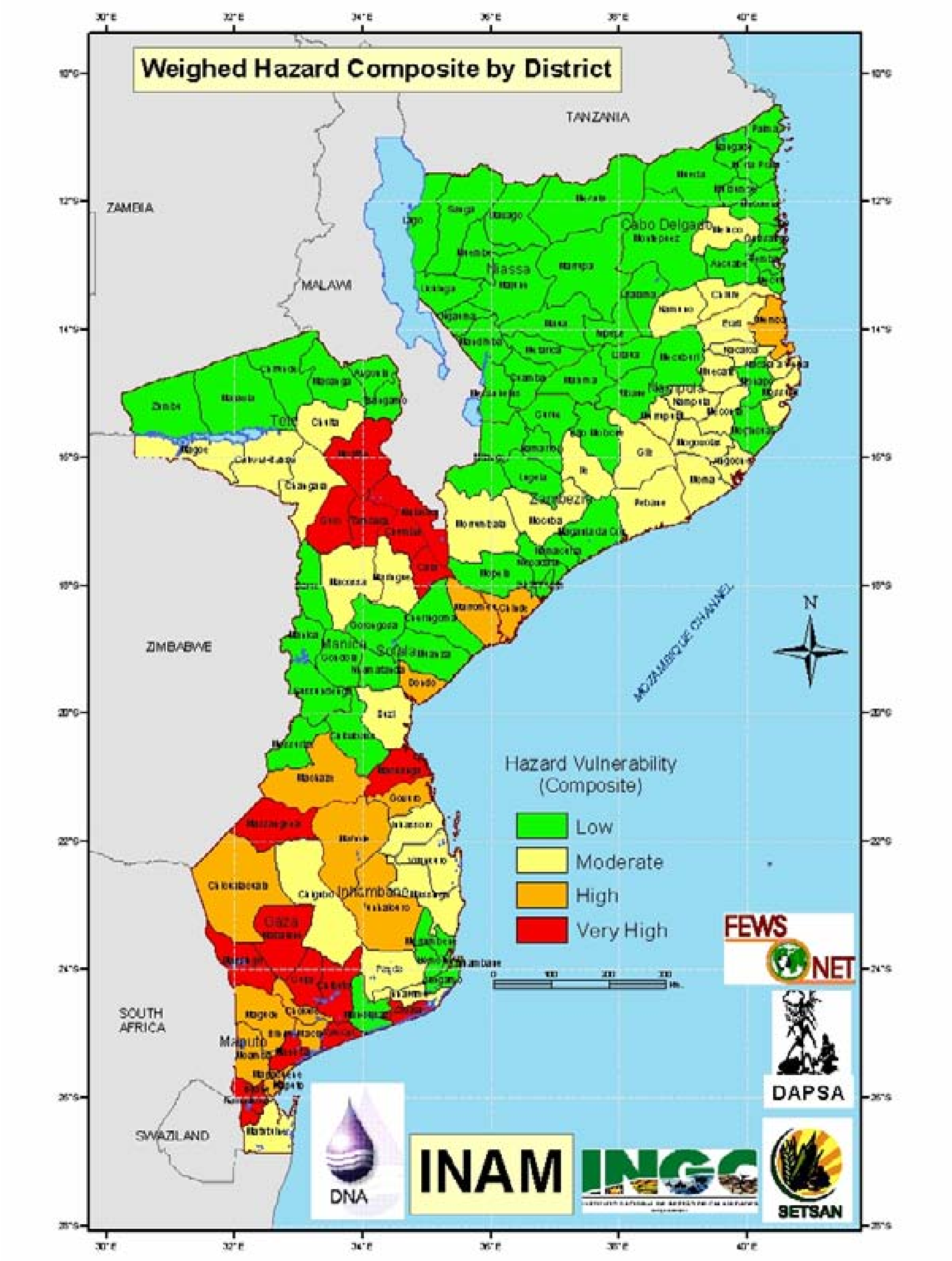
Drought was again prevalent in 2004-2005. About 800,000 households were declared food insecure. Localized areas in all provinces were declared as targets for relief efforts, but the households were concentrated in drought-prone areas of Tete and Gaza districts (Figure 7). About half (37) of the 80 TIA districts contained people declared to be food insecure (FEWS NET 2006). Figure 7 presents a generalized mapping of geographic vulnerability to natural disaster in Mozambique and is not specific to 2004-2005, but there is a strong overlap (USAID 2005). Basing the analysis on the 37 food-insecure districts in 2004-2005, or on the high and very high vulnerable to natural hazard districts in Figure 7, gives similar results.

Comparing the differences in risk-related characteristics between affected and non-affected districts with the TIA 2002 data, we see that the affected districts are more risk prone. The incidence of drought, flood, and plant pest risk is significantly higher in the affected districts where people were more likely to buy food in the hungry season and participate in emergency seed programs (Table 9).

The data in Table 9 suggest that the same risks, particularly drought, recur over time. In other words, the production potential in the affected districts is more marginal than in the unaffected districts. But, contrary to expectations, there was no difference in household income between affected and non-affected districts in 2002 (Figure 8). Indeed, the upper quintile of the affected districts had substantially higher income than the upper quintile of the food-secure districts. In general, the higher income households in the affected districts with more marginal production potential relied more heavily on off-farm sources of income, particularly wage employment, than higher income households in the non-affected districts with more production potential.

The results in Table 9 support the existence of geographic relief traps in Mozambique. But at this stage of Mozambique's development, geographic relief traps are not geographic poverty traps. Relief traps do not harbor more chronic poverty than anywhere else. They are, however, characterized by marginal production potential. Targeting agricultural research at relief traps, such as interior Gaza and southern Tete, is akin to throwing money down a drain, especially if the objective is to stabilize crop production. Agricultural research administrators should not be seduced into making relief traps a priority other than for highly focused livestock production.

Figure 7. Mapping District Vulnerability to Natural Hazard



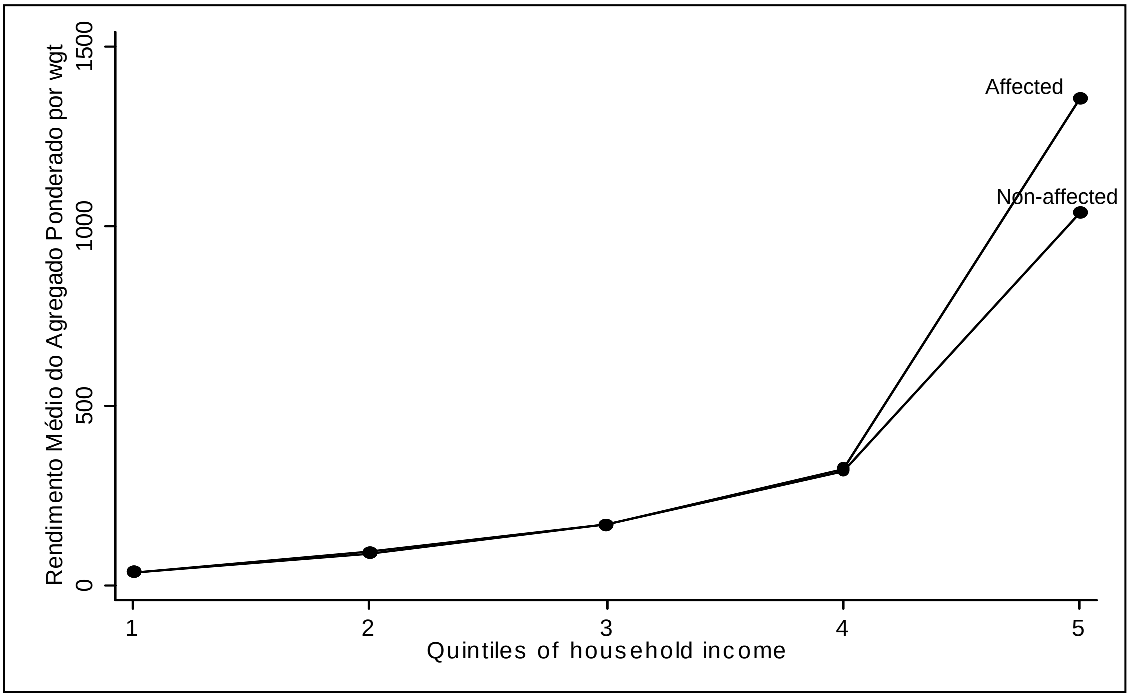
Source: USAID 2005

Table 9. Differences between Affected and Non-Affected Districts in 2005 by Characteristics from the TIA 2002

Characteristics		**37 Affected Districts**	**43 Non-Affected Districts**	**t Value**
Risk	Drought	1.33	0.68	23.02
	Flood	0.70	0.34	19.00
	Plant pest	1.86	1.41	10.05
Propensity to buy	Hunger season	0.73	0.57	12.14
Maize	Last 30 days	0.35	0.22	10.52
Emergency Seed Program		0.20	0.05	15.99

Source: Computed from TIA 2002 and Early Warning 2005

Figure 8. Agricultural Research and Relief: the 800,000 Food-Insecure Households in 2005



