The International Center for Tropical Agriculture (CIAT, its Spanish acronym) is one of 16 food and environmental research organizations known as the Future Harvest centers. The centers, located around the world, conduct research in partnership with farmers, scientists, and policymakers to help alleviate poverty and increase food security while protecting the natural resource base. The Future Harvest centers are principally funded through the 58 countries, private foundations, and regional and international organizations that make up the Consultative Group on International Agricultural Research (CGIAR).

In 2002, CIAT received support from the following donor countries: Australia, Belgium, Brazil, Canada, Colombia, France, Germany, Iran, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Peru, South Africa, Spain, Sweden, Switzerland, Thailand, the United Kingdom, and the United States of America.

Our work was also financed by the following organizations and foundations: the Andean Development Corporation (CAF), the Asian Development Bank (ADB), the European Union (EU), Fundación Polar, the International Development Research Centre (IDRC), the International Fund for Agricultural Development (IFAD), the Kellogg Foundation, the Nippon Foundation, the Rockefeller Foundation, the United Nations Environment Programme (UNEP), the United Nations Food and Agriculture Organization (FAO), the Wallace Foundation, and the World Bank.

CIAT also receives funds for research and development services provided under contract to a growing number of institutional clients.

Information and conclusions reported in this document do not necessarily reflect the position of any donor agency.

ISBN 958-694-058-6

Agricultural Research and Poverty Reduction
Some Issues and Evidence

Edited by:
Shantanu Mathur
and Douglas Pachico

with the collaboration of Annie L. Jones

Economics and Impact Series 2

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

CIAT Economics and Impact Series

This publication is part of a series of reports that aims to disseminate—among decision makers, scientists, and development experts—the economics research results of CIAT and partners. This research covers a broad spectrum of issues related to tropical agriculture and natural resource management, and places special emphasis on evaluating their impact.

Centro Internacional de Agricultura Tropical (CIAT)
International Center for Tropical Agriculture
Apartado Aéreo 6713
Cali, Colombia

Fax: +57 (2) 4450073
E-mail: d.pachico@cgiar.org

CIAT Publication No. 335
ISBN 958-694-058-6
Press run: 500
Printed in Colombia
October 2003

Agricultural research and poverty reduction : Some issues and evidence / edited by Shantanu Mathur and Douglas Pachico, with the collaboration of Annie L. Jones. -- Cali, CO : Centro Internacional de Agricultura Tropical (CIAT), 2003.
268 p. -- (CIAT publication ; no. 335. Economics and impact series, 2)
ISBN 958-694-058-6

AGROVOC descriptors in Spanish:
1. Pobreza. 2. Investigación. 3. Ayuda al desarrollo. 4. Desarrollo económico y social. 5. *Manihot esculenta*. 6. *Phaseolus vulgaris*. 7. Estudios de casos prácticos. 8. Africa al sur del Sahara. 9. Asia occidental. 10. China. 11. Honduras. 12. América Latina.

Local descriptors in Spanish:
1. Impacto de la investigación. 2. Análisis de género. 3. Yuca. 4. Frijol.

AGROVOC descriptors in English:
1. Poverty. 2. Research. 3. Development aid. 4. Socioeconomic development. 5. *Manihot esculenta*. 6. *Phaseolus vulgaris*. 7. Case studies. 8. Africa south of Sahara. 9. Western Asia. 10. China. 11. Honduras. 12. Latin America.

Local descriptors in English:
1. Research impact. 2. Gender analysis. 3. Cassava. 4. Beans.

I. Mathur, Shantanu. II. Pachico, Douglas H. III. Jones, Annie L. IV. Centro Internacional de Agricultura Tropical.

AGRIS subject category: E14 Economía y políticas de desarrollo / Development economics and policies

LC classification: HC 79 .P63 A4

Contents

Foreword

*Lennart Båge**

At a time when donor support for international public goods research is gradually declining—or, at best, 'stagnant', the need to assure ourselves and the international community at large of the direct relevance and impact of our investment in agricultural research endeavors on rural poor people becomes a very prominent issue on the global agenda.

The importance of assessing the impact of agricultural research, particularly in terms of pinpointing its role in poverty reduction, is not something new. Back in the 1970s, when I represented the Swedish Government at the Consultative Group on International Agricultural Research (CGIAR), I argued strongly in support of more rigor in ex-post evaluation of research investments. In fact, my call was echoed by my colleagues around the CG Table, with the result that a large number of excellent studies and impact-research initiatives have spawned over the past 2 decades. Most of these studies spoke out very clearly on the notion of high rates of return to investment in agricultural research.

In the more recent past, some important investors in agricultural research (such as IFAD, USAID, DFID[1], and the World Bank) have been pressing to ascertain the extent to which the research they so generously supported—together with others in the donor community—has responded to the particular needs of the rural poor in developing countries, for whom it was originally intended.

As President of IFAD, I am very pleased indeed to see that the Fund has played a leadership role within the international donor community, in this regard. Not only has it consistently highlighted the need for targeted research and diffusion of pro-poor technologies, but also it has stressed the compelling obligation to assess the effective impact of the adopted research products on poverty reduction, and on improving the livelihoods of rural poor people throughout the world.

---

* President, International Fund for Agricultural Development (IFAD), Rome.

1. For acronyms, see page 265.

It must be noted, however, that in the recent past, IFAD has gone far beyond these debates. It has led several efforts to support the development of analytical tools and methodologies for examining the impact of improved technology on the various income and non-income dimensions of poverty. Such methodologies are not limited to merely measuring higher on-farm yields and biophysical productivity, but also capture other benefits. These include, for instance, expansion of farm employment opportunities and higher wages, the growth of non-farm activities, lower food prices, reduced vulnerability to production-system and other risks, and the processes of truly participatory research systems that also foster benefits such as the empowerment of the poor and disadvantaged persons. Special emphasis is placed on the interrelationships between technological improvements and the empowerment of women—meaning *a more decisive role for women* in decision making, both within and outside the household.

This important publication is the result of the work of specialized authors brought together by Shantanu Mathur and Douglas Pachico to examine both the methodological issues related to impact assessment, and other aspects of the technology system. These include policy formulation and decision making, generation of new pro-poor knowledge, the diffusion of new techniques, and, most importantly, the factors that influence their profitable and sustainable utilization. Spillover benefits, social goals, and environmental impact are also discussed.

Of particular relevance among the many issues discussed in this book, in relation to poverty reduction, is the dominating fact that the research community has not paid sufficient attention to clearly demonstrating the impact of their otherwise fruitful research outcomes on these other dimensions of rural poverty, which are just as important as improved productivity and pecuniary benefits.

It is true, of course, that research and development have been off the radar screen for some time now. Although R&D was a key issue in the 1970s, it fell sharply over the last decade. Meanwhile, bilateral and multilateral financing has considerably diminished. At the Millennium Summit, we committed ourselves to the ambitious poverty eradication agenda, agreed on by world leaders. Concomitantly, R&D priorities have found their way back to the Agenda. The high-level Intergovernmental Summit of the Economic and Social Council of the United Nations (ECOSOC) reconfirmed this, and new bilateral investors in agriculture and rural development are slowly reappearing on the horizon.

I quote from Rodney Cooke's Epilogue to this book that "the proportion of Official Development Assistance for agriculture fell from 20% in the 1980s, and remains only at around 12% today." The recent Monterrey Financing for Development International Conference (FfD) and the Johannesburg Earth Summit certainly provided up-front platforms for reiterating a strong commitment to the agricultural sector, as a mechanism for sustainable development. This notwithstanding, and despite the international community's Millennium Development Goals (MDG) pledge, which focuses so sharply on the livelihoods and welfare of the poorest communities, we have yet to see any significant move forward in global support to agricultural R&D.

The MDG pledge was strongly reconfirmed during the recent 25th Anniversary Session of IFAD's Governing Council, on 18-19 February 2003, and it is hoped that we will soon see some positive movement in investments targeting pro-poor research. One consolation—and, indeed, positive indication—in this direction comes from IFAD's having just concluded a highly successful Sixth Replenishment cycle, and obtained a contribution of a magnitude that is second only to that which led to the establishment of the billion dollar IFAD, 25 years ago. Inconfutable proof of the impact of our investment in agricultural research will help in strengthening our support to this important area of rural development.

I take this opportunity to thank the authors of this compendium, each of whom has provided comments on a vast range of issues related to the impact of research investments on poor rural people. I applaud their depth of thought, and the rigor of their carefully-nuanced and well-articulated analysis, which doubtless will appeal to those entrusted with the task of financing and leading poverty reduction-oriented research in the years to come.

Introduction

*Douglas Pachico** and *Shantanu Mathur***

The chapters in this book have been mostly chosen from original presentations given at the International Workshop "Assessing the Impact of Agricultural Research on Poverty Alleviation", which took place on September 14-16, 1999 in San José, Costa Rica. The papers chosen have been extensively rewritten and updated since then and two new ones were especially commissioned (Chapters 1 and 2). Chapter 1 is based on Michael Lipton's synthesis presentation given at the close of the workshop and gives an excellent overview of the workshop itself. One hundred and fifty six participants from 37 countries and 81 organizations attended the workshop, which was funded by 16 donors[1].

Eight of the papers presented at the workshop were included in a Special Issue of Food Policy (Volume 25, No. 4, August 2000), which tended to look at some broader themes. It presented first a group of synthetic papers that tried to clarify the linkages between agricultural research and poverty, or give a theoretical or broad-based examination of that issue. The second group of papers dealt with the specific relationship of resource degradation and poverty. The final group dealt with technology design and monitoring and evaluation.

The San José Workshop treated a major issue of great importance for the Consultative Group on International Agricultural Research (CGIAR), because elimination of poverty has always been its central concern. Even when the focus of the CGIAR was properly on getting "a bigger pile of rice", this was not driven by the selfish gene trying to maximize the replication of rice DNA. Rather the purpose of the bigger pile of rice was to eliminate hunger, which is surely one of the most severe manifestations of poverty. It can hardly get worse than not having enough to eat. A dedication to the elimination of poverty in its worst forms is not something new or extraneous to the CGIAR, but it is and always has been the absolute central core of our mission.

---

* Director of Research, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

** Coordinator, Research Grants, International Fund for Agricultural Development (IFAD), Rome.

1. ACIAR, BMZ, CGIAR Secretariat, Danida, DFID, Ford Foundation, IAEG of the CGIAR, IDB, IDRC, IFAD, Government of Japan, Kellogg Foundation, SDC, TAC of the CGIAR, UNDP, and USAID. For acronyms, see page 265.

In this context, the workshop examined three critical themes. First, how does agricultural research reduce poverty? Second, what are the relations between poverty and the environment? Third, how can agricultural research be better managed to reduce poverty? To understand how research or its ultimate results of agricultural innovation contributes to poverty reduction, it is important to remind ourselves of the diversity of the poor. The poor may be farmers, city dwellers, herds people, or fisher folk; include small farmers and landless laborers; are mostly female, but also male; are disproportionally very old or very young; and they live in varied environments and sustain themselves through complex and diverse livelihoods.

There is broad agreement about the four principle effects through which agricultural innovation can reduce poverty. Agricultural innovation contributes to improved farm incomes (through increased productivity), cheaper food, more jobs for farm workers, and better economic growth. These different impacts of agricultural research do not reach all the poor in the same way. Obviously, the urban poor benefit from cheaper food, but not from improved farm income. Thus the relationship between agricultural research and poverty reduction is highly varied, affecting different types of poor people in different ways and varying degree.

This present volume presents a set of case studies that provide empirical evidence on the relationship between rural poverty and the results of agricultural research. The first section, Overview of Issues, begins with three chapters that in different forms try to address the broad issues of this relationship, in a similar way to those selected for the Food Policy issue. They are included here to enable this book to be a stand-alone document. The remainder of the first section of the book (Chapters 3 to 8) sets the stage for the empirical results. These chapters look at some more specific dimensions of understanding the impact of agricultural research: the gender dimension, the use of GIS to understand poverty, the issue of dialogue with policymakers, and the issue of innovation as a social process. While still general in outlook, these chapters are dealing with specific dimensions of the relationship between rural poverty and the results of agricultural research.

The second section, Case Study Evidence, is a set of case studies that go into detail based on experience on some of the issues and relationships that have been contextualized in the overview of issues. Chapters 9 to 14 cover a wide area of the developing world—West Asia, the semi-arid tropics, Southwest China, Colombia, sub-Saharan Africa, and Honduras—having been chosen for that purpose. The editors sought empirical data, a mix of studies from different parts of the world, different crops, different ecosystems, and different kinds of technologies. However, all these chapters share the commonality that they are trying to understand how research and new knowledge can create new options that alleviate poverty at the level of rural communities and households.

It is well known at the broad context level that agricultural research has major impacts that go beyond farm households and rural communities on the effect on urban food prices, employment, and overall economic growth. This section of the book does not look at those broad effects of agricultural innovation, but rather at what specifically happens at the rural community and household level. These are studies that are not really trying to aggregate up to the national or sub-continental regional level about what the impacts of agricultural research are. They are not studies trying to show what the total returns to agricultural research are. They are studies trying to look at small specific cases, of what is happening on the ground. They seek to understand at the micro level how some of these more aggregate-level impacts are occurring.

The release of this volume, although appearing 4 years after the San José Workshop, comes at an opportune moment. The World Summit in Johannesburg, 26 August to 4th September 2002, and the World Food Summit: Five Years Later, held in Rome from the 10th to the 13th of June 2002, have called renewed attention to the issues of poverty and sustainability. The World Food Summit: Five Years Later called for an international alliance to accelerate action to reduce world hunger. It also unanimously adopted a declaration calling on the international community to fulfill an earlier pledge to cut the number of hungry people to about 400 million by 2015. That pledge was made at the original World Food Summit in 1996—the largest-ever global gathering of leaders to address hunger and food security—and progress towards it remains disappointingly slow (www.fao.org/worldfoodsummit).

At the 1992 Earth Summit in Rio, the international community adopted Agenda 21, an unprecedented global plan of action for sustainable development. But the best strategies are only as good as their implementation. Ten years later, the Johannesburg Summit provided an exciting opportunity for today’s leaders to adopt concrete steps and identify quantifiable targets for better implementing Agenda 21. The Johannesburg Summit 2002—the World Summit on Sustainable Development—brought together tens of thousands of participants, including heads of State and Government, national delegates and leaders from nongovernmental organizations (NGOs), businesses, and other major groups to focus the world’s attention and direct action toward meeting difficult challenges, including improving people’s lives and conserving our natural resources in a world that is growing in population, with ever-increasing demands for food, water, shelter, sanitation, energy, health services, and economic security.

“Over half the world’s extreme poor depend on farming or farm labor for their livelihoods. Alleviating this poverty will require that, at a minimum, we help these communities double agricultural productivity from the 2000 level by 2015" (page 7 of Johannesburg Summit Brochure, www.johannesburgsummit.org).

This volume helps us understand how some of the strategies might work that can enable us to better overcome these problems and meet these goals on poverty issues. The editors wish to give special thanks to Grant Scobie, who was the intellectual inspiration and guiding spirit of the whole effort that brought about the San José Workshop.

PART ONE

Overview of Issues

Chapter 1

Impact of Agricultural Research on Poverty Reduction: Messages from the San José Workshop

*Michael Lipton**

This chapter is a series of reflections, based on the proceedings of a wonderfully stimulating and well-planned conference. A few outstanding lessons emerged and it is worthwhile summarizing them.

What has changed since, for example, 1960—in what we know about how agricultural research affects poverty, and in what is happening to them? How was the new knowledge used and carried forward in the workshop? What can and should be done as a result?

Poverty

New knowledge

In 1965, we had reliable nationwide household survey data for expenditure or income, per person or per adult equivalent, for 5 to 10 developing economies. Today the number is over 50, many with reserves, and some (notably India) with long series of good data. Valdés (1999) and de Janvry and Sadoulet (2000) used these data to show the substantial fall in the incidence of rural and urban "absolute consumption poverty" in Latin America. The falls were faster and more dramatic in Asia, especially, but not only, East Asia. The intensity of poverty—incidence multiplied by the "depth", which is the proportion by which consumption per equivalent adult fell short of the "poverty line"—has fallen similarly. In these continents both rural and urban poverty incidences have probably fallen more in the past 50 than in the previous 500 years.

However, globally, the absolute numbers of poor remain huge, at about 1.3 billion. Rural poverty is especially large (the urban-rural poverty gap has risen in about as many times and places as it has fallen). Some areas, including most of Africa and large regions almost everywhere, have seen

* Research Professor and Director of the Poverty Research Unit, University of Sussex, GB.

little poverty reduction. Perhaps most worrying of all, both the rate of poverty reduction, and its responsiveness to faster economic growth, were substantially less after 1985 than in 1975-89 (as Valdés [1999] and de Janvry and Sadoulet [2000] show for Latin America). López (1999) suggested that, for **incidence,** this is because the "core poor" are further below the poverty line than are those who escaped poverty in the earlier period, and globally this is true. Around 1995, the average poor person in Africa appeared to survive with a command of only 61 c/person per day (in 1985 prices and exchange rates) over the global consumption bundle, as against 71 c in South Asia, and more elsewhere. However, it does not explain why the **depth** of poverty, too, has been falling more slowly since the late 1980s.

Poverty gaps, regional and other

Most evidence suggests that differences over space and time in rates of growth in average real consumption explain about half the differences in poverty incidence and intensity. But the effect of growth on poverty has been weakening in many countries because inequality has been rising—spectacularly so in Russia and some other transitional economies, and substantially also in parts of Africa and in much of the East (although not, on evidence so far, South) Asia. There are other, although linked, reasons for the slowdown in poverty reduction. The core poor, having proved immune to global growth in the past—sometimes, but not always, because their countries have not shared in it—will clearly be increasingly hard to reach by global growth in future. Growth continues to do too little to reduce poverty in, for example, North and West China, Bihar in India, or the hilly areas of Latin America. These areas tend to be remote, and to contain high concentrations of the illiterate, those at ethnic or linguistic disadvantage, and households with high child/adult ratios. Thus, emigration is more difficult, and local poverty has been slower to decline than in better-endowed rural areas, whether or not its initial levels were higher.

The workshop revealed continuing disagreement on this subject. "Marginal areas" were seldom precisely defined or disaggregated, but presumably connote mainly arid or semi-arid tropics, uplands, and other unreliably watered areas. Certainly "regionalization of poverty" has occurred globally and within nations. China more or less abolished food poverty in the southeast (India did almost as well in the Punjab and Haryana) in 1978-85. However, other regions proved much less responsive, even to China's combination of fast agricultural growth, radical individualistic land distribution, less distorted and less extractive farm prices, and rapid technical progress. This was presumably because they missed out on one of the four, probably the last. In India, the coefficient of variation of poverty incidence and depth grew among both States and Districts between the early 1970s and the late 1980s. Africa, of course, is as a whole an increasingly marginalized region with many agro-ecologies sharing (except in South Africa) absence of much irrigation and water control. If water shortage and unreliability underlie increasing concentration of poverty in ill-watered regions, then the ongoing water-diversion from agriculture—and increasing water scarcity—presents three big challenges to agricultural research to:

(1) Produce varieties using water more cost-effectively;
(2) Develop, with hydrologists and economists, employment-intensive and otherwise poor-friendly approaches to crop/soil/water management; and
(3) Produce varieties and/or crop population patterns that owe their yield-raising power to enhanced performance under moisture stress.

This last is the most familiar, but perhaps the most difficult, given the many genes, environmental features, and genotype x environment interactions involved.

Lack of assets is another familiar cause of poverty. However, these ill-watered, high-poverty areas are less amenable than others to a remedy often proved effective against poverty—land reform (which can often be consensual). Small farms are more labor-intensive and therefore usually produce higher yields from given non-labor inputs; and poverty is strongly linked to land ownership. But both the linkage and the high-yielding, labor-intensive options are not quite so clear in semi-arid areas. Another asset, education, is also normally a strong weapon against poverty, but in areas with few chances for agricultural progress in a marginal (or just underresearched!) rural area it is hard to use extra skills within it to generate extra income within it.

So the poor have special problems with the exit option from marginal rural areas; and it does not help them to pour resources into hopeless places (see Lele's [1975] work on priorities within Africa). But, before despairing of such areas, we should recall the converse: it does help the poor to divert resources to promising, but underresearched, regions. The 64-crore rupee question is which these are. That question has scientific, administrative, and economic aspects. On the scientific aspects I am unqualified to comment. On administrative aspects, it cannot make sense from a poverty-reduction standpoint for National Agricultural Research Systems (NARS) to devote only a small proportion of resources to adapting research by the Consultative Group on International Agricultural Research (CGIAR) and others to (normally highly diverse) marginal areas, while the CGIAR system claims to devote 60% of its research resources to generating products for these areas. On economic aspects, we need to consider (1) Hazell and Ramasamy's (1991) evidence of very high returns to research in some marginal areas, and (2) the fact that any case for pessimism applies only to areas inherently marginal—systematically underendowed for sustainable profitable agriculture by nature. It does not apply to the areas, probably containing far more rural poor, that have had marginal status thrust upon them by deprivation or research, or that can benefit from careful research planning of new "biotecknowledge" about to come onstream.

Poverty and yield stagnation

Agricultural research may urgently need to consider another possible source of poverty slowdown, a source that, like that slowdown itself, is not confined to marginal areas—the flattening-out of growth in tropical staple yields, itself partly due to the prolonged flattening-out of growth in yield **potentials**. Growth rates of food production in developing countries, driven by the declining yield growth of main staples, fell from 3% per year in the 1979s to about 1% in the 1990s. Is the yield slowdown responsible for much of the slowdown in poverty reduction? Did the yield slowdown, by changing the composition of gross national product (GNP), reduce the effect of economic growth on poverty? Work by Datt and Ravallion (1998) in India—where poverty, after fluctuating around 55% through 1960-75, fell to around 38% by 1989—shows that poverty fell faster in times and places where agricultural GNP was growing faster. This is not mainly because later Green Revolution growth in food grain production meant more food (it mainly meant less imports, and besides, India has enormous food grain stocks, often rising well above 20 million tons), but because the extra food:

- Was substantially located with the rural poor—most of the laborers, and many of the small farmers, that grew it—and, even more,
- Lowered and stabilized food prices, helping net food buyers, who predominate among the urban and even rural poor, and
- Created extra workplaces much more affordably (in terms of capital cost per job) than other forms of economic growth.

Obviously, the staples yield slowdown—and agricultural "progress" increasingly focused on displacing labor with tractors, on herbicides, and now on herbicide-resistant (instead of yield-enhancing) genetically modified crops (GMs)—also meant a slowdown in the reduction of poverty, as observed in India after 1989, and in China after 1985.

The rural non-farm sector

What of the role of the rural non-farm sector (RNFS) in poverty reduction? Evidence at this workshop was mixed. Renkow (2000) argued that the RNFS provided big proportions of rural employment and income. This suggests that agricultural research should be reduced relative to RNFS research (or, if that is unpromising, RNFS support or promotion), or should shift priorities to meet the needs of poverty reduction via the RNFS (presumably by addressing more issues of processing, choice of locally made inputs, etc.).

Renkow's (2000) data on the large and growing RNFS are telling, even more than those presented earlier by Chuta and Liedholm (1979). However, much so-called "off-farm" or even sometimes "non-farm" income and employment involve only hired labor on the farms of other people. Other RNFS is often dependent on linkages to agriculture (see Hazell and Ramasamy, 1991). Greeley (1987) has shown for Bangladesh that 25% of the value of rurally purchased rice is added after harvest, much of it labor-intensively. Also, it is not always clear whether the RNFS is more, or less, likely to engage, and provide income for, the poor than the rich—Reardon et al. (1999) and de Janvry and Sadoulet (2000) suggest opposite results for West Africa and Latin America (FAO [1998] reviews these issues well).

Even if the RNFS overrepresents the income or employment of the poor, does this imply that RNFS growth especially favors the poor (so that agricultural and other research should be steered to advance RNFS growth), or that RNFS membership helps perpetuate poverty? This depends partly on which part of the RNFS we are considering. The traditionally boosted crafts sector is usually in decline. However, the agriculture-linked sectors of trade, transport, small catering, and (above all) construction, are dynamic. Yet their growth, while helpful to poverty reduction, is strongly linkaged to agriculture. In any event, overaggregation of RNFS impedes findings, and advice, about it. A sector, even one as diverse as farming, is less difficult to research or prioritize than a "non"-sector whose components include doctors, bricklayers, in India traditional caste sweepers, in Nigeria women who market farm produce at a distance, etc.

Poverty demographics: How they relate to this workshop

Apart from overwhelming static evidence of the concentration of poverty in families of five or more with high child/adult ratios, we know much more about the demographic dynamics of poverty that even 10 years ago. We have long known that falling child mortality leads, as predicted in Malthus's 1830 Britannica article on population (and much more quickly than had been thought by, for example, Warren Thompson in 1959), to falling fertility. We have experienced in almost all of Asia and Latin America, and in its early stages most of Africa, the consequent rise in adult/child, and worker/dependent, ratios. This reaches the rich first, but finally reaches the poor, as does the subsequent rise in the proportion of aged dependents that is affecting East Asia. We have learned, after much controversy, that the fertility transition is a major contributor to poverty reduction, working about equally through its effects in speeding growth (Kelley and Schmidt, 1994) and, 10-15 years later, in improving distribution (Eastwood and Lipton, 2000).

Reduced fertility probably reduces poverty mainly by raising the price of labor and lowering the price of food—Malthus's key insight (rather than his famous, simplistic, and mostly early formulations of a food-population "race"). The expenditure surveys consistently show that below the 1985 real dollar poverty line over 60% of expenditure is on food, about half on staples. Because, as modem demographics (again echoing late Malthus) confirm, higher incomes induce higher standards for living and thus lower fertility, raising food yields and employment intensively remains crucial for poverty reduction. This is less because the higher yields raise food availability—the bigger pile of rice—than because they raise the poor's real income, and restrain and stabilize local food prices, by affordable rural job creation. From the standpoint of poverty reduction we were hugely lucky that the Green Revolution, driven largely by pile-of-rice logic, also happened to be employment-intensive and thus extremely poverty reducing. But the revolution slowed down after the mid-1980s, and its employment-intensity started to decline much earlier (Lipton and Longhurst, 1989), so new impetus is needed. Also, both the yield revolution and poverty reduction have yet to spread to Africa, although the demographic transition, while delayed, is well underway there (see Cohen, 1998). This, as in South Asia, presents a "window of opportunity", but also a window onto fear, for the poor. The opportunity is for a new, probably GM-based, Green Revolution to employ the extra workers, using them as a major source of growth as East Asia did (Bloom and Williamson, 1997), and providing them with extra farm and RNFS opportunities that will dramatically cut poverty. The fear is that lack of productive work expansion will turn the extra workers, relative to dependents, from a blessing to an impoverished curse. This could happen if GM is held up by misguided critics, or if it continues to be diverted into a search for poverty-irrelevant traits by profitability considerations uncorrected by appropriate and properly funded pro bono research.

The urban poor

Rural poverty incidence, intensity, and sheer numbers substantially and persistently exceed urban. But the urban share in the sheer numbers of poor people is growing. Probably, poverty among urban residents is much higher among those whose income is derived mainly from agriculture (whether for subsistence or as employees, and whether within cities, peri-urban, or commuting). Policies for agriculture, including research and extension, cannot therefore neglect urban agriculture, as they almost invariably now do.

Hence it is important that Perlman (1999) placed 26% of the Latin American agricultural workforce in the urban sector. This high proportion may be because of definitions—several Latin American countries put the rural-urban borderline at only 2000 population, as against 5000 in most of Asia. But even in India, urban areas, including cities, have 6%-10% of workers dependent mainly on agriculture, and the African proportions are generally higher. Hence agricultural development can in principle address urban poverty by creating more attractive and rewarding farm output and employment—not just indirectly, through lower prices for net food buyers.

Poverty-reducing conditions for agricultural research outputs

How can the direct poverty impact of agricultural research (on-farm employment and real wages) be pro-poor as well as the indirect, food-buying impact (on food prices)? Assuming a land constraint, there are two simple, but little recognized, "tightrope conditions" for favorable all-round impact.

First, labor productivity must rise, but land productivity must rise faster. Technical progress has to raise yields (strictly, net value added) per area (A) faster than labor productivity (strictly, net value added [Q] per unit of labor [L]); because if Q/A exceeds Q/L with A fixed then L must fall and farm laborers lose. But the rise in Q/L must be positive (else there will be net decline in incentive to employ or to work in self-employment).

Second, food prices should and normally do fall (or are restrained) by research-induced higher growth of national food output. But the price fall must be slower than the rise in total factor productivity in food farming if net food sellers are to gain as well as poor net food buyers.

Both these tightropes were successfully walked, for most poor regions and staple crops, by the Green Revolution. So poverty fell fast where it took hold. We were lucky! Developing-country working-age populations are scheduled to grow by 2% annually while dependents increase much more slowly thanks to demographic transition. Thus, in future, poverty-focused agricultural research, if it is to exploit the "window of opportunity" rather than jump out of it, needs to consider employment impacts much more explicitly than before. Farmers and researchers normally treat employment as a cost, but wages form part of value-added and GNP, and the poor increasingly comprise laborers rather than farmers. A range of options, from mechanical rice transplanters to GM priorities aimed at complementarity with labor-displacing herbicides, indicates the dangers.

Schuh (1999) was absolutely right to emphasize, in his closing remarks, the danger of too many, too complex research aims. He argued that one activity, such as the CGIAR's agricultural research, cannot be competently planned if it has more than one maximand, and that the system therefore performed best when that maximand was clear—to grow more food. In some ways I go further: having stressed the need for other considerations than yield potential in agricultural research in the 1970s, I now feel the pendulum needs to swing back. It is just that "the bigger pile of rice" is not the right single aim for the CGIAR system. That single aim should be "maximum addition to poverty reduction through research impacts on agriculture, including secondary effects". Sometimes maximizing the "pile of rice" will conduce to that aim, sometimes not.

Agriculture

New knowledge from social sciences

Much of this concerns risk and farmers' responses to it, and was reviewed and enlarged by several contributions to the workshop and its working groups. The poor face greater farm as well as non-farm risks (e.g., are less likely to have irrigation and more likely to face illness through unclean drinking water). The poor have less access to means of risk mitigation (loans for smoothing consumption when income is hit), and therefore adopt more risk-averse production systems (e.g., more robust, but lower-value crop and variety mixes).

We have much more evidence than in 1960 that some agricultural research generates substantial rural and urban poverty reduction. Countries, and within countries (and despite migration) regions, districts, and households with higher rates of adoption of Green Revolution technology show faster poverty reduction; and causality from the first to the second is often traceable.

Agriculture in marginal regions

As indicated, these are of many different agro-ecological and economic types, and often lose or acquire marginality over time, so we are less sure about the impact of agricultural research on such areas. Sharp divergences of experience by crops and regions were reported at this workshop. Fan et al. (2000) showed higher overall returns to agricultural research in rainfed than in irrigated regions, and/or in unreliably watered than in other rainfed regions in many, but far from all, Indian cases. Walker (2000) stated that returns to potato agricultural research had long been better in more marginal regions. Otsuka (2000) provided evidence, for several Asian countries, that rice research is more cost-effective in raising yield in irrigated than in reliably rainfed regions, and least of all in unreliably rainfed regions. He concluded, not that these should be left to their fate, but that agricultural research there should shift to less thirsty and more robust crops. He emphasized cash crops, but some staples (millet, sorghum, cassava), some Janus-crops facing both subsistence and markets (beans), and sometimes animals, often promise the best returns to research for marginal areas. Also, as Conway (1998) has argued, GM may have an especially important role to play for some marginal areas. Voss (remarks to this conference) agreed on the excessive single-crop concentration of decisions about agricultural research allocation.

Three overarching issues need emphasis. First, one needs to check **why** a region is marginal—because genuinely "low-potential", because underresearched, or because its infrastructure, especially for water management, is underdeveloped? Second is the need to focus on agricultural research's impact, not only on yield or stability in marginal regions, but also on these and others that contribute to "**the poor's**" use and productivity of marginal environments, and indeed on the poor's total income sources and the impact of agricultural research on these. Third is the special threat to the poor in irrigation-supported areas of regions otherwise classified as semi-arid by the steady, and often justified, drift of water away from agriculture. Hence the special need, in poverty-reducing agricultural research, to seek water-saving varieties, methods, and crop-mixes.

Agricultural liberalization: New kid on the block?

This was perhaps the orphan of this workshop. However, Reardon et al. (1999) robustly argued that, from Latin America to India, domestic food-market integration, notably through supermarkets and their supply channels, was transforming the definition of what would, and would not, work to reduce rural poverty. For those disconnected from such channels, whether by agricultural research achievements or inadequacies or otherwise, deepening marginalization was assured.

Little was said about the poverty impact of agricultural trade liberalization—reduction in agriculture's often highly effective protection rates, which are normally positive in developed and negative in developing world—or, more generally, of falling barriers (and costs) for international farm investment, trade, and transport. Yet such changes could utterly transform (e.g., as per the last paragraph) earlier paradigms for the sort of agricultures, and agricultural research systems that are sustainable poverty-reducers. Low-trade isolates, even within progressive agricultural research, could be much less able to survive. And, in a liberalized environment **without** GM research reform and public-sector agricultural research revival, GM-backed cash crops from the developed world (and from giant farms in Argentina and Brazil) could compete away GM-neglected small or labor-intensive farms in developing-world ecologies.

The growth impact of agricultural trade liberalization has been much analyzed in the economic literature, the distribution effects much less so. Currently many, perhaps most, developing countries have gone far to reduce the massive negative effective protection of agriculture documented by Valdés (1999) and Krueger et al. (1991), among others. However, the anti-agricultural impact of public-expenditure assignments remains, and (especially under fiscal pressures) may even have increased to offset the pro-farm movement in domestic terms of trade. We do not know. The complex long-run vs. short-run considerations regarding the poverty effects of price changes, touched on earlier, apply here too, of course.

Developed countries can be divided into the Cairnes group, net exporters of cereals and/or animal products with little or no effective protection, and the European Union (EU) and Japan. The last two, and probably the group as a whole, have probably liberalized agricultural trade less than many, perhaps most, developing countries. If, as in the past, EU enlargement brings more people behind the common agricultural policy (CAP) wall without offsetting liberalization, on balance effective agricultural protection in the developed world will increase. This will happen despite the Uruguay Round and the serious prospect that the next World Trade Organization (WTO) round will concentrate substantially on agriculture. Yet the huge and continuing reduction in transport and communication costs, relative even to production costs, is likely to lead to continuing liberalization of agricultural trade and investment. And the poverty impact of that—and the consequences for agricultural research—needs to be explored, not least via the food-feed mix.

Targeting Agricultural Research on the Poor

A main message of poverty research is that many anti-poverty policies, from slum upgrading through targeted agricultural extension to microfinance, are often good at reaching the poor, but not the poorest. Is this also true of agricultural research? Does its rate of return—high, although as Thirtle et al. (2000) have shown, less so than some estimates suggest—and its poverty-reducing impact conceal a failure to reach the poorest? Is the surest way to do that to raise supply of food staples, produced labor-intensively to create work-based income entitlements to food, and available locally, reliably, and at moderately falling prices relative to the unskilled wage rate? The answer depends partly, in the very long run, on whether agricultural liberalization will mean much more specialization. This would mean that more of the poor come to depend for their staples not on growing them or working for those who do, but on staples-crop or non-farm production followed by trade, or employment followed by purchase. If so, the **sort** of farm activity, to which pro-poor agricultural extension research is most relevant, will eventually be transformed. However, the poor's gains from agricultural research in the foreseeable future will depend significantly on non-staples or industrial crops. They may depend partly on the composition of agricultural research, inevitably and rightly profit-led in the private sector, and able to shift towards poverty reduction even if unprofitable only in the hard-squeezed pro bono sector.

Crop-mix

The poverty impact of agricultural research depends partly on whether agricultural research improvements concentrate on staples grown and eaten by the poor. Byerlee (2000) showed that in Pakistan a commodity re-ranking of agricultural research, designed to improve such congruence, in partial equilibrium would raise the poor's share of gains from 22% to 27%. Many thought this small. Yet if the total benefit is little affected—and if the proportion is no smaller in general equilibrium (probably it is larger, through employment and price effects alike)—the implication is a 23% rise in poverty-reducing benefits for the same agricultural research outlay.

Trait-mix

It is vital, literally, that pro-poor agricultural research concentrates on making more readily and cheaply available the plant traits that interest the poor as producers, consumers, and workers. These are traits such as higher yield, stability, water-saving, and micronutrient content—not traits such as herbicide resistance or ready combinability that usually do little to stimulate higher production, encourage labor displacement, and are used mainly by wealthy farmers. Nor do they include, as a rule, traits such as shelf life, of interest mainly to wealthy consumers, food processors, and (except for some fruits and vegetables) non-poor suppliers and workers.

Preconditions

Theme 2 group's report stressed that "the scope of targeting agricultural research on the poor depends on a favorable political environment". This can be disaggregated! Some governments want growth above all; do not much care about poverty reduction except as a means to growth (and to political peace, also a means to growth); but are reasonably effective and consistent about seeking growth. In such cases, agricultural research **can** be targeted, as little else can, to steer the **sources** of growth towards labor-using, food-yield-raising, and stabilizing ends. So for growth-only governments (and there are many more such than admit it) agricultural research can be targeted on the poor.

Stability

The poverty impact of agricultural research, as Anderson underlined in the Theme 11 group report, also depends on the stability of its outcomes. Panel-survey data suggest that, depending on region, one quarter to one half of rural people measured in a given year as being in absolute consumption poverty are "transient", not poor in most years. Many of the transient poor are in poverty because of downturns in farm income, often covariate among persons in an area and thus hard to avoid by loans or transfers among them. Transient poverty cannot be dismissed as less important than chronic, because it is often deeper (Gaiha [1988]; Gaiha and Deolalikar [1993] have shown this for rural India), harder to avoid, and focused on households with high ratios of vulnerable children to adults. Hence agricultural research that stabilizes farm incomes has a major anti-poverty impact.

Other issues

Nutrition. This remains a key area for agricultural research impact on poverty, slightly neglected in this workshop; micronutrient breeding is receiving some deserved and long-delayed attention.

GM policy priorities for poverty reduction. These were touched upon. Pineiro (remarks to this conference) pointed out that it matters greatly for poor, but market-oriented, farmers to have access to technologies that as they developed remained competitive with those private-sector elite lines that were being increasingly patented, terminated, etc. This needs pro bono (including public-sector) focus on such things, but may conflict with the CGIAR's food-crop remit.