Source: Constructed from TIA 2002

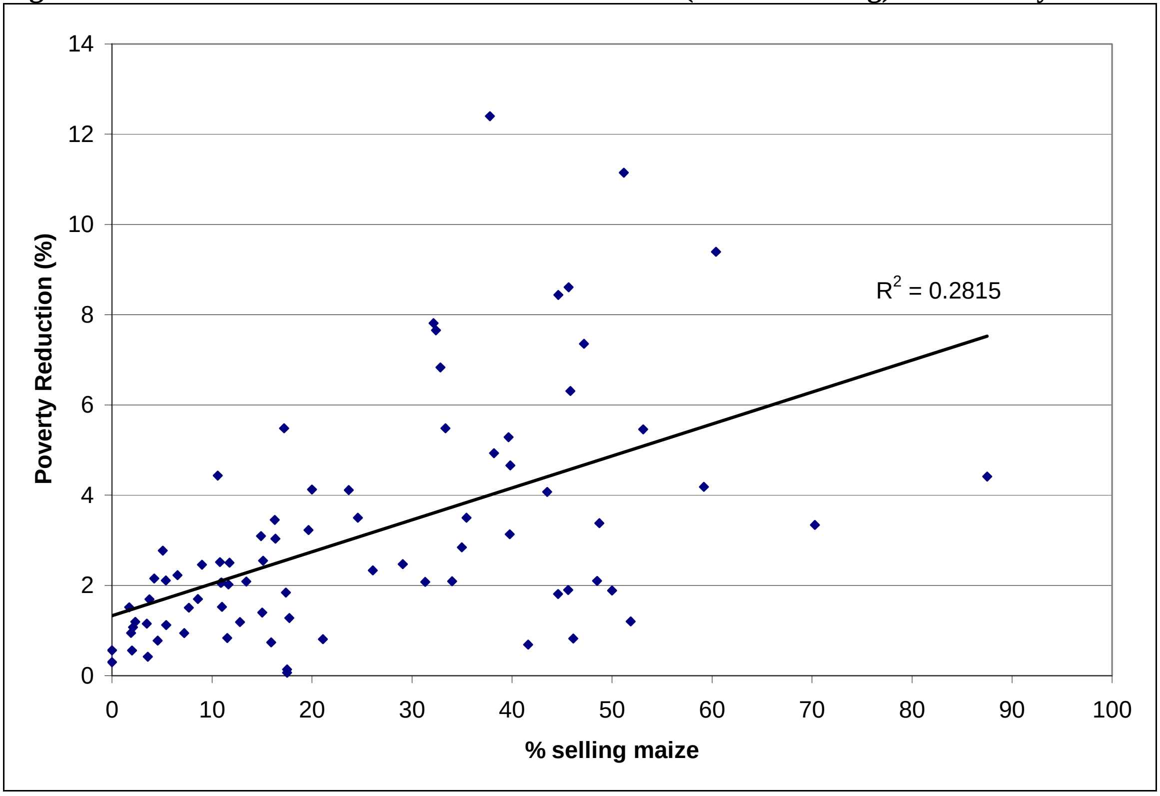
6.5. Poverty Reduction and Markets

Without market demand, the potential for technological change is limited to maintaining the production of staple crops or to animal-health innovations that preserve livestock populations. Maize is an important cash crop for many small-farm households. About one household in four sold maize in 2002 and 2003. Marketed surplus amounted to 8% to 10% of production. But these average data hide a large disparity in maize-market orientation, ranging from 0% to 80%, across districts.

The relationship between maize commercialization and poverty reduction is described in Figure 9. Poverty reduction is positively associated with maize commercialization across the

80 districts in the TIA 2002. This association is not strong, but it is significantly positive. The scatter plot in Figure 9 does not suggest a sharp trade-off between commercialization and poverty reduction. It is more likely that producers in more market-oriented districts will adopt maize-increasing technologies, and the data in Figure 9 say that these producers have sufficient maize production potential and are sufficiently poor for these technologies to impact income poverty favorably.

Figure 9. Relation between Maize Commercialization (Percent Selling) and Poverty Reduction



Source: Constructed from TIA 2002

7. RESULTS: AGROECOLOGIES AND THE ZONAL RESEARCH CENTERS

The ten INIA agroecologies, together with their correspondence to zonal research centers, is given in Table 10. The South, Central, and Northeast Zonal Research Centers have a mandate covering three agroecologies. The Northwest Zonal Research Center is solely responsible for one agroecology, the medium-elevation highlands that border Malawi and Zimbabwe and include parts of Niassa, Tete, and Manica provinces.

The agricultural importance of these ten agroecologies is given in Table 11. The most heavily populated agroecologies are R7 and R8: the interior central and north, and the coastal north. Together these two agroecologies contain about 45% of the rural households, cultivated fields, and chickens. Agroecology R9 is by far the smallest agroecology containing less than 20,000 households. Whether technology can be designed for and adapted to such a small agroecology is questionable.

Table 10. Description of the Agroecologies

Agroecologies		Rainfall	Soil Types	Zonal Center
Zone	**Name**	**(mm/year)**		**Responsible**
R1	Semi-arid interior south	570	Sands	South (Chókwe)
R2	Semi-arid coastal south	500-600	Deep sands	South (Chókwe)
R3	Arid interior south	400-600	Loamy-clays	South (Chókwe)
R4	Mid-elevation central	1,000-1,200	Clays	Central (Sussundenga)
R5	Coastal central	1,000-1,400	Vertisols and fluvisols	Central (Sussundenga)
R6	Dry semi-arid Zambézia and Tete	500-800	Sands-clays	Central (Sussundenga)
R7	Interior central and north	1,000-1,400	Sands-clays	Northeast (Nampula)
R8	Coastal north	800-1,200	Mostly sands, clays on a small scale	Northeast (Nampula)
R9	Interior north of Cabo Delgado	1,000-1,200	Limes and sands	Northeast (Nampula)
R10	High altitude	>1,200	Hard ferralsols	Northwest (Lichinga)

Source: Ministry of Agriculture and Fisheries 1996

Table 11. Agriculture and Livestock by Agroecology

Agro-ecology	No. of Rural Households	No. of Cultivated Plots	Cultivated Area (ha)	Number of Livestock Cattle	Goats[1]	Pigs	Chickens[2]
R1	51,903	119,498	65,443.13	34,683	132,808	22,712	546,998
R2	355,981	1,111,998	461,329.30	114,384	529,017	380,667	2,364,759
R3	92,599	277,095	180,250.10	231,844	193,463	45,007	511,338
R4	185,973	372,381	313,876.90	79,416	644,539	172,622	2,584,971
R5	421,753	1,042,259	544,857.00	10,183	388,454	119,908	3,032,917
R6	247,631	523,946	468,889.20	204,424	1,335,008	271,054	2,243,198
R7	667,014	1,829,381	848,686.70	39,057	672,975	373,975	5,020,489
R8	608,102	1,751,449	729,863.60	92,293	668,522	114,315	5,085,228
R9	18,363	41,731	20,595.78	-	5,593	4,004	192,332
R10	288,886	662,706	463,013.80	65,979	465,150	96,619	2,235,378
Total	2,938,205	7,732,444	4,096,805.51	872,263	5,035,527	1,600,884	23,817,608

Source: Computed from TIA 2002

[1]Goats = goats and sheep

[2]Chickens = chickens, ducks, geese, and turkeys

R6 (the dry semi-arid tropics of the central provinces of Zambezia and Tete) is rich in livestock, especially cattle and goats, compared to the other agroecologies. Livestock also feature prominently in the three southern agroecologies. With the exception of chickens, livestock are very sparse in the more densely populated agroecologies R5, R7, and R8. The scarcity of livestock in these agroecologies poses a major challenge for agricultural development, particularly the dearth of animal traction that was described earlier in this report. Agroecology R10 (the highland agroecology) features a more balanced allocation between crops and livestock, and offers the best prospects for crop-livestock integration.

Several outstanding characteristics of the agroecologies are presented in Table 12. The southern agroecologies have a higher incidence of women-headed households, older household heads, and adult females than the agroecologies located further north. Many men migrate to South Africa; hence, the human resources for agricultural development is qualitatively different in the south than in the other rest of the country where household heads younger than 30 years are common, comprising about one-fourth to one-third of total households. In the three southern agroecologies, it is more likely that the head of the household is older than 60 years or younger than 30 years.

With several other variables in Table 12, such a sharp regional pattern does not emerge. Educational and farm-size differences are muted across agroecologies indicating that lack of differentiation is the norm as few farmers cultivate more than five fields, own more than five hectares, or have more than five years of education.

The outline of regional differentiation becomes transparent with the remaining variables in Table 12. Infrastructure appears to be somewhat superior in the south, particularly in R1. Agroecology R7, the most important in the country from poverty-alleviation and value of production perspectives (as we shall soon see), is starved for power: only 1 farmer in 50 used animal traction, and 1 in 100 employed a tractor. Nationally, the use of animal traction has stagnated at 11% during the past decade. Fertilizer use is also negligible in most of the country. The exception is R10, where fertilizer is sourced from Malawi and where tobacco companies are more in evidence than in the other agroecologies. Although small in area, this highland agroecology seems to be the best poised for agricultural development in Mozambique.

Maize is both a food staple and a cash crop in Mozambique. The incidence of maize marketed varies regionally. Farmers in the southern agroecologies produce maize mainly for subsistence in spite of significantly higher prices than in the rest of the country. In the south, poor production potential in the main growing season results in a muted supply response to strong market demand. A more dynamic pattern of marketed surplus is visible in the remaining agroecologies in Table 12.

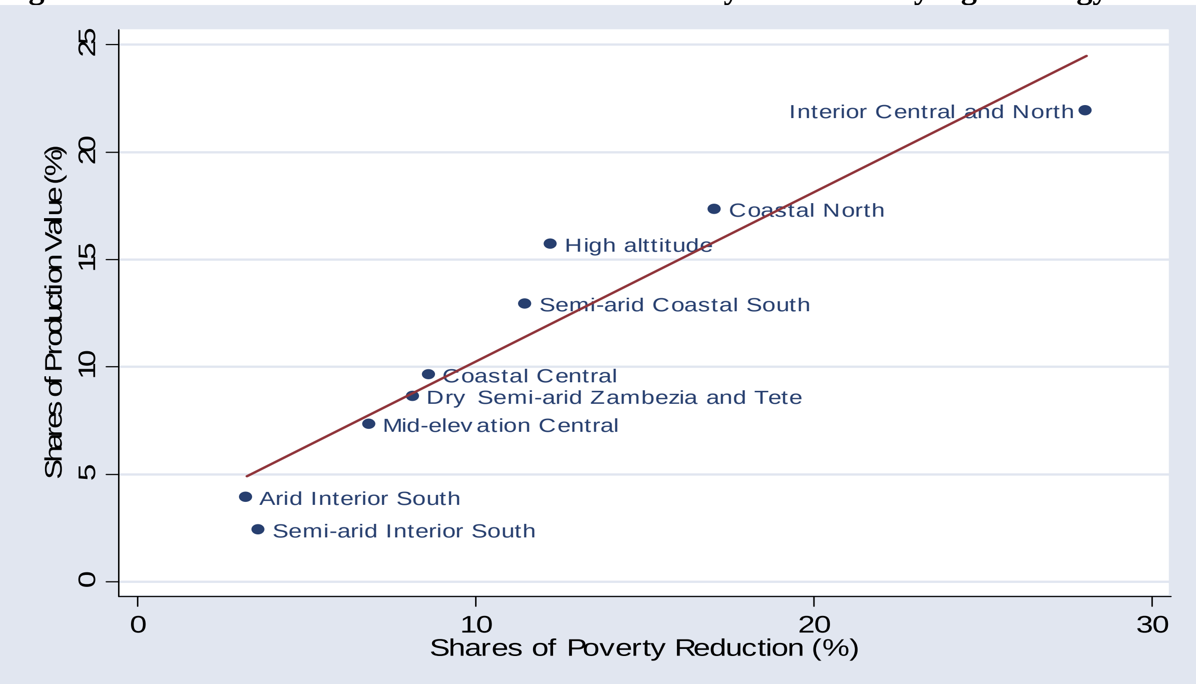
The relative importance of the agroecologies is presented in Figure 10. (We omit agroecology R9 which is too small to be described on our production-value and poverty-reduction graph.) The results for agroecologies mimic our earlier results for districts and commodities: consequences for relative economic importance and potential for poverty reduction are positively associated. Therefore, either value of production or poverty reduction will give similar answers to the questions we ask about research resource allocation and agroecologies.