Poverty environment: Vicious circles? These were intensely discussed in plenary and a series of group meetings. Many interesting results were presented. But the "conclusion" appears to be that environmental decay is sometimes not due to poverty, but to the search for riches. It is sometimes self-correcting as it increases incentives to adopt less exhaustive patterns (of inputs, outputs, or transformations) and sometimes self-worsening past irreversible thresholds (because of tragedies of the commons, or rather of open-access, or otherwise). Can something more general be said? Is environmental sustainability usually helped or harmed by equality? By participation rather than authority, for example, in water management (where Sri Lankan history suggests otherwise)? On this topic one point, at least, seems clear. Real long-term interest rates have been about double the historical norm. They have pervaded international finance since 1979 and surely (accompanied by financial liberalization) have reached even the remotest village by now. This penalizes (1) borrowers as against lenders, and hence the poor as against the rich, and (2) those who plan for the long term as against those who seek maximum income soon, and hence the soil/water-miners as against the conservers.

Afterword

Raising unskilled wage-rates and employment, relative to the price of food staples, is the main way for policy to help the poor. That is because the poor are mainly, and increasingly, workers and net food buyers, and because they spend most of their income on food and much of that on staples, yet often remain undernourished. Hazell (Chapter 3) admirably summarized his and Kerr and Kolavalli's (1999) evidence that most agricultural research helps most of the poor most of the time—and their quest for more evidence; but a participant rightly remarked that we need to record and explain the exceptions frankly. The problem is that sharp exceptions, and a few severely agriculture research-damaged poor, rightly shout loudly; but, less rightly, a boring public-relations silence is generated by a strong general rule, and a billion people helped slowly by agricultural research just over the poverty line. The high-quality BBC2 10.30 News program on 4 October 1999 rightly highlighted the failure of supposedly weevil-resistant cotton in Andhra Pradesh in 1997-98 and the hundreds of following suicides. But it called this typical of the failed promise of the Green Revolution, without reference to the tripled wheat and doubled rice yields that have slowly, but surely, pulled tens of millions out of poverty, and probably saved hundreds of thousands of infant lives, in India alone. Unbelievers, if strongly biased (such as the “organic” lobby), will select evidence to support what they want to believe. Meanwhile, as Rausser et al. (2000) showed, leading-edge agricultural research is being remorselessly privatized. We need, perhaps, to find new ways to communicate and explain what pro bono agricultural research is doing.

The focus of aid is increasingly on poverty. Aid was itself declining in the late 1990s for the first time for almost 40 years. We urgently need to sharpen the focus of pro bono agricultural research on hard-core poverty, and to improve the incentives to the private agricultural research sector to cooperate in this endeavor. In a new, agriculturally liberalizing, demographically transforming, water-scarce, and perhaps GM-dominated world, poverty-focus will require as large a change in the structure of research institutions as was Sir John Crawford’s creation of the CGIAR system.

References

Bloom, D.E.; Williamson, J.G. 1997. Demographic transitions and economic miracles in emerging Asia. National Bureau of Economic Research, Cambridge, MA, USA. 24 p. (Working Paper no. 6268)

Byerlee, D. 2000. Targeting poverty alleviation in priority setting for agricultural research. Food Policy 25(4):429-447.

Chuta, E.; Liedholm, C. 1979. Rural non-farm employment: A review of the state of the art. Michigan State University Press, East Lansing, MN, USA. 96 p.

Cohen, B. 1998. The emerging fertility transition in sub-Saharan Africa. World Develop 26(8):1431-1461.

Conway, G. 1998. The doubly green revolution: Food for all in the twenty-first century. Cornell University Press, Ithaca, NY, USA. 334 p.

Datt, G.; Ravallion, M. 1998. Why have some Indian states done better than others at reducing rural poverty? Economica (UK) 64:17-38.

de Janvry, A.; Sadoulet, E. 2000. Clarifying the research-poverty linkages. Food Policy 25(4):389-411.

Eastwood, R.; Lipton, M. 2000. Impact of changes in human fertility on poverty. J Dev Studies 31(1):1-30.

Fan, S.; Hazell P.; Haque T. 2000. Targeting public investments by agro-ecological zone to achieve growth and poverty alleviation goals in rural India. Food Policy 25(4):411-429.

FAO (Food and Agriculture Organization). 1998. The state of food and agriculture (SOFA) 1998. FAO Agricultural Series no. 31. Rome, IT. Available in http://www.fao.org/docrep/W9500E/W9500E00.htm

Gaiha, R. 1988. Income mobility in rural India. Econ Dev Cult Change 36(2): 279-302.

Gaiha, R.; Deolalikar, A. 1993. Persistent, expected and innate poverty in rural India. Camb J Econ 17(4):409-421.

Greeley, M. 1987. Postharvest losses, technology, and employment: The case of rice in Bangladesh. Boulder, London, USA. 345 p.

Hazell, P.B.R.; Ramasamy, C. (eds.). 1991. The Green Revolution reconsidered: The impact of high-yielding rice varieties in South India. Johns Hopkins University Press, Baltimore, MD, USA. 286 p.

Kelley, A.C.; Schmidt, R.M. 1994. Population and income change: Recent evidence. World Bank Discussion Paper. World Bank, WA, USA. 116 p.

Kerr, J.; Kolavalli, S. 1999. Impact of agricultural research on poverty alleviation: Conceptual framework with illustrations from the literature. International Food Policy Research Institute (IFPRI), WA, USA. 197 p. (Environment and Production Technology Division Discussion Paper no. 56)

Krueger, A.O.; Schiff, M.; Valdés, A. 1991. The political economy of agricultural pricing policy. World Bank, Johns Hopkins University Press, Baltimore, MD, USA. 2 vols.

Lele, U.J. 1975. The design of rural development: Lessons from Africa. Published for World Bank by Johns Hopkins University Press, Baltimore, MD, USA. 246 p.

Lipton, M.; Longhurst, R. 1989. New seeds and poor people. John Hopkins, Baltimore, MD, USA. 473 p.

López, C. 1999. Some fundamentals needing change to alleviate poverty. Paper presented at the workshop on poverty, Assessing the impact of agricultural research on poverty alleviation, 14-16 September 1999, San José, CR.

Otsuka, K. 2000. Role of agricultural research in poverty reduction: Lessons from the Asian experience. Food Policy 25(4):447-463.

Perlman, J. 1999. The dynamics of urban poverty in Rio de Janeiro: Implications for research policy interventions. Paper presented at the workshop on poverty, Assessing the impact of agricultural research on poverty alleviation, 14-16 September 1999, San José, CR.

Rausser, G.; Simon, L.; Ameden, H. 2000. Improving design and monitoring. Food Policy 25(4):499-515.

Reardon, T.; Vosti, S.; Berdegue, J. 1999. Links between poverty and the environment: Focus on asset categories and investment poverty, with illustrations from Latin America and Africa, and implications for policy and research. Paper presented at the workshop on poverty, Assessing the impact of agricultural research on poverty alleviation, 14-16 September 1999, San José, CR.

Renkow, M. 2000. The resource degradation-poverty linkage. Food Policy 25(4): 463-479.

Schuh, G. E. 1999. The household: The neglected link in research and programs for poverty alleviation. Paper presented at the workshop on poverty, Assessing the impact of agricultural research on poverty alleviation, 14-16 September 1999, San José, CR.

Thirtle, C.; Van Zyl, J.; Vink, N. (eds.). 2000. South African agriculture at the crossroads: An empirical analysis of efficiency, technology, and productivity. Macmillan, GB. 349 p.

Thompson, W.S. 1959. Population and progress in the Far East. University of Chicago Press, IL, USA. 443 p.

Valdés, A. 1999. An overview on the nature of rural poverty in Latin America. Paper presented at the workshop on poverty, Assessing the impact of agricultural research on poverty alleviation, 14-16 September 1999, San José, CR.

Walker, T.S. 2000. Reasonable expectations on the prospects for documenting the impact of agricultural research on poverty in ex-post case studies. Food Policy 25(4):515-530.

CHAPTER 2

Impact of Agricultural Research on Rural Poverty: A Review of Some Analytical Issues

*Shantanu Mathur** and *Raghav Gaiha***

Introduction

The importance of impact achievement and assessment in international agricultural research, relatively secondary in the past, has now become a very prominent global agenda. This is partly in response to the declining generosity of the donor community—ostensibly, in general criticism (not entirely unfounded) of the practical relevance of much of global agricultural research. The latter is based on perceptions that the international research community is **often** preoccupied with enriching the shelf of technologies that do not find their way into production systems.

One reaction of the international research community has been to focus on improving the adoptability of their research results and to focus efforts on factors that influence widespread take-up. Other dimensions attractive to the development community are gaining prominence and visibility. For instance, large and growing shares of the resources of the Consultative Group on International Agricultural Research (CGIAR) have been diverted from merely producing higher yielding, less extractive, and more robust germplasm (more explicitly than in the past) towards environmental and social goals. The donors, however, have failed to provide funding commensurate with such goals (Lipton, 1999). To view this merely as a response to inadequate budgetary means would be unfair, albeit funding does remain a formidable issue in itself (Mathur, 2000).

Sometimes it is asserted that the analysis of the benefits of agricultural research should be confined to broadly interpreted efficiency gains (Alston and Pardey, 1995). These include sustainability (i.e., to the extent that there are net benefits from the development and adoption of more sustainable resource use patterns), environmental benefits (e.g.,

* Coordinator, Research Grants, International Fund for Agricultural Development (IFAD), Rome.
** Economist, Faculty of Management Studies, University of Delhi, India.

reduction in pollution), and nutritional benefits (i.e., improvements in dietary quality and health). But **desired** income distributional changes—or more specifically, poverty alleviation—should be excluded from the analysis as these are better accomplished through other policies (i.e., lump sum taxes). Although this is a familiar argument, it is often overlooked that a lump sum tax is not feasible. Moreover, there is a risk of overstating the distinction between efficiency and non-efficiency gains. For example, given the International Fund for Agricultural Development's (IFAD's) focus on smallholders in resource poor regions, some overlap is likely to occur between the efficiency and poverty alleviation objectives.

One issue is that the research community has not given adequate attention to demonstrating the impact of their otherwise fruitful research outcomes on rural poverty in clear and unambiguous terms. From this perspective, an assessment of the impact of agricultural research on poverty **may** help draw attention to the potential of enhanced donor funding for poverty alleviation. Motivated by this concern, some key issues in analyzing the impact of agricultural research on poverty are briefly discussed here. (We interpret agricultural research broadly to include agriculture and other related activities, for example, food processing.)

The objective is not to resolve these issues, but to discuss how they could be addressed in broader terms, including within a sustainable livelihoods framework, and from IFAD's perspective. In doing so, we shall limit ourselves to specifying the building blocks of such a framework, with some necessary overlap. Although some links among them are indicated, a fully integrated version is not feasible at this stage without detailed experimentation/application. We draw upon a major new initiative supported by IFAD, the Department for International Development (DFID), and others, proposed in IFPRI (2000), and some illustrative evidence obtained in the first wave of case studies phase. Among these, of particular interest are Adato and Meinzen-Dick (2002) and Hazell and Haddad (2002).

Linking Research and Poverty Alleviation Strategies

Agricultural research leading to the adoption of improved technology may reduce rural poverty in many ways that are not necessarily mutually exclusive. It can impact on various income and non-income dimensions of poverty, *inter alia*, through: (1) higher on-farm yields, (2) expansion of farm employment opportunities and higher wages, (3) growth of non-farm activities, (4) lower food prices, (5) reduced vulnerability to crop and other risks, and (6) empowerment. Some of these linkages would help explore aspects of food security (e.g., improvements in nutritional status) and whether the benefits are equitably shared by gender. Also, an attempt could be made to examine the interrelationships between technological improvements and empowerment of women, that is, a more decisive role for women in decision making both within and outside the household.

Towards Developing an Appropriate Analytical Framework

Issues

Much of the recent literature and empirical work concentrates on the yield and income effects of agricultural research. An exposition of some of the analytical issues is given below. Some specific questions that arise in this context include:

(1) What is a desirable measure of successful research in a research and development (R&D) continuum? What is the probability that basic research will be successful (e.g., serendipity)?
(2) If it is successful, how soon will the results be available for adoption; how widely applicable will be the results; and when will they be adopted by various farm groups and for how long?
(3) Once adopted, what is their contribution to productivity and incomes of different farm groups—especially smallholders?

An exposition of some methodological considerations in assessing them is given below, followed by a brief discussion of how this methodology could be broadened and extended to address some major concerns of the sustainable livelihoods approach.

Designed to deepen understanding of the multiple and interacting causes of poverty, and to prioritize interventions, the sustainable livelihoods approach focuses on:

(1) How vulnerability to natural and economic shocks influences choice of livelihood and technology;
(2) Interactions among different forms of assets—physical, natural, financial, human, and social capital—and technology;
(3) Multiple livelihood strategies that the poor pursue and the constraints on technological choice that result from this;
(4) How policies and institutions condition livelihood strategies, outcomes, and impacts of interventions; and
(5) The need for disaggregation by ethnic group, gender, and other forms of social differentiation in understanding technological choice and its impact.[1]

Building on a somewhat conventional formulation, a brief description of how some issues that are central to a sustainable livelihoods approach could be addressed is given below. In arguing for a “mix” of largely qualitative case studies and econometric applications, attention is drawn

1. For an admirably clear and succinct view of impact assessment in the CGIAR and its limitations, see Pingali (2001).

to the considerable potential of the latter that could be exploited to address poverty-related concerns. A broad schematic framework is delineated in Figure 1.

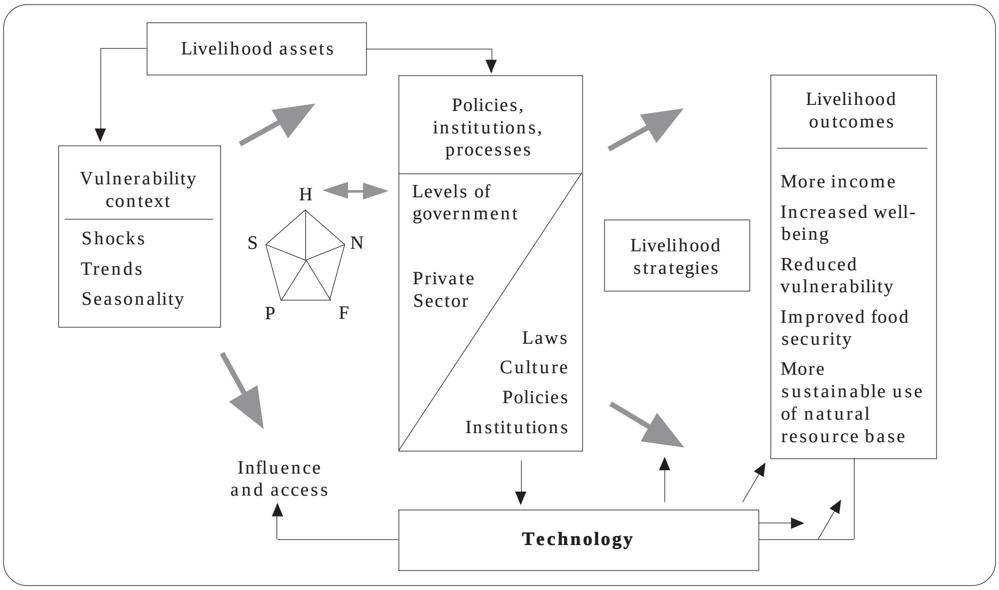


Figure 1. Sustainable livelihood framework. (Types of capital: F = financial, H = human, N = natural, P = physical, and S = social.)

Methodology

Research outcomes. As the outcomes of **basic** research in general and agricultural research in particular are largely uncertain, basing the analysis on a specific probability of success is risky. One option is to use a few, specific, past **experimental** results for their illustrative value. Another, and a more rigorous, option is to approximate outcomes of research/inventions as a stochastic process, conditioned on a measure of basic agricultural research, among others. A Poisson regression model could be employed to examine this relationship.[2] Incorporating predicted values of inventions in a production-function type of specification, along with other variables such as factors of production, climate, soil quality, rural infrastructure, and farmer knowledge and skills, the economic impact of inventions could be assessed.[3] But the feasibility of this procedure will depend essentially on how **rich** are the data on experimental results.

2. Or, given the possibility of overdispersion, a negative binomial regression model could be used. For an intuitive exposition of the assumptions involved in these distributions, see Meyer (1971).
3. A difficulty, however, is that the lags between an invention and its adoption may be long. For an insightful exposition, see Evenson (2001).

However, much of the focus of our exercise, as also of the empirical literature, is on impact assessment of applied/adaptive research (synonymous with agricultural research and extension), controlling for the effects of household, community, and regional characteristics. There are at least two reasons for this. One is that the links between productivity and applied/adaptive research are of considerable interest in themselves from a policy perspective. Another reason is that the complexity of technological choice, given a shelf of technologies, requires a detailed and careful treatment. For the present purpose, therefore, we shall use the salient features of a "reduced" form estimation linking outputs to inputs—including a measure of applied/adaptive research—as described below.

Production function. Either a production function, a cost function, or a supply function could be used at the aggregate level to assess the contribution of research to output. For expositional convenience, we confine ourselves to a production function approach.[4] An extended version of the conventional production function could be specified to capture the impact of knowledge on agricultural output. In this relationship, output (or productivity) depends upon conventional inputs and uncontrolled factors (such as weather), current and past investments in agricultural research and extension, factor prices, and infrastructural variables that directly influence output and institutional aspects of the research system (with implications for the resource cost of generation and transfer of new knowledge). Prices are not commonly included in a production function, but there is a justification in the context of the induced innovation hypothesis. The contribution of research to output is then the basis of an assessment of its direct impact. However, this must be supplemented by an assessment of its indirect effects, the importance of which we discussed earlier.

Spillovers-spatial. New knowledge or technologies produced in, or targeted for, a region can spillover into other regions. Technology adoption in one region may also lead to significant price changes in another. If new technologies are adopted in one region, but not in another, producers in non-adopting regions can experience price reductions without a corresponding reduction in costs. These spillovers need to be assessed while deciding whether to focus attention on developing technologies to maximize productivity gains in a specific production environment or to maximize smaller productivity gains in a wider range of production environments. As available evidence points to significant spillover effects, this choice is not unimportant (Bantilan, 1994).[5] A straightforward extension of the basic model specified above will yield useful insights.[6]

4. For an algebraic exposition of this and other approaches and their relative merits, see Alston et al. (1995), Gaiha (1997), and Evenson (2001).
5. Spatial spillovers have been ignored in several studies on the presumption that spill-ins are offset by spill-outs. In those that deal explicitly with spillovers, some have utilized geo-climatic region data to specify them, while a few others have focused on barriers to them (Evenson, 2001).
6. See, for example, Evenson and Mckinsey (1991), Alston et al. (1995), and Evenson (2001).

Cross-commodity effects. The impact of research on one commodity may be transmitted to another through cross-price effects and technology spillovers. The cross-price effects on commodities that are substitutes or complements in demand are likely to be significant in case the commodity on which the research is focused has a relatively inelastic demand. However, the effects on supplies of commodities that are substitutes in production may be relatively small, because the lower unit costs of production due to new technologies can be partly offset by lower prices for the commodities affected. Although cross-commodity effects require relatively straightforward extensions, data constraints may limit the analysis.[7]

Economy-wide (general equilibrium) effects. Through output market adjustments, technical changes in agriculture may affect the relative prices of agricultural and non-agricultural products not directly affected by the new technology. These indirect changes in product markets may lead to further changes in factor markets. Thus agricultural productivity changes may affect foreign exchange earnings, food prices, domestic capital generation, labor use in non-agricultural production, rural markets for non-agricultural goods, and relative factor prices. Although, in general, predicting the nature of these responses is difficult, it is plausible that under certain conditions non-agricultural production responses would reinforce the direct impacts from a partial equilibrium analysis of the agricultural sector. An analysis of the general equilibrium effects is, however, far from straightforward. Few general equilibrium models are designed for allocating research resources, mainly because the data and computational requirements are much too demanding.[8] A compromise would be to extend/modify a multi-market formulation, given suitable data.[9]

Diffusion. A richer analysis of production-technology relationship could be carried out by modeling diffusion of technology across space and different groups of farmers. A two-stage procedure could be employed in which the first stage focuses on the diffusion of the new technology across different farm-size groups, and the second on the technological impact. Given the data on adopters and non-adopters, it could be hypothesized that the adoption of the new technology depends on personal characteristics (age, gender, and education) of the farmer, access to credit, extension, relative factor prices, technology used in the previous year, and number of current users of the new technology, and soil and other agroclimatic features. In the next stage, a production function could be used with farm output as the dependent variable, and conventional inputs and a probability of adoption (obtained from the first stage) as the explanatory variables. In the Heckman procedure, the first stage uses a

7. For details, see Alston et al. (1995).
8. For a sceptical view based on such considerations, see CGIAR (2000).
9. See, for example, Binswanger and Quizon (1988).

probit and the second an OLS (Greene, 1993). This specification—especially that of the first stage—is motivated by several considerations. Adoption rates often vary by region and size-class of holdings, with smallholders being often the slowest. Going by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) field evidence, the adoption lags could be long among smallholders.[10] One reason is their risk aversion—especially if they are on the verge of subsistence. Although the IFPRI (2000) proposal emphasizes production risks (e.g., because of uncontrollable variables such as weather), it does not address the issue of risk-aversion in any detail. Our presumption is that a failure to incorporate this in the analysis may distort the results. An issue then is whether it is an attitudinal trait or a reflection of the constraint set (e.g., limited access to credit). The results based on a gambling experiment in the ICRISAT villages in a semi-arid region in south India are particularly relevant. At high pay-off levels, virtually **all** individuals are moderately risk averse with little variation according to personal characteristics. Wealth tends to reduce risk aversion slightly, but the effect is not statistically significant. Extrapolating the findings to farming decisions, it is pointed out that differences in investment behavior observed among the farmers facing similar technology and risks has more to do with differences in their constraint sets (e.g., access to credit, marketing, or extension) than in their attitudes.[11] Hypothesizing that risk aversion is a reflection of the constraint set, there is a case for including some aspects of the constraint set as explanatory variables. Other considerations that impinge on adoption are path dependence and across-farm externalities. Path dependence (or technological inertia) on account of, for example, on-farm learning could slow the switch from an old technology to the new. Some insights into this process may emerge from whether an old or new technology was used in the previous year. In addition, other things being given, decisions of other farmers may exercise an important influence. This may be captured through the number of current users. If this variable is considered endogenous, an IV estimation procedure could be used. The superiority of a technology by itself does not guarantee its adoption.[12]

Poverty. Two approaches could be used: One is a familiar econometric formulation in which an index of rural poverty, say, the head-count ratio, is postulated to be a function of agricultural output/productivity, prices, and a measure of inequality in endowments (e.g., distribution of land). Variants of this formulation have been widely used in the Indian poverty literature.[13] To the extent that the effects of agricultural research are reflected in higher agricultural productivity and

---

10. For details, see Reddy and Nigam (1994), and Singh and Bantilan (1994).
11. For details, see Binswanger (1980).
12. For an exposition of the dynamics of switching from chemical controls to integrated pest management (IPM) and reswitching to chemical controls, with some illustrative evidence, see Cowan and Gunby (1996).
13. For a sample, see Bardhan (1985), Gaiha (1989; 1995), and Datt and Ravallion (1998).

price changes, in a given setting, their implications for rural poverty could be assessed in a multi-stage procedure. The two-stage procedure sketched earlier could be extended to examine the relationship between rural poverty and agricultural research induced changes in productivity and prices.[14]

Although this procedure is undoubtedly useful for policy purposes, the results may be sensitive to the poverty cut-off point and the poverty index. In principle, this difficulty could be overcome through a sensitivity analysis, but it will be tedious to do so. It may therefore be worthwhile to supplement the econometric analysis of changes in rural poverty with tests of stochastic dominance. These tests have the merit that they allow comparisons of two different cumulative income distributions (of, say, adopters and non-adopters, or before and after the technological innovation) over a wide range of poverty cut-off points and a class of poverty indices.[15]

Undernutrition. We shall concentrate here on the demand for nutrients in response to price and income changes. As price and income responses are conditioned on household characteristics (e.g., size, age, gender, and education), an appropriately specified demand function could be used. These household characteristics matter because they help capture the effects of differences in nutritional "requirements" of women and children, economies of scale in consumption and tastes.[16] Thus, depending on income and price changes as a result of technological innovations, the implications of these household characteristics for improvements in the nutritional status of vulnerable sections in the rural population (e.g., agricultural laborers, and marginal and smallholders) could be ascertained. An issue that has figured prominently in a few recent studies is whether higher income alone can bring about a significant improvement in nutritional intake, given the preference for some non-nutritional attributes of food (e.g., packaging, flavor, spiciness, and variety) at higher levels. In other words,

---

14. It is arguable that, as markets become more global, agricultural innovation at the national level has less effect on local food prices, especially in urban areas that are well connected to world markets. However, in isolated rural areas, production gains are likely to help the poor by making food cheaper (Pachico and Russell, 1999).
15. Suppose two cumulative income distributions, A and B, are given. If, over a range of incomes, A lies above B everywhere, it follows that there is more poverty in A than B, no matter what the poverty cut-off point (within the admissible range) or the poverty index in the Foster-Greer Thorbecke class (FGT). This is first-order dominance. If, however, these two distributions intersect, the second-order test is applied. In case the area under A exceeds that under B everywhere over the range in question, it follows that poverty is greater under the former, regardless of the poverty cut-off point or the poverty index except the head-count index. For a generalization to higher order dominance tests, see Ravallion (1992).
16. Some authors are skeptical of fixity of food energy requirements. They emphasize that energy intakes could vary within a homeostatic range in the short-term without affecting health and work capacity. Also, adaptation to long-term changes in food energy intake is possible with modest effects on health and productivity. For a sample of applications to the demand for food or nutrients, see Alderman (1989) and Gaiha (1999).

substitution of more expensive food items for those consumed at lower income levels may not necessarily be more nutritious.[17]

Intrahousehold distribution. Intrahousehold distribution of resources—especially food—is often inequitable, with women and children bearing the brunt of deprivation. Available evidence for South Asia points to glaring inequities.[18] If the gender bias is pervasive, undernutrition of women and female children may persist, despite rising incomes. Because intrahousehold food intake data are expensive to collect with (possibly) large margins of error, a direct assessment of the impact of technological innovations may not be feasible.

An alternative approach relies on the presumption that off-farm employment opportunities for women add to their bargaining power in household decision making. In that case, the extent to which technological innovations favor activities/crops that are female intensive, the effects on intrahousehold distribution would be favorable. Regardless of whether a neoclassical (essentially Beckerian) or a bargaining model of household decision making is postulated, an improvement in outside employment opportunities for women has favorable effects on intrahousehold distribution of food and other resources. So, although discriminating between these two formulations empirically is not straightforward, some doubts about the plausibility of the Beckerian formulation with a benevolent household head are hard to resist, given the high incidence of domestic violence against women. Although a precise assessment of the effects on intrahousehold distribution may not be feasible, some inferences about likely changes could be drawn. For a more definitive assessment, use could also be made of anthropometric indicators (e.g., wasting and stunting of children).

Vulnerability. That smallholders are subject to crop income and idiosyncratic shocks is well known. Crop income shocks may affect an entire farming community (e.g., when rainfall is deficient) or may be confined to a subset (e.g., farms in the vicinity of a canal may get flooded when the water level rises unexpectedly), while idiosyncratic shocks affect specific households (through, for example, illness and accidents). However, some recent evidence suggests that such shocks may not involve liquidation of assets (e.g., cattle and land) if other **ex-post** adjustment mechanisms exist.[19] Depending on the possibilities of borrowing and/or higher labor earnings, the adjustment to shock through liquidation of assets may be avoided. In a

17. For a sample of the debate using Indian consumption surveys, see Behrman and Deolalikar (1987), and Subramaniam and Deaton (1996).
18. For a sample, see Chen et al. (1980), Sen (1988), Sen and Sengupta (1983), and Gaiha (1993). For details, see Hoddinott (1992) and Gaiha (1993).
19. In an important contribution, Kochar (1995) questions the finding that households in the ICRISAT sample (for the semi-arid tract in rural south India) are more likely to sell bullocks when profits are low (Rosenzweig, 1989). He does so on the following grounds: (i) the analysis does not relate bullock sales to any exogenous measure of shock; (ii) it does not use instruments to control for the endogeneity of profits; and (iii) since there is an underinvestment in bullocks, it is plausible that households will use bullocks for consumption smoothing only under extremely adverse conditions.

meticulous econometric analysis with the ICRISAT data for rural south India, Kochar (1999) demonstrates that labor income adjustments are more likely than borrowings when negative crop shock is small. But in a more recent analysis that models income and asset dynamics, the effect of a crop shock on a measure of persistent poverty is significant (Gaiha and Imai, 2002). So variability of incomes to a crop shock may be high, not just in the same period, but also in subsequent periods.

In order to capture the effect of technological innovations on variability of household incomes, two sets of (complementary) exercises could be carried out, depending on the availability of detailed household data.

(1) Suppose household income data by source are available for adopters and non-adopters (or, before and after a technological innovation for a **given** set of households. Ideally, for obvious reasons, a with and without comparison must be combined with a before and after comparison). A comparison of the coefficients of variation of the sum of profits and labor income (or, for that matter, of another measure of variability of income) for these two groups **may** reveal that the innovation is income stabilizing. A disaggregation of the analysis by landholding size-class may further indicate that the effects vary for different groups.

(2) As this analysis is not sufficiently detailed to control for differences in age, skills, and labor endowments between the adopters and non-adopters, an alternative econometric approach could be employed. A two-stage Heckman-type procedure would be appropriate in which the first stage focuses on the determinants of adoption of the new technology (along the lines of the specification suggested earlier) and the second on the possibility of whether adoption of a new technology offsets the effect of a shock, taking labor and asset adjustments into account. If panel data sets are available, such an analysis may lead to more definite inferences about the income stabilizing effects of technological innovations.[20]

Empowerment.[21] Empowerment is interpreted in many different ways. As a general proposition, it is taken to imply whether the poor as “individual or collective actors are capable of exercising a decisive influence over their institutional environment to serve needs that they define themselves” (Howe, 2000). More specifically, in the present context, the concern is whether institutional structures and smallholder capacities exist to make public and private sector agencies more responsive to their priorities in both technology and output mixes. With a view to addressing this concern, some key issues in the linkage between empowerment and

20. A variant of the methodology developed in Gaiha and Imai (2002) could be used to assess the impact of a new technology.
21. This section draws upon Howe (2000) and Mathur (2000).

technological innovations are identified first, followed by a brief discussion of methodological considerations. Specifically, as pointed out below, given that empowerment is qualitative in nature, econometric analysis is likely to be of limited value unless of course it is combined with a few carefully designed case studies.

The global agricultural research system is on the verge of a significant shift in so far as a new framework is being emphasized in which the rural poor and research institutions are viewed as equal partners, each contributing to technological changes based on their comparative advantages. This shift reflects a growing recognition that local farmers' organizations have access to location-specific information, both agro-ecological and socioeconomic, and are thus better equipped than their upstream research partners to help carry out applied and adaptive research. Moreover, they can play a critical role in facilitating the community level application of fundamental/basic and strategic research results and in translating them into adaptable technologies by providing insights into traditional practices and innovations, helping discern the incentive structure of communities in natural resource conservation and management, and developing and managing agricultural systems under specific local conditions. As an illustration, IFAD is promoting collaboration between local research entities and farmer-run private microenterprises to produce urea super-granule briquettes. This farmer-driven partnership is proving successful in optimizing the management of soil nutrients in resource-poor rice growing areas of Bangladesh, India, Indonesia, and Nepal. But, equally importantly, it is creating a vibrant local economy in areas where the technology has found rapid adoption as a source of off-farm income for the rural poor. For details of this and other illustrations, see Mathur (2000).

Taking complementarities into account, IFAD (2000) emphasizes that, while indigenous research and extension systems alone may help maintain yields in less-endowed rainfed areas, they must get strong support from public sector and other research agencies to make a dent in poverty—especially in those parts of rainfed areas experiencing rapid population growth and worsening land and water stress.

Some important questions are:

(1) Are local institutions in place to ensure a sufficient supply of skills to support high quality research initiatives?
(2) How can farmers' associations and related social organizational structures be systematically empowered and included as stakeholders in the technology-generation process?
(3) Is there scope for improving the ownership of the beneficiaries in these research undertakings?

Although a definitive analysis addressing these questions may not be feasible, the exercises (based on a mix of case studies and econometric formulations) described below may throw light on the underlying concerns.

A few case studies of farmers' associations would be useful, focused on:

(1) The participation of smallholders,
(2) Their familiarity with indigenous knowledge systems and local agro-ecological and socioeconomic conditions,
(3) Their willingness and ability to understand new technological advances,
(4) Their adaptability to the conditions prevailing in their villages, and
(5) The nature of their interactions with public sector and other research agencies.[22]

Such case studies could help identify a few key indicators. Combining these indicators with other explanatory variables in the model of diffusion (as outlined under "Diffusion", above), an assessment could be made of whether the involvement of smallholders in designing/adapting technologies results in their quicker adoption. Besides, if the benefits of such interactions include higher returns or reduced vulnerability to pests, a similar specification could be employed in the second stage as well.

If the process of empowerment is a self-reinforcing one, some insights into this process may emerge from case studies designed along the following lines. A plausible hypothesis is that moderate, but sustained, economic betterment may induce greater participation of smallholders in technological innovations and their diffusion, and this in turn would lead to a more rapid economic betterment over time (for some corroborative evidence, see Gaiha [2000]). If, for example, active participation of a farmers' association results in a successful technological adaptation in a given agroclimatic context, it may broaden the sphere of collaboration between the farmers' association and research agency. Moreover, if there are dynamic social network externalities, successful adoption in one village could induce a similar adoption in another, and that in turn in a third village over time, and so on (for an exposition and review of evidence, see Dasgupta [1999]). Transmission of such effects would of course depend on whether the benefits exceed a certain threshold level, whether the smallholders have cooperated before, and whether the public/private research agency is responsive to their concerns. This qualitative assessment through case studies could be supplemented by an extended

22. In Mexico, for example, "creolized" varieties of maize or crosses between improved and local maize varieties—developed by farmers—have proved more resistant than the improved varieties to drought and pests, and require less labor at critical times (Adato and Meinzen-Dick, 2002).

version of the diffusion model (as outlined earlier) in which a successful technological adoption in a neighboring village is incorporated as an explanatory variable.

The related issue of how such interactions/partnerships could be promoted is of course largely a question of designing appropriate incentives. An option is the patenting of, say, new crop varieties, and designing mechanisms for sharing of royalty between farmers' associations/village bodies and research agencies. Farmers' associations could be promoted by nongovernmental organizations (NGOs). Alongside, there is a case for promoting village committees/bodies that could forge links between farmers' associations and research agencies as well as facilitate diffusion of new technologies. The International Centre for Research in Agroforestry (ICRAF) and its partners in western Kenya, for example, have focused on building social and human capital through working with village-level committees that disseminate soil fertility replenishment technologies among local farmers (Adato and Meinzen-Dick, 2002).

On the "ownership" of technical innovations, a basic consideration is the sharing of the gains from them. If the gains are widely shared in the village community, and community resources are mobilized through a village development fund for promoting such innovations, a sense of "ownership" is likely to be inculcated over time. Much of course will depend on the awareness of potential gains from these innovations and whether there is a representative village body that could administer the development fund in a transparent manner.[23] However, a successful technological adoption geared to the needs of smallholders runs the risk of usurpation by more influential groups with a strong vested interest. The dynamics of the distribution of gains from such adoptions are not easy to capture in an econometric analysis. Thus, a few case studies focused on inequality in the distribution of land, distribution of gains from technological innovations by size-class, rights to common property resources, and dispute resolution mechanisms could help understand better why some institutional structures are more prone to usurpation by locally influential groups.

Extensions/Modifications

Although there is some overlap between the formulation(s) described in the section above and the concerns of the sustainable livelihoods approach, a few extensions/modifications are suggested below to specifically address these concerns. Without aiming to be comprehensive, we shall confine ourselves to a few propositions that have been emphasized/validated in the first phase of the International Food Policy

23. Gaiha (2003) provides illustrative evidence in the context of watershed development in Mewat, one of the poorest regions in north India.

Research Institute (IFPRI) project. These are extracted from Adato and Meinzen-Dick (2002).

Beyond income poverty

As noted under "Vulnerability", above, a broader focus on well-being must incorporate a measure of vulnerability. In line with the sustainable livelihoods approach, the Heckman-type, a multi-stage procedure could be specified as follows. In the first stage, adoption rates may be conditioned on a wider range of socially differentiated groups, institutions (e.g., security of property rights, and collective action) and (lagged) measures of different forms of capital.[24] In the second stage, an attempt could be made to examine the impact of adoption on income variability (as already discussed), and, in the third, on investment in different forms of capital (e.g., education, farm equipment, and land) in subsequent period(s). An important point is that technologies that stabilize yields and reduce vulnerability may be more important for improving people's livelihoods and well-being than technologies that maximize average production, but with higher fluctuations.

Thus, a comparison of the differential effects of technological choices on vulnerability, as also on the asset structure, would be feasible.[25]

Are multiple livelihoods a constraint? Typically, rural households—especially poor households—are engaged in more than one activity in pursuit of income, food security, and protection against natural and other shocks. These activities include farming, self-employment in non-farm enterprises, and wage employment. As a consequence, time allocation has strategic importance. Depending on the nature of technical change (whether it is labor intensive), it may constrain the pursuit of multiple activities. Analytically, therefore, the feasibility of new techniques may depend on time allocation, among other factors. An option is to analyze technical choice in the context of household welfare maximization, subject to time constraints on various livelihood activities. It may be worthwhile to experiment with a variant of the model developed for assessing the role of rural public works by Datt and Ravallion (1994).

Cultural, historical, and other related factors. There is often a presumption that the roles of cultural, historical, and other initial conditions are hard to capture in an econometric formulation (Adato and Meinzen-Dick, 2002). This assertion cannot be rejected outright. However,

24. Some illustrations from Hazell and Haddad (2001) may be helpful. For example, IPM requires that all farmers in an area cooperate; so collective action is an important requirement. But, because the returns are relatively quick, security of property rights is not so crucial. By contrast, watershed development requires secure property rights, because to carry them out involves long-term investments in check dams, land contouring, and tree planting in water catchment areas, as well as community mobilization.
25. For an insightful exposition of why a grouping by gender matters, see Pingali (2001).

some useful insights cannot be ruled out from a careful econometric analysis that incorporates some aspects of social differentiation (e.g., ethnicity) and attitudes towards or receptivity to external interventions, and dynamics of adoption rates (e.g., lock-in effects). How these insights are incorporated in the model specifications may make a significant difference to the quality of results obtained.