Table 12. Characteristics by Agroecology

Variable	Agro ecologies										
Sub-category	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	National
Women-headed households	0.32	0.31*	0.34	0.21	0.22	0.23	0.21*	0.22	0.20	0.30*	0.24
Younger than 30 years	0.12*	0.1*	0.09*	0.16*	0.30	0.24	0.25	0.27*	0.42*	0.26	0.23
60 years or older	0.17*	0.29*	0.28*	0.18	0.09*	0.16*	0.11*	0.11*	0.11	0.13	0.15
5 years of schooling	0.2*	0.16	0.13*	0.2*	0.17	0.17	0.14	0.13	0.25	0.14	0.15
Females aged 15-64 years	1.61*	1.55*	1.87*	1.46*	1.3	1.46*	1.17*	1.15*	1.55*	1.29	1.32
More than 5.00 ha	0.04*	0.07*	0.05*	0.04*	0.02*	0.06*	0.02	0.02	0.00	0.04*	0.03
5 or more fields	0.02*	0.14*	0.08*	0.01*	0.03*	0.03	0.11*	0.07	0.07	0.07	0.07
Infrastructural index	0.36*	0.25	0.25	0.23*	0.19	0.16*	0.17*	0.20	0.17	0.20	0.22
Hired labor temporary	0.21*	0.16	0.11	0.26*	0.11*	0.21*	0.16	0.09*	0.16	0.25*	0.17
Animal traction	0.13	0.42*	0.54*	0.09*	0.01*	0.02*	0.00*	0.00*	0.00*	0.17*	0.11
Tractorization	0.17*	0.02*	0.06*	0.03	0.02*	0.01*	0.005*	0.00*	0.01	0.05*	0.03
Fertilizer use	0.02	0.02*	0.09*	0.03	0.01*	0.02*	0.04	0.02*	0.00	0.14*	0.04
Pesticide use	0.03	0.04	0.09*	0.10*	0.01*	0.18*	0.17*	0.13*	0.00	0.09	0.08
Proportion who market maize[1]	0.03*	0.01*	0.02*	0.12*	0.05*	0.05*	0.16*	0.09	0.07	0.12*	0.08

Source: Computed from TIA 2002 and 2003
*Statistically significant at 5%
[1] Proportion of growers in 2002

Figure 10. Shares of Value of Production and Poverty Reduction by Agroecology



Source: TIA 2002

The agroecologies separate into four groups in Figure 10. The least important agroecologies are the Arid Interior South and the Semi-Arid Interior South. Neither of these agroecologies command more than a 5% share in value of production or in potential for poverty reduction. The next three agroecologies are of moderate importance, approaching a 10% share in both poverty reduction and value of production. These three all belong to the Central Zonal Research Center. The four "most" important agroecologies are the coastal south (R2), the high altitude border districts (R10), the coastal north (R8), and the interior central and north (R7). Of these four, the latter is by far the most important.

Translating these results for agroecologies into the zonal center mandates show that the Northeast Zonal Center is clearly the most important zonal center with about 40% of value of production and potential for poverty reduction (Table 13). The share for the Central Zonal Research Center varied from about 26% in 2001 to 34% in 2002. The explanation for this fluctuation is that cassava production in Zambezia was most probably overestimated in 2003. In any case, the Central Zonal Research Center clearly occupies the second position in importance. The South and Northwest Zonal Centers are about the same order of magnitude, contributing about 15% to each criterion.

7.1. Commodity Concentration across Agroecologies

The concentration of production across agroecologies is an important issue. In principle, it is easier to make technological progress on commodities where production is concentrated in one or two agroecologies than on commodities where production is scattered across many recommendation domains. If the concept of agroecology is valid as an organizing construct for technology design and transfer, then technologies suitable for one agroecology may not be

Table 13. Total Value of Production of Commodities by Agroecology

Agroecology	TIA 2002 (%)	TIA 2003 (%)	Mean (%)
R1	2.4	0.5	1.2
R2	12.9	8.9	10.4
R3	3.9	1.7	2.5
R4	7.3	8.4	8.0
R5	9.6	22.7	18.0
R6	8.6	6.8	7.5
R7	21.9	24.0	23.2
R8	17.3	15.6	16.2
R9	0.3	0.6	0.5
R10	15.7	10.8	12.6

Source: Computed from TIA 2002 and 2003

appropriate for another. In practice, transferability depends as much on the technology as it does on agroecology, e.g., a new vaccine for Newcastle's disease in chickens should be applicable to most, if not all, chickens. But, in general, more disperse agroecologies imply more recommendation domains which effectively increase the costs of successful agricultural research or diminish the prospects for successful research.

We use an index of diversity to measure concentration in Table 14 for the 32 most important commodities in Table 1. This measure ranges from 0.00 where all production takes place in one agroecology to 0.99 where commodity production is divided equally among the ten agroecologies. Thus, higher values in the last column of Table 14 indicate more diversity.

The simple average of the diversity index is 0.69, but 0.75 seems to be a threshold that separates commodities into two groups of spatial concentration. Commodities with diversity values at or below 0.75 are usually characterized by one or two "dominant" agroecologies. About half of the 32 commodities fall into the group of the spatially concentrated commodities that are epitomized by potatoes and beans in the high altitude agroecology and vegetables in the SAT, interior south. The bulk of potato production takes place in Tsangamo and Angonia, two high altitude districts in Tete, and in the higher plateau area of Niassa . Over 60% of tomato and onion sales occur in irrigated Chokwe district in agroecology R3.

A pattern of spatial concentration of production enhances the prospects for technological success, but also may facilitate the funding of decentralized agricultural research at the provincial or even district level. Economic development is associated with geographic specialization in production. Areas that are already well-defined in terms of production could give rise to farmer groups that could exploit the current interest in decentralization in development. In the medium-term, such farmer groups could lobby provincial and district governments for investment in specific agricultural research for which the public sector would initially loom large as a source of supply. Spatially concentrated commodities could benefit from brighter prospects for technology design and also more funding opportunities.

Geographic diversity is not that much of a problem in cassava and maize, the two commodities with the highest production value. Both crops, especially maize, are spatially dispersed, but even a 10% share is equivalent to more than $10 million in value of production. Spatially scattered commodities tend to be primarily in livestock species and fruit crops. Among field crops, the problem of too much spatial "dispersion" occurs mainly in sweetpotato, rice, and bambara groundnut.

Table 14. Value of Production and Index of Diversity by Commodity and Agroecology

Commodity		Shares of Value of Production by Agroecology (%)										National[1]	
		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	(10^6 U$D)	ID[2]
1	Cassava	3.4	26.9	1.1	2.4	13.7	3.2	21.7	20.4	0.1	7	127.6	0.81
2	Maize	1.9	4.4	5	13.9	6.5	10.2	25.5	7.8	0.4	24.3	113	0.83
3	Sweetpotato	5.5	9.4	3.6	7.7	18.6	25.4	9	2.4	0.2	18.1	30.8	0.84
4	Groundnut	2.5	12.9	1.5	1.9	4	5.1	28.1	37.6	1.1	5.3	26.6	0.75
5	Chicken	3.0	6.1	3.3	8.5	15.5	10.5	18.1	26.3	0.5	8.2	18.8	0.84
6	Rice	0.0	1.7	8.5	1.8	22.6	1.9	24.5	35.2	0.3	3.3	18.4	0.76
7	Tobacco	0.3	0.4	0	1.1	0.3	0.3	27	0.6	0	70.1	16.9	0.44
8	Sorghum	0	0.3	0.1	11.3	3.5	16.1	44.5	17.9	0.4	5.9	15.2	0.73
9	Cashew	0.1	13.9	1.3	0.4	8.7	1.4	9.4	63.6	1	0	13.2	0.56
10	Cotton	0.0	0	0	0	1.6	25.1	41.1	31.4	0	0.8	12.4	0.67
11	Goats	2.3	8.9	3	18.7	5.5	23.8	15.8	11.8	0	10.2	12.3	0.85
12	Cattle	5.5	8.4	26.4	9.8	1.2	22.1	2	3.8	0	21	9.8	0.82
13	Coconut	0.0	75.4	0.2	0	17.6	0.1	0.7	5.9	0	0	8.6	0.40
14	Cowpea	4.9	14.4	4.8	4.1	4.7	5.2	25.9	28.3	0.6	7.1	8.2	0.82
15	Butter beans	1.8	0.7	2.7	4.8	0.5	2.9	6	0.1	0	80.6	8.2	0.34
16	Tomato	2.4	4.5	56.7	5.8	2.2	2.8	4	3	0.2	18.3	5.2	0.64
17	Sugar cane	1.0	2.8	0.7	6.4	13.2	5	44.3	16.6	0.1	9.9	5.2	0.74
18	Pigs	1.1	25.3	2.1	8.3	6.5	13.8	24.2	9.2	0.7	8.8	4.5	0.83
19	Banana	1.4	7.4	0.2	25.8	17.2	4	15	8.2	0.8	20	4.5	0.83
20	Others	5.5	7.8	4.5	17	6	19	13.8	9	0	17.4	3.9	0.86
21	Bambaranut	0.3	16.1	3.3	3.1	4.7	2.2	21.4	39.9	1.2	7.7	3.7	0.76
22	Pigeonpea	0.1	1.3	0.3	14.3	4	4.7	53.4	18.3	0.1	3.6	3.4	0.66
23	Sesame	0	0	0	19.2	1.4	4.1	20.9	53.7	0.1	0.7	3	0.63
24	Potato	0.1	1	0	0.1	0.3	0.8	2.2	13.3	0	82	2.7	0.31
25	Cabbage	2.3	14.5	10.6	18	2.9	13.8	2	0.7	0	35.3	1.3	0.79
26	Onion	1.2	1.2	64.4	12.6	0.9	3.3	4.5	0.1	0	11.9	0.9	0.55
27	Lettuce	0.4	23.7	3.2	59.3	1.7	0.4	1.6	0	0	9.7	0.8	0.58
28	Mango	2.4	23.3	1	19.8	10.4	1.8	5.8	17.8	0	17.6	0.8	0.83
29	Tangerine	0	23.2	0	70.3	1.6	0	2.2	1.9	0	0.9	0.8	0.45
30	Millet	0.4	1	1.2	6.8	10	57	14.6	7.2	0	1.8	0.8	0.63
31	Sheep	0.5	1.5	5.4	5.3	1.5	11.7	13.9	37.9	0	22.1	0.7	0.77
32	Orange	0.1	31.7	0.2	8.5	9.3	0	21.3	22	0	6.8	0.6	0.79
Value (10^6 US$)		11.5	62.5	18.7	35.2	46.1	41.7	105.7	83.7	1.5	76	482.6	
Value (%)		2.4	12.9	3.9	7.3	9.6	8.6	21.9	17.3	0.3	15.7	100	

Source: Computed from TIA 2002

[1] Calculated based on rate exchange of 1$US=23,450 Meticais

[2] Simpson Index of Diversity $\left(ID = 1 - \sum_{i=1}^{10} R_i^2 \right)$ where R_i are shares of value of production in each agroecology

7.2. Matching Commodities to Zonal Research Centers

In the spirit of decentralization and in the recognition that the central and northern regions of the Mozambique comprise the agricultural heartland of the country, the leadership of the commodity programs should be assigned to the zonal research centers. These assignments should be based on several sources of information among which value of production and potential for poverty reduction should figure prominently in the equation. If commodities were distributed roughly equally across two or more zonal research centers or if production was concentrated in the south, it could still make sense to station the commodity leadership at headquarters in Maputo.

The assignment to the lead zonal research center is indicated with an asterisk in Table 15, which summarizes information from several sources. Other "collateral" centers figure in Table 15 if they have a share of commodity production of more than 15% of value of production. In the discussion that follows, we also consider production from the TIA 2003. Finally, we factor in mean levels of production on the main field crops in commodity-specific Table 16 to get a feeling for household productivity across agroecologies. Higher mean levels of production in an agroecology underscore the need for greater research effort in the zonal center that serves that agroecology relative to other zonal centers. An agroecology must have at least 30 observations in the commodity of interest to be presented in Table 16. In the commodity analysis that follows, we focus on mean household production by agroecology and not mean yield because yield depends on widely varying plant populations and field sizes.

7.2.1. Maize

Maize is produced throughout Mozambique. Seven of the ten agroecologies produce more than $6 million worth of maize. The two dominant agroecologies are the interior and central north (R7) and the high altitude region (R10). Collectively, agroecologies R4, R5, and R6 that are serviced by the Central Zonal Research Center contribute more than 30% to the value of production. The more dynamic maize-producing zones with significantly more production per household are agroecologies R4, R6, and R10 where mean annual production per household approaches or exceeds 800 kilos (Table 16). Therefore, based on the information in Tables 15 and 16, the maize national program could be located in one of three zonal research centers, the Central, the Northeast, or the Northwest. The decision by IIAM management to house the national program in the Central Zonal Research Center seems to be a good one from the perspective of the importance of and prospects for maize production.

The maize program needs to be active in all four zonal research centers. Maize is important for food security in the south and value of production in the three southern agroecologies totals more than $10 million. The challenge for the maize program is to address the demand for varieties in the dynamic agroecologies R4, R6, and R10, without ignoring the important needs in the rest of the country. The three coastal agroecologies R2, R5, and R8, with about 20% of maize production, present a daunting challenge. Maize does not enjoy a comparative advantage in these agroecologies, but it will be an important commodity there for many years to come. Lowland maize has been difficult to improve; few varieties are well-adapted to lowland conditions. Mean production is only about 250 kgs per household (Table 16).

Table 15 . Commodity Importance in the IIAM Zonal Centers

	Crop and Value of Production[1] (%)			
Rank	**South**	**Center**	**Northeast**	**Northwest**
1	Cassava	Cassava	Cassava (45)*	Cassava
2	Maize	Maize (34)*	Maize*	Maize*
3	Sweetpotato	Sweetpotato (66)*		Sweetpotato
4	Groundnut		Groundnut (71)*	
5		Chicken *	Chicken (40)*	
6		Rice*	Rice (50)*	
7			Tobacco*	Tobacco (51)*
8		Sorghum	Sorghum (58)*	
9	Cashews		Cashews (58)*	
10			Cotton (73)*	
11		Goats (46)*	Goats	
12	Cattle*	Cattle (48)*		Cattle
13	Coconuts (67)*			
14			Cowpea (55)*	
15		Butter beans		Butter beans (62)*
16	Tomatoes (63)*			Tomatoes (18)
17		Sugar cane (25)	Sugar cane (61)*	
18	(Pigs)	(Pigs)	Pigs (34)*	
19		Bananas (47)*	Bananas (24)	Bananas (20)
20			Bambaranuts (67)*	
21			Pigeonpea (65)*	
22			Sesame (71)*	
23				Potatoes (71)*
24	(Cabbage)	(Cabbage)		Cabbage (35)*
25	Onion (66)*			
26		Lettuce (61)*		
27	(Mango)	Mango (32)*	(Mango)	(Mango)
28		Tangerine (72)*		
29		Millet (73)*		
30			Sheep (52)*	
31	Orange (32)		Orange (43)*	

Source: Computed from TIA 2002
* Highest shares of value of production
( ) Indicates that relative share is high but value of production is less than $3 million
[1] Shares of production value in the research zonal centers

7.2.2. Rice

The dominant agroecologies for rice are two coastal agroecologies (R5 and R8) and the interior central and north (R7). The highly visible Chokwe irrigation district in agroecology R3 only contributed about 9% to the national value of production of $18 million in 2001-2002 and has too few observations to appear in Table 17. Cheap rice imported from the Indian and Pakistani Punjab makes intensive irrigated rice production an unlikely economic proposition.

Table 16. Mean Household Production in kgs of Maize by Agroecological Zones in 2002 and 2003

Zone	2002 Estimate	2002 Standard Error	2002 Group[1]	2003 Estimate	2003 Standard Error	2003 Group
R4	805.33	46.80	a	913.05	55.30	a
R6	514.61	56.41	ab	850.94	41.04	ab
R10	780.38	77.66	a	809.62	44.54	ab
R7	457.98	42.16	ab	643.00	36.54	b
R3	490.56	78.47	ab	570.87	50.63	b
R5	305.45	48.02	b	516.16	46.29	b
R9	408.34	45.75	ab	462.22	62.78	b
R2	108.73	10.14	c	268.01	22.47	c
R8	229.77	15.75	b	258.61	21.10	c
R1	292.01	81.91	b	218.25	25.94	c

[1] Grouping is based on the results of a multiple range test with p=.05; the same letter indicates no significant differences in mean production levels among groups. Agroecologies are ordered by production in 2003.

Investing in rice research in Mozambique is not for the faint of heart. Production is beset by both droughts and floods in lowland-rainfed rice, the dominant agroecology. Such fluctuations in production were evident in the two years of the TIA surveys. Production per household was low in 2001-2002, with only agroecology R8 producing significantly above 80 kgs. Production rebounded in 2002-2003 with five agroecologies producing more than 100 kgs/household.

Based on these data, the Central or the Northeast Zonal Research Center would appear to be the most eligible candidate for the site of the national rice research program, but the choice of either site requires the establishment or rehabilitation of a research station in one of the main rice-growing district clusters. Investing in such a station should be coordinated with a sectoral plan for improving rice production in Mozambique (Agrifood Consulting International 2005). Without a sustained initiative to invest in infrastructure and increase the commercialization of rice in the center and north of the country, research per se is unlikely to make much of a difference.

Table 17. Mean Household Production in kgs of Rice by Agroecological Zones in 2002 and 2003

Zone	2002 Estimate	2002 Standard Error	2002 Group	2003 Estimate	2003 Standard Error	2003 Group
R6	33.04	8.84	c	216.89	53.40	a
R5	72.23	10.51	ab	185.11	14.85	a
R2	39.14	7.27	bc	179.96	41.57	a
R8	113.78	17.04	a	139.11	22.71	ab
R7	73.54	5.69	ab	125.17	9.15	ab
R10	63.86	8.73	ab	89.25	15.92	c
R4	28.60	5.61	c			

7.2.3. Coarse Grains

Sorghum and pearl millet are the other cereals that figure in the top 30 economically important commodities in Table 1. Like rice, mean sorghum production fluctuated sharply between the two survey years. Agroecology R7 and the small agroecology R9 produced most of the sorghum in 2001-2002 (Table 18). Agroecology R6 was also a large producer, particularly in 2002-2003.

Based on the TIA data, one could argue for either the Central or the Northeast Zonal Research Center as the site of a national program. Given sorghum's role as a food security crop for a considerable number of households in Nampula province, the geographic balance would tilt in favor of the Northeast Zonal Research Center.

Success hinges on finding heavier-yielding, photoperiod-sensitive varieties that tolerate bird damage, panicle diseases, and insect pests such as head bugs. High-yielding, short-stature, photoperiod insensitive varieties are not well adapted to the growing season conditions of northern Mozambique, where rainfall at planting is uncertain and the risk of rainfall at harvesting is high. The realization of increased commercial demand for sorghum could substantially help in the definition of research priorities.

Pearl millet ranked near the bottom of the commodity list in Table 1. The lion's share of production takes place in the dry, semi-arid agroecology R6. Pearl millet is highly drought tolerant, but millet production per household is low and variable in the most marginal cultivated areas of agroecology R6 in southern Tete. Mean production per household varied by a factor of 3.0 between the two TIAs in this drought-afflicted region (Table 19). Only one household of 564 producing observations reported millet sales in 2001-2002. The outline of market opportunities to reverse what appears to be declining production is not readily visible. The best strategy for agricultural research could be to wait until the millet's market role is better defined. Searching for more drought resistance in millet is a losing proposition.

Table 18. Mean Household Production in kgs of Sorghum by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	**Estimate**	**Standard Error**	**Group**	**Estimate**	**Standard Error**	**Group**
R91	180.93	32.35	a	*		
R6	125.50	17.87	ab	265.27	15.59	a
R4	152.75	14.27	a	249.78	21.81	a
R3	21.11	2.03	c	247.95	29.89	a
R7	143.15	21.21	a	187.03	12.38	b
R5	60.81	8.91	b	186.77	17.97	b
R8	89.61	10.26	a	130.94	16.42	cd
R10	82.91	9.33	a	90.67	9.28	d
R2	8.71	1.30	c	*		

* Less than 30 observations in 2003

Table 19. Mean Household Production in kgs of Millet by Agroecological Zones in 2002 and 2003

Zone	2002 Estimate	2002 Standard Error	2002 Group	2003 Estimate	2003 Standard Error	2003 Group
R6	71.67	8.20	a	250.65	14.60	a
R3	27.76	0.19	c	157.08	29.45	a
R5	39.89	8.91	ab	94.88	14.14	b
R4	39.11	12.65	ab	1		
R7	31.64	4.04	ab	1		

7.2.4. Cassava

Cassava production is more concentrated than maize with the three coastal agroecologies (R2, R5, and R8) accounting for over 60% of the value of production. The interior north and central agroecology R7 also contributed more than 20% to value of production. In 2001-2002, households in agroecologies R7 and R8 produced, on average, more than 1.5 metric tons (Table 20). The importance of these two agroecologies in national cassava production argues for the location of the national program in the Northeast Zonal Research Center. Having responded to the question of the geographic leadership of the national program, the only other pertinent issue for regional resource allocation focuses on the amount of effort to put into the high altitude agroecology that contributes $9 million to national production. Cassava clearly requires a scientific presence in the South and Central Zonal Research Centers.