Pro-poor outcomes of research. An important point is that technology is a somewhat blunt instrument for targeting the rural poor except mainly through a concentration on certain crops (important to the livelihoods of the poor) and certain areas/regions (of endemic poverty). Assuming that such technological options are correctly identified, an issue is whether there are some institutional arrangements that are likely to result in greater impact on the rural poor. We have drawn attention to a few key institutional variables that could accelerate diffusion as well as add value to livelihood outcomes. With a view to deepening our understanding of such impacts, simulations involving different mixes of institutional variables (e.g., property rights and collective action) would be worthwhile.

Concluding Observations

In this chapter we have attempted to outline some important building blocks of an analytical framework for exploring the linkages between agricultural research (broadly interpreted) and rural poverty (including undernutrition, vulnerability, and exclusion) in a broad sustainable livelihoods framework. Although important links among them were delineated, a fully integrated framework was not specified. This should be explored further through application and detailed experimentation. In any case, a "mix" of econometric applications and case studies along the lines suggested above is necessary for a deeper understanding of the linkages between agricultural research and poverty, mainly because some aspects of the latter are essentially qualitative in nature and thus not amenable to traditional econometric analysis. Some of the formulations are, therefore, tentative, and refinements or extensions are subject to empirical validation. Nevertheless, a point of departure of the preceding exposition is the emphasis on the potential of econometric applications in addressing some key strategic concerns in rural poverty alleviation.

A major priority for agricultural research is to address integrated farming systems moving beyond component technologies, and discerning synergies and trade-offs. Pro-poor options in such contexts involve building on indigenous knowledge systems and traditional practices, while trying to transcend yield barriers in neglected dry lands and uplands based on sustainable natural resource use and management. In support of such concerns, attention must be given to fostering and promoting strategic partnerships and innovative institutional arrangements, including farmers' associations. A challenge then is to incorporate these concerns systematically in a broader analytical framework. Our present attempt to address some major concerns is no more than a modest extension of current approaches.

Acknowledgements

We have benefited from the constructive advice of Raghbendra Jha, Julian Hamilton-Peach, Osvaldo Feinstein, K.L. Krishna, and P. Scandizzo. Any deficiencies that remain are our sole responsibility. The views expressed here are personal and not necessarily those of the organizations to which we belong.

References

Adato, M.; Meinzen-Dick, R. 2002. Assessing the impact of agricultural research on poverty using the sustainable livelihoods framework. Food Consumption and Nutrition Division (FCND) Paper no. 128–Environment and Production Technology Division (EPTD) Paper no. 89. International Food Policy Research Institute (IFPRI), WA, USA. 57 p.

Alderman, H. 1989. The impact of changes in income and schooling on the demand for food quantity and quality in rural Pakistan. International Food Policy Research Institute (IFPRI), WA, USA. (Mimeo)

Alston, J.M.; Pardey, P.G. 1995. Research evaluation requirements in the CGIAR. A report commissioned by the Impact Assessment Task Force of the Consultative Group on International Agricultural Research (CGIAR). CGIAR, WA, USA. (Mimeo)

Alston, J.M.; Norton, G.W.; Pardey, P.G. 1995. Science under scarcity: Principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca, NY, USA. 585 p.

Bantilan, M.C.S. 1994. Spillover effects of agricultural research. *In*: Bantilan, M.C.S.; Joshi, P.K. (eds.). Evaluating ICRISAT research impact. Summary Proceedings of a Workshop on Research Evaluation and Impact Assessment, 13-15 Dec 1993, ICRISAT Asia Center. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, IN. p. 96-101.

Bardhan, P. 1985. Poverty and “trickle down” in rural India: A quantitative analysis. *In*: Mellor, J.W.; Desai, G.M. (eds.). Agricultural change and rural poverty: Variations on a theme by Dharm Narain. Johns Hopkins University Press, Baltimore, MD, USA. p. 76-95.

Behrman, J.R.; Deolalikar, A. 1987. Will developing country nutrition improve with income? A case study for rural India. J Political Econ 95:492-507.

Binswanger, H.P. 1980. Attitudes toward risk: Experimental measurement in rural India. Am J Agric Econ 62:395-407.

Binswanger, H.P.; Quizon, J.B. 1988. Distributional consequences of alternative food prices in India. *In*: Pinstrup-Anderson, P. (ed.). Food subsidies in developing countries: Costs, benefits, and policy options. Johns Hopkins University Press, Baltimore, MD, USA. p. 301-319.

CGIAR (Consultative Group on International Agricultural Research). 2000. The future of impact assessment in the CGIAR: Needs, constraints and options. Proceedings of a workshop organized by the Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee (TAC), 3-5 May 2000. Food and Agriculture Organization, Rome, IT. Available in http://www.cgiar.org/tac/spia0500/spiameet.htm

Chen, L.C.; Huq, E.; D'Souza, S. 1980. A study of sex-biased behaviour in the intra family allocation of food and the utilisation of health care services in rural Bangladesh. International Centre for Diarrheal Disease Research (ICDDR), Dacca, and Department of Population Sciences, Harvard School of Public Health, USA. (Mimeo)

Cowan, R.; Gunby, P. 1996. Sprayed to death: Path dependence, lock-in and pest control strategies. Econ J 106:521-542.

Dasgupta, P. 1999. Economic progress and the idea of social capital. *In*: Dasgupta, P.; Serageldin, I. (eds.). Social capital: A multifaceted perspective. World Bank, WA, USA. p. 325-424.

Datt, G.; Ravallion, M. 1994. Transfer benefits from public works employment: Evidence for rural India. Econ J 104:1346-1369.

Datt, G.; Ravallion, M. 1998. Farm productivity and rural poverty in India. J Dev Studies 34:62-85.

Evenson, R.E. 2001. Economic impacts of agricultural research and extension. *In*: Gardner, B.L.; Rausser, G.C. (eds.). Handbook of agricultural economics. Vol. 1A. Elsevier, Amsterdam, NL. p. 574-616.

Evenson, R.E.; Mckinsey Jr., J.W. 1991. Research, extension, infrastructure, and productivity change in Indian agriculture. *In*: Evenson, R.E.; Pray, C.E.; Ahmed, Z.; Binswanger, H.P.; Boyce, J.K. (eds.). Research and productivity in Asian agriculture. Cornell University Press, Ithaca, NY, USA.

Gaiha, R. 1989. Poverty, agricultural production and prices in rural India – A reformulation. Camb J Econ 13:333-352.

Gaiha, R. 1993. Design of poverty alleviation strategy in rural areas. Food and Agriculture Organisation (FAO) Economic and Social Development Paper. FAO, Rome, IT. 234 p.

Gaiha, R. 1995. Does agricultural growth matter in poverty alleviation? Dev Change 26:285-304.

Gaiha, R. 1997. Measurement of impact of agricultural research financed through technical assistance grants programme of IFAD. International Fund for Agricultural Development (IFAD), Rome, IT. (Typescript.)

Gaiha, R. 1999. Food, prices and income in India. Can J Dev Studies 20:31-58.

Gaiha, R. 2000. Do anti-poverty programmes reach the rural poor in India? Oxf Dev Studies 28:71-95.

Gaiha, R. 2003. Deprivation amidst opportunity: Lessons from Mewat area development project. International Fund for Agricultural Development (IFAD), Asia and the Pacific Division, Rome, IT. (In press)

Gaiha, R.; Imai, K. 2002. Shocks, vulnerability, and persistence of poverty in semi-arid south India. An invited contribution to a symposium on chronic poverty in world development. International Fund for Agricultural Development (IFAD), Rome, IT.

Greene, W.H. 1993. Econometric analysis. Second edition. Macmillan, NY, USA. 791 p.

Hazell, P.; Haddad, L. 2002. CGIAR research and poverty reduction. *In*: CGIAR stakeholder meeting report, SDR/TAC: IAR/01/02 Rev. 1. Summary Record of Proceedings and Decisions CGIAR Annual General Meeting 2001. Technical Advisory Committee (FAO-UN) of the Consultative Group on International Agricultural Research (CGIAR), WA, USA. 67 p. Also available in http://www.worldbank.org/html/cgiar/publications/agm2001/agm2001.html

Hoddinott, J. 1992. Household economics and the economics of households. Trinity College, Oxford, GB. (Mimeo)

Howe, G. 2000. Evolution of IFAD's strategic response to rural poverty. International Fund for Agricultural Development (IFAD) Update no. 7. IFAD, Rome, IT.

IFAD (International Fund for Agricultural Development). 2000. Rural poverty report 2000: The challenge of ending it. Oxford University Press, NY, USA.

IFPRI (International Food Policy Research Institute). 2000. Impact of agricultural research on poverty reduction: An integrated economic and social analysis, Phase II. WA, USA. (Mimeo)

Kochar, A. 1995. Explaining household vulnerability to idiosyncratic income shocks. Am Econ Rev 85:159-164.

Kochar, A. 1999. Smoothing consumption by smoothing income: Hours of work responses to idiosyncratic agricultural shocks in rural India. Rev Econ Stat 81:50-61.

Lipton, M. 1999. Reviving global poverty reduction: What role for genetically modified plants? 1999 Sir John Crawford Memorial Lecture. Consultative Group on International Agricultural Research (CGIAR), WA, USA. 39 p.

Mathur, S. 2000. Developing new institutional architecture for international agricultural research. International Fund for Agricultural Development (IFAD) Update no. 7. IFAD, Rome, IT.

Meyer, P.L. 1971. Introductory probability and statistical applications. Second edition. Addison-Wesley Publishing Co., MA, USA. 367 p.

Pachico, D.; Russell, N. 1999. Does research reduce poverty? Growing Affinities, December. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 1, 7-11.

Pingali, P. 2001. Milestones in impact assessment research in the CGIAR, 1970-1999. Standing Panel on Impact Assessment (SPIA) - Technical Advisory Committee (TAC) - Consultative Group on International Agricultural Research (CGIAR). Printed for the CGIAR by the International Maize and Wheat Improvement Center (CIMMYT). CIMMYT, MX. 37 p.

Ravallion, M. 1992. Poverty comparisons. A guide to concepts and methods. World Bank, WA, USA. 123 p. (Living Standards Measurement Study Working Paper no. 88)

Reddy, L.J.; Nigam, S.N. 1994. Germplasm enhancement in groundnut. *In*: Bantilan, M.C.S.; Joshi, P.K. (eds.). Evaluating ICRISAT research impact. Summary Proceedings of a Workshop on Research Evaluation and Impact Assessment, 13-15 Dec 1993, ICRISAT Asia Center. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, IN. p. 38-45.

Rosenzweig, M. 1989. Credit market constraints, consumption smoothing, and the accumulation of durable assets in low income countries: Investments in bullocks in India. Bulletin, University of Minnesota, Economic Development Center, no. 89-8, MN, USA. 38 p.

Sen, Amartya. 1988. Family and food: Sex bias in poverty. *In*: Srinivasan, T.N. (ed.). Rural poverty in South Asia. Colombia University Press, NY, USA. p. 453-472.

Sen, Amartya; Sengupta, S. 1983. Malnutrition of rural children and the sex bias. Econ Political Weekly 18:855-864.

Singh, R.P.; Bantilan, M.C.S. 1994. New technology and differential effects on employment and poverty. *In*: Bantilan, M.C.S.; Joshi, P.K. (eds.). Evaluating ICRISAT research impact. Summary Proceedings of a Workshop on Research Evaluation and Impact Assessment, 13-15 Dec 1993, ICRISAT Asia Center. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, IN. p. 83-86.

Subramaniam, S.; Deaton, A. 1996. The demand for food and calories. J Political Econ 104:133-162.

CHAPTER 3

The Impact of Agricultural Research on the Poor: A Review of the State of Knowledge

*Peter B.R. Hazell**

Introduction

Each year, donors and national governments spend about 8 billion US dollars on agricultural research in the developing countries. Of this amount, the Consultative Group on International Agricultural Research (CGIAR) system spends $300 million (or less than 4%). Widespread evidence shows that this research has led to significant increases in agricultural productivity and incomes in the developing world (Lipton and Longhurst, 1989; Walker and Ryan, 1990; Hazell and Ramasamy, 1991; Kerr and Kolavalli, 1999). Research by the CGIAR has been further credited with generating the increases in food production that have outstripped population growth and thus averted widespread shortages (Tribe, 1994). Moreover, publicly funded agricultural research has been found to have an exceptionally high rate of return (Alston et al., 1998). Yet, despite such indications, the impact of CGIAR research on poverty remains controversial. New seed technologies have been seen at times to benefit the rich rather than the poor, the landed rather than the landless, and men rather than women and children.

Critics have focused on three areas of concern. First, that the uptake of modern technologies associated with commercialization is an inequitable process that at best increases rural inequality, but more likely augments absolute poverty. Second, that in the shift to cash cropping, small-scale farmers sacrifice their own food crops and expose their families to higher food insecurity. Third, that commercialization worsens regional inequities because it favors areas that have greater potential for agricultural production. This chapter reviews the empirical evidence on each of these issues, but first lays out a conceptual framework for analyzing impacts.

* Director of the Environment and Production Technology Division, International Food Policy Research Institute (IFPRI), USA.

Conceptual Framework

Agricultural research that leads to improved technologies has five potential ways in which to benefit the poor. It can:

(1) Benefit poor farmers directly through an increase in their level of own-farm production. This may involve producing more or better food for their own consumption, or increasing the output of marketed products that increase farm income.
(2) Benefit small-scale farmers and landless laborers through greater agricultural employment opportunities and higher wages within the adopting regions.
(3) Benefit a wide range of rural poor within adopting regions through growth in the local non-farm economy.
(4) Increase migration opportunities for the poor to other regions and urban areas.
(5) Lower food prices for all.

But these benefits do not necessarily materialize for the poor, because innumerable conditioning factors help determine who benefits. These factors work in a myriad of complex and often conflicting ways, and the outcomes are difficult to determine a priori.

On-farm productivity impacts

Only by adopting new technologies will poor farmers obtain on-farm benefits from them. This requires that the new technologies are appropriate and profitable for the farming conditions of poor farmers and that they have access to the necessary knowledge and inputs to adopt the technology. In principle, improved crop varieties are scale neutral and can be adopted by farms of all sizes, but the same is not always true of other technologies or of complementary inputs such as irrigation and machines, and access to fertilizers and credit. If the institutions that provide these services and inputs are biased in favor of large farms, then the poor may not be able to adopt, or only be able to do so much later.

Poor farmers also need secure ownership or tenancy rights if they are to invest in new technologies that do not have immediate returns (e.g., improved tree crops or better soil management techniques), and to obtain credit to finance such technology investments. Insecure rights to land may also increase poor farmers' vulnerability to eviction should larger-scale farmers and landlords decide that they want to expand their own, cropped area as the result of more profitable technologies. Insecurity problems can be particularly severe when land is highly concentrated and most farmers only have very little land at the outset. Some tenancy contracts offer security, but reduce incentives to adopt new technologies because the tenant bears all the costs and risks of production, yet has to share the crop output with the landlord.

Under risky agroclimatic conditions, poor farmers may be reluctant to adopt profitable new technologies because they require investments in inputs that could be lost in an unfavorable year. On the other hand, larger-scale farmers are more likely to be able to handle such risks because they have larger reserves and better access to credit and insurance.

Farmers who adopt new technologies often succeed in lowering their production costs per unit of output (although not usually per hectare), and hence can better compete in the market. Moreover, if the technology is widely adopted and market prices fall as a result, then the decline in unit costs may be essential for maintaining farm income. In this case, farmers who do not adopt will be disadvantaged not only by stagnant production, but also by declining prices and tighter profit margins. This profit squeeze can be detrimental to non-adopters within adopting regions, and to farmers who live in regions that are not appropriate for the new technology. However, poor farmers who are net buyers of food may benefit more as consumers from the price decline than they lose as producers.

Even when poor farmers do benefit from significant productivity gains, these benefits are not always shared equitably amongst household members. In many societies, men and women have responsibility for growing different crops, and which crop benefits from technological change will also determine who has control of the increased production. Technological change for women's food crops may more easily translate into improved nutrition and well-being for women and children than does technological change for men's cash crops.

Agricultural employment and wage impacts

Many yield-enhancing technologies increase total on-farm employment, particularly if they expand the gross cropped area (e.g., irrigation and short-season crop varieties). But whether this translates into higher wage earnings for the poor largely depends on the elasticity of the supply of labor. If labor is abundant in the adopting region, then the additional employment will have little effect on wages, and farmers will have limited incentive to invest in labor-replacing machines. But, if labor supply is inelastic, then wages will rise sharply and labor-displacing machines may become attractive. The initial mechanization may be targeted on labor-intensive tasks such as plowing and threshing, but once farmers invest in tractors then the incremental costs of mechanizing other tasks may become relatively low, and more widespread displacement of labor can occur. Mechanization may also occur prematurely if government policies, such as cheap credit for large farms, make it less costly than it would be otherwise.

For local poor people in adopting regions, seasonal or permanent migrants from other regions may dilute the additional wage earnings induced by technological change. This can be an effective way of spreading the benefits to the poor in other regions, but will not be of benefit to the local poor. Population growth has a similar diluting effect.

Impact on the local non-farm economy

Agricultural growth generates important income and employment multipliers within the local non-farm economy. These are driven by increased farm demands for additional farm inputs, investment goods, and marketing services (demands that often increase per hectare with technological change), and rural household demands for consumer goods and services as farm incomes rise. These multipliers can be large, often with US$0.5 to $1.0 of additional value added created in the local non-farm economy for each dollar of additional value added, created in agriculture (Haggblade and Hazell, 1989). The rural non-farm employment elasticities are also large; each 1% increase in agricultural output is often associated with a 1% increase in rural non-farm employment (Hazell and Haggblade, 1991). Multipliers of this size mean that technological change in agriculture can potentially generate significant new opportunities for the poor in non-farm income earning activities. These may arise in the form of greater non-farm employment opportunities and higher wages, and in opportunities for starting or expanding non-farm businesses of their own. The increasing competition for labor between agriculture and the local non-farm economy can also contribute to higher agricultural wages, adding to agricultural wage earnings for the poor. A considerable body of empirical evidence shows that small-farm and landless-labor households typically obtain significant shares of their total household income from non-farm sources (Hazell and Haggblade, 1993). They are therefore already well positioned to gain from growth in the rural non-farm economy.

The benefits of growth in the rural non-farm economy are more concentrated in rural towns than in the villages, so they impact on an important segment of the urban poor as well as on the rural poor. The distribution of the benefits between rural areas and local towns depends largely on the state of infrastructure connecting the two, on population density, on government policies, and on average per capita income levels (Haggblade et al., 1989).

Impact on interregional migration

Technological change in agriculture is typically site specific and does not benefit all regions equally. The Green Revolution, for example, was initially concentrated in irrigated regions, and only later spread to some of the more favorable rainfed areas. Technological change can, therefore, contribute to widening disparities between regions. But interregional migration acts to buffer these gaps, and provides an efficient way of spreading the benefits to poorer regions that have more limited agricultural growth potential.

As mentioned above, rapid agricultural growth also stimulates important rounds of secondary growth in the rural non-farm economy, and this provides increased opportunities for the rural poor to migrate and settle in local towns. But these growth impacts also spread more widely, and agricultural growth contributes to that of the national economy at large (Mellor, 1976). This generates additional migration opportunities for the poor to larger towns and cities, and can lead to greater remittances back to the rural poor.

Impact on food prices and food security

Technological change can lead to an increase in the aggregate output of affected commodities.

If the national demand for these products is downward sloping (i.e., trade policy or high transport costs constrain export opportunities) then the output price will fall. Lower food prices are of benefit to rural and urban poor alike, and because food typically accounts for a major share of their total expenditures, the poor gain proportionally more than the non-poor from a decline in food prices. These price reductions may not be very large in an open economy with low transport costs, and more countries now fall into this category than before because of recent rounds of market liberalization policies. But many poor countries continue to face high transport costs because of poor infrastructure, remoteness from world markets, or inefficient marketing institutions, and may still face considerable domestic price endogeneity even after market liberalization. In many landlocked African countries, for example, domestic prices still fall sharply when domestic food production increases suddenly.

The food price benefits may also be enhanced if technological change leads to a reduction in production costs per unit of output, because farmers can then maintain or increase profits even at lower sales prices. But whether consumers benefit from these lower costs depends on whether the food marketing and distribution system is sufficiently competitive that cost savings at the farm gate are passed up through the marketing chain. In some cases, the cost savings are simply captured as additional profits in the marketing chain.

Technological changes that smooth seasonal food supplies (e.g., irrigation and short-season rice varieties) can also help smooth seasonal price variation, and this can be of considerable benefit to the poor. The rural poor may also obtain enhanced food security from increased production within their region if it displaces food purchases from outside the region that previously had to be priced to cover high transport costs.

Net impacts for different types of households

As discussed above, many factors condition whether technological change will benefit the poor, and these factors also interact in complex ways. Predicting whether poor people will gain in each of the five ways discussed above is therefore difficult. The problem is even more challenging because poor people have complex livelihood strategies, and are often part farmers, part laborers, part non-farmers, and always consumers. They may gain or lose in each of these different dimensions at the same time, so that the net impact can remain ambiguous. Poor farmers, for example, might be able to gain from increased on-farm production as technology adopters, but may lose or gain from increases in agricultural wages or reductions in food prices depending on whether they are net buyers or sellers of labor or food. Again, a small non-farm business entrepreneur might gain from cheaper food, but business profits might fall or rise depending on whether or not hired labor costs rise faster than sales. Understanding household livelihood strategies is therefore fundamental for assessing the impact of technological change.

Impact Studies

Given the complexity of the factors conditioning the impact of technology on the poor, assessing impact empirically is a complex task. Not surprisingly, many studies have proved inconclusive or questionable; they were simply not well designed for the task.

Many studies have proved misleading for a variety of reasons. Some were based on anecdote rather than fact or failed to establish an adequate counterfactual situation or to identify the true causality of change. Some were not representative. Others were too narrow in scope and did not consider all the indirect ways in which the poor are impacted, or were too short term in perspective.

Some of the key analytical issues that need to be addressed in impact studies are reviewed below.

The scope of the analysis

Many studies have focused on the direct impact of improved agricultural technologies on poor farmers. But this is often only a small proportion of the overall impacts on the rural and urban poor. The direct effects are captured by poor farmers who adopt improved technologies in the regions in which they are released, and who produce more output that they can consume themselves or sell. However, important benefits spillover to other households or regions. These include the benefits that may arise from the generation of new employment, higher wages, and less costly food. These spillover effects have received inadequate empirical attention, despite their enormous potential impact on poor people, including landless laborers, the non-farm rural poor, and the urban poor. To capture these different effects requires a research design that operates at different scales of analysis (household, village, regional, national).

Inter-household and interregional effects form one important dimension to the scope of the analysis. Intra-household effects form another. Recent work undertaken by the International Food Policy Research Institute (IFPRI) and others shows that significant biases along gender and generational lines can arise when the distribution of production increases within households. It also shows that technologies can reduce or reinforce these biases depending on who grows or owns the crops that are affected. Assessing the impact of improved technologies at this level requires information about individuals within households.

Establishing an adequate counterfactual situation

To assess the impact of a new technology on poverty, the researcher must be able to assess what the situation would be like if the technology had not been adopted—the counterfactual situation. Many studies fail to establish an effective counterfactual situation, and often rely on a simple before-and-after analysis. This can be considerably misleading, for many other factors may have changed along with the technology. Some critics of the Green Revolution, for example, tend to use the situation before the Green Revolution as a counterfactual, and conclude that many of the poor would be better off if a switch back to the old technologies occurred. But these critics forget that populations have grown enormously since the Green Revolution began, and that the situation would be drastically worse for the poor today if yields were to return to their pre-Green Revolution levels.

The best counterfactual is a comparable region or group of farmers who are identical in all respects to the adopters except that they have not had a chance to adopt the technology themselves. Such situations are extremely rare, and most often comparator groups have to be used that differ in other attributes too. The danger of this is that systematic reasons may explain why the comparator group has not adopted (e.g., the technology is not appropriate to their conditions, or they do not have access to credit). These other reasons would also have affected the impact of the technology had it been adopted. Such sample biases can be controlled through econometric techniques, but this requires the collection of particular types of data. Establishing appropriate counterfactuals for assessing the indirect benefits of technological change is even more difficult, and the need for sophisticated modeling or econometric approaches is difficult to avoid.

Controlling for other factors

Many other factors besides improved technologies affect changes in agricultural production and its impact on the poor. At the farm level, prices, access to inputs, credit, and markets, educational levels, and the distribution of land affect both the rate of uptake of improved technologies and the extent to which they benefit the poor. Improved technologies may fail to benefit poor farmers not because they are inherently biased against the poor, but because the distribution of land or access to inputs and markets is unfair. Only when these are taken into account does it become possible to explain why similar technologies can have highly different impacts on the poor in different regions, or at different points in time. The need to control for other factors is even more challenging when assessing the indirect benefits for the poor. For example, changes in rural employment opportunities and wages in the farm and non-farm sectors are affected by macro, trade, and agricultural sector policies, as well as by prevailing prices, public investments in rural infrastructure, health and education, and public employment programs. Teasing out the specific impacts of production increases caused by improved technologies needs to be done within an analytical framework that allows for all these important factors. Similar problems arise in trying to assess the indirect benefits to the poor resulting from changes in food prices, or from improved migration opportunities. Such difficulties can only be resolved by examining countries over longer periods of time, and by comparing the experiences of different countries, or regions within a country (see, for example, Datt and Ravallion, 1997; 1998; Fan et al., 1999).

Allowing for time lags

Long time lags often occur between expenditures on agricultural research and the widespread adoption of improved technologies that the research develops. Further lags may occur between the adoption of improved technologies and their production and poverty impacts. For example, some technologies require long-term investments (e.g., farm trees, livestock improvement, and watershed development) before any additional production is achieved. Most of the indirect benefits arising from improved technologies also take time, because factor and product markets must adjust. The analytical framework must be sufficiently dynamic to capture and aggregate these kinds of lagged benefits.

Controlling for risk

Agricultural production is inherently risky, and yields and prices can fluctuate markedly from one season to another, particularly in rainfed farming systems that are home to many of the rural poor. Assessments of the impact of improved technologies on the poor need to average out these random effects either by taking enough years in “with” and “without” analyses or by using an analytical framework that specifically controls for weather and price variables.

Understanding institutional constraints

To have impact on the poor, good science must be targeted on the right problems and the resulting technology must reach and be adopted by farmers. Inadequate information flows, adverse incentive structures (e.g., top-down), and overly complex organizational structures can thwart the effective design and implementation of technically sound interventions. Whenever possible, these institutional features conditioning the relationship between agricultural research and the poor must either be controlled for, or explicitly studied.

Defining the benefits

New technologies, practices, and policies can potentially affect a wide range of indicators. Process indicators assess whether the new intervention is being used and used as intended. Intermediate outcome indicators assess intermediate outcomes of the intervention, such as impacts on crop yields, postharvest losses, soil fertility, and improved forest management. Welfare outcome indicators assess the well-being of adopters and non-adopters of the intervention. Welfare can be measured in a number of ways (e.g., income, expenditure, food consumption, nutrition status, and decision-making ability), at a number of different levels (e.g., community, household, and individual), for different types of individuals (e.g., adopters, non-adopters, farmers, non-farm rural, and urban).

Review of Empirical Evidence

Despite the difficulties of designing and implementing sound impact studies, a wealth of relevant empirical material is available in the literature. Lipton and Longhurst (1989) definitively reviewed this, and Kerr and Kolavalli (1999) have provided a recent update. Because relatively little of this evidence derives from rigorous studies with sound counterfactuals, synthesizing the findings remains a subjective and potentially controversial task. The following section represents the joint views of the author and his IFPRI colleague, Mark Rosegrant (Rosegrant and Hazell, 2000).

Impact of technological change

Concerns about the adverse impact of modern agricultural technologies on the poor reached their zenith in the 1970s when critics debated the negative impacts of the Green Revolution. Critics argued that, because of their better access to irrigation water, fertilizers, seeds, and credit, large-scale farmers were the main adopters of the new technology. Smaller-scale farmers were either left unaffected or were made worse off because the Green Revolution resulted in lower prices, higher input prices, and efforts by larger-scale farmers to increase rents or force tenants off the land. It was also argued that the Green Revolution encouraged unnecessary mechanization, with a resulting reduction in rural wages and employment. The net result, some critics argued, was an increase in the inequality of income and land distribution, an increase in landlessness, and a worsening of absolute poverty in areas affected by the Green Revolution (see, for example, Griffin, 1972; 1974; Frankel, 1976; Farmer, 1977; ILO, 1977; Pearse, 1980).

Some village- and household-based studies conducted soon after the Green Revolution technologies were released lent some support to the critics (e.g., Farmer, 1977). However, the conclusions have not proved valid when subjected to the scrutiny of more recent evidence (Barker and Herdt, 1978; Blyn, 1983; Pinstrup-Andersen and Hazell, 1985; Lipton and Longhurst, 1989; Hazell and Ramasamy, 1991). Although small-scale farmers lagged behind large-scale farmers in adopting the Green Revolution technologies, most of them did eventually adopt and benefit from increased production and from greater employment opportunities and higher wages in the agricultural and non-farm sectors. Nor did the distribution of land worsen in most cases (Rosegrant and Hazell, 2000). Many other poor people also benefited from the Green Revolution through increased employment and business earnings in the farm and non-farm sectors and from lower food prices (Pinstrup-Andersen and Hazell, 1985). This is not to say that the Green Revolution was equitable everywhere, but that the conditions under which it and other yield-enhancing technologies are likely to be equitable are now reasonably well understood. They include:

(1) A scale-neutral technology package that can be profitably adopted on farms of all size;
(2) An equitable distribution of land with secure ownership or tenancy rights;
(3) Efficient input, credit, and product markets so that farms of all sizes have access to needed modern farm inputs and receive similar prices for their products;
(4) A mobile labor force that can migrate or diversify into the rural non-farm economy; and
(5) Policies that do not discriminate against small farms (e.g., no subsidies on mechanization, or scale-biases in agricultural research and extension).

Impact of commercialization

Critics of commercialization also fear that small farms will be left out of the commercialization process and will be unable to compete in the market as competition increases and prices fall. At the same time, they fear that if small farm households forgo some or all of their traditional food crops to grow more cash crops for the market, then this will increase their dependence on purchased foods. This will expose the household to higher food security risk because of volatile market prices and uncertain income from cash crops. It will also lead to a reallocation of income within the household in favor of men (who typically grow cash crops) with possibly adverse nutritional consequences for women and children (e.g., Gross and Underwood, 1971; Hernández et al., 1974; Lappe and Collins, 1977).

A recent study (Von Braun and Kennedy, 1994; Von Braun, 1995) refutes the critics of commercialization. The study summarizes a series of comparative studies of selected sites where farm households had recently switched from semi-subsistence staple food production with low levels of external inputs to production of more crops for sale in the market or to production with more purchased inputs. These studies find that, with few exceptions, commercialization of agriculture benefits the poor by directly generating employment and increased agricultural labor productivity. Both the households that are commercializing their production and the hired laborers receive direct income benefits. Further, in all but one study site, the increased household income generated by commercialization was associated with improved nutrition for children in the household.

However, although commercialization by itself rarely has adverse consequences on household welfare, it can be damaging when combined with failures of institutions, policies, or markets. Government policies must therefore facilitate the transition to commercialized agriculture in a manner that benefits the poor and does not simply replace subsistence-related production risks with new market and policy failure risks, which may be even more devastating to the poor. Important policy goals should include avoidance of trade shocks and appropriate sequencing of input and output market reforms.

Regional disparities

It has also been argued that agricultural intensification and commercialization that proceeds in certain regions, but not in others, can worsen regional disparities, with lagging regions falling farther behind as commodity prices drop in the wake of increasing productivity in the rapidly growing regions. The widening productivity gap between commercializing regions and slower growing, subsistence-oriented regions could both accentuate relative income differences and even cause an increase in absolute poverty in the lagging regions. In the study sites examined in Von Braun (1995), however, indirect income benefits were generated through the increased demand for goods and services by the direct income beneficiaries as well as by increased demand for inputs for commercialized agriculture. The wage rate and other employment benefits from commercialization spread to other regions when labor migrates from other regions into scheme areas. The more mobile the labor force, the more the benefits from commercialization will spread across the economy and other regions. Similar results have been found for the spread of modern rice technology in Asia (a classic process of commercialization). In a comprehensive cross-country comparative study, David and Otsuka (1994) found that the differential impact of new rice technology across regions did not worsen income distribution because of the significant indirect effects that worked through labor, land, and product markets. Interregional labor migration from unfavorable to favorable regions tended to equalize wages across regions, allowing landless labor and small-scale farmers in unfavorable areas to benefit also. Landowners in lagging regions were sometimes worse off, but also partially protected their incomes through diversification out of rice.

Although well-functioning product and factor markets help to equalize wages and incomes across regions, they are not always sufficient. In India, for example, many areas of low potential rainfall have seen little improvement in poverty levels even while irrigated and high potential rainfall areas have progressed (Fan and Hazell, 1999). Regional inequalities have also worsened in China in recent years (Knight and Song, 1992). Worsening regional disparities seem most likely to occur when agriculture is still the predominant source of national employment, and when the non-farm economy is growing at only moderate rates. In these circumstances, the opportunities for out-migration from, and rural income diversification in, backward areas is likely to be smaller than needed. Where regional disparities worsen, increased public investment is needed in backward areas, particularly in roads, agricultural research and development, and education (Fan and Hazell, 1999).

Conclusions

Despite more than 40 years of research on the food problems of the developing world, and despite dramatic increases in food production as a result, controversy still abounds about whether agricultural research is beneficial to the poor. A huge body of empirical evidence has relevance to this theme, but it includes few studies that meet acceptable standards of analysis. This is particularly so with respect to establishing an adequate counterfactual (without technology) situation for comparative purposes, controlling for the many other variables that condition the multifaceted impacts of technological change on the poor, and assessing the indirect as well as the direct impacts.

Without such studies, drawing simplistic and misleading conclusions is all too easy. The most dangerous of these would be that governments and donors should cease to maintain adequate levels of investment in agricultural research on the food problems of the poor. No sound empirical basis exists for such a conclusion, yet if adopted and subsequently proven wrong, the consequences for the poor would be dire indeed. Agricultural research is a longer-term endeavor with long lead times between the initiation of new research and impact in farmers' fields. Funding decisions today will largely determine the kinds of research outputs that will be available to benefit the poor 10 to 20 years hence. More representative and best practice case studies are urgently needed to resolve this controversy once and for all.

Acknowledgements

In writing this paper, I benefited from a recent literature review and synthesis paper written for IFPRI and the Impact Assessment and Evaluation Group (IAEG), now the Standing Panel for Impact Assessment (SPIA), by John Kerr and Shashi Kolavalli (Kerr and Kolavalli, 1999). I also benefited from recent joint work with Lawrence Haddad and Mark Rosegrant on these topics.

References

Alston, J.M.; Marra, M.C.; Pardey, P.G.; Wyatt, T.J. 1998. Research returns redux: A meta-analysis of the returns to agricultural research and development. International Food Policy Research Institute (IFPRI), WA, USA. 44 p. (Environment and Production Technology Division Discussion Paper, no. 38)

Barker, R.; Herdt, R. 1978. Interpretive analysis of selected papers from changes in rice farming in selected areas of Asia. International Rice Research Institute (IRRI), Manila, PH. 166 p.

Blyn, G. 1983. The green revolution revisited. Econ Develop Cultural Change 31:705-725.

Datt, G.; Ravallion, M. 1997. Macroeconomic crises and poverty monitoring: A case study for India. Rev Develop Econ 1:135-152.

Datt, G.; Ravallion, M. 1998. Farm productivity and rural poverty in India. J Dev Studies 34:62-85.

David, C.; Otsuka, K, (eds.). 1994. Modern rice technology and income distribution in Asia. Rienner, Boulder, CO, USA. 473 p.

Fan, S.; Hazell, P. 1999. Are returns to public investment lower in less-favored rural areas? An empirical analysis of India. International Food Policy Research Institute (IFPRI), WA, USA. 40 p. (Environment and Production Technology Division Discussion Paper, no. 43)

Fan, S.; Hazell, P.; Thorat, S. 1999. Linkages between government spending, growth and poverty in rural India. International Food Policy Research Institute (IFPRI), WA, USA. 81 p. (Research Report 110)

Farmer, B.H. 1977. Green revolution? Technology and change in rice growing areas of Tamil Nadu and Sri Lankur. MacMillan, GB. 429 p.

Frankel, F.R. 1976. India's green revolution: Economic gains and political costs. Princeton University Press, Princeton, NJ, USA. 232 p.

Griffin, K. 1972. The green revolution: An economic analysis. United Nations Research Institute for Social Development, Geneva, CH. 153 p.

Griffin, K. 1974. The political economy of agrarian change. Macmillan, GB. 264 p.

Gross, D.R.; Underwood, B.A. 1971. Technological change and calorie costs: Sisal agriculture in Northeastern Brazil. Amer Anthropol 73:725-740.

Haggblade, S.; Hazell, P.B.R. 1989. Agricultural technology and farm-non-farm growth linkages. Agric Econ 3:345-364.

Haggblade, S.; Hazell, P.B.R.; Brown, J. 1989. Farm-non-farm linkages in rural sub-Saharan Africa. World Develop 17:1173-1201.

Hazell, P.B.R.; Haggblade, S. 1991. Rural-urban growth linkages in India. Indian J Agric Econ 46:515-529.

Hazell, P.B.R.; Haggblade, S. 1993. Farm-non-farm growth linkages and the welfare of the poor. *In*: Lipton, M.; van der Gaag, J. (eds.) Including the poor. World Bank, WA, USA. p. 190-204.

Hazell, P.B.R.; Ramasamy, C. (eds.). 1991. The green revolution reconsidered: The impact of high-yielding rice varieties in South India. Johns Hopkins, Baltimore, MD, USA. 286 p.

Hernández, M.; Hidalgo, C.P.; Hernández, J.R.; Madrigal, J.; Chávez, A. 1974. Effect of economic growth on nutrition in a tropical community. Ecol Food Nutr 3:283-291.

ILO (International Labor Organization). 1977. Poverty and landlessness in rural Asia. Geneva, CH. 288 p.

Kerr, J.; Kolavalli, S. 1999. Impact of agricultural research on poverty alleviation: Conceptual framework with illustrations from the literature. International Food Policy Research Institute (IFPRI), WA, USA. 197 p. (Environment and Production Technology Division Discussion Paper no. 56)

Knight, J.; Song, L. 1992. Income inequality in rural China: Communities, households and resource mobility. Institute of Economics and Statistics, University of Oxford, GB. (Oxf Appl Econ Discussion Paper Series no. 150 XY/ N-1)

Lappe, F.M.; Collins, J. 1977. Food first: Beyond the myth of scarcity. Houghton Mifflin, Boston, MA, USA. 466 p.

Lipton, M.; Longhurst, R. 1989. New seeds and poor people. John Hopkins, Baltimore, MD, USA. 473 p.

Mellor, J.W. 1976. The new economics of growth: A strategy for India and the developing world. Cornell University Press, Ithaca, NY, USA. 335 p.

Pearse, A. 1980. Seeds of plenty, seeds of want: Social and economic implications of the green revolution. Oxford University Press, NY, USA. 262 p.

Pinstrup-Andersen, P.; Hazell, P.B.R. 1985. The impact of the green revolution and prospects for the future. *In*: Price Gittinger, J.; Leslie, J.; Hoisington, C. (eds.) Food policy: Integrating supply, distribution and consumption. Published for World Bank by John Hopkins, Baltimore, MD, USA. p. 106-118.

Rosegrant, M.; Hazell, P.B.R. 2000. Transforming the rural Asia economy: The unfinished revolution. OUP for the Asian Development Bank, HK. 512 p.

Tribe, D. 1994. Feeding and greening the world: The role of international agricultural research. CAB International in association with the Crawford Fund for International Agricultural Research, GB. 274 p.

Von Braun, J. 1995. Agricultural commercialization: Impacts on income and nutrition and implications for policy. Food Policy 20:187-202.

Von Braun, J.; Kennedy, E. 1994. Agricultural commercialization, economic development, and nutrition. John Hopkins, Baltimore, MD, USA. 411 p.

Walker, T.; Ryan, J. 1990. Village and household economies in India's semi-arid tropics. Johns Hopkins, Baltimore, MD, USA. 394 p.

Chapter 4

Innovation Is a Social Process: What Does This Mean for Impact Assessment in Agricultural Research?

*Thomas Kuby**

Introduction

Legitimizing funding for agricultural research increasingly depends on demonstrating a visible impact on social and economic development—especially on poverty prevention, food security, and environmental protection. Impact assessment has become an important theme. In November 1999, for instance, the European Consortium for Agricultural Research in the Tropics (ECART) and the Association for the Strengthening of Agricultural Research in Eastern and Central Africa (ASARECA) organized a workshop in Uganda that aimed to establish impact assessment as a regular professional activity of agricultural research in the region. The focus was on institutional rather than on methodological issues. Like the CIAT 1999 poverty workshop, the ASARECA workshop also looked at the linkages between research and development.

Conceptual clarification is needed. Parallel to the increase of awareness for impact assessment a revitalization of linear models of innovation can be observed (Figure 1). Assessing impact might look easier if one could, at least in theory, establish a straight causative line between research and development. In reality, however, things are hardly ever that simple, especially when it comes to evaluate the really important development impacts such as poverty reduction. Although it is still comparatively easy to measure changes in the poverty level of a country or region over time, it is very rarely possible to attribute such changes to a single project, let alone specific agricultural research results. There is no use in playing down such attribution difficulties; the challenge is to deal with them productively.

With this intention, I present the argument of modern innovation research that innovation is a complex social process that cannot be reduced to a linear model. This done, I refer to some recent conceptual

* Senior Evaluation Expert, German Agency for Technical Cooperation (GTZ), Germany.

work of the internal evaluation team of the German Agency for Technical Cooperation (GTZ) that supports the conviction that, despite the complexity of the matter, impact assessment can be accomplished. The aim is to learn from science for the practice of impact assessment.

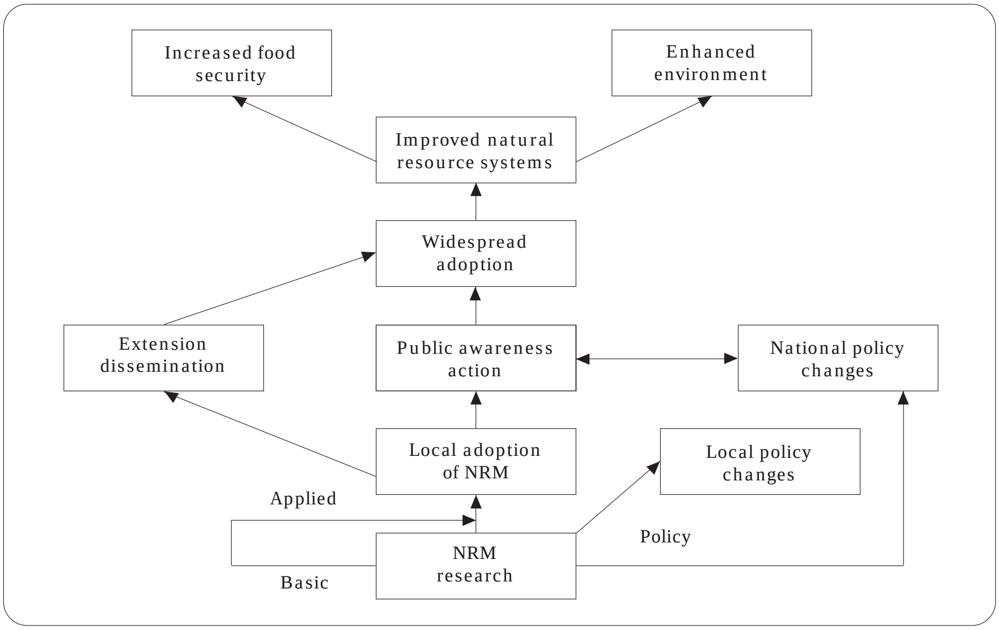


Figure 1. Recent linear impact model for natural resource management (NRM) research.

Overcoming Linear Models of Innovation

In order to understand how agricultural research **does** impact on development, we need to understand how it **could** have such impacts. To develop this understanding is the subject of innovation research. Let us try a rough sketch of how this important branch of social science started out with linear concepts, modified them, and eventually arrived at the notion of innovation as a social process.

Linear models of innovation

Reviews of early concepts of innovation usually begin with Schumpeter who, in keeping with his dramatized notion of the entrepreneur, saw innovation as a sudden, outstanding event that takes its origin from science, breaks through established technological barriers, and thus changes society. Up to the 1970s, the general consensus is that research and development (R&D), diffusion, and adoption are the main successive phases of any innovation process. Aregger (1976), in a standard work on innovation in social systems, spoke of "R&D-type models". Characteristically, they give research the decisive role in innovation, separate the whole process into distinct phases, and follow a linear, causative logic. The basic idea is that research has an output—a new technology and new practice, or a new object—that must be adopted in order to translate into economic and social development. Hence, the focus is on adoption or, to be more precise, on the "enablers" of adoption. Anything that might play a role in getting farmers to accept and apply an innovation is thoroughly investigated. How important are the characteristics of the innovation itself? What are successful communication channels? How do differences in education, location, or social interaction influence the adopters/receivers of an innovation? These are the main questions considered to merit scientific attention. Early innovation research has a clear "push-bias". Whilst agricultural research is associated with the source (or origin) of the innovation, farmers are seen to be at the receiving end. Aptly named the "receivers", they are mainly thought of as individuals who do not play an active role in the innovation process.

Rogers (1971) gave an overview of innovation research at the end of the 1960s, looking at some 1500 individual studies. As Rogers himself concluded, the survey revealed a considerable bias:

- Most of the studies dealt with results from physical or biological science such as fertilizers, herbicides, or antibiotic drugs; whereas innovation in the areas of ideas, political behavior, or human learning was almost totally excluded.
- The attention of the researchers was turned towards the individual adopter; group and system aspects of innovation hardly played a role.
- Innovation processes in modern (western) countries were much more thoroughly investigated than innovation and diffusion processes in traditional societies.
- Practically all of the 1500 studies reviewed dealt with the antecedents of adoption, whereas only 38 of them investigated consequences.

In the 1970s and 1980s, innovation research gradually departed from this uniformity.

Modifications of the linear model

Rogers (1971) introduced an important modification of the linear model. Citing Sharp's investigation of the introduction of the steel axe to a tribe of aborigines[1], he warned of the assumption that innovations would only have intended desirable consequences. Negative effects could not be excluded and farmers could not be expected to accept a new technology merely on faith. Research, therefore, should investigate and explain consequences, and conceptualize innovation as a process that includes not only R&D, diffusion,

1. For more details, refer to http://www.cc.gatech.edu/~kristin/writing/report.html

and adoption, but also consequences. Rogers acknowledged that studying consequences requires more time, deals with things that are difficult to measure, and has a big problem of attributing observed changes to individual research initiatives. Nonetheless, he urged all change agents to recognize their responsibility for the consequences of the innovations they introduce. To this end he proposed a new model for innovation research that integrated antecedents, process, and consequences into one coherent frame. At the same time, the model acknowledged the influence of norms and variables of the social system. Rogers' new model was a big step in directing research towards what we now call impact assessment. However, the individual farmer was still in the center, and Rogers continued to assume that individual knowledge and innovativeness, the degree of persuasion, and the individual decision-making process were the main determinants of adoption. Like most of the researchers of the 1950s and 1960s, Rogers built on a linear, causative linkage between research and development, with the difference that his new model did not stop at adoption, but continued the line to include the consequences of an innovation.

Other modifications of the linear model followed. One I would like to mention here has come to be known under the name of "induced innovation school" (Hayami and Ruttan, 1985). According to this theory, innovations are "pulled" rather than "pushed". Successful adoption mainly depends on economic incentives, especially on a shift in relative factor prices. Such a shift is considered sufficient to cause farmers to search for technical alternatives. The induced innovation theory has contributed considerably to making the economic conditions that enable or constrain innovation explicit. But it is still a linear concept that sees innovation essentially as a one-dimensional process that answers, in this case, not to the "push" of supply, but to the "pull" of demand.

More or less the same can be concluded from a further modification that Aregger, in his already mentioned investigation, classified as "problem solving". Today we would call this type of research "client-oriented" because it identifies the needs and abilities of the user (the farmer) as the decisive factors of any innovation. The problem-solving model is, so to speak, "two-directional". A feedback loop to the innovator is to assure that the output of research is compatible with what users need. The model has particular merits in giving a strong incentive for client-oriented research. However, for the argument presented here, it is of secondary importance whether the link between researchers and farmers is forward, backward, or two-directional. The question that needs to be answered is whether a linear model of any kind is an acceptable generalization of the reality of innovation.

Beyond the linear model

To structure my review of new insights of research in innovation I return to the main stages of the process, that is:

- R&D (the source),
- Diffusion (the channel), and
- Adoption (the receiver).

The analytical strength of these distinctions is convincing. There can be no doubt that research and development exist and produce a potentially innovating output, that R&D results are made known by the originators and tested by the users, and that adoption occurs. The difference between old and new research approaches is not about the analytical distinction of these steps, but about their properties and interconnection.

If we say that a process consists of "steps", which are different, but connected, we actually give a general description of a "system". Coughenour was one of the first to conceptualize innovation in such terms by distinguishing an "innovation system", a "linkage system", and a "practitioner system" as the constituting elements (or subsystems) of the overall innovation system (Coughenour, 1976; Chamala and Coughenour, 1987). The three subsystems directly correspond with the three phases constituting the linear model. So far, therefore, the system view is not much of a new insight. But it leads there. Whilst the constituting parts of the innovation process were formerly conceived as universally valid and separated, they are now seen as specific and connected.

Specificity of the innovation system

Without differences there would not be new ideas. Different views, options, and horizons are, as Engel (1997) observed, a precondition for innovation: "Nothing", he said, "could be worse than a contented network of social actors who agree on everything" (Engel, 1997, p. 151). Fortunately, such dull networks do not exist. The widely confirmed observation that specific "mental models" guide human action also holds for research communities. Johnson (1995, p. 31-34) gives a good description of the specificity of mental models frequently found amongst R&D personnel. He pointed out that the search for new knowledge is never totally unprejudiced: "The specific combination of skills, education, knowledge, and experience which characterizes the personnel of the R&D department, will influence ... the problems formulated, the methods chosen, and the solutions sought". This means that new ideas, procedures, objects, or technologies resulting from research cannot be equated with progress per se. They represent a specific form of progress that corresponds to, and carries the marks of, the routines and habits of thought of the R&D-community.

Research results are specific for other reasons too. With examples taken from the history of technology, Schmookler (1962) convincingly demonstrated that inventions follow economic incentives. Their frequency corresponds with capital investment rates and the expectation of increased profits will influence not only the topics of research, but also the solutions. Johnson (1995, p. 24) pointed out that institutional factors play an important role inasmuch as they have a fundamental influence on information flows and learning. The technological capability of a national system is conditioned by its institutional setup and this setup changes from nation to nation: "National economies differ regarding the structure of the production system and regarding the general institutional setup. Specifically, we see basic differences in historical experience, language, and culture reflected in the national idiosyncrasies..." (Lundvall, 1992, p. 13). Dosi (cited in Lundvall, 1992) spoke of "technological trajectories", meaning a specific concept of progress that is rooted in the institutional and economic setup, remains stable for long periods, and determines the general direction of progress. Following these trajectories leads research to solutions that look generic within the boundaries of one institution, but reveal themselves as quite specific when taken outside.

Specificity of the user system

If the innovation system produces specific solutions, the user system has specific requirements for accepting them. This becomes apparent if users are seen not as passive, individual receivers of a new technology, but as social groups that play a decisive role in shaping it. Innovation in agriculture happens through the interaction of farmers, veterinary doctors, district extension managers, farm advisers, technical specialists, and many more. But their interaction not only serves the transfer of knowledge and information, it also reflects social power and influence, the particular interests, concerns, and preferences of different social groups. It is on the basis of a thorough analysis of the characteristics of this interaction that today innovation is understood as a social process (Engel, 1997, p. 126).

The recognition of innovation as a social process replicates some of the technology debate of the 1970s. In this debate, a technical perception of technology development was gradually replaced by the recognition that technology is basically a social construct. It might therefore help to recapitulate some of the major arguments. Several of them came from Stewart. In her path-breaking analysis of technology in developing countries she explored the topic of technological compatibility (Stewart, 1978). By analyzing technical requirements and the process of technology choice, she gave a concrete description of how a new technology must "fit" into its environment in order to be introduced and applied. Stewart spoke of four requirements that impose restrictions on any development of productive technology:

(1) The nature of the product,
(2) The resources used for its production,
(3) The scale of production, and
(4) The complementary products and services needed.

Any or all of these requirements determine whether or not a new technique fits into an existing system. It is the degree of "fit" that decides over adoption or rejection. If the technique produces things that no one wants, if it uses resources that are not available, if it operates on an inappropriate scale, and if it requires complementary products and services that are not there, the technology will not be accepted, irrespective of how "good" the proposed innovation might be in technical terms and how much "push" is applied to its diffusion. In this way the user system heavily influences technology development.

The user system also influences technology development through the process of technology choice. A new technique or technology must fit existing requirements, as we just saw. But the requirements are different for different social groups. What is available or appropriate for one may not be available or appropriate for another. It is therefore important to understand the process of technology selection. Stewart showed how technology decisions by, for instance, subsidiaries of multinational companies differ in a systematic way from decisions made by local, small, self-employed enterprises. Her case studies supplied convincing evidence that technology choice varies in accordance with the nature of the decision maker. The findings of Stewart's research can be summed up as follows:

- Technology is not with an accidental agglomeration of hardware, but an integrated technical and social system that exhibits specific characteristics and constraints.
- In order to be adopted, a new technique must be compatible with the specific characteristics of the existing technology system.
- Adoption of a new technique happens on the basis of a selection process that varies in accordance with the nature of the decision maker.
- Decision makers interact not as isolated individuals, but as social groups with specific interests, preferences, and patterns of perception.

A new technique, in order to be **adopted**, must be **adapted**. Through a process of modification, alteration, and complementation it must be made compatible with the specific technical and social features of the existing system. If we distinguish between what an innovation is and what it means, even the meaning of an innovation must be in congruence with the value system of the receiver. Clearly such a complex process of adaptation could never be the result of purely intentional actions.

The process of adaptation

Innovation is not a single event, but a continuous process. It is the outcome of many incremental improvements that result in progress not because of a governing idea, but because of a highly recursive process of adaptation and assimilation. Adaptation happens in the user system through the users themselves, who play an active role in innovation. But adaptation happens in other places too, practically during all stages of the transformation of an idea into practice.

To account for the complexity of the process, Engel has proposed an "interplay model" that breaks the linear logic of earlier conceptions of innovation. It describes innovation in agriculture primarily as an achievement of the interaction of multiple social actors with highly diverse interests and perceptions. The diversity of types of knowing relevant to agricultural innovation is explicitly acknowledged. There is no straight, causative line, neatly divided up into phases and leading from one end to the other. The distinctions between individual phases are blurred. It even cannot be maintained that innovation always starts with research; users may just as well start it, it requiring an element of research only at a later stage.

Compared with a linear model, the interplay model seems chaotic. My attempt to draw a graphic of this model resulted in a sponge-like structure with dozens of larger and smaller cells and a cross-pattern of causation arrows laid over it (Figure 2). Each cell can be thought of as a social actor—a group, an institution, the lobby organization, extension services, etc.—with its own habits of thought, interests, and traditions. In such a structure, innovation is never totally accidental because it runs in "trajectories" that span larger groups of actors and have a high degree of stability over time and space. But the concrete overall result of intentional actions for diffusion is unpredictable. "Pushing" an innovation can be done of course, and will often make a difference, but not a big one. Sooner or later, the effects will get tangled up in a maze of complexities and become indistinguishable. If innovation happens like this, what does it mean for impact assessment?

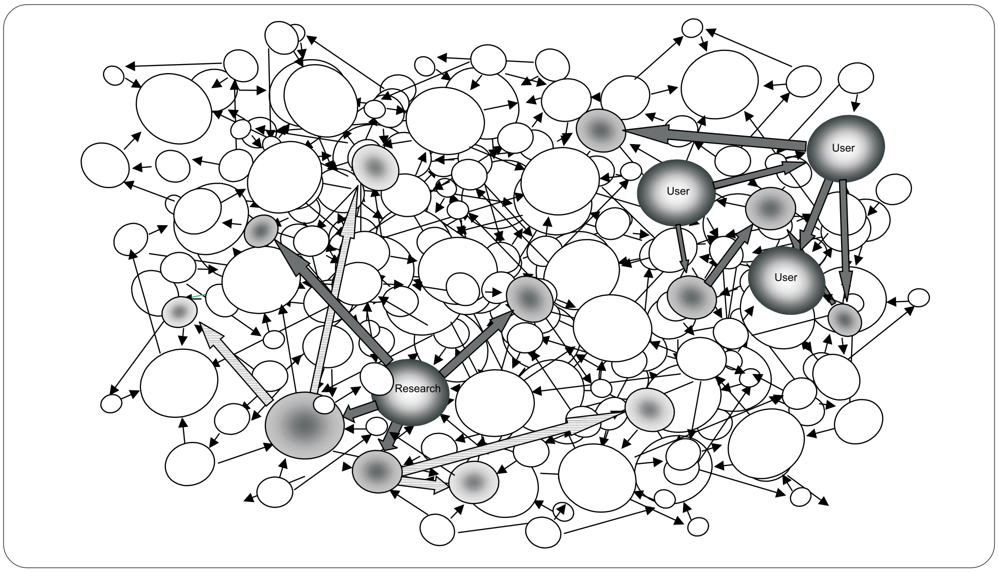


Figure 2. Social innovation system (each cell can be thought of as a social actor).

Consequences for Impact Assessment

Innovation as the result of social interaction—such a concept not only stands against planned impacts, but it also seems to make impact assessment impossible. If we look at the process from the research side, aiming for highly aggregated development results like poverty prevention, food security, and environmental protection, we are bound to acknowledge that such results are outside the control of the intentional actions of a single project. A project can work towards such goals, but what it does on its own will hardly ever guarantee that they are actually reached. If, on the other hand, we look at the impact chain from established development results, aiming to attribute them to a particular research activity, we cannot find (except under very special circumstances) a trace back to the actor. What presents itself as an "impact gap" when looked at from the research side, turns into an "attribution gap" when seen from highly aggregated development results. The "impact gap" affects management; the "attribution gap" affects impact assessment.

Much is to be said about the "impact gap" and how to deal with it in management. However, as an outsider to agricultural research, I would rather leave such advice to others. Röling has extensively written on the issue (see Röling and Jiggins [1998] for improved version). My impression is that his premises are much like the ones I have been following in this chapter. Although he seems to have done his earlier research on the basis of a linear innovation model, he now considers such models no longer an acceptable guideline for action. He confirms that innovation must primarily be understood as an outcome of social interaction. This, he says, has thrown agricultural research into a fundamental policy crisis. Röling's contributions to a new policy suggest that the recognition of innovation as a social process is a necessary conceptual basis for achieving full management effectiveness.

I have the same optimism with respect to impact assessment. Of course, things would be easier if we could work with a straightforward linear model instead of one that leads into an impenetrable maze of social interaction. Impact assessment for the Green Revolution was easier. The R&D output was a "hard" technology and it was indeed possible to trace a major agricultural innovation directly back to research. However, today such a case is rare. More typically, researchers produce "soft" results, such as information or advice that other actors use as inputs in broad innovation processes. The researchers contribute to the innovation process, but others contribute even more. In such cases, analysts usually encounter very significant challenges in attempting to attribute broad development impacts to one actor or another—particularly to the researchers who do their work so far back in the early stages of the innovation process. Nonetheless, impact assessment has become a must for agricultural research, and can be done. To say that impact assessment is difficult does not mean that it is impossible. Rather, it helps to develop impact assessment in appropriate forms.

To propose a possible approach I would like to share with you some of the conceptual thinking that my colleagues and I recently did for preparing the setting up of an internal evaluation unit in GTZ. As you may know, this organization has quite a track record in utilizing a goal-oriented planning method called Zielorientierte Projekt Plannung (ZOPP), based on a causative impact chain of the 1970s (called logframe). The ZOPP method nourishes the belief that a project that executes planned activities (a), (b), and (c), in an environment corresponding with the assumptions of the plan, will produce outputs that, by fulfilling the project purpose, contribute to the overall development goal. The method supports a comparison of planned and achieved results of projects and programs up to direct, empirically verifiable benefits. But beyond such a point it tends to be counterproductive. Even though technical cooperation may be said to be closer to development results than research, a "maze of complexities" remains in between. This maze does not allow for clear cause-and-effect linkages. In dealing with highly aggregated development results, the "factor weight" of a single project is far too small to be isolated from a mass of other causes.

Learning from field experience, my colleagues and I modified the ZOPP impact chain in two rather central aspects. First, we redefined the steps by which a project or program typically achieves results. While the original ZOPP only considered five such steps, we now distinguish seven:

(1) Inputs,
(2) Activities,
(3) Outputs,
(4) The use of these outputs,
(5) Direct benefits,
(6) Indirect benefits, and
(7) Highly aggregated development changes.

Second, we cut the hitherto continuous "impact chain" in two, acknowledging an "attribution gap" between direct and indirect benefits. With these modifications, the impact model allowed us to separate a seemingly unfeasible impact assessment into two doable tasks (Figure 3):

(1) Projects and programs are expected to deal with the **lower part** of the model. They are required to reliably and systematically monitor their work from inputs up to direct benefits. At the same time, they are no longer expected to account for indirect benefits, let alone their contribution to overall development change.

(2) The **upper part** of the model, beyond the attribution gap, describes the task of project-independent evaluation. In contrast to the focus of project evaluation—"Has the project done what it planned to do?"—project-independent evaluation works with a regional or sector perspective. The question to be answered is about development results irrespective of any contributor.

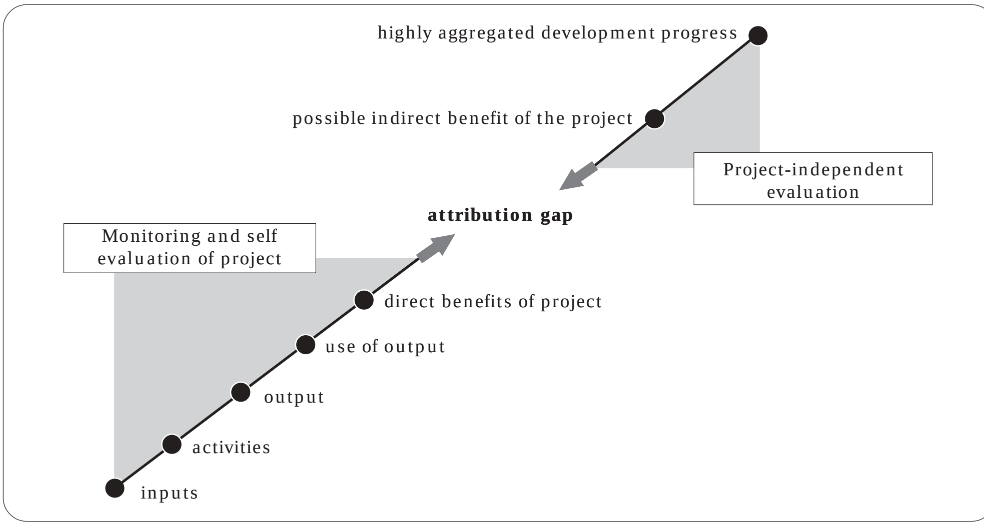


Figure 3. German Agency for Technical Cooperation (GTZ) impact model.

Engineers know that building a bridge from only one shore usually does not work. However, building it simultaneously from two shores, constructing half an arc on either side and making them meet in the middle, mostly succeeds. The same, I believe, is true for impact assessment. A project knows everything about its activities and outputs, but cannot verify its effect on overall development. On the other hand, observed development results usually cannot be traced back to a single project. But if project monitoring and evaluation describe the project from inputs to direct benefits and if, at the same time, project-independent evaluation provides a general pattern of development change, then chances are high that a plausible connection can be established.

In today's international evaluation debate it is widely accepted that, with respect to highly aggregated development results such as poverty reduction, project impact assessment must abandon the false ideal of "scientific proof". Instead, it should aim for plausibility. In the political arena, where the funding decisions are made, plausibility lies at the core of credibility. I would argue that, with the media full of environmental destruction, poverty, and war, nothing could be more devastating for the credibility of a development organization than an "82.3% success rate" reported in a glossy report with photographs of smiling target groups. People know that development is difficult and complex. Whilst they expect accountability, they will, in the long run, believe plausible arguments more than bombastic "proofs". Stories without facts will not do. Accountability requires facts about the (research) project as well as about development change. It is a realistic assumption that we can get these facts, provided we know what to expect from project monitoring and what to leave for others. It is also realistic to assume that, with project performance and results on the ground established, a plausible connection can be found (GTZ Working Group, 2002). Impact assessment is possible. If agricultural research makes use of this possibility, it will not have a problem with answering today's demands for accountability.

References

Aregger, K. 1976. Innovation in sozialen Systemen. Paul Haupt, Bern, Stuttgart, DE.

Chamala, S.; Coughenour C.M. 1987. Model for Innovation Development, Diffusion and Adoption (MIDDA): A system for agricultural development. J Exten Syst 3:47-55.

Coughenour, C.M. 1976. A theory of instrumental activity and farm enterprise commitment applied to woolgrowing in Australia. Rural Sociol 41:76-98.

Engel, P.G.H. 1997. The social organization of innovation: A focus on stakeholder interaction. Royal Tropical Institute, Amsterdam, NL. 239 p.

GTZ Working Group. 2002. Establishing plausibility in impact assessment. Paper presented at the CGIAR International Conference "Why has impact assessment research not made more of a difference?" 4-7 Feb 2002, San José, CR.

Hayami, Y.; Ruttan, V.W. 1985. Agricultural development: An international perspective. Revised edition. Johns Hopkins University Press, Baltimore, MD, USA.

Johnson, B. 1995. Institutional learning. *In*: Lundvall, B.A. (ed.). National systems of innovation: Towards a theory of innovation and interactive learning. Pinter, London, GB.

Lundvall, B.-Ä. (ed.). 1992. National systems of innovation: Towards a theory of innovation and interactive learning. Pinter Publishers, London, GB.

Rogers, E.M. 1971. Communication of innovations: A cross-cultural approach. Free Press, NY, USA. 476 p.

Röling, N.; Jiggins, J. 1998. The ecological knowledge system. *In*: Röling, N.; Wagemakers, A. (eds.). Facilitating sustainable agriculture: Participatory learning and adaptive management in times of environmental uncertainty. Cambridge University Press, Cambridge, GB. p. 283-312.

Schmookler, J. 1962. Economic sources of inventive activity. J Econ Hist 22:1-20.

Stewart, F. 1978. Technology and underdevelopment. Macmillan, London, GB. 303 p.

CHAPTER 5

Measuring the Impacts of Agricultural Research on Poverty Reduction: Improving the Dialogue between Policymakers and Research Managers

*Jeffrey Alwang** and *Paul B. Siegel***

Introduction

Increased agricultural productivity has been a primary engine of economic development in less developed countries (LDCs). Technical change in agriculture, the major source of increased productivity, requires sustained investments in agricultural research and extension. Substantial returns to agricultural research and extension have been reported in different countries throughout the world, including countries of sub-Saharan Africa (SSA). Masters et al. (1998, p. 84) report that "returns to research in Africa are similar to those found elsewhere, showing high payoffs for a wide range of programs." A notable exception is the low rate of return to research reported from Malawi. Frisvold and Ingram (1995, p. 59) report "... research has yet to generate broad sectoral productivity growth in SSA agriculture." Ahmed et al. (1995) question how accurate are conventional estimates of rates of return to agricultural research in SSA countries because of the prevalence of policy distortions. On the other hand, economic development in SSA has lagged behind other regions, largely because of the stagnation of agricultural productivity, especially among smallholders (Frisvold and Ingram, 1995).

Increased agricultural productivity can benefit the rural poor in a number of ways, especially when it raises returns to their meager asset base. However, debates are ongoing on how the benefits of technical change are distributed among subgroups within countries. Historically, many of the benefits of agricultural research and extension have accrued to better-endowed farmers and to urban consumers, bypassing poor rural producers (Binswanger and von Braun, 1993).

* Professor, Department of Agricultural and Applied Economics, Virginia Tech, Blacksburg, VA 24061, USA.

** Consultant, Social Protection Unit, World Bank, Washington D.C. 20433, USA, and Senior Lecturer, Dept of Economics and Management, Tel Hai Academic College, Upper Galilee, 12210, Israel.

During the 1990s, many SSA countries experienced numerous policy changes whereby traditional biases against agricultural and rural sectors were reversed. Also, the need for active pro-poor policies and investments is receiving increased attention. For example, agricultural research and extension was largely oriented to meeting the demands of export agriculture and paid little attention to the production constraints faced by smallholders, but is increasingly being redirected toward the needs of smallholders and the rural poor (Pardey et al., 1997; Rukuni et al., 1998). However, public investments in research and extension are under increased scrutiny as budget pressures tighten. In fact, in many SSA countries, budget allocations for agricultural research have been declining, and dependence on external financing (e.g., donor expenditures) has increased (Pardey et al., 1997). Policymakers are increasingly calling upon research managers to consider poverty reduction objectives when making resource allocations.

Exercises in research priority setting help managers understand how to allocate research investments to achieve progress toward objectives, which include economic efficiency. However, others such as poverty reduction are also important. It is often argued that agricultural research is a blunt instrument for obtaining non-efficiency objectives and, therefore, that research budgets should be allocated with efficiency alone in mind, leaving poverty reduction objectives to be addressed through alternative policy instruments (Alston et al., 1995). Given the increased poverty-reduction focus, it is appropriate for ex-ante planning and ex-post evaluation to include measures of the impact of agricultural research programs on the poor.

Background on Measuring Research Impacts and Measuring Poverty

Agricultural research evaluation: Economic surplus analysis

The primary means of evaluating the impacts of agricultural research is through economic surplus analysis in a partial equilibrium framework (Alston et al., 1995; Mills, 1998). When surplus analysis is used to examine the impacts of agricultural research on the poor (producers and consumers), they are usually grouped according to expenditure quintiles, or through the use of some other means of distinguishing between poor and non-poor households. Parameters (such as technology adoption, and supply and demand elasticities) are estimated for the respective subgroups (e.g., smallholders vs. commercial farmers, by agro-ecological zone, household headship), and the surplus gains and losses associated with each research portfolio are evaluated. Although gains and losses can be disaggregated by subgroup, there is no direct measure of the impact on the absolute or relative poverty of the subgroups or between them, and differences among households within broadly defined subgroups are ignored.

Mills (1997) and Mutangadura and Norton (1998) are recent examples of analyses based on economic surplus methods that focus on the distributional impacts of agricultural research. Mills (1997) evaluated, ex-ante, the expected impacts of sorghum research on producers and consumers in Kenya using a spatial multi-market model on four different agroecological regions. Mutangadura and Norton (1998) used farm types (large- and small-scale farmers), and natural region (high/low potential) to distinguish ex-ante between agricultural research impacts on different producer groups in Zimbabwe. Researchers were asked to estimate the productivity gains and probability of adoption of their research results under assumptions of zero funding increase and a 50% increase in their budget. The economic surplus gains and adoption rates for producers were estimated separately for the farm types and regions. These estimates were combined with crop acreage and yield information (by farm type and natural region) to generate net present values (NPV) that were incorporated into a multi-objective linear programming model. To examine how distributional concerns would affect the optimal research portfolio, and to assess the efficiency losses (i.e., tradeoffs) associated with targeting research toward the benefit of smallholders, the model was run with different weights placed on research objectives. These objectives were (1) efficiency, and (2) distribution of benefits. The model was run with different assumptions about budget constraints.

Economic surplus methods provide several advantages, including ease of use, theoretical soundness, and consistency with other measures of economic benefits and costs. Thus, for example, the impact of a sorghum research program on the poor can be compared to alternative poverty-targeted investments. A disadvantage of surplus methods as they are commonly applied is that they do not provide clear-cut evidence about the impact of a research program on aggregate poverty. Although rigorous application of an economic surplus analysis to agricultural research on the poor can provide evidence about which groups benefit most, it will not show how different measures of poverty change. Thus, research priority setting (and evaluation) efforts and national dialogues about poverty reduction tend to be disconnected. In such national dialogues, commonly understood measures of poverty are used, and policymakers and research managers need information on how a changing research portfolio will affect these measures. Such information should facilitate and improve communication on objectives and tradeoffs subject to budgetary constraints.

Poverty profiles and poverty measures

Poverty profiles (e.g., Alwang and Siegel, 1994; World Bank, 1996) are used to focus policy discussions, design and target specific programs, and as baselines for systems of monitoring changes in poverty over time. A typical poverty profile begins with a quantifiable poverty line, uses household data to measure incomes or consumption relative to this line, and aggregates over households to create a measure of poverty. This measure, often of the Foster, Greer, Thorbecke (FGT) class, can be decomposed to show how poverty varies across subgroups of society, such as region of residence, household headship, or sector of employment (Foster et al., 1984). The FGT class of poverty measures is defined as:

$$P_\alpha = \int_0^z \left(\frac{z-i}{z}\right)^\alpha f(i)di \qquad (1)$$

where i is income or expenditures of the poor, z is the poverty line and is measured in the same units as is i, and α is a parameter of inequality aversion. When $\alpha = 0$, then P_α collapses to the headcount index (the prevalence of poverty), and when $\alpha = 1$, then P_α gives the poverty gap index. For different values of α, the index provides information on different dimensions of the poverty problem. The FGT indices are often used because they are additively decomposable, which facilitates analysis. Additive decomposability means that the aggregate poverty measure, θ, can be decomposed as:

$$\theta = \sum_{i=1}^{m} f_i \theta_i \qquad (2)$$

Where there are m population subgroups (indexed by i), for example, regions of the country, f_i is the proportion of households in the i^{th} subgroup ($\sum f_i = 1$), and θ_i is the measure of poverty for the i^{th} subgroup. See Ravallion (1992) for a detailed discussion of additive decomposability, which he calls additivity. Using additivity, the contribution to overall poverty coming from a population subgroup can be decomposed rigorously. Similarly, the impacts on poverty of income transfers or economic growth in general can be assessed.

Typically, a poverty profile contains estimates of the impact of overall growth on poverty. These measures, called growth elasticities, are computed using the assumption that the overall distribution of well-being is unaffected by the change in question. As an example, consider the headcount (H) index of poverty (the percentage of total population below the poverty line, z). It is well known (Datt and Ravallion, 1992) that the headcount of poverty is related to mean consumption (μ) via the formula $\mu L'(H) = z$, where $L'(H)$ is the slope of the Lorenz curve evaluated at z. A simple growth elasticity can be obtained using this relationship. $L'(H)$ can be inverted to examine the sensitivity of the headcount to changes in μ, holding the Lorenz curve fixed. The other FGT indices can be obtained using analagous relationships (see Datt and Ravallion [1992] for details). The advantage of these relationships is that secondary data (e.g., information used to create the Lorenz curve) can be used to fit a paramereterized Lorenz curve and yield the elasticities without reverting to the primary data (which can often be difficult to access).

The problem with such methods is that growth is rarely distributionally neutral. Specifically, agricultural growth occurs through sequential adoption of technologies by regions, crop, agroclimatic conditions, etc. When growth is sector-specific or affects the distribution of well-being, then these simple methods are inappropriate. Productivity growth can be directly incorporated into measures of sector-specific, poverty-growth elasticities by reverting to primary data, or by developing a more detailed decomposition of the poverty-inequality-growth relationship (i.e., modeling shifts in the Lorenz curve).

Proposed Method for Measuring Research Impacts on Poverty

The impact of increased agricultural productivity on income distribution and poverty reduction depends on a number of factors. Often these factors and their impacts are not easily quantifiable. For instance, if increased productivity stimulates the demand for labor and the poor tend to be large-scale suppliers of off-farm labor, then indirect labor market effects may outweigh the direct effects of productivity gains on farming incomes of the poor. The methodology proposed here ignores many of these higher-order effects and focuses on the first-order impact of yield changes on household incomes. With household-level data, income growth associated with crop-specific yield changes can be aggregated to create measures of change in poverty and inequality.