Cassava is afflicted by several sources of biotic stress, mostly brown streak disease and mosaic virus. Effective agricultural research should be able to solve these problems. Cassava is a versatile crop and offers more opportunities for post-harvest research than other root and tuber crops. Mozambique needs to participate more fully in the "silent revolution" of expanding post-harvest uses for cassava that is occurring in other countries of SSA (Nweke, Spencer, and Lynam 2003).

Table 20. Mean Household Production in kgs of Cassava by Agroecological Zones in 2002 and 2003

Zone	2002 Estimate	2002 Standard Error	2002 Group	2003 Estimate	2003 Standard Error	2003 Group
R9	1057.61	96.60	b	3083.09	639.91	a
R5	1356.10	359.80	ab	2051.88	228.21	a
R6	1116.90	287.59	ab	1689.85	121.07	ab
R8	1583.52	114.95	ab	1599.97	128.55	bc
R10	1032.93	83.38	b	1505.61	232.55	bc
R7	1814.55	237.22	a	625.05	109.90	d
R2	1111.20	174.21	b	354.41	28.24	e
R1	767.34	85.20	b	300.66	54.60	e
R4	574.61	44.63	b	183.31	24.12	f
R3	303.15	134.10	bc	71.66	9.58	g

7.2.5. Sweetpotato and Potato

Sweetpotatoes and potatoes are the other two root and tuber crops that appear in Table 1. Somewhat surprisingly to most observers of Mozambican agriculture, sweetpotatoes occupied the third position of economic importance in 2001-2002. They are cultivated in very small plots throughout the country as indicated by their high diversity index in Table 14. The most important agroecologies are R5, R6, and R10. These data indicate that the hub of sweetpotato activities should be in the Central Zonal Research Center in either the R5 or R6 agroecologies. The production data in Table 21 argue for a central presence in R5. The south and northwest centers have sufficient production to warrant sweetpotato research.

Despite its wide spatial distribution, the emphasis in sweetpotato is mostly the same throughout the country: high pro-vitamin A content in material that resists water deficits in the dry-season propagation of planting material. The negative linkage between dry matter content and orange-flesh needs to be thoroughly broken if uptake by farmers is to be high. Perhaps more than any other crop, success in Mozambique hinges on progress in plant breeding at the regional and international levels.

Potatoes enjoy markedly different market prospects from sweetpotatoes and, as we saw, their production is concentrated in R10 under the mandate of the Northwest Zonal Research Center. Research priorities are clean seed of the dominant varieties, especially red-skinned Rosita, and late blight resistance in white-skinned materials (Demo et al. 2006).

7.2.6. Grain Legumes

Economically, groundnuts are the most important grain legume and are produced throughout Mozambique. But agroecologies R7, R8, and R9 account for over 60% of production. These agroecologies are the only areas where mean production approaches 100 kg per household (Table 22). Hence, leadership for groundnut research should reside in the Northeast Zonal Research Center. With more than $4 million in production, a research presence is also warranted in the south. Testing elite varieties that adapt well to the upland and coastal conditions of agroecologies R7 and R8 is the priority. Expanding crop and post-harvest management options to minimize the threats of rosette and aflatoxin is the priority and a

Table 21. Mean Household Production in kgs of Sweetpotatoes by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R5	1,095.43	59.49	a	695.06	83.15	a
R7	330.87	41.00	b	430.34	75.60	b
R6	551.59	181.09	ab	258.69	33.30	c
R8	288.36	53.95	b	251.73	96.89	bcde
R1	469.89	65.24	ab	203.78	33.76	d
R4	417.92	66.75	ab	182.53	27.50	d
R10	375.21	32.10	a	172.08	24.71	d
R3	156.38	36.60	c	96.52	15.13	e
R2	160.57	28.75	c	93.46	12.06	e

necessity if the export market is the target. Bold-seeded varieties are particularly important for export.

In 2001-2002, *phaseolus vulgaris* (called butter beans in Mozambique) and cowpeas attained about the same level of value of production at about $8 million. Thanks largely to higher prices, the value of production of butter beans increased to over $15 million in 2002-2003. Although both commodities are grain legumes, they present markedly different prospects. Butter beans fetch high market prices, and they are mainly grown as a cash crop. In the two survey years, mean household production of butter beans in its principal agroecology (R10) ranged from about 135 to 290 kgs (Table 23).

Cowpeas are much more of a subsistence crop and are as prized for their leaves as much as for their beans that are often shriveled. The quality of cowpea production in Mozambique is decidedly inferior to that obtained in other countries of SSA, particularly west Africa (Personal communication, J. Lowenberg-Deboer, 2006). Even in its dominant agroecology, cowpea production is small with mean values of 45 kgs in 2002 and 70 kgs in 2003 (Table 24).

Table 22. Mean Household Production in kgs of Groundnuts by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R7	75.99	7.70	a	96.78	5.12	a
R8	93.28	9.49	a	65.59	3.79	b
R6	22.03	3.69	bc	61.11	4.97	b
R10	34.53	4.03	b	48.26	4.50	c
R4	23.93	2.33	c	39.49	7.21	cd
R2	22.87	3.44	bc	37.92	3.27	c
R3	16.69	3.37	c	32.49	3.64	cde
R5	22.66	4.62	bc	28.73	5.21	cde
R1	22.26	3.42	bc	24.07	4.19	e
R9	54.88	8.04	ab	1		

Table 23. Mean Household Production in kgs of Butter Beans by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R10	134.29	19.33	a	291.90	8.61	a
R7	69.53	12.83	ab	172.98	30.51	b
R4	46.59	15.66	b	114.75	25.46	c
R6	29.53	6.94	b	67.13	9.75	d
R3	31.55	20.29	c	45.97	14.95	e
R2	5.04	3.53	c	40.92	8.22	e
R1	26.86	4.74	b			

The location of research centers is not an issue for either butter beans or cowpea. As discussed earlier, butter beans production is concentrated in the high altitude agroecology that is under the auspices of the Northwest Zonal Research Center. Butter beans have sufficient mass in that agroecology to make a dent in the level of absolute poverty. The bulk of cowpea production takes place in agroecologies R7 and R8, which are the responsibility of the Northeast Zonal Research Center. At issue is the amount of research resources to devote to cowpea grown mostly in a subsistence setting. Identifying consensus points of research to leverage low productivity resulting from an array of biotic and abiotic constraints is a challenge.

Two more grain legumes are in the top 30 commodities in Table 1. Both pigeonpea and bambaranut share traits similar to cowpeas. They are beset by low prices and (seemingly) negligible marketed surplus. Nonetheless, one can make the case that the TIA data significantly understate the commercialization of pigeonpea which occurs later than most other field crops in the second season for medium- and late-duration varieties. And, in contrast to bambara groundnut where only tens of kgs are produced per household (Table 25), mean pigeonpea production approached or exceeded 100 kgs in several agroecologies in 2003 (Table 26).

Table 24. Mean Household Production in kgs of Cowpeas by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R7	43.29	5.74	a	58.31	3.40	a
R5	14.66	3.66	bc	48.72	4.18	b
R4	19.94	2.31	bc	45.95	4.75	b
R8	39.90	5.05	a	39.55	3.64	bc
R10	32.79	3.26	a	37.57	4.13	bc
R6	16.81	4.60	bc	37.01	2.48	bc
R2	11.88	1.23	c	29.49	1.94	d
R3	13.82	3.19	bc	23.27	1.60	e
R1	12.86	2.17	bc	19.78	3.91	e

Table 25. Mean Household Production in kgs of Bambaranut by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R4	13.23	2.17	b	48.16	7.51	abc
R7	25.99	2.32	a	42.16	4.11	abcdf
R3	8.01	0.48	c	40.62	9.21	ab
R8	36.37	2.97	a	39.56	3.63	abcdf
R5	23.82	5.67	ab	36.19	4.83	abcd
R2	10.19	1.29	c	35.81	4.13	a
R6	7.80	1.99	bc	29.73	3.72	abde
R10	20.61	2.67	ab	28.42	4.16	abde
R1	7.94	2.85	c	1		

Table 26. Mean Household Production in kgs of Pigeonpea by Agroecological Zones in 2002 and 2003

	2002			2003		
Zone	Estimate	Standard Error	Group	Estimate	Standard Error	Group
R7	46.67	4.97	ab	120.96	10.62	bcd
R6	14.37	4.64	bc	96.86	10.10	bc
R5	12.16	4.68	bc	95.51	13.79	ab
R10	29.77	9.62	bc	85.98	18.76	abcd
R4	19.77	4.67	b	60.08	11.87	a
R8	36.25	3.40	a	40.10	4.56	a
R2	21.62	2.68	ab			

Also as with cowpeas, agroecologies R7 and R8 account for more than half of the national production of bambara groundnut and pigeonpea. Again, the question of where to site research is not a difficult one. The relevant question is whether or not any resources should be invested in either crop. Of the two, pigeonpea seems to have better prospects with a well-identified opportunity in the Indian dhal market and with technical backstopping from ICRISAT. Cost-effective management of the pod borer complex will ultimately be instrumental in translating that opportunity into a reality.

Globally, soybean is the commodity with the most successful introductions in the twentieth century across a range of countries. India and Brazil are outstanding examples of the successful soybean introduction. Interest is growing in soybeans in Mozambique, and projects have been designed to promote smallholder production of the crop. As yet, these small initiatives have not borne fruit. The value of soybeans is still significantly below our threshold value of $3 million, and there is no guarantee that it will become a smallholder's crop any time soon. IIAM needs to maintain a monitoring brief on soybeans to respond to the needs of varietal testing for projects that try to foment the crop in Mozambique. Soybeans are usually grown on heavier soils in a mechanized setting. The extent to which they are a "smallholder's" crop bears watching.

Organizationally, it makes sense to combine the grain legumes into one program as it is now organized. The hub of activities should be in the Northeast Zonal Research Center with research support in each of the other zonal research centers.

7.2.7. Cash Crops

The important cash crops of tobacco, cashew, cotton, coconut, sugar cane, and sesame are spatially more concentrated than other commodities. Their assignments are uncontroversial in Table 15. The key question for public-sector research is not where to conduct investigations, but when to commence and when to stop research.

7.2.8. Horticultural and Fruit Crops

The bulk of horticultural sales takes place in the domain of the South Zonal Research Center. The Central and Northwest Zonal Centers also warrant a research presence on horticultural species such as cabbage. Fruit crops, such as banana and mango, are more widely distributed than vegetable crops, such as tomatoes and onions. The Central Zonal Research Center seems like the economic choice for centralizing activities if IIAM decides to invest further in fruit crops. Unlike vegetable crops where domestic demand is sufficient to sustain technological change, fruit crops seem to need export market opportunities to justify targeted research investments. Neighboring South Africa has more than 100 full-time equivalent scientists working on fruit crops – more scientists than on any other major commodity area. This abundance of regional expertise could be taken to mean that fruit crop research warrants more investment or that investment should be very selective because larger growers who export will rely on the best technical assistance in the region. Finding the right niche in fruit crop areas of specialization is one of the challenges for agricultural research in Mozambique.