The approach combines well-established methods for decomposing inequality by source of income with methods for decomposing changes in poverty measures into growth- and distribution-related sources. Kakwani (1993), for example, shows that changes in a poverty index (θ, often an FGT class of poverty indices, but not restrictedly so) can be decomposed into a component associated with changes in mean incomes and one associated with changes in inequality (usually summarized by shifts in a Lorenz curve). He goes on to show how the impact of sector-specific growth on overall poverty can be predicted, as long as the sectors are mutually exclusive (for example, growth in maize-related incomes are independent of changes in groundnut incomes). Under such conditions, the additive decomposability of the poverty measure can be used to partition changes in aggregate poverty into their sector-specific sources.

For instance, define $\chi(| \quad f(z, \sigma_j, L(m_{ij}))$ as the measure of poverty, μ_j as mean income for the j^{th} sector, m_{ij} as income of the i^{th} person or household from the j^{th} sector-specific income source, and S_j as the share of j^{th} sector income in total income. Changes in θ can be written:

$$d\chi \,|\, \frac{\in\chi}{\in\sigma} S_j d\sigma_j \; 2 \; \frac{\in\chi}{\in L} . \frac{\in L}{\in\sigma_j} d\sigma_j \; 2 \; —— \frac{\in\chi}{\in m_{ij}} dm_{ij} \qquad (3)$$

Changes in overall poverty are thus attributable to a pure sectoral growth effect (the first portion of the RHS), the impact of sectoral growth on changes in distribution (the second component), and a pure redistribution component. The second effect arises because different households along the total distribution of well-being are affected differently by a change in sector-specific income. For instance, if only relatively well-off households grow burley tobacco, an increase in its productivity will shift the Lorenz curve in such a way that it lowers the slope ($L'(H)$) at z. Thus, although the first component would predict a fall in aggregate poverty, the fall would be offset by the sector-specific redistribution component, ignoring labor market effects.

Households in most LDCs, especially in rural areas, receive incomes from a variety of sources, so that the partition of a poverty measure into mutually exclusive groups based on sector-specific sources of income is inappropriate. (This is particularly true for the many households with small landholdings in SSA countries.) For example, it is impossible to discuss poverty in agriculture alone, because few families receive income only from agriculture. Likewise, within agriculture, different crops represent different components of income. Instead, we need to partition aggregate income inequality into its component sources. The third component of Equation 3 captures this source-household specific effect. Sector-specific changes in income accruing to individual households along the well-being distribution lead to changes in overall inequality depending on the sources of income of the poor.

By measuring, for example, how agricultural income contributes to inequality in rural areas, we can determine how growth in agricultural income will lead to changes in overall inequality. Similarly, we can decompose agricultural income into its (crop-specific) sources to determine how technical change or policy change will affect income inequality. In fact, several decompositions of inequality exist and can be used to predict how total inequality will change following a change in income. These changes in inequality can then be combined with the poverty decompositions to tell how sector-specific income sources are likely to affect overall poverty.

Decompositions of inequality

A straightforward decomposition of inequality attributes overall inequality (as measured by a Gini coefficient) into its contributing sources (say K different income sources exist). Denote i_i as the total income of household i ($i = 1,\ldots,n$) and i_{ik} as the income of household i from source k. The distribution of total household income can be written $I = (f(i_1), \ldots, f(i_n))$, where $f(i_i)$ is the rank of household i divided by the total number of households when households are ordered in terms of increasing income. Similarly, the distribution of income component k can be written $I_k = (i_{1k},\ldots,i_{nk})$. Using this notation, the Gini coefficient can be written (see Stark et al., 1986):

$$G = \frac{(2\operatorname{cov}[I, F(I)])}{\mu} \tag{4}$$

To decompose the Gini coefficient by source of income, some additional notation is needed. Denote S_k as the share of income from source *k* in total income (that is $S_k = \mu_k/\mu$), and G_k as the Gini coefficient for income inequality from source *k* (that is $G_k = 2\operatorname{cov}[I_k, F(I_k)]/\mu_k$). Call R_k the Gini correlation of income from source *k* with total income:

$$R_k = \frac{\operatorname{cov}[I_k, F(I)]}{\operatorname{cov}[I_k, F(I_k)]} \tag{5}$$

Then, the overall Gini can be written:

$$G = \sum_{k-1}^{K} R_k G_k S_k \tag{6}$$

Income from source *k* affects the overall distribution of income in three ways: via its share of total income (the S_k component); through the inequality within the sample of income from source *k* (G_k); and through the correlation between source *k* income and total income (R_k). This decomposition can be incorporated into the Kakwani (1993) decomposition of poverty to separate the mean and the distribution effects of a change in a specific source of income on the aggregate measure of poverty. The decomposition can be applied either ex ante or ex post. Ex ante, a change in component-specific income can be used to predict the overall change in inequality and poverty. Ex post, we can examine how a change in inequality or poverty is caused by changes in component-specific income.

Combining the effects

To combine these effects, the analyst needs to model the relationship between a change in the Gini coefficient (from the inequality decompositions) and the change in the Lorenz curve (from the poverty decomposition). Unfortunately, there is no one-to-one mapping in the required direction (infinite combinations of changes in the Lorenz are consistent with a given change in the Gini). However, quick inspection shows that if sufficient information is available to measure the change in inequality from sector-specific changes in income (via Equations 5 and 6), then the shift in the Lorenz curve is directly inferable. We can always revert to primary data to forecast the change in income for specific households and thus measure the sources of change in poverty or inequality.

Alston et al. (1995) give a detailed account of issues such as adoption lags and technology depreciation, details that we are ignoring here. Four components then affect the impact of crop-specific research (and technical change) on household income and poverty. The first is the existing allocation of acreage to each crop (a_{ij}, with the vector of this acreage for the i^{th} household being denoted $\mathbf{a_i}$). The second is the forecasted change in yields caused by the new technology. This effect is denoted $y_j\,(1+d_j)$, where d_j is the percent increase in yield associated with the new technology, y_j is the "base yield" for crop j and $\mathbf{y_i}$ is the (Jx1) vector of yields for the i^{th} household. Define Δ as the (Jx1) vector of $1+d_j$. The third component of the effect of research is the probability of adoption of the new technology (p_j—the vector being $\mathbf{p_i}$). The final factor is the per-acre cost of production associated with existing and new technologies ($\mathbf{c_i}$). A specific research program may affect the yield, the probability of adoption, or the cost component, or combinations of each effect.

Data on acreage distributions, yields, and costs can be obtained from household agricultural surveys. The remaining components can be elicited from the scientists, using expert opinion, participatory methods, or in a number of ways (see Alston et al. [1995] or Mutangadura and Norton [1998] for examples). In practice, scientists need to be involved in the elicitation process, but participatory methods focused on farmers can help understand the determinants of technology adoption.

Each of the n potential resource portfolios can be evaluated in such a way, and nx3 vectors of yield changes, adoption probabilities, and cost changes can be constructed. Just as the "base yields" will vary from farm to farm, adoption probabilities will depend on considerations such as asset bases, access to credit, and agricultural services. In the following example, we assume that adoption probabilities are constant throughout the income distribution. These probabilities are, however, likely to vary substantially.

If these components are combined, then in matrix form the expected impact of the research vector is expressed:

$$E[I_i] \,|\, A_i'Y_i \div 'P_i \; 4 \; A_i'C_i \qquad (7)$$

Equation 7 is used to create a predicted agricultural income. This income (computed at the household level using primary data) is then used to recompute the poverty or inequality indices. In practice, $\mathbf{p_i}$, the vector of adoption probabilities, needs to be defined for each household. In order to compute the change in poverty, each household must be assigned a realized ex-post income level. Thus, multiplying y_{ij} by adoption probabilities is not correct; a threshold adoption probability must be adopted, and if the household-specific probability exceeds the threshold then the yield change associated with the technology should be applied. Because the poverty and inequality measures rely on household-specific information, forecast technology parameters (yields) have to be household-specific. Note that if an approximate measure (i.e., Equation 3 or 6) is used, then expected adoption rates can be used with group mean incomes.

Background Information on Malawi

We give an illustrative application of the method using data from Malawi, a country of interest because it has a history of policy biases that adversely impacted the rural poor. The government recently declared its intent to use agricultural research as a means of reducing rural poverty. With its history of research and extension priorities that either ignored, were inappropriate, or were inimical to the majority of the rural poor, Malawi's policymakers and the research-extension establishment continues to struggle with setting priorities that reduce, rather than perpetuate, widespread rural poverty.

Agriculture in Malawi has been characterized by a high degree of dualism between smallholder and estate subsectors. About 90% of rural households are smallholders. Production, marketing, and pricing policies reinforced Malawi's dualistic agricultural sector, maintained through its land policies. Smallholders were permitted to grow staple food crops and some cash crops, while marketing restrictions and pricing policies were enforced through the state marketing agency. Smallholders also faced restrictions with respect to input markets and prices (in some cases inputs were subsidized to "compensate" for low producer prices). In contrast, estates were permitted to produce lucrative export crops (notably burley tobacco, tea, and sugar), and to market them at international prices. Also, estates were allowed to import inputs. This dualistic system was designed and justified to stimulate agricultural-led growth. Estate-based, export-oriented agriculture was intended to be the engine of growth. Smallholders were to provide cheap food and labor for the estates, with income generated in the estate subsector supposed to be the vehicle for poverty alleviation. This "trickle-down" strategy failed because of several reasons, including the failure of agricultural research and extension to make significant inroads in increasing smallholder productivity. See Sahn and Arulpragasm (1991; 1993), Smale (1995), Zeller et al. (1998) for reviews of past policies.

Smallholders constitute about 80% of the population of Malawi and about 90% of the country's poor (World Bank, 1996). The median area under cultivation in the smallholder sector is about 0.6 hectares. Smallholders use hand hoes and other simple implements during cultivation. Production is almost exclusively rainfed with a single rainy season, which results in pronounced seasonality in factor and product markets. On the average, smallholder households receive about 70% of their cash and imputed income from on-farm production (poorer households with smaller landholdings tend to obtain a higher share of income from off-farm sources).

Smallholders devote the vast majority of land to the production of food staples, with maize accounting for about 70% of area planted to crops (World Bank, 1996). Per capita maize consumption in Malawi is the highest in the world. Although the objective of most Malawian smallholders is to be self-sufficient in maize, most are not (Smale, 1995). Small landholdings and low yields explain this failure to achieve maize self-sufficiency. Low maize yields and small landholdings are linked, because smallholders, who are unable to produce enough maize, seek off-farm employment to finance maize purchases and other consumption requirements, and often neglect their own fields (Alwang and Siegel, 1999).

Publicly funded (by government and donors) research and extension, mostly provided by the Ministry of Agricultural and Livestock Development (MoALD), serves smallholders. The estate subsector has its own research and extension services, generally funded by members. The major estate-focused research entity is the Agricultural Research and Extension Trust (ARET), which is funded by a 1% levy on tobacco auction floors. The main MoALD research institution is the Department of Agricultural Research and Technical Services (DARTS). Agricultural research funding levels have been below the 2% target share of total agricultural gross domestic product (GDP), and about half of the budget is donor-funded (Pardey et al., 1997; GoM, 1999).

Agricultural research in Malawi has been based on a distinct commodity-based approach, with the division of the research establishment into commodity groups. Commodity-based research programs are linked to international crop research centers, such as the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) for maize and CIAT for beans. The international crop research centers have strongly influenced research priorities within the commodity groups, with development of high-yielding varieties being a major objective. In the case of maize, until the early 1990s, priority was on open-pollinated, fertilizer-responsive maize varieties. It was thought that hybrid seed was too expensive and required better-input supply networks. However, adoption of improved maize and bean varieties has been constrained by the introduction of high-yielding varieties that Malawians dislike because of their unfavorable taste, processing, storage, and cooking qualities (Ferguson et al., 1990; Smale, 1995; Rukuni et al., 1998). The major success story of the early 1990s was the introduction of flinty hybrid maize varieties, locally bred, that solved these problems (Smale, 1995; Rukuni et al., 1998).

Over the years the GoM has made concerted efforts to promote improved technologies among smallholders through maize credit clubs, subsidized seed and fertilizer, and even free seed and fertilizer packages (distributed on several occasions in the 1990s as a response to widespread drought). Often these programs were targeted to “compensate” smallholders for legal, institutional, and policy biases. However, the majority of smallholders were not beneficiaries of this “system” of compensation, which created “dualism within dualism” in the smallholder subsector (Sahn and Arulpragasam, 1993). In 1993, about 30% of households had access to maize-linked credit and about 35% of maize plantings were hybrid varieties (Smale, 1995; Zeller et al., 1997).

Following the demise of the Banda dictatorship in 1994, the elected Government of Malawi (GoM) has attempted to articulate and implement a strategy that makes smallholder-led growth and poverty reduction the cornerstone of its development strategy (GoM, 1995). The major thrust of this strategy is guaranteeing the food security (actually maize self-sufficiency) of smallholders. The 1994 MoALD Strategy and Action Plan (GoM, 1994) established the Maize Productivity Task Force based on the conclusion that "increasing the productivity of smallholder maize production was the key to the development of the agricultural sector and the reduction of poverty" (Rukuni et al., 1998, p. 1082). However, although the agricultural research system has publicly declared poverty reduction to be among its top priorities, the "system" has not been significantly restructured. An exercise in research priority setting undertaken in conjunction with working groups preparing the MoALD Strategy and Action Plan ranked the objectives of increased productivity, efficiency, growth, and equity in descending order of importance (Babu and Khaila, 1996). This raises some questions about the declared, versus the perceived, priorities.

Reforms instituted through the structural adjustment program, adopted by the GoM in 1996, were a watershed in officially making poverty-reducing, smallholder-led development the foundation of its development policy. Reforms included annulment of legal restrictions on the production and marketing of crops by smallholders, and rescinded legal restrictions on input marketing and purchases by them. As of the 1996-97 crop season, smallholders were free to select crop production and marketing mixes. However, lack of confidence in food markets and the lack of financial markets, along with the lack of appropriate research and extension for high-value crops for smallholders, perpetuates the vicious cycle of poverty (Zeller et al., 1998; Alwang and Siegel, 1999). Further, the dualism within the smallholder subsector persists, because the better-endowed smallholders are those capable of adopting improved hybrid maize technologies and higher-value crops (notably burley tobacco).

An Illustrative Application of the Method to Malawi

To provide a baseline, we begin by calculating poverty indices (headcount, depth, and severity) for Malawian smallholders. The data are from the National Sample Survey of Agriculture (NSSA), which was carried out during the 1992-93 season (see World Bank [1996] for details). As can be observed in Table 1, poverty is pervasive among Malawian smallholders, with about 42% of all households below the poverty line. Some regional differences exist, with poverty most pronounced in the more densely populated southern region, where landholdings are smallest and soil-water conditions are less favorable.

Table 1. Smallholder poverty by region in Malawi.

Region	Poverty indices[a] (%)		
	Headcount	Depth	Severity
All Malawi	41.6	20.2	13.2
Northern	40.7	19.4	12.7
Central	33.8	15.8	10.1
Southern	47.3	23.6	15.5

a. From the National Sample Survey of Agriculture (NSSA) 1992-93. The poverty line used is the World Bank's (1996) relative poverty line.

Table 2 presents the relative distributions of scientist research time and smallholder crops. Although most smallholder land in 1992-93 was planted to cereals (about 70% of total land area was planted to maize alone), a much smaller percentage of total scientist time is devoted to cereals. In contrast, a relatively high proportion of scientists' time is devoted to tubers compared to the land devoted to such crops. Overall, scientists devote about three fifths of their time to staple food crops (cereals, tubers, legumes, and oilseeds), which account for about four fifths of land use by smallholders, and the remainder of the time to fruits and ornamentals, industrial crops, and vegetables and spices. The allocation of scientists' time seems to reinforce the traditional bias of "smallholder crops" being staple food crops.

Table 2. Distribution of research scientists by crop, crop acreage, and yields, Malawi.

Crop	Estimated total scientist research time[a] (%)	Estimated total smallholder land planted (1992-93)[b] (%)
Cereals	24	72
Tubers	17	2
Legumes and oilseeds	20	8
Fruits and ornamentals	9	N/A
Industrial crops	13	4
Vegetable and spices	17	9
Burley tobacco	–[c]	5

a. SOURCE: Agricultural Sciences Committee, National Research Council of Malawi, 1999. Percentages include all researchers in Malawi, including the Agricultural Research and Extension Trust (ARET) and private institutions.
b. SOURCE: National Sample Survey of Agriculture (NSSA), which does not have reliable estimates of fruit and ornamental plantings.
c. Burley tobacco is included in the industrial crops research portfolio.

Smallholders' cropping and land use patterns are likely to have changed significantly since the time of the survey (because of reforms and other factors such as changing relative prices). Burley tobacco acreage is likely to suffer from severe underreporting of problems because smallholders were prohibited from planting and marketing most types of tobacco at the time of the survey, but they have significantly increased plantings since the 1995-96 season (Zeller et al., 1998).

In practice, because of the fragmentation of agricultural research in Malawi, each institution or organization conducts planning and priority setting. The National Research Council of Malawi is supposed to serve as a coordinating body of agricultural research (GoM, 1999). The national planning process needs to be formalized and integrated on a real-time basis with the planning of the individual research institutions and organizations. As part of a priority-setting exercise conducted in 1994 by DARTS, research managers were asked to estimate crop-specific yield increases associated with a 50% increase in their budget. Table 3 presents a subjective combination of these forecasted yield increases. A notable problem with these elicited values and one that tends to be common with ex-ante studies is that the forecasted yield changes show only small differences across a wide variety of research programs. Such similarities obviously increase the influence of current (in the survey year) cropping patterns on the research's poverty-reducing impact. The information on adoption rates in Table 3 was not used in the subsequent application of the model, but is presented for interest (as explained earlier, the model requires household specific assumptions about adoption rates).

Table 3. Estimated yield changes and technology adoption rates from 50% increase in commodity-specific research budget.

Commodity	Yield change (% increase)	Proportion adopting
Maize	0.25	0.20
Roots/tubers	0.20	0.60
Groundnuts	0.25	0.10
Other grain legumes	0.30	0.25
Vegetables	0.15	0.60
Cotton	0.15	0.10
Rice	0.20	0.15
Sorghum/millet	0.25	0.15
Oilseeds	0.20	0.20

SOURCE: Based on Mutangadura and Norton (1998), and estimates by George Norton.

Another problem evident in Table 3 is the absence of burley tobacco, whose spread to smallholders has been touted as a main engine of poverty reduction in Malawi (Zeller et al., 1998). Because burley tobacco research is conducted by ARET, it is not included in DARTS planning and budgets. Clearly, this is an instance where priority setting for poverty reduction needs to be completed at the national level, incorporating the planning mechanisms of all research entities. An obvious issue is how to break down the official barriers perpetuated by the dualistic smallholder-estate system, and to translate policy reforms into institutional reforms and actions.

An important advantage of the model is that it can be used to create a profile of the impacts of research allocations on specific subgroups of the poor. For instance, research impacts are disaggregated by region of residence in Table 4 and by household headship in Table 5. To generate results in Tables 4 and 5, Equation 7 was computed using the forecast yield changes from Table 3 as an estimate of Δ. The headcount index of poverty following implementation of each research program was recomputed using the "forecast" income from Equation 7.

Table 4. Impacts of 50% increase in agricultural research budget by commodity on national and regional poverty indexes[a].

Commodity	National	Region		
		Northern	Central	Southern
Maize	39.9	38.5	32.4	45.6
Roots/tubers	41.5	40.1	33.7	47.2
Groundnuts	41.3	40.0	33.4	47.2
Other legumes	41.0	40.5	33.4	46.4
Cotton	41.5	40.7	33.7	47.1
Vegetables	40.2	39.9	32.4	45.7
Rice	41.5	40.4	33.7	47.2
Sorghum/millet	41.4	40.4	33.8	47.1
Oilseeds	41.6	40.7	33.7	47.3
"Baseline"	41.6	40.7	33.8	47.3

a. Computed using Equation 7 to re-estimate income and aggregate into the poverty headcount index. Poverty index was computed using the 1992-93 National Sample Survey of Agriculture (NSSA) data. "Baseline" from Table 1.

Table 5. Poverty indices by household headship following productivity gains[a].

Commodity	Male-headed household		Female-headed household	
	Poverty	Extreme poverty	Poverty	Extreme poverty
Before research	36.6	19.4	52.3	28.0
After research on:				
Maize	34.9	18.3	50.6	26.8
Roots/tubers	36.5	19.3	52.1	27.9
Groundnuts	36.3	19.3	52.1	27.7
Other legumes	36.1	19.0	51.3	27.4
Cotton	36.4	19.3	52.3	28.0
Vegetables	35.4	18.6	50.3	27.0
Rice	36.5	19.4	52.1	28.0
Sorghum/millet	36.4	19.3	52.2	27.9
Oilseeds	36.6	19.4	52.3	28.0

a. "Poverty" refers to the headcount (proportion) of households below the upper poverty line, and "extreme poverty" is the headcount below a lower line (see World Bank [1996] for information on the poverty lines used).

According to Table 4, maize research has the biggest overall potential impact on poverty reduction, and has a particularly strong potential impact in the north and the south. In the north, the impact is because of the high concentration of maize production. Maize is also widespread in the south where poverty rates are highest. Vegetable research should also reduce poverty, particularly in central Malawi, where agriculture is more diversified, and vegetable production is most common. With its relatively large share of the research budget and limited plantings, additional funds for research on tubers and roots would not have much of an impact on poverty reduction.

Across the board, the measured impacts on poverty of changes in the agricultural research portfolio are relatively small. This small impact is caused by several factors, including the flatness of the Lorenz curve near the poverty line, evidenced by the relatively large poverty depth index in Table 1. Other factors behind the relatively small poverty-reducing impact of changes in the research portfolio include the high degree of dependence on off-farm income for the poorest of the poor, and the relatively small percentage yield increases forecast by the scientists. Because the impacts on poverty are so small, changes in depth and severity indices—which are even smaller—are not presented here (although they are straightforward to compute).

The impact of increased research on burley tobacco is not shown in Table 4 because, as mentioned, burley was not part of the DARTS research portfolio. The poverty indices were recomputed using an illustrative 20% predicted yield increase from a 50% increase in the tobacco research budget. As of 1992-93, few poor smallholders grew burley tobacco. Because of this, the results indicate that burley tobacco research would have a negligible impact on poverty. However, since 1992-93, burley production has spread dramatically among even poor smallholders, particularly in the central region. To obtain a reasonable estimate of the current poverty reduction impact of increased burley tobacco research, new household data, such as those currently being collected by the National Statistical Office (the Integrated Household Survey Programme) need to be used in the future. These data reflect more accurately the post-reform cropping patterns and include measures of income and expenditures.

Smallholder households that are male-headed are much less likely to be poor and extremely poor than female-headed households. Such findings are common in SSA countries. As Table 5 shows, research has a slightly different impact on each subgroup. Although both subgroups benefit most from maize and vegetable research, a higher proportion of female-headed households are lifted out of poverty through this research. In addition, research on legumes has a stronger poverty-reducing impact among female- than among male-headed households. Research on rice, roots and tubers, groundnuts, cotton, and oilseeds has virtually no effect on poverty among any of the subgroups.

Agricultural research alone is likely to have only a small impact on rural poverty reduction in Malawi, although there are some differential impacts by region and headship. Based on the results presented in

Tables 4 and 5, priority areas for poverty reducing research should be maize and vegetables, whereas crops like roots and tubers, sorghum and millet, oilseeds, and cotton have negligible poverty-reducing impacts. As mentioned previously, these results might not be appropriate for current research priorities, because they are based on data that were collected before significant reforms took place. These reforms have changed the opportunity set and incentives facing smallholders, and resulted in changing cropping patterns, and the model needs to be updated.

The results reflect the problems encountered when using agricultural research for poverty reduction. Because Malawian smallholders (and those from other SSA countries) have smallholdings, depend on off-farm income, and face multiple constraints, many will be hard-pressed to benefit from agricultural research. The poverty problems faced by a large proportion of Malawi's smallholder population require a broader rural research and extension strategy in combination with policy reforms and instruments to enhance smallholders' meager asset base (Sahn and Arulpragasam, 1991; 1993; Rukuni et al., 1998; Alwang and Siegel, 1999). In order to appraise accurately the impact of research on smallholders, however, a comprehensive effort to model labor and commodity market effects is required. The method used in this paper can be easily combined with such broader modeling efforts.

Strengths, Limitations, and Extensions of the Method

The method presented in this chapter can provide a basis for dialogue between policymakers and agricultural research managers when deciding on resource allocations and assessing the impacts on poverty reduction. In contrast to widely used economic surplus methods, the proposed method has the advantage that it is consistent with commonly used measures of poverty. This should be helpful for research priority setting exercises.

Considerable attention has been devoted to developing measures of poverty and decomposing these measures in order to understand better how different factors influence household welfare. These existing measures and decompositions can easily be fine-tuned and applied to answer questions about poverty impacts of alternative agricultural research agendas. The major strength of the method is that it produces measures that are common "language" in national poverty debates. It also can be easily applied to widely available household survey data. These poverty measures have great flexibility, for example, when partitioning subgroups and comparing impacts on different subgroups. This is important because of the heterogeneity that exists in rural areas of developing countries. In the example, we disaggregated the sample of households by region and headship. It would also be possible, for example, to disaggregate the sample by "remoteness" based on distance from markets, rather than by a broadly defined "region" (where not all households might be remote).

Although the method can be implemented with relative ease using household surveys, the baseline data (e.g., cropping patterns and prices) generate a bias, especially in countries undergoing reforms and economic adjustment. A major weakness of the model, like many economic surplus measurement techniques, is that it reinforces existing (at the time of data collection) policy biases. In the Malawi case, policies in the early 1990s were biased toward maize production, and existing acreage reflects this fact. Following price and market reforms, the relative profitability of different crops has changed dramatically. Because of adoption lags, however, the full impact of policy reversals is not yet evident in cropping patterns and yield data. Thus, the household survey data need to be updated.

In addition, for rural households that obtain a significant percentage of income from off-farm sources, the proposed method (as presented) does not account for factor and product market effects that result from technical change. Also, because economic models on the impacts of agricultural research largely depend on data from research scientists, on expected yield responses, adoption rates, etc., more attention needs to be devoted to the generation of such data. Agricultural scientists and economists need to work together to improve these data.

In the application, we did not apply all of the poverty decompositions that could potentially be carried out. Application of these decompositions can provide information on which income sources are contributing to overall poverty reduction, and how agricultural research (and other public investments) can impact poverty. This should be a focus of future analyses.

A more forward-looking application of the method might involve the modeling of household adoption, production, and consumption decisions in a liberalized regime; the results of these models, disaggregated by region and farm type, could be used to predict the effects of different research portfolios on aggregate measures of poverty. Estimates of household income (from farm and off-farm sources) can be generated using programming models, which take into account different constraints and policy regimes (e.g., Alwang and Siegel, 1999). Alternatively, multi-market models (e.g., Mills, 1997), or computable general equilibrium models could be used to generate forecasts of price changes and to capture labor market effects. In short, changes in cropping patterns, yields, and household income need to be estimated, and then poverty measures can be recomputed, using the household data, to assess the impact of agricultural research on poverty.

Another extension of the model would be to construct optimization models for a country's agricultural research portfolio, such as Mutangadura and Norton (1998), with measures of poverty (e.g., headcount indices) as elements in the objective function. Using such an approach, efficiency-equity tradeoffs can be quantified and the marginal contribution on poverty reduction of budgetary outlays on different research topics (e.g., a given crop, or a broader theme such as soil conservation) could be calculated.

Acknowledgements

The authors would like to acknowledge the assistance provided by Professor George W. Norton, Department of Agricultural and Applied Economics, Virginia Tech. Funding was provided by Tel Hai Academic College's International Research Fund.

References

Ahmed, M.A.; Masters, W.; Sanders, J.H. 1995. Returns to research in economies with policy distortions: Hybrid sorghum in Sudan. Agric Econ 12:183-192.

Alston, J.M.; Norton, G.W.; Pardey, P.G. 1995. Science under scarcity: Principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca, NY, USA. 585 p.

Alwang, J.; Siegel, P.B. 1994. Zambia rural poverty assessment. Human Resources Division, Southern Africa Department, World Bank, WA, USA. 150 p. (Report Number 12985-ZA)

Alwang, J.; Siegel, P.B. 1999. Labor shortages on small landholdings in Malawi: Implications for policy reforms. World Dev 27:1461-1475.

Babu, S.C.; Khaila, S. 1996. Priority-setting in food and agricultural policy research: A case study and lessons from Malawi. Q J Int Agric 35:176-191.

Binswanger, H.P.; von Braun, J. 1993. Technological change and commercialization in agriculture: Impact on the poor. *In*: Lipton, M.; van der Gaag, J. (eds.). Including the poor. Proceedings of a symposium organized by the World Bank and International Food Policy Research Institute. World Bank, WA, USA. p. 169-189.

Datt, G.; Ravallion M. 1992. Growth and redistribution components of changes in poverty measures: Decompositions with applications to Brazil and India in the 1980s. J Dev Econ 38:275-295.

Ferguson, A.E.; Millard, A.V.; Khaila, S.W. 1990. Crop improvement programmes and nutrition in Malawi: Exploring the links. Food and Nutr Bull 12:273-278.

Foster, J.; Greer, E.J.; Thorbecke, E. 1984. A class of decomposable poverty measures. Econometrica 52:761-776.

Frisvold, G.; Ingram, K. 1995. Sources of agricultural productivity growth and stagnation in sub-Saharan Africa. Agric Econ 13:51-61.

GoM (Government of Malawi). 1994. Ministry of Agricultural and Livestock Development: Strategy and Action Plan. Lilongwe, MW. 64 p.

GoM (Government of Malawi). 1995. Policy framework for policy alleviation programme. Lilongwe, MW. 27 p.

GoM (Government of Malawi). 1999. Malawi agricultural and natural resources research master plan. Agricultural Sciences Committee, National Research Council of Malawi, Lilongwe, MW. 156 p.

Kakwani, N. 1993. Poverty and economic growth with application to Cote d'Ivoire. Rev Income and Wealth 39:121-139.

Masters, W.A.; Bedingar, T.; Oehmke, J.F. 1998. The impact of agricultural research in Africa: Aggregate and case study evidence. Agric Econ 19:81-86.

Mills, B.F. 1997. Ex-ante agricultural research evaluation with site specific technology generation: The case study of sorghum in Kenya. Agric Econ 16:125-138.

Mills, B.F. (ed.). 1998. Agricultural research priority setting: Information investments for the improved use of research resources. International Service for National Agricultural Research (ISNAR), NL. 151 p.

Mutangadura, G.; Norton, G.W. 1998. Agricultural research priority setting under multiple objectives: An example from Zimbabwe. Agric Econ 20:277-286.

Pardey, P.G.; Roseboom, J.; Beintema, N.M. 1997. Investments in African agricultural research. World Dev 25:409-423.

Ravallion, M. 1992. Poverty comparisons: A guide to concepts and methods. World Bank, WA, USA. 123 p. (Living Standards Measurement Study Working Paper no. 88)

Rukuni, M.; Blackie, M.L.; Eicher, C.K. 1998. Crafting smallholder-driven agricultural research systems in southern Africa. World Dev 26:1073-1087.

Sahn, D.E.; Arulpragasam, J. 1991. The stagnation of smallholder agriculture in Malawi. Food Policy 16:219-234.

Sahn, D.E.; Arulpragasam, J. 1993. Land tenure, dualism, and poverty in Malawi. *In*: Lipton, M.; van der Gaag, J. (eds.). Including the poor. Proceedings of a symposium organized by the World Bank and International Food Policy Research Institute. World Bank, WA, USA. p. 306–334.

Smale, M. 1995. Maize is life: Malawi's delayed green revolution. World Dev 23:819-831.

Stark, O.; Taylor, J.E.; Yitzhaki, S. 1986. Remittances and inequality. Econ J 96:722-740.

World Bank. 1996. Malawi: Human resources and poverty. Human Resources Division, Southern Africa Department, World Bank, WA, USA. 90 p. (Report no. 15437-MAI)

Zeller, M.; Diagne, A.; Mataya, C. 1998. Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity and crop income. Agric Econ 19:210-229.

Chapter 6

Poverty and Gender: A Strategy for Action

*Jacqueline A. Ashby**

Introduction

Women constitute nearly 60% of the world's one billion poor. Of one-third billion people living in absolute poverty, over 70% are women. Over the 1980s and 1990s, the number of women living in absolute poverty has risen by 50% (in contrast to 30% for men).

As the world population doubles, the need for food will more than double, and world agricultural output per unit of labor will need to increase by a factor of 10, mostly in the Third World (Marris, 1999). Food and Agriculture Organization (FAO) estimates show that women account for more than half the labor required to produce the food consumed in the developing world. In Africa, where female farming is of paramount importance, nearly 70% of the staple food in the continent is produced by women farmers and is of increasing importance as more men migrate from rural areas in search of work (Saito et al., 1990). This makes women in the Third World an important group, not only as beneficiaries of poverty alleviation, but also as contributors to the economic growth required to end poverty.

The different roles, rights, and resources that men and women have in society are an important determinant of the nature and scope of poverty. This is especially (although not uniquely) the case among rural populations in the Third World, where there is a central relationship between the capacity of rural households to produce enough income or food year round to meet their basic nutritional needs and the control women have over inputs and outputs in the food production-to-consumption system. Numerous studies show that rural women have not benefited as much as have men from decades of technical change in

---

* Director of Development and Rural Innovation, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

agriculture, but that new technologies contributed to reducing their control of assets within their household, increases in their workload as family laborers, displacement of their wage labor, reduced income-earning opportunities, and a lowering of their own and their children's nutritional status (for a summary, see Kaaria and Ashby, 2000). Although studies analyzing gender inequity abound, international agricultural research remains at best complacent, and at worst indifferent in the face of the rising poverty of rural women. There is a persistent reluctance in agricultural science bureaucracies to act on the need for a fundamental reorientation in order to be responsive and relevant to the special needs of poor women for technical innovation. The way agricultural research is organized, its problems defined, its priorities determined, and its resources allocated needs to change if there is to be any hope of making research accountable for an impact on the poverty of women.

This chapter examines the dimensions of poverty and the relationship between gender and the poverty of rural people in the Third World. This analysis is applied to formulate a strategy for the application of science and technology to improving food production and environmental protection, an agenda of central importance to rural women in the Third World.

The Dimensions of Poverty

Between 1965 and 1992, according to Marris (1999), global poverty was reduced by about one third to the extent that half a billion people came out of absolute poverty. Nonetheless, the absolute numbers of poor remain huge, at about 1.3 billion.

Absolute material deprivation is one dimension of poverty. The United Nations (UN) Human Development Report (UN, 1997) for example, uses five statistical indicators, all of which affect men and women differently, and are pertinent to describing gender-differentiated deprivation:

(1) Life expectancy,
(2) Malnutrition under 5 years of age,
(3) Illiteracy,
(4) Access to safe water, and
(5) Health services.

These indicators help to signal a degree of deprivation below which material survival is severely threatened, but they cannot tell us much about a number of other dimensions of poverty that are especially important to women.

Income is a key aspect of poverty because in the absence of any other material assets, it reflects the capacity of the individual or household to obtain the minimum amount of goods needed to survive in society by sale or exchange of their labor. For example, the UN classifies a Third World person as poor if trying to live on less than US$1 per day (adjusting for international differences in price levels). For the poor who lack material assets (the "laboring poor"), their income depends on the value of their labor. One interpretation is that unemployment, underemployment, low paid work, and unpaid work necessary to the maintenance of social life—and performed largely by women—subsidizes the cost of wage labor in the market and provides a pool of cheap labor when required, thus keeping down overall wages and production costs. Thus, efforts to reduce the poverty of low-wage people, and particularly women, through income generation need to take into account the possibility that poverty based on the low value of their labor is a functional component of global as well as local market structures. Alleviation of this kind of poverty over the next half century will depend on increased overall economic growth, population control to keep the supply of labor from growing faster than demand, and a demand for labor that exceeds supply (Marris, 1999). This has some important gender implications, explored in the next section.

Any discussion of the dimensions of poverty needs to go beyond the measurement of income required to provide the minimum amount of goods for survival. A useful framework for analyzing the gender dimensions of poverty differentiates four dimensions that complement one another: starvation, subsistence, social coping, and participation (Dean, 1999, p. 8, after George and Howards, 1991). Relative poverty is as important as material poverty once starvation is overcome or basic physical survival is achieved. Inequality therefore, remains an important dimension of poverty even when we consider subsistence, which has socially defined standards that vary from one culture to another. Projections suggest that the richest countries of the First World (about one tenth of world population), with over half of world gross domestic product (GDP) will soon be more than 10 times better off than the poorest countries of the Third World (Marris, 1999). Some analysts show that wealth is becoming more concentrated. According to a UN report, the world's 358 billionaires in 1996 were wealthier than the combined annual incomes of the poorest 45% of the world's population (2.3 billion people). Whereas the richest 20% of the world's population were 30 times better off than the poorest 20% in 1960, by the mid 1990s they were 61 times wealthier (cited in Dean, 1999).

Sen (1997) provides a concept of relative poverty highly pertinent to analyzing the gender dimensions of poverty based on the individual's capacities or capability to do many of the things valued in the society. This is similar to Runciman's (1966) concept of relative deprivation and Peter Townsend's (1979, p. 31-57) concept of relative poverty, defined as the "lack of resources to obtain the types of diet, participate in the activities, and have the living conditions and amenities which are customary, or are at least widely encouraged and approved, in the societies to which they belong." An important contribution by Townsend was to define the poverty line as a situation in which people are excluded from participation in key aspects of the public life of ordinary citizens, a concept that others have built upon (e.g., Scott, 1994) to interpret poverty in terms of either participation in, or "social exclusion" from, the ordinary things that other members of society enjoy.

The high degree of global material inequality at the end of the 20th century influences what it means to be poor in relative terms. An example is the emergence of a privileged group in the labor force and among consumers whose members have access to personal computers from childhood, are highly computer skilled, and are Internet literate. Their influence in the global economy can make access to computers and computer skills an important element of relative deprivation and social exclusion and, ultimately, determine the value of the labor of vast numbers who have not acquired these skills.

The concept of social exclusion is important for rural women because it provides a framework for understanding poverty in terms of different dimensions of participation, whether privileged participation or deprived participation. Jordan (1996) distinguishes between communities "of fate" and communities "of choice" as dimensions of poverty or wealth. Communities of fate are entrapped by a particular set of social and ecological circumstances, including coercion and subordination, both highly relevant dimensions of the poverty of women in Third World societies, as discussed in more detail in the next section. Communities of choice, in contrast, have the freedom and the power to define and benefit from social exclusion and privilege.