7.2.9. Livestock

The prevalence of livestock varies considerably by species across the ten agroecologies and the four zonal research centers. With the exception of R8 for sheep, no agroecology contributes more than 30% of value of production to any livestock species (Table 15). The center for cattle and pig research could be economically justified in any of the three zonal centers except the Northeast, where chickens are the main livestock species. Goat production is highest in the agroecologies served by the Central Zonal Research Center. Based on these data, livestock scientists could make a better argument for posting in the headquarters in Maputo, particularly if more applied and less adaptive research were called for to advance the productivity of the species. The list of important problems in the livestock sector is a long one that includes Newcastle's disease in chickens, Trypanosomiasis and East Coast Fever in cattle, African Swine Fever, high kid mortality in goats, and dry-season weight loss in cattle. The recent establishment of an ILRI regional representative in Mozambique and the assistance in the promotion of fodder tree species from the World Forestry Center (ICRAF) should help to increase the effectiveness of national livestock specialists to find solutions to several of these longstanding problems. Research that will contribute to expanding the use of animal traction, which has stagnated at 10% of households for the past 10 years, is also a priority.

8. COMPARING ACTUAL AND DESIRABLE RESOURCE ALLOCATIONS

The results in the previous section set the stage for comparing research resource allocations. We assembled a database of IIAM staff to engage in this comparative analysis. It is important to recognize that our results in this section are preliminary because that database still requires considerable improvement as IIAM should use it as a planning tool over time. Before we compare scientist allocations across commodities, we place IIAM's current scientific resources in the context of other NARS in SSA.

The IIAM human resources database contains about 1,200 total staff of whom about 120 are full-time equivalent scientists. The latter all have at least the equivalent of an "Ingeneiro's degree" from the national university and are not working full-time in the administration division of the institute.

A ratio of support staff to scientists of 9.0 seems high, but it is also close to the average for SSA about 15 years ago in 1991. In a sub-sample of 115 agricultural research agencies located in 23 countries, the 1991 weighted average was 9.7 support staff per researcher (Pardey et al. 1999). Most providers of research fell in the modal category of five to ten support staff per full-time equivalent scientist.

More recent data from southern and eastern Africa suggests that IIAM is overstaffed with support personnel. In South Africa, the support staff to researcher ratio has be declining from about 6.0 in 1993 to 3.5 in 2000 in a 30-agency sample (Liebenberg, Beintema, and Kirsten 2004). In Kenya, the ratio of support to scientific staff declined from about 9.0 in 1991 to about 6.5 in 2000 following a retrenching of support staff and greater outsourcing of services in the national agricultural research institute KARI (Beintema, Murithi, and Mwangi 2003). In four other countries of the region in IFPRI's ASTI (Agricultural Science and Technology Indicators) series, only Malawi approached or exceeded the level of IIAM in support staff per scientists. Uganda, Zambia, and Tanzania had ratios that centered around three to four support staff per scientist in 2000.

There is one large difference in research resource allocation between the research agencies, mainly NARS, in the Pardey sample and IIAM. Our "desirable" 2% rule gives a total budget for IIAM of about $12 million. To translate this budget into scientists requires an estimated cost per scientist year. In 1991, the average cost per researcher across 147 R&D agencies in SSA was about $60,000 (Pardey et al. 1999). This amount is equivalent to about $90,000 in 2002-2003 prices. Dividing $12 million by $90,000 gives a scientific strength of about 133 scientists. Using the "undesirable" global average of about 1.00% results in a cadre of 66 scientists. Essentially, the IIAM staffing of about 120 scientists is equivalent to a 2% human capital allocation with a 1% budgetary allocation. Therefore, each scientist seems to have only 50% of the operating resources to work with compared to their colleagues in other research institutions in SSA.

Compared to other NARS, IIAM has relatively more scientists posted at its headquarters in Maputo. From a sample of 14 NARS in SSA in 1991, an average of 43% were posted at headquarters (Roseboom, Pardey, and Beintema 1998). With the trend towards decentralization of research in SSA, this estimate now is probably significantly less than a 40:60 ratio of headquarters to out-posted scientists. The same ratio is also falling at IIAM, but presently about 60% of the 120 IIAM scientists work at headquarters in Maputo; hence, national agricultural research in Mozambique is still substantially above the all-SSA average in its level of centralization.

Across the zonal centers, the present allocation of 46 total scientists seems to be unduly skewed to the South Zonal Center with 14 (30%) of the out-posted scientists. Based on our earlier analysis, a reasonable economic allocation would be South (15%), Central (30%), Northeast (40%), and Northwest (15%). The present allocation is South (30%), Central (24%), Northeast (28%), and Northwest (17%). The tendency to post more scientists in the south is most likely explained by the aforementioned greater availability of research infrastructure in terms of experimental stations and laboratories for the conduct of crop and livestock research.

A more subtle difference pertains to the number of scientists allocated to crop and livestock commodity research, that is, those that are "inside the box" for our priority-setting exercise. In the Pardey et al. (1999) sample of 24 NARS, 63% of agricultural researchers worked in crop or livestock programs (Pardey et al. 1999). (The remainder worked on forestry, fisheries, natural resources, and other activities.) If we take the 2% desirable allocation for agricultural research and further assume that five-eighths of the scientists should be available for research resource allocation to commodity research inside the box, then we have an estimate of about 75 full-time equivalent scientists available for commodity research on crop and livestock species.

The present staffing pattern at IIAM shows that about 55 scientists are engaged in commodity research. The other large areas are management and administration (17 scientists), services (26 scientists), forestry (11 scientists), natural resources management (9 scientists), and general crop and livestock staff whose work could not be attributed to a specific commodity.

Reasons for this difference between 75 and 55 scientists "inside the box" could partly be definitional. For example, we grouped scientists working on germplasm and biodiversity in natural resources and not on commodity research. Nonetheless, shifting to or explicitly accounting for scientist time inside the box is one way to increase staff strength on commodity crop and livestock research. Having an appreciable number of scientists in areas not directly attributed to commodity crop and livestock research seems unwarranted at this stage of Mozambique's economic development for a NARS like IIAM, even with a very broad mandate.

Estimates of the actual allocation by commodity are difficult to attain because several scientists spend their time working on multiple commodities within a larger program, such as grain legumes. Hence, the data in the resource allocation table provide a rough estimate of the actual allocation, which needs to be further refined. We also treat fruits and vegetables with a broader commodity grouping; therefore, the original 30 commodities in Table 1 are reduced to 25 commodities or larger commodity groups in our research resource allocation table.

We compare the actual allocation to both economic-congruence and poverty-impact estimates in Figure 4 to arrive at a starting point on which to base a desirable allocation, which is described in the last column of Table 27 and is referred to as an illustrative best-bet allocation. We assume that IIAM is restricted to a budgetary allocation of 55 commodity scientists.

Table 27. Comparing Research Resource Allocations by Commodity

Commodity	Economic Congruence Allocation[1]	Poverty Reduction Allocation[2]	Actual	Direction for Change	Illustrative Best-bet Allocation
Cassava	14.53	16.36	7.00	+	9.00
Maize	12.83	14.77	6.00	+	8.00
Sweetpotato	3.50	2.63	2.00	=	2.00
Rice	2.08	2.09	5.00	-	3.00
Sorghum	1.73	2.13	1.00	=	1.00
Tobacco	1.93	0.66	0.00	=	0.00
Groundnut	3.02	3.33	2.75	+	4.00
Cotton	1.44	1.51	2.00	=	2.00
Cashew	1.50	1.33	4.00	-	3.00
Goats	1.40	1.37	2.50	+	3.00
Coconut (incl. copra)	0.98	0.65	0.00	=	0.00
Chicken	2.13	2.07	4.00	-	3.00
Butter beans	0.93	0.84	2.75	-	2.00
Cattle	1.11	0.48	8.00	-	6.00
Cowpea	0.93	1.13	1.00	=	1.00
Sheep & other animals	0.08	0.10	1.00	=	1.00
Sugar cane	0.59	0.31	0.00	=	0.00
Pigs	0.51	0.61	2.00	=	2.00
Bambaranut	0.42	0.49	0.00	=	0.00
Pigeonpea	0.36	0.46	0.50	+	1.00
Potato	0.31	0.18	0.33	+	1.00
Other crops	0.33	0.07	0.00	=	0.00
Sesame	0.36	0.23	0.00	+	1.00
Millet	0.09	0.15	0.00	=	0.00
Fruit crops	0.90	0.63	1.00	-	0.00
Vegetables	0.94	0.42	2.00	=	3.00
Total	55.00	55.00	55.00		55.00

Source: Computed from TIA 2002, IIAM Human Resource Database 2006

[1] Scientific emphasis based on economic importance

[2] Scientific emphasis based on potential for poverty reduction

Our starting point allocations based on economic congruence and expected poverty impact are heavily slanted towards cassava and maize, the two main staple crops. There are economies of scale in agricultural research; hence, allocating 14 to 16 scientists to cassava research and 13 to 14 scientists to maize research in Table 27 would be excessive. The actual number of 6 to 7 scientists for maize seems small, and cassava research with 7 scientists seems understaffed even with an IITA presence in Mozambique. Both cassava and maize receive a plus sign in the direction of the change column to indicate that they should be given more emphasis.

Several arguments can be put forth for cassava receiving more resources relative to maize. In principle, more market-oriented maize farmers from Mozambican border districts can access improved maize varieties and hybrids, such as SR-713, from other countries. Our discussion of the data in Table 2 highlighted brighter prospects for technology borrowing within the southern African region for maize than for cassava. Eventually, the private sector will produce maize hybrids in Mozambique. There are few, if any, alternative suppliers of cassava technologies.

Moreover, cassava is a vegetatively propagated commodity that requires a broader disciplinary base than cereal species that are propagated with sexual seed and that emphasize one discipline: plant breeding. Cassava is the main staple food crop of Mozambique's lowland coastal agroecologies that we argued were largely unique to Mozambique. Biotic stresses are the main yield reducers in cassava; agricultural research is poised to tackle the problems of disease and insect pests. Drought and low soil fertility are much tougher foes, and they are the main production constraints to increased maize production.

Relative to its economic importance and expected poverty impact, rice seems to be over-invested in Table 27. Both economic importance and expected poverty impact argue for an allocation of about three full-time equivalent scientists. For rice, the problem is not the number of scientists per se but the location of those scientists. As we saw in the last section, IIAM needs to develop a small rice station in agroecologies R5 or R7. The rate of investment in rice research needs to be linked to funding for a more comprehensive approach to rice production in Mozambique.

A smaller disparity appears to exist within the grain legumes program. Groundnut should command more resources relative to beans. Both crops are relatively well-commercialized and share the same prospects, but groundnuts is economically more important and is one of the few field crop alternatives for the coastal agroecologies.

Livestock's actual allocation significantly exceeds the congruence and poverty allocations. But our illustrative "best-bet" desirable allocation does not deviate that far from the actual allocation for livestock species or groups. Livestock played an expanded role in the past and need to figure more prominently in the future if agricultural economic development is to accelerate in Mozambique. Moreover, livestock are probably somewhat undervalued relative to crops in the TIA surveys. Of the livestock groups in Table 27, goats are assigned a plus because technologies cannot be as easily borrowed within the region as for other species or livestock groups. Overall, livestock species account for about 25% to 30% of the illustrative best-bet allocation.

In both the actual and the illustrative desirable allocations, several commodities or groups of commodities do not receive any resources. The case for private-sector research support for tobacco and sugar cane was discussed earlier. Coconut could qualify for public-sector research support because it is an important commodity in the lowland coastal agroecologies. But demand is weak and, historically, lethal yellowing, which is wreaking havoc in the sector, has only been controlled in other infected countries by elimination of trees and the subsequent effective enforcement of quarantine procedures. Smallholders in Mozambique are not likely to eliminate trees to combat this devastating disease. A French-assisted project is also working with large growers to propagate disease-resistant or tolerant material. IIAM should maintain a watching brief on coconut.

Two discrepancies between the actual and desirable allocations warrant comment. Sesame receives a small research resource allocation in Table 27 in the desirable column. Priorities include the testing and adaptation of white-seeded varieties for export and pest management on flea beetle at emergence. Sesame has established itself and has done better than other recent introductions, including sunflower, soybeans, and paprika, in the small-holder sector.

The absence of scientific staff for fruit crops also deserves explanation. Fruit crops are characterized by weak domestic demand. Research only makes sense if a well-defined export opportunity materializes. For that to happen, the government needs to improve access to land for plantation establishment. Even if these opportunities are identified and materialize, it is likely that growers would tap into the South African agricultural research system for technical assistance on fruit crops. The recent investment in tissue culture facilities gives IIAM the capacity to respond to demand for clean material for propagation when this sub-sector begins to mature.

9. CONCLUSIONS

In this priority-setting exercise for Mozambique's recently consolidated and decentralized public-sector agricultural research institute, we focused on what the national agricultural survey data had to say about commodities, agroecologies, economic importance, and absolute poverty. Several observations and findings weave their way throughout our study, and they bear repeating here in order of importance. The productivity of IIAM in the next 15 to 20 years is directly tied to the success of the cassava and maize programs. These two food security commodities represent more than half the value of production and more than half the potential for alleviating poverty via technological change across the 30 most economically important commodities in the country. The roles of maize and cassava in Mozambique are similar to the role of rice in Asia; technological change in either crop will be a powerful force for development.

As IIAM decentralizes its scientific human resources to its four zonal center locations, it should not lose sight of the primacy of the Northeast Zonal Research Center in both economic importance and the potential for poverty reduction. Our analysis suggests that the Northeast Zonal Research Center contributes about 40% to value of commodity production and to absolute poverty alleviation. The temptation is that too many resources are allocated to the South Zonal Research Center because the research infrastructure in the south is wider and deeper than in the center and north of the country. Much of that research infrastructure is located in agroecologies R1 and R3 that rank eighth and ninth (among Mozambique's ten agroecologies) in economic importance and scope for poverty alleviation. If the three other zonal research centers are to fulfill their promise, a few key facilities need to be rehabilitated and strengthened in the center and north. The scarcity of research infrastructure is most constraining in the coastal agroecologies. And, as we saw from a comparison of regional with Mozambican value of production, the commodities on the coast are largely unique to Mozambique. Their relative importance is significantly less in the rest of the southern African region, which limits the scope for borrowing technologies from other countries.

It may also be tempting to merge the activities of the Northwest Zonal Center with a neighboring zonal research center because its mandate contains only one agroecology, the higher altitude (largely) border districts. However, with a sustained investment in research, this agroecology offers the best hope for rapid technological progress and for crop-livestock integration of any of the ten agroecologies. It benefits from being more market-oriented than the other agroecologies and also has greater access to productivity-enhancing inputs. From the perspectives of economic importance and poverty reduction, the Northwest Zonal Research Center is on a par with the South Zonal Research Center that covers three agroecologies.

Targeting agricultural research to marginal regions of low production potential to tackle chronic poverty is one temptation that the management of agricultural research in Mozambique does not have to face. In analyzing the national rural survey data over two years, we did document geographic traps of chronic poverty: districts in the lowest mean income quintile in one year are also in the lowest mean household income quintile in the next year. But many of these same districts are characterized by reasonable agricultural production potential in terms of soils, rainfall, and higher population densities. Hence, the trade-off between localized chronic poverty and production potential is not steep.

In contrast, geographic relief traps, areas that have a higher incidence of food insecurity than other regions largely because of a greater likelihood of drought, can be a real source of

distraction for agricultural research. However, the national survey results show that these areas are not characterized by more widespread or deeper poverty than others as households tend to have more diversified income sources of both agricultural and off-farm income. In almost any agricultural year, some areas will be declared food insecure and pressure will be placed on research administrators to assist in "drought proofing" these regions. Unfortunately, production potential in these regions is low and the opportunity costs of working in these localities are high given IIAM's limited resources.
Summing up, our analysis of the national survey data indicates that public-sector research in Mozambique will be more successful in addressing chronic poverty than in tackling transitory poverty.

Our results do not generate many surprises. We found that economic importance and the potential for poverty reduction went hand-in-hand. The more important is the commodity in household income, the greater is the scope for poverty reduction. Income poverty is pervasive in rural Mozambique. Increasing producer income via technological change is almost always going to have a positive effect on reducing rural poverty. Proportionally, and as expected, higher income producers who cultivated tobacco and tomatoes did not benefit as much as growers of other crops in our simple poverty-reduction simulations. In reality, these effects are much more complicated than our simple methodology suggests, but we believe that our emphasis on relative magnitudes underestimates the effect of technological change on poverty because most producers are net consumers in Mozambique, i.e., they can benefit from lower prices without adopting the technology as long as other do so to increase supply.

Some of Mozambique's "vital statistics" in agricultural research are not that much different from the rest of SSA. This is not a good thing. The estimated research intensity is about 0.8% of value of agricultural production, considerably below several countries in southern Africa but spot on the all-SSA average.

Other statistics differ markedly from those of comparable institutions in SSA. If we take 2% as the recommended level, IIAM's 120 scientists are consistent with that norm, but expenditure per scientist only appears to be about half the SSA average. Finding that IIAM's scientific staff is constrained by operating budget is not surprising. The ratio of total support staff to scientists at about 9:1 was in line with the all-SSA average in 1991, but is now most likely on the high side. Finally, IIAM is less decentralized than its counterparts in other SSA countries.

We assembled a human resources database that shows about 55 of IIAM scientists can be attributed to crop and livestock commodity research. It is perhaps surprising that we could not account for the time of more scientists in commodity research, but IIAM has a broad mandate and the definition of what constitutes commodity research needs to be established with greater care.

The present research resource allocation at IIAM does broadly reflect economic importance and poverty reduction criteria as the actual allocation of 55 scientists does not depart that much from our illustrative best-bet allocation. More emphasis could be given to the staple food crops maize and cassava, and potato, sesame, and goats. IIAM seems to be over-invested in rice and most of the other livestock species. Any over-investment in livestock is not that much of a problem because the livestock populations are still recovering in a country decimated by the civil war. An over-investment in rice is inefficient, particularly if IIAM makes the investment and the rest of the government does not follow suit.

Because it was based on the national survey data with a rigorous sample design, this priority-setting exercise was less subjective than most. But it also suffers from most of the same limitations as the other conventional exercises. Coverage is incomplete in several respects. Forestry products were not included because data on timber production is not covered in the national agricultural survey. Information on forestry products needs to be canvassed at the provincial level where data on timber production should be compiled. Information on own-farm consumption of fruits and vegetables is also not available. Only about 50% of IIAM scientists were included in this round of priority setting that focused on the more macro-commodity level. Setting priorities for the non-commodity scientists at IIAM is considerably more difficult. A review of priorities within commodities with some organized stakeholder involvement is most likely the next priority for priority setting at IIAM. Moving to a project-based research and accounting system would facilitate priority setting.

In the short term, these estimates from the TIA 2002 and 2003 should be compared to emerging information from the TIA 2005, which incorporates a panel design that enables the analyst to control the influence of household-specific variables. These estimates have provided the raw material for a priority-setting workshop that resulted in a "consensus" allocation of scientists by commodity across IIAM's four zonal research centers. That allocation is given in Table A1 and is consistent with greater decentralization and with a shift of resources from headquarters and the South Zonal Research Center to the Central, Northeast, and Northwest Zonal Research Centers. The results of the workshop reinforced the priority for investing in promising "new" areas, such as sesame in the Northeast Zonal Center and potato in the Northwest Zonal Center. This report has also laid the foundation for an investment plan that makes the case for additional public-sector resources to bridge the gap, an actual research intensity of 0.8% and a desirable research intensity of 2% (IIAM 2006).

APPENDIX A

Table A1. Desirable Research Resource Allocation by Principal Commodity and Zonal Research Center in Number of Scientists

Species	Maputo	South	Central	Northeast	Northwest	Total
Crop	**4**	**12 (-1)**	**7 (+4)**	**13 (+4)**	**4 (+2)**	**40 (+9)**
Cassava	2	2	0 (+1)	3	0	7 (+1)
Maize	0	2 (-1)	2 (+1)	1 (+1)	1	6 (+1)
Sweetpotato	0	2	1	0	1	4
Grain legumes	1	(+1)	1	3	2	7 (+1)
Rice	0	4 (-2)	1 (+1)	(+1)	0	4
Sorghum	0	0	1	1*	0	2
Cashew	0	1	0	3	0	4
Coconut	0	(+1)	0	0	0	(+1)
Cotton	0	0	0	2 (+1*)	0	2 (+1*)
Sesame	0	0	0	(+1)	0	(+1)
Vegetable crops	1	1	0	0	(+1)	2 (+1)
Potatoes	0	0	0	0	(+1)	1
Fruit crops	0	1	(+1)	0	0	1 (+1)
Livestock	**11 (-2)**	**4**	**5**	**1 (+2)**	**0 (+2)**	**21 (+2)**
Total	**15 (-2)**	**16 (-1)**	**12 (+4)**	**14 (+6)**	**4 (+4)**	**62 (+11)**

Source: Priority-Setting Workshop, 2006, May 31, Namaacha, Maputo, Mozambique

* This scientist works on both sorghum and cotton

( ) Denotes changes in scientific staffing from the existing allocation

REFERENCES

Agrifood Consulting International. 2005. Development Strategy for the Rice Sector in Mozambique. Final Report. Prepared for the Cooperazione Italiana. Maputo, Mozambique.