Powerlessness is therefore a key dimension of a definition of poverty, although it is poorly operationalized in research. One way to conceptualize poverty in terms of powerlessness is to analyze the social distribution of risk or opportunity. At the negative end of this powerlessness spectrum might be the risk of loss of control over one's own body (e.g., of being sold into slavery or prostitution). At the positive end of the spectrum might be the opportunity to migrate to wealthier and higher-wage societies.

Understanding poverty in terms of powerlessness has to be related to lack of resources as well as to social exclusion from participation or levels of income. For this reason, the concept of asset accumulation is an important one. Assets may be material capital (land, usufructory rights of important natural resources, savings, jewelry, livestock, or other kinds of physical capital), human capital (education and skills), or social capital (organization). Different categories of impoverishment can be identified from the cross-classification of income with asset accumulation. For example, people with relatively high income, but low asset accumulation, will be more vulnerable to unemployment or business downturns that pitchfork them into poverty, than will people with lower incomes, but enough assets to tide them over difficult times. Asset accumulation is therefore particularly important to identifying poverty in terms of exposure to the risk or vulnerability.

In summary, some dimensions of poverty can be usefully defined for analyzing relationships between gender and poverty related to starvation (or absolute material poverty), subsistence, social coping, and participation. Income levels and, in the absence of other assets, the value of labor are essential determinants of absolute material well-being as well as the capability to achieve the minimum goods defined by the society in question as necessary for subsistence. Beyond material survival, socioecological factors (race, gender, geographical location) can be as important as income in determining access to or exclusion from the things that society defines as important for well-being, as well as degrees of participation and powerlessness. Asset accumulation is a factor in the capability of individuals to cope with hardship and to manage risk.

Gender and Poverty

The different roles, rights, and resources that men and women have in society are an important determinant of the nature and scope of their poverty. These differences are culturally constructed and historically determined; they are supported by social organization and economic systems. As such, they can change; and it is a widely held thesis that the allocation of work and the valuation of women's labor have to change if the poverty of men and women is to be eliminated.

The relationship between poverty and gender is especially important because of the positive effect that increasing women's incomes and education has on nutrition, child survival, and, as child survival rates improve, on declining birth rates. When unwaged household production is valued, women's contribution is estimated at between 40%-60% of total household income (Goldschmidt-Clermont, 1987). This means that efforts to control population growth and provide employment for the poor must build on the provision of decent incomes and education for poor women.

Different types of women experience different degrees of poverty or wealth in society. Third World rural women may be unpaid or paid family laborers; they may be wage laborers outside the household, independent or joint entrepreneurs involved in a small business or in trading; they may be landowners in their own right or jointly with relatives. It is therefore erroneous to discuss Third World women and poverty as if one generic situation were common to all women. Unfortunately, however, there is a dearth of comparative studies that relate different types of women to corresponding levels and types of poverty, taking into account the several dimensions of poverty discussed in the previous section, and compare their poverty with that of men. This is a serious gap in the research.

At present, therefore, the best we can do is to draw together a series of observations based on individual studies, each of which offers some insights for the overall picture of gender-related poverty and inequality.

Women's income and poverty

A number of studies conducted in the last decade show that poverty and food availability depend on women's income, because men and women spend income under their control in different ways. The level of women's income is substantially and positively related to household calorie availability, child health, and survival. Women typically spend a high proportion of their income on food and health care for children; men use a higher proportion for their own personal expenditures (Von Braun and Pandya-Lorch, 1991). For example, one study in Guatemala estimates that average yearly profits from nontraditional export crops would double household food expenditures if women, rather than their husbands, controlled them.

Women's assets, participation, and poverty

Unequal rights and obligations, heavy time pressure to do multiple jobs, lack of access to land, capital, and credit, low levels of participation in agricultural extension support programs, education, and collective organizations all prevent women from achieving the same levels of productivity as men. Many examples of these constraints have been documented. For example, plots of land controlled by women have lower yields than those controlled by men because of lower access to technology and inputs such as fertilizer and labor. The potential for growth and food security that could result from improving women farmers' access to resources, technology, and information are as large or larger in some cases than the gains expected from breeding "super-plants". Some estimates show that reducing the time burdens of women could increase household cash incomes by 10%. Estimates of how much women farmers' yields could increase, just by giving them the same level of inputs and education as men farmers enjoy, range from 7%-24% (Scott and Carr, 1985; Von Braun and Webb, 1989; Buvinic and Mehra, 1990; Carney, 1992; Alderman et al., 1995).

Rural women's constraints to labor productivity, their confinement to drudgery in traditional, low-return activities, their restricted opportunities for asset accumulation, and their unequal access to property rights, capital, education, information, and knowledge are features of poverty in the form of the deprived participation that characterizes "communities of fate" entrapped by social and ecological circumstances, including coercion and subordination (Jordan, 1996).

Access to technology and poverty

The failure of technological innovation in agriculture to make a substantive improvement in the well-being of rural women is a dimension of their poverty rooted in their powerlessness and social exclusion. The record is mixed with respect to new agricultural technologies that have **not** been designed to benefit women, but have had unintended or indirect effects on women; in some cases, women along with men, have succeeded in adopting new varieties and other production technologies; in other cases, women have been unable to process high-yielding varieties developed without attention to postharvest qualities; in other cases, women laborers have been displaced by the introduction of high-yielding varieties together with less labor-intensive or more male labor-using technologies. In contrast, technology transfer aimed at women has been largely restricted to a few of women's existing activities, in particular traditional work related to housekeeping and childcare. For example, cooking stoves have received a vast amount of attention worldwide. There have been several large-scale initiatives, such as the United Nations Development Fund for Women (UNIFEM) global program, along with a vast number of projects attempting to provide improved technology to women in their traditional productive work, but "the transfer of larger and more complex technologies to women has been virtually non-existent" (Everts, 1998). Much technology transfer aimed at women has been carried out in isolation from research, hampering adaptations of inappropriate technologies and novel inventions responsive to women's needs and constraints, even where understanding of these is comprehensive.

A different example is the Women in Rice Farming Systems (WIRFS) program developed at the International Rice Research Institute (IRRI) to institutionalize gender concerns within agricultural research (Paris et al., 1995). This program found that a research agenda that incorporated women's priorities took the program beyond rice commodity research to address other features of farming, such as small livestock, the benefits of which accrued specifically to women, but which by definition were outside the mandate of the Rice Research Center and Networks. By taking women's needs and constraints as a starting point and relating these to the division of labor and power within households, the WIRFS program was able to identify new priorities for research. This enabled the program to develop innovations that simultaneously reduced drudgery, increased women's labor productivity, and provided increased income over which women retained control. Despite its impact in reorienting research and technology development "from within" to specifically benefit women, the WIRFS program remains an isolated example of success within the research institution that initiated it.

Powerlessness, risk, and poverty

The violence that affects the lives of poor women in the Third World is better documented now than previously and shows the many facets of their powerlessness in the most elementary respects: millions of female babies destroyed at or soon after birth such that there is a big "population gap" in female vs. male births in the Third World; the sale of young girls into forced labor, prostitution, or as child brides; the ritual mutilation of female sexual organs; and physical violence used to control women's labor in the household. Other forms of social violence include abandonment of mothers to cope in female-headed households, and denial of property rights.

Poor rural women are highly vulnerable to deprivation in terms of nutrition, health, education, asset accumulation, skill building, and participation in collective organization because they tend to provide the "safety net" that protects their children and household against catastrophic poverty. The foundation of this safety net function is the division of labor that allocates a disproportionate share of un-waged or under-waged household and family maintenance work to women. The United Nations Development Programme (UNDP) estimated the value of this type of work at $16,000 billion of global output; of this, women carried out $11,000 billion worth (UNDP, 1995).

Third world women's un-waged work includes activities (e.g., cooking meals, fetching water and firewood, or caring for the sick) that make it possible for laborers, small farms, and businesses to work and produce at lower returns to labor and capital than they could otherwise manage. One example illustrates this process. We costed the labor family women put into a single activity, cooking for field workers in the course of production of a field crop, at what it would cost the male head of household to hire a non-family member to do this task. The cost of hiring made the production of the crop unprofitable; and the conclusions of the economic analysis were borne out by the decisions of male producers in the community not to produce this crop if they did not have a family member to cook for the field workers (Ashby and Guerrero, 1985).

A detailed case study carried out in Kenya illustrates a situation of which there are multiple examples: women are increasingly the sole providers of labor on farms, because men migrate to higher wage opportunities, and women's labor is of lower value in the labor market. The added pressure on women's time led to low labor productivity on farm, particularly in female-headed households where women neglected on-farm tasks in order to hire out their labor to obtain income to meet the immediate food needs of the household (Mutoro, 1997).

Another study suggests that women's small enterprises, such as food processing and trading, provide a similar "safety net" function. Most of the enterprises owned by women are very small (maximum 25 employees), have low profit margins, are part-time or seasonal, and are frequently run from the home so as to be combined with household responsibilities. Female entrepreneurs often do not increase investment in one specialized activity in order to maximize growth in their business; instead, they diversify to minimize risks to stabilize income, which guarantees basic food security. This safety-first orientation is often a response to the more risky strategies undertaken by other family members that are underwritten by the women's provision of a safety net (Downing, 1991).

This finding that innovators' risk taking in poor households is underwritten by the family, and in particular by women, who provide basic food security, is similar to the results of a study that examined the family background of poor farmers introducing risky new agricultural technologies and found that the early innovators were more likely to belong to extended families. The individual innovators were young men who did not own much land and who worked as sharecroppers or farm laborers, but who belonged to an extended family unit with assets of land and household labor that enabled them as a group to absorb losses and cushion the individual from economic catastrophe. Young women did not have access to this pattern of familial support for agricultural innovation (Rivera and Ashby, 1985).

The low value of women's time and women's work is an important reason why development efforts that provide technologies and income earning opportunities directed at women's traditional activities have largely failed to have a significant impact. Unless there is an activity with a higher return to labor that generates additional income and that does not undermine the "safety net" function of women's economic contribution to the household, women have no incentive to save time in traditional activities, especially if this requires expenditure on new technology.

Therefore, one of the key interventions needed in poverty eradication is the identification of new opportunities for income generation that has superior returns to labor compared with women's traditional work. These need to be combined with support mechanisms for the "safety net" functions for the household provided by women's work and income.

A Strategy for Action

Several actors in the international development effort to eliminate poverty have taken important steps towards mainstreaming attention to gender and impact on poor rural women over the past 3 decades. In 1979, the UN Convention on the elimination of all forms of discrimination against women was adopted. In 1989, the declaration on violence against women followed. The Beijing declaration and platform for action formulated in 1995 at the UN Fourth World Conference on Women was another milestone. Other important commitments are stated in the World Bank since the publication of its paper "Enhancing Women's Participation in Economic Development" in 1994. The Organization for Economic Cooperation and Development (OECD) gave its position statement "Gender Equality: Moving towards Sustainable People-Centered Development in 1995; and the European Union policy statement "Integrating Gender Issues in Development Cooperation " was also issued in 1995. However, action lags far behind the statement of good intentions. For example, the Consultative Group on International Agricultural Research (CGIAR), a $360 million consortium supported by the same donors who issued the above statements, integrated gender analysis as a program in its mainstream research agenda in 1996. A headcount of the number of research studies considering gender reported shows a rise from 140 studies in 1995 to 227 in 1998. There is no reason for complacency about this steady improvement. An analysis of these studies shows that only 11, or 14%, of the studies reported were specifically developing technology to benefit rural women.

The full integration of gender analysis and the participation of men and women farmers as partners in international agricultural research and technology development requires a three-pronged strategy that consists of:

(1) Catalyzing collaborative research to generate sound evidence on the benefits in terms and impact of differentiating the needs of men and women as users of technology, and recognizing their different contributions as participants in research.
(2) Supporting capacity building with the centers to increase skills and knowledge to use gender analysis effectively and appropriately.
(3) Promoting information dissemination and exchange about best practices and lessons learned.

Key elements of a strategy

If we are to take the phrase “empowering women in agriculture” as more than a cheap slogan, then we have to work from the foundation relationship between gender and the several dimensions of poverty outlined earlier. Mainstreaming gender into the existing research agenda will not be enough if that agenda is systematically failing to take into account the sources of income and the assets upon which women in poor households depend. The effects of globalization create a pressing need to find alternative sources of income in situations where traditional means are no longer economically viable. These effects require us to go beyond adjusting technology to fit with the traditional responsibilities and constraints faced by poor men and women farmers. We need to be actively looking at new alternatives in the global economy and the gender-differentiated needs for technology, skills, and information required for a frontal attack on poverty.

Strengthening the capacity of global agricultural research to take on this task has at least three important elements. The first is to identify new livelihood opportunities for the poor in relation to a changing demand for agricultural technology that is analyzed separately for men and for women. A coordinated diagnostic research initiative is needed to identify rapidly the priority geographical areas and populations in which gender-differentiated research and technology development has potential for high payoff in combating poverty. This diagnosis needs to include the development of a geographic information system (GIS) minimum database, using available data with expert input to identify areas of the world where women’s special needs require priority attention. The diagnosis also requires the design sample of areas using the GIS minimum database to define priority geographic areas for rapid appraisal of gender differentiated opportunities and needs. Another necessity, in sampled areas, is to network with grassroots organizations and nongovernmental organizations (NGOs) to select technology innovation opportunities that look promising for rural women.

The second element of a strategy for action is to organize research so that it is more responsive, relevant, and accountable to specific client groups, especially poor rural women. Researchers and client groups need to make use of the large body of information already in existence on gender, agriculture, and technology for women. Research systems need strong interactions among technology designers, technology producers (such as small-scale artisans, some of whom may be women in the Third World), and technology users (see for an example, Everts [1998]). Working together, this is a constituency that could select priority entry points where research is needed to promote the development of innovative agricultural technology by and for rural women in selected areas, and the policy interventions needed to ensure access. Research organizations, such as the CGIAR centers and national agricultural research programs, need to institutionalize regular technology evaluations by a network of gender-differentiated user groups, as feedback to research on technology design. A consolidated, interactive, user-friendly database on evaluations of technologies for women, with regular consultation to update the diagnosis of needs and the evaluation of technologies, and monitoring and evaluation of impact of gendered research would provide a solid foundation for relevance to poor women.

As a third element, strategy for action must include support for rural women to increase their access to and control over assets, whether in the form of physical, human, or social capital. The development of technological innovations to benefit women is essential. The focus should be on poverty alleviation, and protecting women’s traditional rights to land and other resources, including water, forest, and grazing. Often this requires enabling policy in tandem with participation in an effective, collective, community-based organization. In general, women’s access to collective organization for resource management, health and childcare, credit, information, marketing, and small enterprise development needs strong support. Formal education and access to informal education and skill building is an essential ingredient of the effort to build women’s access to secure non-traditional sources of income with forward linkages to improving child survival rates and decline in the birth rate.

Poverty and gender are fundamentally related through the powerlessness of women. The control women have over assets, inputs, and outputs in the food production-to-consumption system, including income, is a key determinant of their family’s capacity to meet basic nutritional needs year-round. Few poor rural women exercise much choice over their bodies or their lives. They are members of a community "of fate", constrained by intra-household dynamics in which their bargaining power is weak, their access to assets constrained, and the pressure on their time to undertake the drudgery of domestic production and reproduction is relentless. Research and development is still pitifully inadequate to address the need to improve the appropriateness of technology that can relieve drudgery, increase the value of women's time, enhance food security, and increase the income they control. Preaching about poverty and gender is tiresome and there is a surfeit of analysis. Action is needed to change agricultural research and development institutions so that they become responsive to the huge, unarticulated demand of poor rural women for technical innovation.

References

Alderman, H.; Hoddinott, J.; Haddad, L.; Udry, C. 1995. Gender differentials in farm productivity: Implications for household efficiency and agricultural policy. FCND Discussion Paper no. 6. International Food Policy Research Institute (IFPRI), WA, USA.

Ashby, J.A.; Guerrero, M. 1985. The contribution of women's domestic labor in small farm production systems in Cauca, Colombia. Unpublished paper. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO.

Buvinic, M.; Mehra, R. 1990. Women and agricultural development. *In*: Eicher, C.K.; Staatz, J.M. (eds.). Agricultural development in the Third World. Johns Hopkins University Press, Baltimore, MD, USA.

Carney, J.A. 1992. Peasant women and economic transformation in the Gambia. Develop Change 23:67-90.

Dean, H.; with Melrose, M. 1999. Poverty, riches and social citizenship. St Martin's Press Inc., NY, USA.

Downing, J. 1991. Gender and the growth of microenterprises. Small Enterprise Develop 2:4-12.

Everts, S. 1998. Gender and technology. Empowering women, engendering development. Zed Books, London, GB. 171 p.

George, V.; Howards, I. 1991. Poverty amidst affluence: Britain and the United States. Elgar, Aldershot, GB. 224 p.

Goldschmidt-Clermont, L. 1987. Economic evaluation of unpaid work in the household: Africa, Asia, Latin America and Oceania. International Labor Organization, CH. 213 p. (Women, Work and Development Series no. 14).

Jordan, B. 1996. A theory of poverty and social exclusion. Polity Press, Cambridge, GB. 276 p.

Kaaria, S.; Ashby, J.A. 2000. An approach to technological innovation that benefits rural women: The "Resource-Consumption" approach. PRGA Working Paper no. 13. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. Available in http://www.prgaprogram.org/publica.htm

Marris, R. 1999. Ending poverty. Thames and Hudson, NY, USA. 120 p.

Mutoro, B.A. 1997. Women working wonders. Small-scale farming and the role of women in Vigha District, Kenya. A case study of Northern Maragoli. Thela Publishers, Amsterdam, NL. 342 p.

Paris, T.R.; Diaz, C.P.; Hossain, M.; Vasallo, A.B. 1995. The process of technology development and transfer to women: A case study of the microrice mill in Guimba, Nueva Ecija, Philippines. *In*: Quick, G.R.; Paris, T.R. (eds.). Enhancing incomes of rural women through suitable engineered systems. Proceedings International Workshop, International Rice Research Institute (IRRI), 10-13 May 1994, Los Baños, PH. p. 71-89.

Rivera, J.; Ashby, J.A. 1985. Innovation, risk-taking and the family life cycle of the small farm in Cauca, Colombia. Unpublished paper. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO.

Runciman, W.C. 1966. Relative deprivation and social justice: A study of attitudes to social inequality in twentieth-century England. Routledge and Kegan Paul, GB. 338 p.

Saito, K.A.; Weidemann, C.J. 1990. Agricultural extension for women farmers in Africa. World Bank, WA, USA. 57 p.

Scott, G.L.; Carr, M. 1985. The impact of technology choice on rural women in Bangladesh. World Bank Staff Working Papers no. 731. World Bank, WA, USA.

Scott, J. 1994. Poverty and wealth: Citizenship, deprivation and privilege. Longman's, GB.

Sen, A. 1997. On economic inequality. Clarendon Press, Oxford, GB.

Townsend, P. 1979. Poverty in the United Kingdom. Penguin, GB.

UN (United Nations). 1997. Poverty and human development. Oxford University Press, GB. 248 p. (Human Development Papers)

UNDP (United Nations Development Programme). 1995. Human development report. Oxford University Press, NY, USA.

Von Braun, J.; Webb, P. 1989. The impact of new crop technology on the agricultural division of labor in a West African setting. Econ Develop Cult Change 37:513-534.

Von Braun, J.; Pandya-Lorch, R. (eds.). 1991. Income sources of malnourished people in rural areas: Microlevel information and policy implications. International Food Policy Research Institute (IFPRI), WA, USA. 206 p. (IFPRI Working Paper on Commercialization of Agriculture and Nutrition no. 5)

World Bank. 1990. Poverty, World Bank development report. Oxford University Press, GB.

CHAPTER 7

Rural Poverty in Latin America: Determinants and Exit Paths

Alain de Janvry and *Elisabeth Sadoulet**

Introduction

Despite rapid urbanization and the convergence in poverty rates between rural and urban areas, rural poverty remains an important welfare problem in most countries of Latin America, a huge wastage of human resources, a frequent source of political destabilization, and a cause of environmental pressures. The policy record in dealing with rural poverty has been highly uneven and generally disappointing, with the sources of gains in reducing the relative number of rural to urban poor mainly due to population shifts as opposed to successful rural poverty reduction. We venture to say that an important reason why the policy record has been lacking is that there has been much misunderstanding on the causes and dynamics of poverty. Setting the record straight regarding what creates rural poverty and how specific individuals and communities have escaped poverty is thus an important part of a solution. With significant progress in democratic rights, the decentralization of governance, the thickening of civil society organizations, and the potential offered by new technological and institutional innovations, times may be right for improved information about the causes of poverty and the paths out of poverty to be used for the design of more effective anti-poverty strategies. It is the objective of this chapter to present this information and to show how it could be used for improved anti-poverty policy design. We explore in particular the role that technological change in agriculture can play as an instrument for poverty reduction, and the conditions under which it can be made to be more effective for this purpose.

* Professor of Agric. Econ., and Associated Professor of Agric. Econ., respectively, University of California at Berkeley, USA.

Retrospective on Rural Poverty: The Development Record

In the aggregate, the performance of Latin America toward rural poverty has been favorable, at least compared to urban poverty (Figure 1).

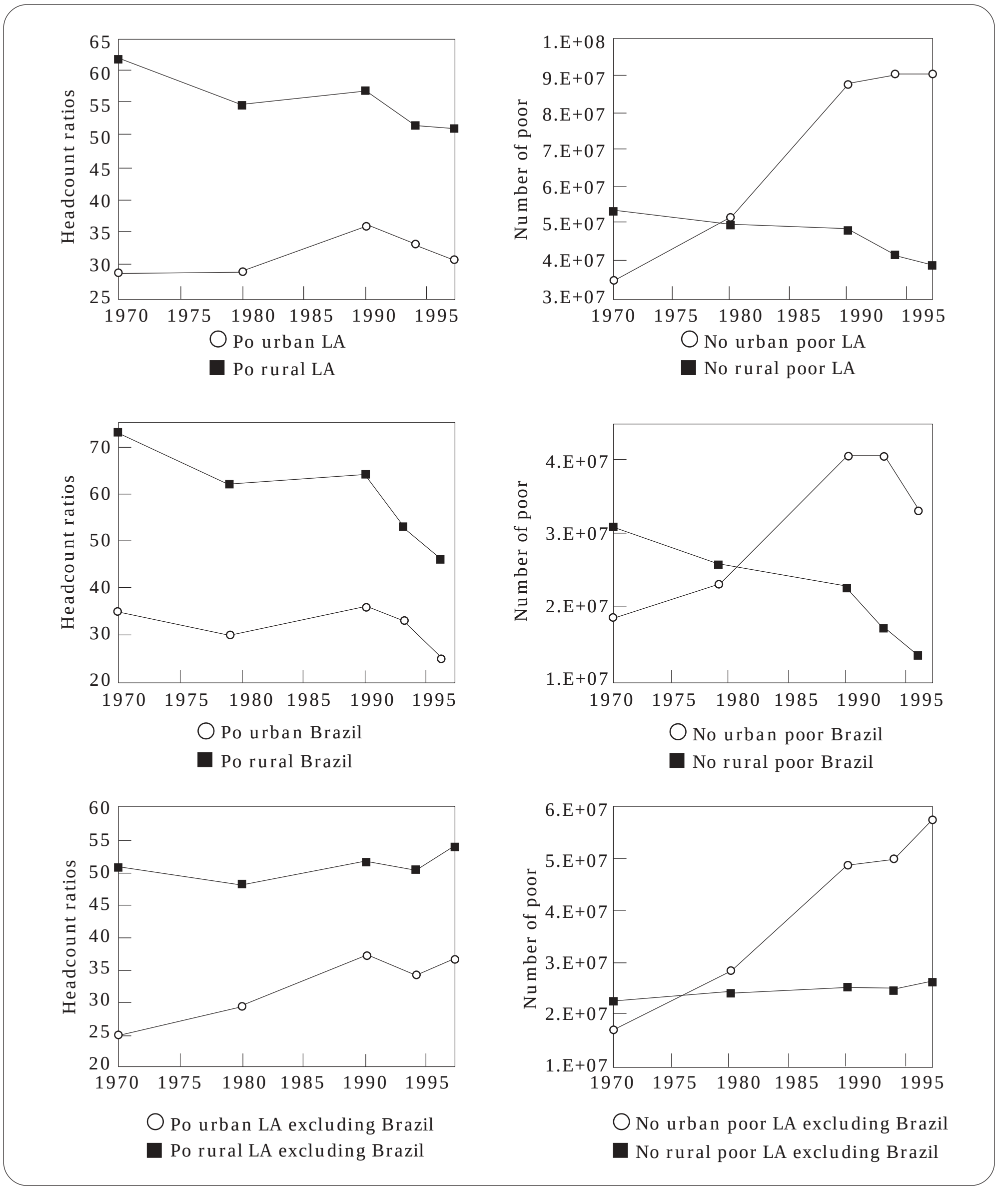


Figure 1. Rural and urban poverty, Latin America. Data for "Latin America" are the population weighted aggregates for Brazil, Chile, Colombia, Costa Rica, Honduras, Mexico, Peru, and Venezuela. These eight countries with consistent data over the period 1970-97 account for 80% of the population of Latin America.

Over the last 27 years, the incidence of poverty in the rural sector has fallen, and the number of rural poor has also declined, while the incidence of urban poverty failed to decline and the absolute number of urban poor rose sharply. This overall performance, however, hides considerable heterogeneity and is dominated by successful rural poverty reduction in Brazil. For the rest of Latin America as an aggregate, the incidence of rural poverty has been constant or rising, and the number of rural poor has been increasing. Heterogeneity is thus an important issue and global statements have to be looked at with caution.

We start by characterizing the nature of rural poverty in Latin America and how it has evolved between 1970 and 1997 (Table 1, and below).

Rural poverty is extensive

Using a poverty line defined as twice the expenditure to achieve a minimum nutritional requirement, the incidence of rural poverty was 51% across Latin America in 1997 (own calculations based on data in CEPAL [1999]). It was above 50% in half of the 12 countries with data, namely Mexico (53%), Colombia (54%), Peru (61%), El Salvador (62%), Guatemala (75%), and Honduras (80%). Thus, despite relatively high income levels, the Latin American countries have high incidences of rural poverty because of the unequal distribution of income that characterizes them, both between sectors and within the rural sector.

The incidence of rural poverty (P_0^r) is considerably higher than the incidence of urban poverty (P_0^u)

In 1997, the ratio of headcount ratios for the rural and urban sectors was 1.7 for Latin America. It is greater than one in all countries. For many countries (Chile, Colombia, Costa Rica, Guatemala, Mexico, and Panama), this ratio is 1.4. It reaches 1.6 in El Salvador, 1.8 in Brazil, 2.3 in Uruguay, and 2.4 in Peru. There is hence a huge gap in the incidence of poverty between the rural and urban populations, to the disadvantage of the former.

The share of the rural sector in the total number of poor remains high despite urbanization

For Latin America, the share of the rural sector in total poverty is only 30%. In the aggregate, poverty is thus principally urban. However, rural poverty accounts for a majority of the total number of poor in Panama (52%), Honduras (55%), Costa Rica (58%), El Salvador (62%), and Guatemala (68%).

Rural poverty is considerably deeper than urban poverty

Defining extreme poverty as the income necessary to cover the cost of the minimum nutritional requirement, extreme poverty characterized 27% of the

Table 1. Poverty in Latin America, 1970-97.

	Year	Rural P_0 (P_0^r) (%)	Urban P_0 (P_0^u) (%)	Total P_0 (P_0) (%)	Rural population (r) (% of total)	Percentage of total poverty that is rural	Rural P_0/ Urban P_0 (P_0^r/P_0^u)	No. rural poor/ No. urban poor (R/U)	No. of rural poor
Rural poverty:									
Brazil	1970	73.0	35.0	51.8	44.1	62.2	2.1	2.0	30,912,041
	1979	62.0	30.0	41.2	35.0	52.7	2.1	1.0	25,807,211
	1990	64.0	36.0	42.7	23.9	35.8	1.8	1.0	22,628,902
	1993	53.0	33.0	37.2	21.0	29.9	1.6	0	17,247,595
	1996	46.0	25.0	28.8	18.2	29.0	1.8	0	13,521,882
Latin America (7 countries excluding Brazil)	1970	50.9	25.1	35.3	39.5	57.0	2.0	1.3	22,276,579
	1980	48.3	29.4	35.8	33.9	45.7	1.6	0.8	23,825,031
	1990	51.7	37.2	41.1	27.0	34.0	1.4	0.5	25,180,894
	1994	50.5	34.3	38.3	24.9	32.8	1.5	0.5	24,483,975
	1997	53.9	36.8	40.8	23.4	30.9	1.5	0.4	25,931,703
Latin America (8 countries)	1970	61.7	28.8	42.5	41.7	60.5	2.1	1.5	53,267,397
	1980	54.6	29.0	37.6	33.9	49.1	1.9	1.0	49,410,781
	1990	56.9	35.9	41.3	25.6	35.3	1.6	0.5	47,806,315
	1994	51.5	33.2	37.4	22.8	31.4	1.5	0.5	41,309,017
	1997	51.0	30.9	35.0	20.6	30.0	1.7	0.4	38,783,735

(Continued)

Table 1. (Continued.)

	Year	Rural P_0 (P_0^r) (%)	Urban P_0 (P_0^u) (%)	Total P_0 (P_0) (%)	Rural population (r) (% of total)	Percentage of total poverty that is rural	Rural P_0/ Urban P_0 (P_0^r/P_0^u)	No. rural poor/ No. urban poor (R/U)	No. of rural poor
Rural extreme poverty:									
Brazil	1970	42.0	15.0	26.9	44.1	68.8	2.8	2.2	17,785,010
	1979	35.0	10.0	18.8	35.0	65.3	3.5	1.9	14,568,587
	1990	38.0	13.0	19.0	23.9	47.9	2.9	0.9	13,435,911
	1993	30.0	12.0	15.8	21.0	39.9	2.5	0.7	9,762,789
	1996	28.0	8.0	10.7	18.2	39.0	2.9	0.6	6,760,941
Latin America (7 countries excluding Brazil)	1970	22.8	7.6	13.6	39.5	66.2	3.0	2.0	9,972,928
	1980	23.4	8.8	13.7	33.9	57.7	2.7	1.4	11,516,209
	1990	28.5	11.5	16.1	27.0	47.9	2.5	0.9	13,885,601
	1994	27.3	10.1	14.3	24.9	47.3	2.7	0.9	13,213,193
	1997	29.1	11.1	15.3	23.4	44.5	2.6	0.8	13,987,376
Latin America (8 countries)	1970	32.2	10.9	19.8	41.7	67.9	3.0	2.1	27,797,448
	1980	28.7	9.3	15.9	33.9	61.2	3.1	1.6	25,963,428
	1990	32.5	12.2	17.4	25.6	47.9	2.7	0.9	27,319,867
	1994	28.3	11.0	14.9	22.8	43.3	2.6	0.8	22,735,212
	1997	26.8	9.7	13.2	20.6	41.9	2.8	0.7	20,410,464

SOURCE: Data from the Comisión Económica para América Latina y el Caribe (CEPAL), Social panorama in Latin America, 1994 to 1998. The eight countries used for the Latin America aggregate are: Brazil, Chile, Colombia, Costa Rica, Honduras, Mexico, Peru, and Venezuela.

rural population in Latin America in 1997. It affected 41% of the rural population in Peru, 53% in Guatemala, and 59% in Honduras. The ratio of extreme poverty headcount ratios for the rural and urban sectors was 2.8 for all of Latin America. It reached 2.0 in Chile, 2.3 in El Salvador, 2.5 in Mexico, 2.9 in Brazil, and 5.9 in Peru. Extreme poverty is thus a phenomenon that disproportionately affects rural households.

The incidence of rural poverty and the number of rural poor have declined, but not in the "rest of Latin America" excluding Brazil

The incidence of rural poverty declined rapidly in the 1970s (from 62% to 55%), increased in the 1980s (from 55% to 57%), and has declined sharply since (from 57% to 51%). The number of rural poor has also declined. This is a remarkable success. However, much of this effect is due to the rapid decline in rural poverty in Brazil. For the "rest of Latin America" in Table 1, the incidence of rural poverty has failed to decline (it rose from 51% in 1970 to 54% in 1997) and the absolute number of rural poor increased by 16%.

The rural headcount ratio is convergent with the urban ratio

While the headcount ratio in the rural sector remains higher than that in the urban sector, the two ratios have been converging in basically every country. For Latin America, the ratio P_0^r / P_0^u fell from 2.1 in 1970 to 1.7 in 1997. For most countries, this ratio was above 2 in the 1970s, falling to 1.4 in the late 1990s. This suggests that labor markets have become increasingly integrated both through permanent and seasonal migration, and that off-farm sources of income are increasingly the same in the two sectors.

The share of rural poverty in total poverty has declined

This decline has been quite dramatic. We analyze later the determinants of this decline. For Latin America as a whole, rural poverty accounted for 61% of total poverty in 1970, but only for 30% in 1997.

Rural poverty is responsive to aggregate income growth and to income shocks

Overall, rural poverty fell during the 1970s, rose during the 1980s when most countries were affected by the debt crisis, and it has fallen again in the 1990s with economic recovery. In specific countries that were affected by economic crises in the 1990s, rural poverty rose again. This was the case in Mexico during the peso crisis (1994-96), and in Venezuela (1990-94). Rural poverty is thus anti-cyclical with aggregate economic growth. In general, however, rural poverty is less sensitive to aggregate income growth than urban poverty, and it is also less sensitive to downturns than urban poverty.

Rural inequality rises with recession, but may not have declined with recovery

Although evidence is weak, rural inequality seems to have increased during the 1980s while countries were adjusting to the debt crisis. In the 1990s, the recovery of growth does not seem to have led to declining rural inequalities. This is consistent with data on inequality at the aggregate level (Londoño and Székely, 1997; de Janvry and Sadoulet, 1998). Thus, although late growth has been effective in reducing poverty, this does not appear to be the case for inequality. Hence, if high inequality is a policy concern, it needs to be addressed through direct instruments as opposed to indirectly through growth.

Rural poverty is multidimensional

Income is an important dimension of welfare. The welfare contribution of income is measured by indicators of income poverty, income security, and income inequality. Control over income is an important determinant of consumption expenditures. Poverty is, however, multidimensional, including such other elements as basic needs (health, education), the satisfaction of being employed, empowerment, the strength of community relations, legal and human rights, and political freedoms (World Bank, 2000). In general, the satisfaction of basic needs in rural areas is only a fraction of what it is in the urban sector. In El Salvador, infant mortality is 17% higher in rural than in urban areas, while it is 31% higher in Guatemala. Hence, for rural households, basic needs poverty generally compounds income poverty. However, it also says that poverty in a broad sense can be attacked not only by income gains but also by gains on many other fronts. In Chile, for instance, while gaps persist in the incidence of income poverty between rural and urban sectors, health achievements (infant mortality under 5 years of age) have reached parity (Valdés and Wiens, 1996).

The rural poor are heterogeneous in assets positions

Poor rural households are highly heterogeneous in their control over productive assets. These assets are multidimensional. They include:

- Land and other natural assets: water, animals, trees, soil fertility.
- Human assets: number of working adults in a household, education, experience.
- Institutional assets: access to credit, access to insurance, access to extension and information, transactions costs in relating to markets.
- Social assets: social capital, membership to corporate communities.
- Public goods assets: access to public goods such as health services, educational facilities.
- Regional assets: location in areas with neighborhood effects, agro-ecological niches.

It is important to observe that household positions relative to these different assets tend to be correlated at low income levels, while not at higher income levels. Hence, while there are important substitution effects among assets in generating income, households in poverty are poorly endowed in all assets. This can be seen from the characterization of the asset positions of poor and non-poor households in the Mexican ejido in Table 2. It is notable that the group of rural poor has lower endowments in all assets.

Market failures affect differentially the rural poor

Because of high transactions costs on product and factor markets, rural households are differentially integrated into markets: some are net sellers, some net buyers, some self-sufficient (i.e., not integrated into markets), and others both sell and buy during the same agricultural season. This distinction is important because a same price effect will have markedly different consequences on a household's real income according to the nature of its market integration. For instance, a fall in the market price of maize in Mexico due to the North American Free Trade Agreement (NAFTA) will hurt net sellers, leave autarkic households unaffected, benefit net buyers, and some net sellers become self-sufficient, while some autarkic households become net buyers.

Data for Nicaragua (Davis et al., 1997) and Mexico (de Janvry et al., 1997) show the following distribution of households in the four market integration categories:

Percentage of farm households	Maize Nicaragua	Beans Nicaragua	Maize Mexican ejido
Net buyers	23	28	27
Self-sufficient	30	30	32
Net sellers	39	37	28
Sellers and buyers	9	5	13

These data show that, contrary to conventional wisdom, most landed rural households are not net sellers of these major food crops. A price policy that turns the terms of trade in favor of these crops will consequently not benefit a majority of the households.

Institutional gaps affect differentially the rural poor

Access to credit and technical assistance is overall minimal among the rural poor. In the Mexican ejido, the main technical assistance program, Alianza para el Campo, only reaches 13% of the households, and only 18% have access to formal credit (World Bank, 1998). In Nicaragua, 9% of all farm households have access to technical assistance, and 9% to formal

Table 2. Income strategies and asset positions, poor and non-poor Mexican ejido.

	Above poverty line	Below poverty line	Test of difference[a]
Number of observations	507	510	
Total household income (pesos)	22,267	2,195	**
Income by source (pesos)			
Agriculture	7,206	-469	**
Animals	37,333	540	**
Agricultural wage	799	346	**
Non-agricultural wage	4,313	404	**
Self-employment	2,111	308	**
Remittances	1,388	124	**
PROCAMPO transfer	1,149	741	**
Other	2,717	941	**
Income by source (% share of total income)			
Agriculture	32.4	-21.4	**
Animals	16.8	24.6	**
Agricultural wage	3.6	15.8	**
Non-agricultural wage	19.4	18.4	**
Self-employment	9.5	14.0	**
Remittances	6.2	5.6	**
PROCAMPO transfer	5.2	33.8	**
Other	12.2	42.9	**
Asset positions			
Land assets (exogenous in ejido)			
Irrigated area owned (ha)	1.8	0.7	**
Rainfed area owned (ha)	9.0	6.1	**
Pasture area owned (ha)	5.2	3.3	**
Common property area owned per household (ha)	26.9	23.1	**
Human assets			
Number of adults	4.0	3.3	**
Age of household head	53.5	50.1	**
Average years of education among adults	5.2	4.0	**
Per capita US migration assets	2.5	1.3	**
Per capita Mexico migration assets	5.7	5.3	**
Institutional assets			
Access to formal credit (% of households)	19.7	15.7	*
Access to technical assistance (% of households)	10.3	3.9	**
Social assets			
Indigenous (% of households)	13.6	28.7	**
Regions (% of households)			
North	25.0	17.0	**
North Pacific	14.8	8.0	**
Center	27.2	28.0	
Gulf	15.8	18.2	
South	17.2	28.8	**

a. * = Significant at the 95% confidence level. ** = Significant at the 90% confidence level.

credit. These institutional gaps lower the income-generating capacity of the meager asset endowments that the poor have.