Alston, J.M., C. Chan-Kang, M.C. Marra, P.G. Pardey, and T.J. Wyatt. 2000. *A Meta-analysis of Rates of Return to Agricultural R&D: Ex Pede Herculum?* IFPRI Research Report 113. Washington, D.C.: International Food Policy Research Institute.

Alston, J.M., G.W. Norton, and P.G. Pardey. 1995. *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca, New York: Cornell University Press.

Alwang, J., and P.B. Siegel. 2003. Measuring the Impacts of Agricultural Research on Poverty Reduction. *Agricultural Economics* 1-14.

Arndt, T., and V.W. Ruttan. 1977. Valuing the Productivity of Agricultural Research: Problems and Issues. In *Resource Allocation and Productivity in National and International Agricultural Research*, eds. T. Arndt, D.G. Dalrymple, and V. M. Ruttan. Minneapolis, Minnesota: University of Minnesota Press.

Beintema, N.M., and Gert-Jan Stads. 2004. *Investing in Sub-Saharan African Agricultural Research: Recent Trends*. 2020 Africa Conference Brief 8. Washington, D.C.: International Food Policy Research Institute.

Beintema, N.M., F.M. Murithi, and P. Mwangi. 2003. *Kenya*. ASTI (Agricultural Science and Technology Indicators) Country Brief No. 8. Washington, D.C.: IFPRI-ISNAR.

Bias, C., and C. Donovan. 2003. *Gaps and Opportunities for Agricultural Sector Development in Mozambique*. Research Report No. 54. Maputo, Mozambique: MADER, Directorate of Economics, Department of Policy Analysis.

Bohn, A., D. Byerlee, and M.K. Maredia. 1998. Investment in Wheat Improvement in Developing Countries. In *Research Efficiency in the Presence of Technology Spillovers: The Case of National and International Wheat Improvement Research*, eds. M.K. Maredia and D. Byerlee. CIMMYT Research Report. El Batan, Mexico: CIMMYT.

Boughton, D.E., D. Mather, D. Tschirley, T. Walker, B. Cunguara, and E. Payongayong. 2006. *What's Driving Mozambique's Rural Income Growth? A Comparative Analysis of the 1996 and 2002 National Agricultural Sample Surveys*. Research Report No. 61E. Maputo, Mozambique: Ministry of Agriculture.

Brennan, J.P. 1992. *Economic Criteria for Establishing Plant Breeding Programs*. CIMMYT Economics Working Paper 92-01. El Batan, Mexico: CIMMYT.

Byerlee, D. 2000. Targeting Poverty Alleviation in Priority Setting for Agricultural Research. *Food Policy* 25: 429-445.

Byerlee, D., and G. Alex. 2003. *Designing Investments in Agricultural Research for Enhanced Poverty Effects*. Agriculture and Rural Development Working Paper Series No. 6. Washington, D.C.: World Bank.

Deininger, K., and L. Squire. 1996. A New Data Set Measuring Income Inequality. *The World Bank Economic Review* 10.3: 565-591.

Demo, P., C. Dominguez, S. Cumbi, and T. Walker. 2006. The Potato Sub-Sector and Strategies for Sustainable Seed Production in Mozambique. Maputo, Mozambique: ICRISAT and CIP. Unpublished report.

Dollar, D., and A. Kraay. 2000. *Growth Is Good for the Poor*. Washington, D.C.: Development Research Group, World Bank.

Eicher, C.K. 2001. *Africa's Unfinished Business: Building Sustainable Agricultural Research Systems.* MSU Department of Agricultural Economics Staff Paper No. 2001-10. East Lansing: Michigan State University.

Elbers, C., P. Lanjouw, J. Mistiaen, B. Ozler, and K. Simler. 2003. *Are Neighbors Equal? Estimating Local Inequality in Three Developing Countries*. FCND Discussion Paper No. 147. Washington, D.C.: IFPRI.

Evenson, R.E. 2002. *Economic Impacts of Agricultural Research and Extension*. Economic Growth Center Reprint No. 578. New Haven, Connecticut: Yale University.

Evenson, R.E., and D. Gollen, eds. 2002. *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research*. Wallingford, U.K.: CABI.

FEWS NET. 2006. *Mozambique: Food Security Update*. Maputo, Mozambique: FEWS NET.

IIAM. 2006. *Investment Plan for 2007-2011*. Maputo, Mozambique: IIAM.

International Food Policy Research Institute (IFPRI). 2006. Exploring Regional Growth Linkages and Market Opportunities for Agriculture and Food Security in Southern Africa. Paper presented at the Southern African Meeting on Food Security and Economic Policy, April 15-21, 2005, Johannesburg, South Africa.

Kelley, T.G., J.G. Ryan, and B. Patel. 1995. Applied Participatory Priority Setting in International Agricultural Research: Making Trade-offs Transparent and Explicit. *Agricultural Systems* 49.2: 177-216.

KIT. 2000. Mozambique Proagri: Institutional Reform of the Agricultural Research System. Amsterdam, Netherlands: Royal Tropical Institute. Unpublished report.

Liebenberg, F., N.M. Beintema, and J.F. Kirsten. 2004. *South Africa*. ASTI (Agricultural Science and Technology Indicators) Country Brief No. 14. Washington, D.C.: IFPRI-ISNAR.

MADER. 2002. *Relatorio Geral Do TIA*. Maputo, Mozambique: Ministry of Agriculture and Rural Development.

McSween, S., T. Walker, V. Salegua, and R. Pitoro. 2006. *Economic Impact on Food Security of Varietal Tolerance to Cassava Brown Streak Disease in Coastal Mozambique*. Research Report No. 1E. Maputo, Mozambique: CESE-DFDTT, IIAM.

Medina Castro, H. 1993. *Prioridades de investigacion agropecuaria en los paises de America Central*. San Jose, Costa Rica: Instituto Interamericano de Cooperacion para la Agricultura (IICA), Programa II, IICA.

Ministry of Agriculture and Fisheries. 1996. *Agroecological Zones and Production Systems.* Working Document 2/B, Program of Investment in Agricultural Extension, Process of the Formulation of Proagri. Maputo, Mozambique: Ministry of Agriculture and Fisheries.

Ministry of Plan and Finance. 2004. *Second Poverty Evaluation*. Maputo, Mozambique: Ministry of Plan and Finance.

Nweke, F.I., D.S.C. Spencer, and J.K. Lynam, eds. 2003. *The Cassava Transformation*. East Lansing, Michigan: Michigan State University Press.

Pardey, P.G. 2001. *Slow Magic: Agricultural Research a Century after Mendel*. Food Policy Research Report. Washington, D.C.: International Food Policy Research Institute.

Pardey, P.G., J. Roseboom, N.M. Beintema, and C. Chan-Kang. 1999. *Cost Aspects of African Agricultural Research*. EPTD Discussion Paper No. 42. Washington, D.C.: International Food Policy Research Institute.

Pingali, P.L., and H.P. Binswanger. 1984. *Population Density and Agricultural Intensification: A Study of the Evolution of Technologies in Tropical Agriculture*. Research Unit Report ARU22. Washington, D.C.: World Bank, Agriculture and Rural Development Department.

Pingali, P., Y. Bigot, and H.P. Binswanger. 1987. *Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa*. Baltimore, Maryland: Johns Hopkins University Press.

Pitoro, R. 2006. Analysis of Rural Income in Mozambique in 2002 and 2003 and Implications for Agricultural Development. Maputo, Mozambique: IIAM. Unprocessed.

Ravallion, M. 1993. *Poverty Comparisons: A Guide to Concepts and Methods*. Washington, D.C.: World Bank.

Reardon, T., P. Matlon, and C. Delgado. 1988. Coping with Household-level Food Insecurity in Drought-affected Areas of Burkina Faso. *World Development* 16.9: 1065-74.

Rogers, E.M. 1995. *Diffusion of Innovations* (Fourth Edition). New York, New York: The Free Press.

Roseboom, J., P. Pardey, and N.M. Beintema. 1998. *The Changing Organizational Basis of African Agricultural Research*. EPTD Discussion Paper No. 37. Washington, D.C.: International Food Policy Research Institute.

Schumway, C.R. 1977. Models and Methods Used to Allocate Resources in Agricultural Research: A Critical Review. In *Resource Allocation and Productivity in National and International Agricultural Research*, eds. T. Arndt, D.G. Dalrymple, and V.M. Ruttan. Minneapolis, Minnesota: University of Minnesota Press.

Simler, K.R., and V. Nhate. 2005. *Poverty, Inequality, and Geographic Targeting: Evidence from Small-Area Estimates in Mozambique*. FCND Discussion Paper No. 192. Washington, D.C.: IFPRI.

Thirtle, C., L. Lin, and J. Piesse. 2002. The Impact of Research-led Agricultural Productivity Growth on Poverty Reduction in Africa, Asia, and Latin America. London, U.K.: Imperial College of Science, Technology, and Medicine. Unpublished paper.

USAID. 2005. Building Capacity for Disaster Preparedness: Mozambique. MIND Final Report. Maputo, Mozambique: Chemonics International, Inc.

Walker, T. 1996. Quick Participatory Priority Setting or Mediocrity of the Masses. Lima, Peru: International Potato Center. Unprocessed.

Walker, T. 2000. Reasonable Expectations on the Prospects for Documenting the Impact of Agricultural Research on Poverty in Ex-post Case Studies. *Food Policy* 25: 515-530.

Walker, T., and M.H. Collion. 1997. Priority Setting at CIP for the 1998-2000 Medium Term Plan. Lima, Peru: International Potato Center. Unprocessed.

Walker, T., and K. Fuglie. 1999. The Economics of Generating International Public Goods from Investing in Potato Plant Breeding. In *Impact on a Changing World: Program Report 1997-98*. Lima, Peru: International Potato Center.

Walker, T., D. Tschirley, J. Low, M. Pequenino Tanque, D. Boughton, E. Payongayong, and M. Weber. 2004. *Determinants of Rural Income, Poverty, and Perceptions in Mozambique in 2001-2002*. Research Report No. 57E. Maputo, Mozambique: Ministry of Agriculture and Rural Development.

World Bank. 2005. *Mozambique Agricultural Development Strategy: Stimulating Smallholder Agricultural Growth*. AFTS1, Agriculture, Environment, and Social Development Unit, Country Department 2, Africa Region. Washington, D.C.: World Bank.