Heterogeneity of income strategies

Heterogeneous access to assets, heterogeneous exposure to market failures and to institutional gaps, and heterogeneous access to public goods induces income-earning strategies that are highly diverse across households. This can be illustrated with information for the Mexican ejido sector and landed households in Nicaragua (Table 3). The data are striking in that, among these landed households, 75% in Mexico and 34% in Nicaragua derive more than half of their income from off-farm activities. Off-farm sources of income serve as substitutes for farm incomes derived from access to land. Thus, in Mexico, the share of total household income derived off-farm falls from 76% on small farms to 42% on larger farms. In Nicaragua, where access to off-farm incomes is less, this share falls from 68% to 16%. What is interesting, however, is that control over the assets needed to derive income from off-farm activities rises with access to land. As a result, those with larger farms are able to derive larger incomes from off-farm activities, even though off-farm incomes rise with farm size less than do farm incomes. In Mexico, off-farm incomes yield 4242 pesos on small farms and 8726 pesos on large farms. In Nicaragua, small farmers earn 702 cordobas off-farm while larger farmers earn 1498 cordobas. Among off-farm sources of income, agricultural wage income is the most equalizing, while other incomes (non-agricultural wage income, self-employment in micro-enterprises, migration, and rents) are highly related to land assets. Land-poor households are thus confined to easy-entry, farm labor market activities that are low paying, while wealthier households can enter high paying activities. Hence, due to extensive credit market failures, land endowments are important in explaining relative abilities to diversify in non-farm activities.

Change in the Relative Number of Rural and Urban Poor: Aggregate Analysis

Success in rural development initiatives should help reduce the number of rural poor relative to the number of urban poor. Over the 1970-97 period, this ratio has indeed declined markedly, from about 1.5 to 0.4 (Table 1). We can ask whence this success has come. It could have come from a decline in the headcount ratio in the rural sector, an increase in the headcount ratio in the urban sector, and a shift in population from the rural to the urban sector.

Table 3. Sources of income by farm size, Mexico and Nicaragua[a].

Sources of income in the Mexican ejido by farm size, 1997					
Farm size in hectares	<2	2-5	5-10	10-18	>18
Number of households (%)	17	31	23	17	11
Total income in pesos of 1994	5,270	7,797	14,834	16,570	20,351
Total farm income	719	2,336	6,854	9,355	12,316
Total off-farm income	4,552	5462	7,980	7,215	8,036
Wages	2,014	2,827	4,180	2,938	2,131
Self employment, remittances, and other	2,538	2,635	3,800	4,277	5,905
Total income in % shares	100	100	100	100	100
Total farm income	14	30	46	56	60
Total off-farm income	86	70	54	43	39
Wages	38	36	28	18	10
Self employment, remittances, and other	48	34	26	26	29
Sources of income in Nicaragua by farm size, 1996					
Farm size in manzanas	<2	2-5	5-10	10-18	>18
Number of households (%)	21	24	30	15	11
Total income in 1996 cordobas (per capita)	1,027	1,561	2,090	3,626	9,557
Total farm income	325	896	1,615	2,939	8,059
Total off-farm income	702	665	475	687	1498
Wages	512	338	262	206	356
Self employment, remittances, and other	190	327	213	481	1142
Total income in % shares	100	100	100	100	100
Total farm income	32	57	77	81	84
Total off-farm income	68	43	23	19	16
Wages	50	22	12	6	4
Self employment, remittances, and other	18	21	10	13	12

a. Numbers are rounded.

Let the ratio of the number of rural (R) to urban (U) poor be written as:

$$\frac{R}{U} = \frac{P_0^r}{P_0^u}\frac{r}{1-r} \qquad (1)$$

where P_0^r is the headcount ratio in the rural sector and P_0^u in the urban sector, and r is the share of rural in total population. The change in this ratio between two periods can be decomposed into four effects as follows:

Role of a change in the rural headcount ratio

$$r(1-r)P_0^u dP_0^r \quad (2)$$

Role of a change in the urban headcount ratio

$$-r(1-r)P_0^r dP_0^u \quad (3)$$

Role of a change in the share of population in the rural sector

$$P_0^u P_0^r dr \quad (4)$$

Role of interaction terms

$$P_0^u (1-r) dP_0^r dr + P_0^r r dP_0^u dr \quad (5)$$

Results of this decomposition are presented in Table 4. In the 1970s, the incidence of rural poverty was declining relative to the incidence of urban poverty, and population was rapidly leaving the rural sector. *R/U* was consequently falling for two reasons: a faster decline in the incidence of rural than urban poverty and rapid outmigration. However, the population effect was dominant, explaining 76% of the fall in *R/U* while the decline in P_0^r only accounted for 28% of the decline.

Table 4. Roles of P_0 and population in the change in rural poverty relative to urban poverty.

Period	Average annual rates of growth				Shares in $d(R/U)$			
	GDP_{pc}	P_0^r	P_0^u	r	R/U	% role of P_0^r	% role of P_0^u	% role of r
Brazil								
70-79	5.3	-1.8	-1.7	-2.5	-4.3	47	-44	114
79-90	0.3	0.3	2.0	-3.4	-6.1	-5	29	70
90-93	-0.6	-6.1	-1.0	-4.2	-8.6	-77	-37	71
93-96	2.2	-4.6	-3.0	-4.7	-1.4	-410	-752	524
Other Latin American countries (7 countries)								
70-80	2.6	-0.5	1.8	-1.5	-4.4	11	37	50
80-90	-0.5	0.7	2.6	-2.3	-4.8	-13	49	57
90-94	3.0	-0.6	-0.9	-2.0	-1.3	50	-166	225
94-97	0.9	2.2	0.8	-2.0	-2.9	-73	80	87
All Latin American countries (8 countries)								
70-80	3.8	-1.2	0.1	-2.0	-4.5	28	1	76
80-90	-0.2	0.4	2.4	-2.8	-5.6	-7	39	61
90-94	1.4	-2.5	-0.9	-2.9	-4.3	-48	-48	95
94-97	1.5	-0.3	-0.8	-3.3	-2.2	-118	-118	206

During recession in the 1980s, the incidence of urban poverty was rising much faster than that of rural poverty, but rural-urban migration was continuing. The fall in *R/U* was consequently explained at 39% by rising P_0^u and at 61% by outmigration. Population movements were thus still the dominant force in reducing *R/U*.

Finally, in late recovery (1994-97), *R/U* was falling even though urban poverty declined more rapidly than rural poverty because there was continuation of migration. The falling incidence of rural poverty explained only 16% of the fall in *R/U*, while population movement contributed 235% of the decline in *R/U*.

Similar results are obtained for Brazil and the "rest" of Latin America. These results show that, in all three growth episodes, population movements were the dominant force in explaining the decline in *R/U*. By contrast, we observe the relatively weak performance of growth and of rural development interventions in reducing total poverty through falling headcount ratios in the rural sector. Note that this analysis underestimates the role of migration in explaining *R/U* since migration is likely to help reduce P_0^r and to increase P_0^u. Hence, the result we present here on the role of migration in affecting the number of rural poor relative to the number of urban poor errs on the conservative side.

Determinants of Rural Poverty

We now turn to household-level data to analyze the determinants of poverty and incomes among rural households. We use for this a data set for the Mexican ejido, a population of smallholders benefited by the Mexican land reform among whom there is extensive poverty. Results show that access to land is an important determinant of total income, particularly irrigated land, which yields six times more income per hectare than rainfed land (Table 5). One hectare of irrigated land increases household income by 21% among the lowest 40% of farm sizes. Human assets (number of adults and average level of adult education in the household) also create large income effects. Remittances from migration to the United States are the third important source of income. For migration to be successful, the size of the migration network to which a household has access is key (Winters et al., 1999). Ethnicity has a high income cost (at a low level of significance). Indeed much rural poverty in Mexico is tied to the status of indigenous. Finally, there remain regional effects even after controlling for the differential assets position of households, with households in the Center differentially poorer than those in the North.

Disaggregating income by source and analyzing the determinants of each source shows the relative importance of particular assets for each income source. We find the following points.

Table 5. Determinants of household income and of probability of being in poverty, 1997.

Assets	Total income Robust regression		Agricultural income Robust regression		Animal income Robust regression		Agric. wage income Tobit		Non-agric. income Tobit	
(Number of observations = 956)	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
Land assets (exogenous in ejido)										
Irrigated area owned	1112	0.02	884	0.05	48	0.52	-49	0.75	-139	0.54
Rainfed area owned	223	0	84	0.18	101	0	-169	0.01	-259	0.01
Pasture area owned	27	0.43	-5	0.86	27	0.03	-9	0.80	2	0.98
Common property area per household	6	0.30	-1	0.78	4	0.19	-20	0.08	7	0.54
Human assets										
Gender of household head (man = 1)	-2916	0.47	-1932	0.59	1112	0	2535	0.29	-1489	0.75
Age of household head	92	0.02	5	0.88	20	0.08	-109	0	-16	0.80
Average years of education among adults	1609	0	642	0	206	0.01	-889	0	1983	0
Number of adults	673	0.05	-287	0.17	-156	0.07	1153	0	2779	0
Per capita Mexico migration assets	-25	0.83	-22	0.79	40	0.23	38	0.66	-229	0.21
Per capita US migration assets	818	0	172	0.24	158	0	-313	0.06	205	0.38

(Continued)

Table 5. (Continued.)

Assets	Total income Robust regression		Agricultural income Robust regression		Animal income Robust regression		Agric. wage income Tobit		Non-agric. income Tobit	
(Number of observations = 956)	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value	Coefficient	*P*-value
Institutional assets										
Used technical assistance (dummy)	1863	0.38	2801	0.09	-193	0.77	2161	0.28	-671	0.83
Used formal credit (dummy)	948	0.61	2728	0.08	-367	0.37	1260	0.30	68	0.98
Social assets										
Indigenous (dummy)	-1331	0.18	-803	0.22	-135	0.77	359	0.76	-1849	0.39
Regional effects (base = North)										
North Pacific	-3897	0.13	-1141	0.56	458	0.49	-1597	0.34	-9823	0
Center	-3641	0.04	-623	0.61	187	0.64	-4322	0	-3552	0.10
Gulf	-1735	0.45	-1125	0.53	595	0.29	1289	0.39	-2914	0.29
South	-1213	0.53	1027	0.46	1319	0.04	-6821	0	-7403	0
Social welfare assets										
PROCAMPO transfer (pesos)	0.8	0.17	-0.06	0.17	0.4	0.14	-0.4	0.44	-0.5	0.51
Constant term	2942	0.53	1621	0.68	-2696	0.01	4682	0.17	-251584	0
Pseudo-*R* square	0.20		0.11		0.11		0.02		0.02	

Role of access to agrarian institutions

While access to credit (18% of the households) and technical assistance (7% of the households) is dismally low among ejido households after withdrawal of the state from delivering these services, these two services make very high contributions to agricultural income. Hence, what matters for poverty reduction is the complementarity between access to land and institutional development to help achieve more productive use of the land.

Role of education

Adult education has positive payoffs in agriculture, livestock, non-agricultural wage income, and self-employment income. There is, however, a hierarchy in the way these sources of income valorize an additional year of adult education in an ejido household:

- Livestock income: NP$206
- Self-employment income: NP$640
- Agriculture income: NP$642
- Non-agricultural wage income: NP$1983

Hence, rural education is best valorized in non-agricultural labor markets, indicating that the type of education that has the highest payoff in rural areas should prepare adults to access non-agricultural employment. Education has a negative role on agricultural wage income because educated household members seek employment on more remunerative markets. Similarly, education is negative on remittance income because the better educated migrate less to the United States since they are better able to take advantage of their (modest levels) of education on the Mexican urban labor market.

Role of migration networks for migration to the United States

Migration assets are measured as the number of members from the immediate and the extended family of a household who are migrating or have had recent migration experience. Existence of these networks is key for success in receiving remittance income. Networks serve the function of providing information about how to migrate and find employment in the United States, and provide assistance to cover the costs involved.

Regional effects

Even after controlling for the asset position of households and their access to infrastructure, regional effects are important for wage income, with North and Gulf favored over the other regions. Hence, there is a regional dimension to poverty suggesting the validity of regional targeting in poverty reduction.

What Role for Agricultural Technology in Poverty Reduction?

We have characterized the importance and the recent evolution of rural poverty in Latin America, and sought explanations for rural poverty at both the aggregate and the household levels. We concluded with a concern with the increasing inability to attack rural poverty through a declining incidence of poverty among rural populations. This raises the question of what can be done to attack rural poverty other than through migration. Determinants of income have shown the importance of assets endowments, including institutional and social assets. Also important in determining income levels is the productivity of assets use. This is affected by technology. We should consequently ask how agricultural technology is expected to influence income levels among the poor, both rural and urban.

Technology and poverty: Direct and indirect effects

Technological change in agriculture can act on poverty through two channels. First, it can help reduce poverty directly by raising the welfare of poor farmers who adopt the technological innovation. Second, technological change can help reduce poverty indirectly through the effects which adoption, by both poor and non-poor farmers, have on:

- The price of food for consumers.
- Employment and wage effects in agriculture.
- Employment and wage effects in other sectors of economic activity through production, consumption, and savings linkages with agriculture (Adelman, 1975), lower costs of agricultural raw materials, lower nominal wages for employers (as a consequence of lower food prices), and foreign exchange contributions of agriculture to overall economic growth.

Through the price of food, indirect effects can benefit a broad spectrum of the national poor, including landless farm workers, net food-buying smallholders, non-agricultural rural poor, and the urban poor for whom food represents a large share of total expenditures. Indirect effects via employment creation are important for landless farm workers, net labor selling smallholders, and the rural non-agricultural and the urban poor. Hence, the indirect effects of technological change can be very important for poverty reduction not only among urban households, but also in the rural sector among the landless and many of the landed poor.

When are there trade-offs between the direct and the indirect effects of technological change? Within a given agro-ecological environment, if land is unequally distributed and if there are market failures, institutional gaps, and conditions of access to public goods that vary systematically with farm size, then optimum farming systems will differ across farms. Small-scale farmers will typically prefer farming systems that are less capital intensive and less risky, while large-scale farmers would prefer farming systems that are less intensive in labor and they can afford to assume risks. In this case, unless land were equally distributed, heterogeneity of farming systems prevails and there are typically trade-offs between indirect and direct effects. The more unequally land is distributed and the more market failures, institutional gaps, and access to public goods are farm-size specific, and in Latin America in general, the sharper the trade-off.

The degree of tradability of commodities benefiting from technological change is also key in determining the relative importance of direct and indirect effects. With non-tradables, or within the range of price bands between export and import prices, falling prices extract the net social gains from technological change to the benefit of rural and urban consumers. However, even in an open economy where the price of food is internationally determined, indirect effects are important through the multiple roles of agriculture in economic development (financial contribution and foreign exchange contribution).

Quantifying the relative magnitudes of the direct and indirect poverty reduction effects of technological change is quite difficult because these effects are interrelated and depend on the structure of the economy, the characteristics of poverty, and the nature of technological change. Because general equilibrium effects are involved, we can use a computable general equilibrium (CGE) approach. We constructed a model that typifies the structure of Latin American countries importing cereal (Sadoulet and de Janvry, 1992).

We can use this model to simulate the impact of a 10% increase in total factor productivity due to technological change in all crops. Results show that, in Latin America where urban poverty dominates aggregate poverty, the urban poor capture 70% of the aggregate increase in real income. Overall, indirect effects account for 86% of the total effect on the real income of the poor. With high levels of urbanization and a large share of the rural poor households highly dependent on off-farm income sources, the indirect effects of technological change are thus largely dominant.

Technological change in agriculture can thus serve as an instrument for poverty reduction. But the distribution of these gains between direct and indirect effects, and hence across households in poverty, depends on the structure of the economy, the nature of poverty, the focus of technological change by crops, farming systems, and traits, complementary rural development programs to target diffusion on specific social sectors, and policy interventions in price formation (degree of tradability). How to best use the technology instrument for poverty reduction thus depends on each particular context. Employment creation in agriculture, the design of improved production systems for small-scale farmers, and aggregate productivity effects will be the dominant instruments for poverty reduction according to particular contexts. The allocation of budgets to research, particularly when smallholder farming systems differ from those of commercial agriculture and when labor-saving technological options are available, needs to be adjusted to each particular situation.

There are several caveats to these results. The first is that, at a lower level of aggregation, one would find situations in particular regions of Latin America where direct effects dominate. Hence, the optimum balance between direct effects and indirect effects needs to be determined for each particular regional context. The second is that the dilemma for research budget allocation between generating direct and indirect effects disappears with certain types of research. Biotechnology, for instance, helps dissociate research on traits from research on varieties, by contrast to traditional breeding where they were confounded. Research on genes that convey different forms of biotic and abiotic resistance may be neutral to varieties and farming systems, and hence achieve both direct and indirect effects.

What to expect from agricultural technology for the rural poor

In reviewing the status and the determinants of rural poverty, we have made the following observations:

(1) Rural-urban migration has been a major contributor to the decline in rural poverty. Hence, there exists an “exit path” to rural poverty and this path has been very important in Latin America. The existence of this path out of poverty is not a surprise, but the surprise is how important it has been quantitatively in explaining declining rural poverty relative to urban poverty whenever declines occurred, and yet how little policy has done to optimize the economic and social impact of these transitions.

(2) For households with sufficient access to land, and with market, institutional, public goods, and policy conditions that allow them to achieve high productivity in resource use, to have low transactions costs in relating to markets, and to face favorable prices on markets, there is an “agricultural path” out of poverty. This path has been surprisingly weakly prevalent, and apparently weaker in the 1990s than in the 1970s. This is the path that traditional approaches to rural development have pursued. Weak success in the 1990s should raise concerns about the effectiveness of rural development interventions and stress the need for a major overhaul of such interventions.

(3) For a very large majority of poor rural households in Latin America, the income strategy they pursue is one that combines cultivation of a small plot of land with access to off-farm sources of income. The double element of surprise here is how pervasive this income strategy is today, and how some microholders have been quite successful in using this strategy to overcome poverty despite low farm assets. There thus exists a "pluriactive path" out of poverty that has been very important for the households that did not abandon rural areas. Yet, most scholars have systematically ignored it until recently and policymakers continue to ignore it, and major administrative gaps exist in dealing with its needs for public support.

(4) Finally, there also exists an "assistential path" out of poverty. The key policy issue is one of targeting and transfer of the right type of assistance to help households in this path escape poverty. This regroups several situations:
   (i) Chronic poor that were in poverty traps because of insufficient control over a minimum bundle of assets to allow them to escape low-level equilibria and move on to higher income levels. This is the "assistential path out of poverty traps", where assistance consists in a one-time transfer of productive assets.
   (ii) Chronic poor that are unable to help themselves, even with asset transfers. This includes many of the young, the aged, the disabled, etc. In this case, transfer is of a flow of income or food to reach the poverty line. This is the "assistential path into sustained welfare".
   (iii) Transitory poverty that is due to shocks such as illness, bad weather, or macroeconomic crises. Provision of safety nets is important, not only to prevent distress, but also to avoid irreversibilities whereby the poor respond to crises by taking children out of school, where nutritional deficits lead to stunting of children growth, and where farmers decapitalize by selling productive assets. This is the "assistential path through safety nets".

What can be said about the role of agricultural technology for each of these paths out of poverty?

Exit path. If the exit path is to be promoted as a way of reducing rural poverty, the key is to assist migrants relocate among the non-poor, otherwise all that is achieved is a sectoral relocation of poverty. Agricultural technology has a clear indirect role here in inducing overall economic growth, and thus employment and wages for migrants. There are also ways in which exit can create positive externalities on those who remain in farming, including through the adoption of technological change. Key for successful exit is education of a type that prepares rural children for non-farm jobs. The more labor markets are integrated across sectors, and the more economic activities are decentralized so that rural households can participate in similar non-agricultural activities as urban households, the easier the transition. And, as networks of migrants from the community become thicker, migration is made easier, but also harder to detain through local rural development interventions (Winters et al., 1999).

Agricultural path. This is the path that has been most classically pursued in land reform and rural development programs. Where this is being pursued through land reform to create “viable” family farms, complementarity between land and institutional reforms in support of the competitiveness of beneficiaries has been a condition for success (Warriner, 1969). Where this has been pursued via rural development programs for the existing smallholders, key aspects of interventions have focused on:

- Reducing market failures for smallholders (Carter and Barham, 1996).
- Constructing agrarian institutions for the delivery of credit, the supply of technical assistance, availability of ex-ante safety nets for the provision of risk-coping instruments, and the reduction of transactions costs.
- Technology for smallholders: direct effects can be achieved through the supply of improved crops, farming systems, and traits specific to this clientele. Technology should address not only production issues (through precision farming, production ecology, and biotechnology), but also information technology to identify market opportunities and reduce transactions costs.
- Provision of public goods accessible to smallholders and complementary to their particular types of investments.
- A macroeconomic and sectoral policy framework that does not discriminate against agriculture and smallholders.

Because of the heterogeneity of poverty, and hence also the heterogeneity of potential solutions to poverty, local information is key. Rural development initiatives have been reorganized since experiences with integrated rural development in the 1960s to mobilize local information and engage the poor in the identification of solutions (World Bank, 1997). For this reason, new approaches to rural development have stressed:

- Decentralization and improved capacity of local governments,
- Promotion of grassroots organizations often assisted by nongovernmental organizations,
- Participation of organized beneficiaries,
- Devolution to user groups of control over common property resources and local public goods, and
- Collective action for the management of common property resources, the delivery of local public goods, and bargaining over policymaking.

In technology, considerable broadening of the range of traits potentially available for smallholders through new advances in precision farming and biotechnology also calls for using a participatory approach (Ashby and Sperling, 1995). While the transformation is still largely experimental, traditional state-led approaches to technological innovations have been replaced by negotiated partnerships between public, private, and civil society representatives.

Pluriactive path. In this path, land and hence technology are important, but the way land is used, labor mobilized, and which technology is needed are strongly conditioned by the totality of the household strategy. This strategy differs markedly from that of a household on the "agricultural path", most particularly regarding household time allocation. Households on this path have a double set of activities. As part farmers, they can benefit from the direct effects of technological change; as part workers and microentrepreneurs, they can benefit from the indirect effects of technological change.

(1) Households as part-farmers.

For these households, farming is part time, often in the hands of women and elders more than of adult men, and often with discontinuous presence of adult labor and decision makers on the plot. Hence, technology should be labor saving as opposed to labor intensive, a common mistake in the design of technology for smallholders that are perceived as having a labor surplus because they engage in off-farm activities. Technologies should also not be excessively sensitive to discontinuities in the presence of adult workers on the farm since they have to pursue the vagaries of job opportunities on labor markets and immediate availability has a high premium. Much of the production is food for home consumption. Since, due to transactions costs in accessing food markets, shadow prices (for self-sufficient households) and purchase prices (for net buying households) are higher than prices for net sellers, this farming can be economical even when market prices are too low for net sellers to be competitive (Fafchamps et al., 1995). This agriculture can absorb modern technology with purchased inputs despite lack of a marketable surplus: cash expenses are met with revenues from wages and other off-farm activities. Yet its specific technological demands have been grossly neglected by formal research.

An important contribution of technology is to increase labor productivity in food production to free labor for more productive pursuits off the farm. Another important contribution is to increase the productivity of z-goods production. In subsistence farming, households members, particularly women, devote a high share of working time to gathering wood, fetching water, preparing food, and tending to children. These tasks are like fixed costs on the household, absorbing a high share of disposable working time. If these tasks can be made more efficient (e.g., planting energetic trees on the land lot, for instance as hedges), considerable income gains may result. Yet, the technology of z-goods production has been badly neglected in the setting of research priorities.

(2) Households as part-workers and microentrepreneurs.
As part-workers, these households depend on employment creation in agriculture, particularly if they have few other assets. Agricultural technology has important roles to play through indirect effects. One is by employment creation in the fields of large-scale farmers. Pro-poor technology should thus be labor intensive (as opposed to technology for part-farmers, which should be laborsaving, an apparent paradox). Laborsaving chemical herbicides, Roundup-ready seeds, and mechanization are not favorable to part-workers (Nuffield Foundation, 1999). Another indirect effect is through linkage effects with agriculture in non-agricultural activities. A dynamic agriculture helps create local demand for non-tradables through the expenditure of farm incomes. Chile has been successful in reducing rural poverty not through an "agricultural path", but through employment creation in labor-intensive field activities (fruits and vegetables) and in agroprocessing (López and Valdés, 1997). Off-farm employment in non-agricultural activities is enhanced by infrastructure investment, the decentralization of economic activity, the development of secondary towns, neighborhood effects, and coordination in the location of economic activity.

That the pluriactive path can be an effective way out of poverty is demonstrated by contrasting the income strategies of non-poor and poor smallholders (households with less than 5 hectares of land) in the Mexican ejido. In support of the proposition, we observe that 35% of these smallholders are above the poverty line. Non-poor minifundists rely more on non-agriculture wage income, self-employment, and remittances from the United States than do poor minifundists. Non-poor minifundists have greater endowments in human assets (number of adults, educational levels, and migration assets) and are less ethnic. They are also geographically concentrated in specific regions, particularly the North and North Pacific, while at a disadvantage if in the South. Land reforms that create access to a small plot of land can thus be successful in bringing households out of poverty provided these households have high human and social asset endowments and are located in regions that offer them non-farm income opportunities. Creating "viable" family farms through land reforms is thus not necessary. Part-time farms are cheaper to set up if these other conditions hold.

Conclusion

Even though rural poverty in Latin America has declined, and aggregate poverty is increasingly urban, the number of rural poor remains high and there is considerable heterogeneity across countries. More importantly, we have shown that the decline in the relative number of rural to urban poor has been fundamentally the result of rural-urban migration that displaces poverty to the urban sector. With rural poverty creating not only hardships for large numbers of households in the rural sector, but also negative externalities on the urban sector, this observation stresses the urgent need of identifying instruments to raise rural incomes. We have shown that household asset endowments, and the institutional, social, and geographical context where assets are used, are key determinants of rural incomes. Productivity of asset use is also important in determining the income-generating value of asset endowments. This is where agricultural technology has a role to play. We showed that technology could affect poverty through both direct and indirect effects. The relative importance of these two effects depends on the structure of the economy, the characteristics of poverty, and the nature of technology. Using a general equilibrium model that captures the archetype features of a Latin American economy, we found that indirect effects that materialize through employment creation, higher aggregate income growth, and lower food prices are more important than direct effects in reducing aggregate poverty. The rural poor capture one third of the benefits, while the urban poor capture the remaining two thirds. Where rural poverty is large, direct effects on the rural poor are evidently important as well.

We have shown that, corresponding to the heterogeneity of asset and contextual positions of rural households, a multiplicity of pathways out of poverty exists. The dominant form of exit has been migration that has largely relocated poverty to urban environments. For this path, agricultural technology has a role to play in enhancing indirect effects through food prices, employment creation, and higher aggregate growth. The agricultural path out of poverty has been traditionally pursued in rural development programs. Its success depends importantly on the development of new farming systems for small-scale farmers. Identification of these systems requires a participatory approach to research because local information is highly imperfect for scientists. The most important path out of poverty for the Latin American rural poor should, however, rely on pluriactivity. This path has not been recognized in traditional rural development programs, and neither has it been sufficiently taken into account in the design of technology. For these households, technology has an important role to play both through indirect effects as workers and net buyers of food, and through direct effects as producers of part of their own food needs. Catering to this path out of poverty requires a redesign of rural development, focusing on a territorial and multisectoral approach that provides institutional support to the multiplicity of sources of income that characterize the vast majority of the Latin American rural poor.

Rural development initiatives must thus seek complementarity of interventions between building the asset position of the poor and improving the productivity of asset use, in particular through technological change. The delivery of technological change for rural poverty reduction needs to be tailored to the specific features that poverty takes, in particular regional settings. A regional approach to using technology for poverty reduction is thus essential. And this approach needs to give an important role to participation to adjust the setting of research priorities to the heterogeneous demands of the rural poor, and to achieve an optimum balance between direct and indirect effects on aggregate poverty.

References

Adelman, I. 1975. Growth, income distribution, and equity-oriented development strategies. World Dev 3:67-76.

Ashby, J.; Sperling, L. 1995. Institutionalizing participatory, client-driven research and technology development in agriculture. Dev Change 26:753-770.

Carter, M.; Barham, B. 1996. Level playing fields and laissez-faire: Postliberal development strategy in inegalitarian agrarian economies. World Dev 24: 1133-1149.

CEPAL (Comisión Económica para América Latina y el Caribe). 1999. Social panorama in Latin America, 1998. Santiago, CL.

Davis, B.; Carletto, C.; Sil, J. 1997. Los hogares agropecuarios en Nicaragua: Un analisis de tipologia. Department of Agricultural and Resource Economics, University of California at Berkeley, CA, USA.

de Janvry, A.; Sadoulet, E. 1998. Growth, poverty, and inequality in Latin America: A causal analysis, 1970-94. Department of Agricultural and Resource Economics, University of California at Berkeley, CA, USA.

de Janvry, A.; Gordillo, G.; Sadoulet, E. 1997. Mexico's second agrarian reform: Household and community responses 1990-94. Center for U.S.-Mexican Studies, University of California at San Diego, CA, USA.

Fafchamps, M.; de Janvry, A.; Sadoulet, E. 1995. Transactions costs, market failures, competitiveness, and the state. *In*: Peters, G.; Hedley, D.D. (eds.). Agricultural competitiveness: Market forces and policy choice. Dartmouth Publishing Co., VT, USA. p. 343-354.

Londoño, J.L.; Székely, M. 1997. Persistent poverty and excess inequality: Latin America, 1970-1995. Inter-American Development Bank, WA, USA. (Working Paper no. 357)

López, R.; Valdés, A. 1997. Rural poverty in Latin America: Analytics, new empirical evidence, and policy. Technical Department, Latin America and the Caribbean Region, Washington D.C., The World Bank, WA, USA. 43 p.

Nuffield Foundation. 1999. Nuffield Council on Bioethics. Available in: http://www.nuffieldfoundation.org/bioethics/publication

Sadoulet, E.; de Janvry, A. 1992. Agricultural trade liberalization and low income countries: A general equilibrium-multimarket approach. Am J Agric Econ 74:268-280.

Valdés, A.; Wiens, T. 1996. Rural poverty in Latin America and the Caribbean. Annual Conference on Development in Latin America and the Caribbean, The World Bank, WA, USA.

Warriner, D. 1969. Land reform in principle and practice. Clarendon Press, Oxford, GB. 457 p.

Winters, P.; de Janvry, A.; Sadoulet, E. 1999. Family and community networks in Mexico-U.S. migration. Department of Agricultural and Resource Economics, University of California at Berkeley, CA, USA.

World Bank. 1997. Rural development: From vision to action. ESSD Studies and Monographs Series no. 12. WA, USA. 168 p.

World Bank. 1998. Economic adjustment and institutional reforms: Mexico's ejido sector responds. Mexico Country Management Unit, Latin America and the Caribbean Region, WA, USA.

World Bank. 2000. World development report 2000/1: Attacking poverty. Draft copy. WA, USA. 352 p.

CHAPTER 8

Targeting Agricultural Research and Development for Poverty Reduction: General Principles and an Illustration for Sub-Saharan Africa

David Bigman and *Michael Loevinsohn**

Introduction

This chapter presents a methodology for estimating the impact of agricultural research, development, and extension on the rural poor and for incorporating these estimates in order to set priorities for agricultural research and development (R&D) projects and programs by taking into account their impact on poverty. This methodology has the following main components:

(1) Estimate the impact of R&D projects on the yields and the level of output of the relevant crops,
(2) Estimate the resulting effects of these crops on market prices and on the incomes of farmers who grow them,
(3) Estimate the effects on the income of **poor** farmers,
(4) Estimate the effects on the purchasing power of the poor consumers in rural and urban areas, and
(5) Evaluate the effects on the incidence and depth of poverty.

Poverty has clear geographical dimensions. Large differences between the standard of living of the populations in different geographical areas and "pockets of poverty" are common in all countries, developed and developing. The reasons for these differences in the standard of living and the incidence of poverty are the differences in the agroclimatic conditions, the geographic conditions (particularly distance to main urban centers and main transport routes), the endowments of natural resources (including water), and the terrain. In addition, government policies that reflect a host of economic, political, or demographic considerations all too often have a regional bias that augments rather than mitigates the differences. As a result, to take just a few examples:

* Senior Research Officers, International Service for National Agricultural Research (ISNAR), The Hague, the Netherlands.

- Mean per capita consumption of the rural population in the Indian state of West Bengal is only half of the consumption level in the Punjab, and the Headcount measure of poverty in West Bengal is nearly four times higher than its level in the Punjab (Datt and Ravallion, 1993);
- The incidence of poverty in the "inland" provinces in eastern China is much higher than in the coastal provinces;
- In Bangladesh, the Headcount measure of poverty in rural areas varies between less than 10% in some districts and more than 60% in others (Ravallion and Wodon, 1997);
- In Nigeria, more than two-thirds of the rural poor households concentrate in less than 20% of the villages;
- In Burkina Faso, the incidence of poverty in around one-fifth of the villages is less than 25%, whereas in more than half of the other villages the incidence of poverty is well over 60% (Bigman et al., 2000);
- In Ecuador, the incidence of poverty varies between less than 10% in some districts to nearly 60% in others (Hentschel et al., 1999).

Indeed, in many developing countries the differences in the standard of living between regions are often larger than the differences within regions.

Poverty has geographical dimensions also at more local levels. Districts and even villages within the same agroclimatic regions can differ considerably in their standard of living. This can be because of differences in their proximity to the urban centers or to the main transport roads, the quality of the access roads, the availability of public services, and/or the distance to the source of drinking water. Households in villages close to the city have much greater trading opportunities and can be engaged more in non-farm activities; farmers in more remote villages, or in villages without access to transport roads during the rainy season, must produce mainly for self consumption. Differences in access to public services, including agricultural extension services, and in the quality of the road infrastructure are often the main reasons for the large differences between villages within the same region and they reflect mostly the bias in government policies (Table 1).

Table 1. Quality of health services in rural communities in Nigeria as indicative of the impact of quality of the access road to the community[a].

Health services in the community (% of total)	Access road to the community	
	Paved	Unpaved
Health post	30.8	17.3
Mobile clinic	21.7	11.5
Health worker	29.7	15.2
No health services	17.8	56.0
All communities	100.0	100.0

a. The quality of extension services is also strongly influenced by the quality of the access road.

Agricultural research, development, and extension services also have clear geographical dimensions: The larger the country and the more varied its agroclimatic conditions, the larger the differences between the crops grown in different regions and between their farming systems. As a result, commodity-based research programs affect mostly those regions in which these commodities are the main crops, and thematic research programs affect mostly the regions that have the specific conditions (soil, climatic, etc.) that are the subject of the research. Even a relatively small country such as Kenya exhibits considerable geographic diversity in agricultural production because of significant differences in climate and soils between regions. In the densely populated medium-rainfall zone, the main crops are coffee and horticulture products, whereas in the arid and semi-arid lands, where the population density is much lower, farming is more subsistence oriented with the main crops being maize, beans, and cassava. Farmers in the semi-arid and arid zone will therefore benefit only marginally and indirectly from a research program on cash crops such as horticulture products, sugarcane, or coffee, but they are the main beneficiaries of a research program on cassava.

Agricultural R&D also has significant geographical dimensions at more local levels. In some regions, neighboring areas differ in their crop selection because of location-specific soil problems, such as acidity, alkalinity, salinity, etc. In other regions, particularly in countries of sub-Saharan Africa (SSA), the distance to the urban center and the access to an all-weather road are factors that have a strong impact on the farming system and on the selection of crops. As noted earlier, farmers that reside further away from the urban center or from the main transport road must grow crops mostly for self-consumption, whereas farmers in the same agroclimatic region, but closer to the urban centers, can specialize in high-value crops. In Kenya, maize is grown in all geographical areas. In some areas, however, it is grown primarily by small-scale producers for home consumption, while in other areas production is predominantly in large-scale mixed farms that produce maize, wheat, and barley (Table 2; see Kilambya et al., 1998). However, these different systems require different production technologies, different genetic material, and a different organization of extension services. Research and development projects that improve production technologies used by large-scale farming will benefit the small-scale producers only marginally.

There are large differences in the standard of living and the prevalence of poverty between different geographical areas on the one hand, and differences in the cropping patterns and farming systems between many of these areas on the other hand. This suggests that agricultural R&D programs combined with well-designed extension services can be an important policy instrument to reduce poverty. By targeting agricultural R&D on commodities that are common in the farming systems of the poor, and targeting the extension services on areas where the poor concentrate, these measures can bring about an increase in output and/or reduction in production costs of the poor. Thus incomes would be raised and the incidence and depth of poverty reduced.

Table 2. Characteristics of farming systems in the coastal zone of Kenya.

Production system	Share of production system in zone (%)	Commodities (and % shares) in the different farming systems
1	35	Coconut (40), mango (30), citrus (10), cashews (10), cassava (5), groundnut (4), bixa (1)
2	20	Maize/beans (40), cassava (30), livestock (10), sesame (10), cowpeas (5)
3	15	Citrus (40), maize/beans (30), livestock (10), sesame (10), cowpeas (10)
4	8	Cotton (25), maize (25), beans (15), cassava (15), groundnut (10), cowpeas (5), livestock (5)
5	6	Rice (100)
6	5	Sisal (100)
7	7	Livestock (90), millet (10)
8	2	Bixa (100)
9	2	Citrus (100)

SOURCE: Kilambya et al. (1998, Table 33).

The Methodology

The method developed in this chapter for assessing the impact of an agricultural R&D program on poverty has three stages. First, the geographical distribution of the gains from the research program is estimated. Second, the impact of the program is evaluated on the incomes of the rural population in these geographical areas. Third, the effects of these income changes on the spread and depth of poverty are calculated in each of the areas and in the country as a whole.

The general method of estimating the costs and benefits of projects has been developed in the International Service for National Agricultural Research (ISNAR) and the International Food Policy Research Institute (IFPRI) (see Alston et al., 1995). The method consists of the following steps:

(1) Estimate the potential for developing a new technology in the research project, the expected increase in yield as an effect of adopting this technology, and the probability that farmers will adopt it. On the basis of these estimates, the economic costs and benefits of the research project can be estimated for the main population groups—the farmers that adopted the new technology and the consumers that benefited from lower prices.
(2) Estimate the economic costs and benefits of this innovation. These costs and benefits are estimated for each year over the entire period during which the innovation is expected to be operative.
(3) Calculate the net present value of the innovation as the discounted value of the stream of costs and benefits during this time period.

The first step of estimating the research **potential** has, in fact, two components: One is estimating the probability that the research will be successful in that it will generate the "technological innovation" that will yield the desired **outcome**, namely the increase in yields or the reduction in costs. The second component is estimating the probability of adoption, that is, the "adoption profile" (Mills and Kamau, 1998). This probability depends on the expected increase in the yield, the expected additional costs of adopting the new technology—that depend, in turn, on the additional inputs that are required for implementing the new technology—and the prevalence of the farming systems for which this technology is most suitable. The probability of adoption may also depend on local spatial variables, primarily the distance to the urban center and/or to the main transport routes. These spatial variables are significant for several reasons. First, the costs of adopting the new technology include the costs of transporting the necessary inputs and/or outputs. Second, the frequency of the visits of extension workers tends to decline with the increase in the distance from the urban centers. Third, the distance from the village to the urban center reduces the capacity of the local farmers to adopt production technologies for tradable crops. Fourth, the distance to the urban centers also reduces the farmers' capacity to obtain the credit that may be necessary to buy the new inputs. The geographical distribution of the gains from the **outcome** of the research program thus depends not only on the agroclimatic conditions (determining the crops that farmers can grow) in the country's regions, but also on these local spatial conditions (Table 1).

The impact of the local spatial conditions on the one hand, and differences in the socioeconomic characteristics between villages (including differences in the size of the plots under cultivation) on the other hand, are the reasons for the multiplicity of farming systems within the same agroclimatic region. In Kenya, the Kenyan Agricultural Research Institute (KARI) estimates that there are 33 major farming systems in the country's five agroclimatic regions. In the coastal area, KARI identified nine farming systems, ranging from farms that concentrate on high-value crops such as coconut, mango, and citrus, to subsistence-oriented farms in which maize, beans, and cassava are predominant. Table 2 gives details of these farming systems in order to highlight the large differences between them. In the more arid zones, the farming systems are fewer in number and less varied, but farming systems dominated by maize and beans and farming systems in which livestock dominate are significantly different (Kilambya et al., p. 140-141).

In Ethiopia, the Household Survey of 1988 shows that the average landholding of the households in the lowest quintile was only 5% of that of the households in the highest quintile, and they have a much higher degree of specialization. The coefficient of variation of the areas allocated to different crops for households in the lowest quintile varied between 0.70 and 0.85, depending on the agroclimatic region, whereas the coefficient of variation for households in the highest quintile varied between 0.4 and 0.5.

In some regions, farming systems in smaller geographical areas tend to be relatively similar, because the same agroclimatic local geographic conditions affect them all. In these regions, the smaller the geographical area for which the outcome of the research is estimated, the smaller the difference between households within these areas, and the larger the differences **between** areas. In other regions, particularly in countries of Latin America and the Caribbean, differences in the size of the plots owned by the farmers and the forms of ownership—anging from the giant plantations of the rich farmers to the poor sharecroppers—determine the differences in their crop selection within relatively homogeneous agroclimatic conditions.

The second part of estimating the impact of agricultural R&D programs on the incomes of the poor requires a detailed mapping of poverty in the country. The method of estimating the spatial distribution of poverty in a country will be discussed and illustrated later. Once this mapping has been accomplished, the final step is to evaluate and compare the performance of targeted programs in order to select the most desirable one(s). This evaluation requires proper performance measures that express the social costs and benefits from the program. The measures that are commonly used for evaluating the performance of poverty alleviation programs are:

- Type I “error”—The “error of inclusion”: The size of the **non-poor** population that is covered by the program because of inaccurate targeting, and their share in the **total** population that is covered by the program (also referred to as “vertical inefficiency”).
- Type II “error”—The “error of exclusion”: The size of the **poor** population that is **excluded** from the program because of inaccurate targeting, and their share in the country’s **total poor population** (also referred to as “horizontal inefficiency”).
- The budgetary costs of the program—including the program’s administrative costs. For agricultural R&D programs, these costs include those of conducting the research and those of disseminating the new technology.
- The effects of the program on the behavior of households and the implications of these effects for the households’ welfare and the government budget. (Targeted income transfer programs often give incentives to households to alter their personal characteristics or change their work effort in order to qualify for the program.)
- The effects of the program on poverty reduction.

The performance of the program thus depends on the **criteria** that are used to determine eligibility for the program, the **instruments** that are used to implement the targeted program, and the **performance measures** that are used to evaluate the program.

The extent to which poverty was reduced as an effect of the program is obviously the most direct and self-evident performance measure for evaluating a poverty alleviation program. The specific indicator to be used for measuring the reduction in poverty must be carefully selected, however, and this in turn requires a proper selection of the **poverty measure**. If poverty is measured by the Headcount measure, for example, then a program that raises the income of the target population would achieve the greatest reduction in poverty if it is targeted on those areas where the individuals are the **least** poor, leaving out the more extreme poor. For this reason, the Headcount measure is not a suitable performance measure for evaluating a program aimed at alleviating poverty, and this example only highlights the potential problem with using an improper performance indicator.

Among the criteria noted above for evaluating a targeted program, the errors of inclusion and exclusion generally received most attention, because of their intuitive appeal. But these criteria do not provide a complete measure for the budgetary implications of a program. Clearly, however, the larger the Type I error, the higher the costs of the targeted program. Likewise, the larger the Type II error, the smaller the cost increase with a non-targeted program that provides the same reduction in poverty. For income transfer programs, Ravallion and Chao (1989) suggested a performance measure that defines the gains from targeting as:

> "…. the amount by which the budget for a non-targeted program would have to increase in order to achieve the same reduction in poverty that can be attained through targeting."

They termed this measure the "equivalent gain from targeting." This performance measure may not be a good criterion, however, if the corresponding poverty measure is the Headcount ratio because it would leave out the areas in which households are the poorest. Ravallion and Chao did not constrain the poverty measure in their definition, but in their illustration they used the Poverty Sensitivity measure.

For geographical targeting in general, and for geographical targeting of agricultural R&D programs in particular, the performance measure is based on a comparison of the program's performance in one area with its performance in another (and this comparison may also include a non-targeted program). The performance measure used in this chapter for ranking alternative geographically targeted programs is:

> "A program targeted on one geographical area is more beneficial than a program targeted on another area if, <u>with the same budgetary costs,</u> the reduction in poverty with the first program is larger than the reduction in poverty with the alternative program."

The Analytical Model

The impact of an agricultural R&D program targeted on specific crops on a country's poverty depends on the following factors:

- The increase in the yield of these crops as an effect of the technological innovation resulting from the research program,
- The number of poor farmers that adopted the new technology, and
- The share of these crops in their farming system.

The agroclimatic regions in which these crops are grown and the share of these crops in the farming systems of the poor in these regions thus determine the geographical distribution of the program's impact on poverty. The impact of the new technology that resulted from the commodity program on the yield of the target crop(s) depends on the specific **research project** that was carried out within this program, that is, the specific factor input (e.g., seeds, fertilizers, or machinery) that was the subject of the research. Clearly this is a simplifying assumption because some research projects are not part of a commodity program. To highlight the contribution of each of these factors, we introduce the following analytical model.

Let

$$Q_A \mid F_A(X_{A1},...,X_{Ap}) \qquad (1)$$

be the production function of crop *A* that is the subject of the research program, where (X_{A1},..., X_{Ap}) are the quantities of the *p* factor inputs required for production. The technological innovation that resulted from the research program is assumed to have the effect of a **factor augmenting technical change**. That is, a technological innovation that "augments" the input (measured in efficiency units) of the production factor that was the subject of the specific research project within the commodity program. Let the increase in input of the *k*-th factor, **measured in efficiency units**, as an effect of the research project be denoted as ΔX_{Ak}. The increase in the ratio 'yield/output' as an effect of this increase in input productivity is given by: $\Delta Q_A = F'_{Ak} \cdot \Delta X_{Ak}$; where $F'_{Ak} = \partial F_A / \partial X_{Ak}$ is the marginal product of F_A with respect to the *k*-th factor input. The extent to which the technological innovation that resulted from the research project "augmented" the input of that factor is assumed to be function of the direct research expenditures on that project, and given by:

$$\div X_{Ak} \mid \psi_{Ak \notin} R^{\kappa}{}_{Ak} \qquad (2)$$

The parameters ρ_{Ak} and ε, which measure the impact of the innovation on the productivity of the *k*-th factor, indicate, in turn, the average and marginal "productivity" of the research expenditures in this program, namely their contribution to raise the average and marginal productivity of the specific factor input.

The increase in the income of farmers who adopted the new technology depends on the share of the commodity in their farming system, and on the increase in the output of that commodity as an effect of the innovation. It also depends on the price elasticity of demand for the product—in the event that the increase in supply is large enough to affect the market price. In the present analysis, we assume that this effect is small in order to simplify the notations. For an individual farmer in the *i*-th geographical region, this increase in income is given by:

$$\div Y_i \mid w_{iA} \notin P_A \notin F'_{Ak} \notin \psi_{Ak} R^{\kappa}_{Ak} \qquad (3)$$

where w_{iA} is the share of commodity *A* in the farming system of that farmer in the *i*-th area. To simplify the notations, we assume that an **area** is defined as a **farming system within a geographical area**.

The probability that farmers in a given **area** adopt the new technology is a function of the dissemination costs in that **area** and the socioeconomic characteristics of the local farming population. The probability of adoption may also depend on the socioeconomic conditions in the region. In Zambia, a relatively small proportion of the rural population adopted new maize varieties developed in the 1980s because the new technique added to peak labor demand (Collier and Cunning, 1999, p. 81). The dissemination costs are a function of the size of the rural population in that **area**, and they are given by $D_i = \alpha_i \{S_i \cdot N\}$, where S_i is the share of the *i*-th **area's** (rural) population in the country's total (rural) population and *N* is the country's total (rural) population. The proportionality factor, α_i, which determines the dissemination costs per household, is primarily a decision variable, but it is also affected by the distance of the **area** from the urban center, the quality of the roads, and possibly also by other **area**-specific characteristics. The probability of adopting the new technology is assumed to be determined as an exponential function of the dissemination costs as:

$$A_i \mid \nu_i[(\zeta_i)^{\nu}{''} S_i \notin N€] \qquad (4)$$

This formulation assumes that the probability of adoption by an individual farmer is increasing with an increase in the population density in the region, and the parameter $\theta > v$ represents the sensitivity to this effect. This parameter reflects the importance of access to information through social learning mechanisms that, in SSA, is often more important than either the extension services or the household's educational endowment.

The **total** increase in the income of the entire poor population residing in that **area** is therefore given by:

$$A_i \notin \div Y_i {''} S_i \notin H_i \notin N€ \qquad (5)$$
$$\left(P_A \notin F'_{Ak} \notin \psi_{Ak} \notin R^{\kappa}_{Ak}\right\} \notin \left(\nu_i \notin / \zeta_i \vartheta \notin w_{iA} \notin {''} S_i \notin N€ \, 1\,2\,0 (\notin H_i \right\}$$

This increase in the income of the poor will also be (approximately) equal to the reduction in the poverty gap. The quality of that approximation depends on the extent to which the increase in the income of the poor changes the **number** of the poor in the region. Two groups of variables determine the size of that increase. One is the group of variables that measure the increase in the income of a farmer who produces commodity *A* as an effect of the technological innovation that resulted from the R&D project. The other is the group of variables that measure the impact of that increase on the overall increase in income of the poor populations in the target **area**, taking into account the rate of adoption of the new technology, the share of commodity *A* in the farming system in that area, and the share of the poor in the overall population in that **area.**

Three alternatives must be considered in evaluating the desirability of a research program targeted on commodity *A* and on **area** *i*:

(1) Targeting the program on another **area**—by targeting and redirecting the dissemination expenditures; but this would be a different project (i.e., item no. 2)
(2) Targeting a different commodity program on the same **area**—by redesigning the R&D project; and
(3) Targeting a different commodity program on another **area**—by redirecting both the R&D and the dissemination expenditures.

Let us examine each of these alternatives sequentially. First, targeting the same commodity program on another **area**: From Equation (5) we can conclude, after some algebra, that, **with the same budgetary costs**, a program targeted on **area** *i* will bring about a larger reduction in poverty than the same program targeted on **area** *j* if, and only if:

$$\nu_i \notin w_{iA} \notin {}'' S_i \text{€}^{12\chi 4\nu(} \notin H_i \; \} \; \nu_j \notin w_{jA} \notin {}'' S_j \text{€}^{12\chi 4\nu(} \notin H_j \qquad (6)$$

Equation (6) clarifies that the selection of the **area** for targeting depends not only on the incidence of poverty in that **area**, but also on the likelihood that the farmers in the target **area** will adopt the new technology, and on the share of that commodity in their farming system. Notice that the expression $[\gamma_i \cdot w_{iA} \cdot \{S_i\}^{(1+\theta-\nu)} \cdot H_i]$ can be written as $[w_{iA} \cdot S_i \cdot H_i] \cdot [\gamma_i \cdot \{S_i\}^{(\theta-\nu)}]$, where the first expression indicates the share of the commodity in the farming system of the country's **total** poor population, and the second expression indicates the impact of the **area**'s socioeconomic characteristics on the probability of adoption.

The second alternative is to target the research program on a different commodity, but in the same **area**. (Another possibility, closely related to this alternative, is selecting a different research project within the same commodity program, namely a project that will be targeted on a different factor input.) From Equation (5) we can conclude that, **with the same**

budgetary costs, targeting a different commodity program on the same **area** will be less beneficial, in the sense that it will bring about a smaller increase in the income of the farmers in that area, if, and only if:

$$\div Y_i / A (| \Psi_A \notin F'_{Ak} \notin \psi_{Ak} \beta \notin w_{iA} \} \div Y_i / B (| \Psi_B \notin F'_{Bk} \notin \psi_{Bk} \beta \notin w_{iB} \quad (7)$$

The latter condition clarifies that the selection of a proper commodity program depends not only on the prospects of achieving a large increase in yield, but also on the **value** of this increase for the farmers, and on the share of the commodity in the farming system in that **area**. It should be noted, however, that implicit in the condition in Equation (7) is the assumption that the probability of adoption depends on the socioeconomic and geographic conditions in the **area**, but not on the characteristics of the specific crop. It may be the case, however, that the adoption rates differ between crops because of, for example, significant differences in the costs of the necessary inputs. In India, a main obstacle to poor farmers' adoption of high-yielding cottonseed is the need for expensive fertilizers and new hybrid seed each year. Indeed, the specification of the various conditions in our model is primarily illustrative and would have to be re-examined and econometrically tested in empirical studies.

The third alternative is to target the research on a different commodity program in a different **area**. Equation (5) clarifies that the decision depends on the following measures:

- The impact of the innovation on the income of farmers in that **area** who adopted the new technology, given by:

  $$[P_A \cdot F'_{Ak} \cdot \rho_{Ak} \cdot R^{\varepsilon}_{Ak}] \cdot w_{iA}$$

  The decision variable that determines this impact is the direct R&D expenditures $R_{Ak.}$ The actual impact of this decision depends, however, both on the marginal productivity of the R&D project—measured by the increase in yield as an effect of the innovation that resulted from the research—and on the share of the commodity in the farming system in the **area**, and on its market price. The market price is relevant to farmers who can engage in trade.
- The probability that farmers in the **area** will adopt the new technology, given by:

  $$[\gamma_i \cdot (\alpha_i)^v \cdot \{S_i \cdot N\}^{\theta}]$$

  The decision variable that determines this probability is the dissemination costs per household in the **area**, α_i, but the rate of adoption depends also on area-specific socioeconomic and geographic conditions.
- The size of the general population in the **area**.
- The incidence of poverty in the **area**—as indicated by the Headcount measure.

These conditions emphasize that a successful implementation of an agricultural R&D program aimed at reducing poverty depends both on the choice of crops that are grown in the farming systems of the poor and/or on the choice of geographical areas in which the incidence of poverty is high. Equally important for the success of the program are **area**-specific socioeconomic and geographic characteristics that determine the effectiveness of the dissemination program. Agricultural R&D, therefore, may not be a suitable policy instrument for poverty reduction in **areas** where the rate of adoption of the new technology is likely to be very low, and other policy instruments should therefore be considered. Even in these **areas**, however, the effectiveness of agricultural R&D as a policy instrument for poverty reduction should be evaluated against the costs and benefits of **available** alternative policy instruments aimed at achieving this goal.

The same conclusion also applies to other programs. The impact of an anti-poverty program targeted on specific areas depends both on the relative size of the poor population in the target areas and on the socioeconomic, agroclimatic, and geographic conditions in these areas, because these conditions determine the program's effectiveness. In some geographical areas, agricultural R&D may prove to be the most effective policy instrument for raising the income of the rural poor, while in other perhaps equally poor areas, other policy instruments could be more effective. The selection of an effective anti-poverty policy therefore requires two types of decision—first, a choice of the area for targeting, and second, a choice of the most effective instrument for implementing that policy. These choices cannot be made sequentially, however, because the effectiveness of most programs depends on the socioeconomic and geographic conditions in the area in which they are implemented.

Using the same set of equations, we can also calculate the increase in the **total income** of the population in each **area** as an effect of an agricultural R&D program, and the conditions for selecting the target **areas** in order to maximize the increase in farmers' total income. These conditions are likely to be considerably different from the conditions for maximizing the reduction in the poverty gap, and the differences are larger the larger the difference between the poor and more affluent farmers in their farming systems and in the rate of adoption of a new technology. As a result, the commodity programs and the **areas** that will be selected for targeting poverty-reduction programs are likely to be considerably different from the commodity programs and the **areas** that will be selected in order to maximize the total income of the rural population. A direct result of these differences is that commodity programs targeted on specific areas with the objective of maximizing the increase in **total income** are likely to lead to an increase in **income inequality** among the rural population.

The difference between these two goals—maximizing the increase in total income, and maximizing the reduction in poverty—has important implications for the selection of agricultural R&D as a policy instrument for the reduction of poverty. To illustrate these implications consider the case in which **area** *i* is the **area** selected on the basis of the criteria for maximizing the increase in total income. Assume, however, that with the same budgetary costs a program targeted on **area** *j* can bring about a larger reduction in poverty. In this case, the larger the difference in the increase in total income between these two programs, the larger the increase in income inequality as a result of targeting the program on area *i* rather than on area *j*. This difference in the increase in total income therefore represents the **opportunity costs** of targeting the program on area *j* in order to achieve the maximum reduction in poverty. This difference also has another interpretation, however. If the economic costs of re-distributive measures aimed at bringing income inequalities back to their previous level are larger than this difference, then a combination of measures will be **less** desirable than the direct measure of targeting agricultural R&D in order to achieve the maximum reduction in poverty. The combination of measures includes targeted agricultural R&D aimed at achieving the maximum increase in **total** income together with re-distributive measures aimed at preventing an increase in income inequality.

Poverty Mapping

In the SSA countries, geography is often the single most important factor that determines the incidence and depth of poverty. However, the mapping of poverty in these countries cannot be determined by agroclimatic conditions alone for two reasons. First, differences in these conditions provide only a partial explanation for differences in the incidence of poverty. In semi-arid regions, for example, production is intrinsically risky and large areas are too dry for rainfed agriculture; these areas are generally the poorest, but in these areas the population pressures on the land are still relatively small and households' plots tend to be relatively larger. Farmers with larger plots are generally more affluent despite the difficult climatic conditions. In the more humid regions, by contrast, the fertile lands attract many migrants and, with the rise in population density, the average size of the plots is shrinking, the share of landless rural workers is rising, and, as a consequence, the incidence of poverty is also rising. Moreover, local factors are equally important in determining the incidence of poverty. Thus, for example, in many humid regions the soil quality is relatively poor and many of these areas are more prone to malaria, which can significantly reduce farmers' production capacity and income. Distance to the urban center and the quality of the road are often equally significant factors that determine crop selection because they determine the capacity of farmers to market their products. As a result of these additional factors, many studies that focused on the production potential of the area as the principal explanatory variable that determines the incidence of poverty in rural areas did not produce a conclusive result (see Heisey and Edmeades [1999] for a list of references).

Poverty mapping in the SSA countries therefore cannot be determined on the basis of the agroclimatic conditions alone and must incorporate additional and more direct indicators that can explain variations in income and consumption in the different geographical areas. In the absence of reliable data on income or consumption, indirect indicators such as life expectancy, child mortality, and child morbidity in different geographical areas may also be used. The main source of direct data on income or consumption in a country is the Household Income and Expenditure (HIE) Survey, which collects detailed data of a representative sample of households in the country's main administrative regions. In many SSA countries, the income data were found to be deficient, however, and the poverty assessment had to be based on the expenditure data. The sample of households in the survey is generally selected so as to provide a statistically adequate representation not only of the entire population in the country, but often also of the population in the country's main administrative regions. This sample is not sufficient, however, to determine the geographical distribution of poverty in small geographical areas or in the **agroclimatic** areas—the areas relevant for the analysis of the impact of R&D projects—for two main reasons:

(1) In most cases, administrative regions have considerably different boundaries than the agroclimatic areas. Without additional information, it will not be possible therefore to stratify the sample of households that were included in the Income and Expenditure Survey according to the agroclimatic areas in which they reside.
(2) The administrative regions are relatively large and often quite heterogeneous in terms of the standard of living. In many SSA countries, there are considerable differences in the standard of living between districts and villages within the same administrative regions as a result of differences in local geographic conditions. The sample size of the survey in these smaller areas is far too small, however, for statistically valid inferences.

The objective of this section is to describe the method of using the HIE Survey data for mapping poverty in smaller geographical areas of sub-districts, or even villages (for details, see Bigman et al., 2000). The method is based on using the HIE Survey data in combination with data from a wide variety of other sources that provide information on the characteristics of these areas and their populations. The first and most important step is to bring together the information from the different sources at the level of the village on the basis of the geographical coordinates and organize the data as a geographical information system (GIS). Information on larger areas (districts, climatic regions, etc.) will be incorporated into the system according to the coordinates of their borders. The complete method of estimating the incidence of poverty in small geographical areas involves the following four steps (the description below is for mapping poverty at the level of individual villages.)

(1) Arrange the data taken from a wide variety of sources (Table 3) in the form of a GIS, according to the geographical coordinates of the villages. These data can include demographic and socioeconomic information on the population in the village (e.g., from the population census—if available). Second are community-level data, including information such as the distance to urban centers, the distance to the school and/ or the health clinic, the condition of the road, the distance to the source of drinking water, etc. The third is region-level information on agroclimatic, soil, and geographic conditions, including the distance to the main city or town. The entire data set is integrated at the level of the village using geo-referencing, and organized in the form of a GIS database.

Table 3. Data sources for the study in Burkina Faso.

Level of aggregation	Data source	Coverage
Household	Priority survey (1994): Provides data on income and expenditure for 8642 households	Survey sample (473 villages)
Village	Priority survey (1994): Community component of the survey that covers infrastructure and communal services	Survey sample (473 villages)
Village	National census (1985): Demographic data	National
Village	Ministry of Water Management and Infrastructure (1995): Data on health and water infrastructure, distances to infrastructure, public administration, and social groupings	25 out of 30 provinces
Village	Ministry of Education (1995): Data on primary school infrastructure and teacher/pupil ratios	National
Department	Ministry of Agriculture (1993): Data on various indicators ranging from average literacy rates to vegetation indices	National
Department	Directorate of Meteorology (1961-1995): Data on temperature (31 locations), evapotranspiration (15 locations), and rainfall (160 locations)	National
Province	Ministry of Agriculture (1993): Data on cattle per households	National

(2) This data set, together with the detailed data of the HIE Survey, is used in an econometric analysis to construct a prediction model of the probability that a household in that village is poor—as a function of household-, community-, and regional-level variables. In this analysis, the dependent variable is the probability that the household is poor (using logit or probit econometric estimation) and the analysis is conducted for all the households that were included in the survey. The household-level explanatory variables can therefore be divided into two groups. The first is the group of variables that describe the relevant characteristics of the individual households that are available in the Income and Expenditures Survey (e.g., the size of the household, age and sex distribution, school attendance, etc.). The second is the group of "area" (village, district, etc.) explanatory variables that characterize the area in which the household resides. These variables are identified according to the coordinates of the village in which the household resides and the coordinates of the "area". These explanatory variables

can include characteristics of the households in the community from the Census (e.g., **average** household size in the village, typical dwelling conditions such as average number of rooms per household), characteristics of the village (e.g., number of households in the village, distance to the urban center, proximity of school), and agroclimatic conditions in the area. (See Table 3 for the list of possible explanatory variables that were used in the Burkina Faso study).

(3) The predictions of the econometric model are applied to derive estimates of the probability that a household in a village with these characteristics will be poor.

(4) The villages can then be divided into several groups, ranging from the villages with the highest incidence of poverty to the villages with the lowest incidence of poverty. The villages can then be denoted on the map according to these categories (see example below).

The quality of the estimates in the econometric analysis depends first and foremost on the quality of the data that can be obtained from the various sources to characterize the "area". The variables used to characterize the "areas" in the study on Burkina Faso, and for which data were available from various sources, are listed below. They highlight the fact that even in countries like Burkina Faso, which may not be known to have extensive socioeconomic, geographic, and agroclimatic data, a very substantial data set can be made available for this type of analysis. The list is of the final set of variables that were used in the econometric analysis.

Variables used in the econometric analysis in the Burkina Faso study

Aggregation level	***Variable (average per 'area')***
Village	Children 0-6 per adult (15-50 years) in household
Village	Children 7-14 per adult in household
Village	Elderly (50+) per adult in household
Province	Literate head in household
Province	% male adults literate in household
Province	% female adults literate in household
Province	Livestock units per capita
Village	Distance to nearest rural primary school
Village	Teachers per child 7-14 years
Village	Distance to nearest health facility
Village	Whether nearest facility has safe water
Village	Number of pumps per rural community
Village	Existence of an all-weather road
Department	Cultivated area in department per capita
Department	Average rainfall
Department	Absolute value of deviation of rainfall from average
Department	Average length rainy season
Department	Average vegetation index
Department	Homogeneity rainy season

The classification of villages according to the above four categories of poverty represents, in fact, different levels of the poverty line. In the study on Burkina Faso, three poverty lines were selected and they determined, in turn, four categories of poverty for the villages—ranging form the “extreme poor” to the “non-poor”. This classification significantly reduces the error of inclusion (Type I) of a program targeted on the “extreme poor” villages. The villages in this category in the study in Burkina Faso were 25% of the total number of villages, but they included about two-thirds of the rural poor households. This classification also reduces the probability that villages classified as “non-poor” (which could therefore be the target of cost-recovery programs) have a large number of poor households. The objective of the study in Burkina Faso was to examine criteria for targeting government health and education programs on the poor villages. For targeting agricultural R&D programs the relevant target areas is often much larger, according to the country’s agroclimatic regions. In some regions, however, where significant differences exist between farming systems in subregions because of local geographic or soil condition, targeting agricultural R&D on smaller geographical areas will be desirable.

Concluding Remarks

In 1997, the Consultative Group on International Agricultural Research (CGIAR) system adopted new policy guidelines that gave the highest priority to alleviating poverty by means of targeted resource conservation and management, targeted research and development to increase the productivity in the farming systems of the poor, improvements in the policy environment, and support to the national research capacity. These guidelines evolved from the CGIAR policy goals of 1990 that gave the highest priority to enhancing the nutritional status and well being of the low-income people (see Anderson, 1998). The implementation of these guidelines requires a methodology for assessing the impact of agricultural R&D projects on poverty. To make these assessments, a considerable amount of analytical work has been devoted in the past 2 years to the development of a methodology for identifying the geographical areas in which the poor concentrate. The analytical model presented in this chapter indicates that this is only one part of the methodology required for that evaluation. Other important parts are a detailed mapping of the incidence of the benefits from the R&D program across geographical areas and farming systems, and a method for estimating the incidence of poverty in the target areas.

The analytical framework requires also an assessment of other possible policy tools to assist the target population because the goal of poverty reduction can be achieved by other measures that are more cost-effective than agricultural R&D. The impact of a new technology that was developed in a given research program depends not only on its contribution to increase yields, but also on the rate of adoption of this technology. The impact on the poor farmers may therefore be reduced if the rate at which they adopt the new technology is particularly low. The rate of adoption among the poor may be slowed down either because of the initial investments that are required to adopt the new crop (new seeds, fertilizers, etc.) and because of the lack of the necessary know-how. This lack of know-how is one of the major hurdles in the adoption of non-traditional crops. To increase the impact of agricultural R&D on the poor, it is therefore necessary to complement the R&D project with intensive efforts of the extension services to disseminate the new technologies and direct assistance to the farmers that adopt these crops.

References

Alston, J.M.; Norton, G.W.; Pardey, P.G. 1995. Science under scarcity: Principles and practice for agricultural research evaluation and priority setting. Cornell University Press, Ithaca, NY, USA. 585 p.

Anderson, J.R. 1998. Selected policy issues in international agricultural research. On striving for public goods in an era of donor fatigue. World Develop 26: 11149-11162.

Bigman, D.; Dercon, S.; Guillaume, D.; Lambotte, M. 2000. Community targeting for poverty reduction in Burkina Faso. *In*: Bigman, D.; Fofack, H. (eds.). Geographical targeting for poverty reduction. World Bank, WA, USA. p. 125-154. (World Bank Regional and Sectoral Studies)

Collier, P.; Cunning, J.W. 1999. Explaining African economic performance. J Econ Lit 37:64-111.

Datt, G.; Ravallion, M. 1993. Regional disparities, targeting, and poverty in India. *In*: Lipton, M.; van der Gaag, J. (eds.). Including the poor. Proceedings of a symposium organized by the World Bank and the International Food Policy Research Institute (IFPRI). World Bank, WA, USA. p. 91-115. (World Bank Regional and Sectoral Studies)

Heisey, P.W.; Edmeades, G.O. 1999. World maize facts and trends 1997-98: Maize production in drought-stressed environments; technical options and research resource allocation. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), MX.

Hentschel, J.; Lanjouw, J.O.; Lanjouw, P.; Poggi, J. 1999. Combining census and survey data to study spatial dimensions of poverty: A case study of Ecuador. *In*: Bigman, D.; Fofack, H. (eds.). Geographical targeting for poverty reduction. World Bank, WA, USA. p. 101-125. (World Bank Regional and Sectoral Studies)

Kilambya, D.; Nandwa, S.; Omamo, S.W. 1998. Priority setting in production-factor research program. *In*: Mills, B. (ed.). Agricultural research priority setting: Information investments for improved use of resources. International Service for National Agricultural Research (ISNAR), The Hague, NL. p. 137-149.

Mills, B.; Kamau, M. 1998. Methods for prioritizing research options. *In*: Mills, B. (ed.). Agricultural research priority setting: Information investments for improved use of resources. International Service for National Agricultural Research (ISNAR), The Hague, NL. p. 53-69.

Ravallion, M.; Chao, R. 1989. Targeted policies for poverty alleviation under imperfect information: Algorithm and applications. J Policy Model 11:213-224.

Ravallion, M.; Wodon, Q. 1997. Poor areas or only poor people? Research Policy Working Paper no. 1798. World Bank, WA, USA.

PART TWO

Case Study Evidence

CHAPTER 9

Assessing Links between Rural Poverty and Natural Resource Endowments: Evidence from West Asia

*Abelardo Rodríguez**

Introduction

Water availability and natural resource management (NRM) are key limiting factors in dryland agriculture. This chapter presents highlights of research on the links between these factors and rural poverty alleviation in West Asia. There is a widespread perception that poverty determines natural resource degradation and that, in turn, resource degradation exacerbates the poverty of the natural resource stewards—the rural poor. The relationship between poverty and environmental degradation was determined by studying various NRM scenarios and assessing their impact. Elements from two case studies of water management (in Pakistan and Syria) and one of land and soil conservation (in Yemen) were selected as most relevant for discussion. Aspects of poverty and environmental degradation within the three study areas are examined and conditions for possible future improvements outlined. Caution must be used to avoid generalizations of poverty levels in NRM scenarios without considering the distribution of resources. Evidence from West Asia shows that wealth and resource degradation are related through livelihoods that take advantage of market, institutional, and policy failures. For the poor and the wealthy, savings on household resources, increased yields, or increased net benefits constitute incentives to adopt improved NRM technologies. However, depending on the context, these incentives may not be enough to guarantee adoption.

Three Case Studies in West Asia

Water management in highland Balochistan, Pakistan

Balochistan is the least developed province in Pakistan. It hosts less than 7% of the national population and has the lowest population density.

---

* Agricultural Economist, International Center for Agricultural Research in the Dry Areas (ICARDA), based in Cairo, Egypt.

However, indigenous water management practices in the harsh semi-arid and temperate environment of the highland area of this province have allowed the establishment of relatively large concentrations of people (AZRI, 1994). Various endogenous and exogenous factors have determined transformation, substitution, or expansion of the systems, which are:

- The *Karez* system (*Qanat* in Persian or *Foggara* in Arabic)—developed to supply drinking water and irrigation; uses tunnels to carry water from the foothills to the cropped valley (Ahmad, 1990);
- Spate irrigation (*sailaba* agriculture)—used in the cropping areas, relies on the torrential water flow from the hillsides or on natural water catchment (Kahlow and Hamilton, 1996); and
- *Khuskhaba* agriculture, which "harvests" water in the flatlands adjacent to the cropping areas (AZRI, 1994).

The *Karezes* in the Quetta valley began to dry up in the 1970s because of the introduction of tubewells adjacent to water collection sites. Groundwater surface irrigation systems proliferated and, eventually, groundwater extraction exceeded the rechargeability of the aquifer. During the 1980s and 1990s, farmers had to drill deeper boreholes or rely on *khushkaba* or *sailaba* agriculture (AZRI, 1994). The deterioration of the tribal regulatory framework for access and extraction of groundwater, the availability of extremely low-cost electricity from the government, and the favorable market for subtropical fruit in national markets contributed to the decay of the *karezes* and led to their replacement by tubewells (van Steenbergen, 1997). For the last 20 years, the inhabitants of highland Balochistan have faced declining water tables and the continued expansion of fruit and vegetable exports by those who own tubewells. Therefore, distribution of wealth is a function of arable land and access to water.

Sailaba agriculture irrigation systems provide a livelihood for families living in the mountains or the foothills. These systems are designed to cope with uncertain amounts of water runoff by varying the levels of irrigation in terms of time and space. Water availability determines different levels of irrigation in small plots divided by bunds. Well-defined land tenure determines the sequence of irrigation and, depending on the number of plots and irrigators within a catchment area, specific irrigation rules prevail to ensure equitable access to water and to offset the otherwise inevitable polarization in water distribution (Ahmad et al., 1998). Because of the torrential nature of the water flow, coordination among farmers to divert water and repair damaged bunds and weirs is essential. This system is expanding, but whether or not it can accommodate the rate of agricultural intensification is unclear. At present, some farmers are extracting groundwater from 10- to 20-m wells. Vegetable and fruit production from small plots (0.02 to 0.1 ha) has enriched the household diet and increased income (through smaller income outlays for home consumption and/or sales at nearby markets). Small-scale, low-pressure irrigation systems, as a complement to *sailaba* agriculture, provide a potential means for sustainable increased income.

Khuskhaba agriculture is common in the valley floors, where large extensions of arable land are available for use by farmers with land titles or as tenants. In this system, part of the land is used for water catchment, with the remainder used for cropping. Water runoff from the catchment area is transferred to the cropped area to boost yield. The objective is to stabilize and increase yield at the expense of the arable land not used for cultivation. A large proportion of farmers in highland Balochistan depends on this type of agriculture. They tend to be less market oriented than are farmers practicing spate irrigation. Flocks of small ruminants, owned by farmers or semi-nomadic and nomadic herders, graze cereal stubble in *sailaba* and *khushkaba* lands. Unfortunately, a major part of these animals' diet comes from the rangelands, which have become overgrazed in many areas of highland Balochistan (AZRI, 1994).

In the late 1980s, the International Center for Agricultural Research in the Dry Areas (ICARDA), in collaboration with the Arid Zone Research Institute (AZRI), began to work with farmers on the valley floors. The aim was to improve the food security of the *khushkaba* end-users and to search for a way to ameliorate pressure on the rangelands (Rees et al., 1991). Adaptive research over 7 years showed that low-input, micro-catchment water harvesting in *khushkaba* land did not actually improve yields of wheat (*Triticum sativum* Lam.) when taking into account the amount of land used to harvest the water. Rather, it increased gross margins by 23%—through a reduction in variable costs—and reduced its variability by 19% (Rodríguez et al., 1996). This would appear to make micro-catchment water harvesting marginally attractive to farming families practicing *khushkaba* agriculture in a high-risk environment; the adoption rates of this technology are low, possibly because net yield increases are more relevant to subsistence farmers. A similar scenario was identified regarding the use of micro-catchment and water tanks in India (Thomas Walker, personal communication, 1999).

Research shows that it is difficult to create a strong incentive for water harvesting on lands with a low resource endowment (e.g., valley bottoms). Available statistics suggest that, on the average, only about 150,000 of 700,000 ha of rainfed land in highland Balochistan are cropped (AZRI, 1994). An estimated 40%-50% of the rainfed land is in the valley bottoms. Clearly, farmers are reluctant to adopt new NRM practices in highly risky environments. Therefore, while the challenge to increase *khushkaba* farmers' income through improved and sustainable NRM remains, ICARDA has shifted its research efforts toward the *sailaba* agricultural systems (WRRI, 1998). At least three factors hinder the widespread adoption of *khushkaba* agriculture—the fluctuating population of Afghan refugees affecting the livelihoods of farmers in the Quetta valley, variable wheat import policies in the province, and farmers' perceptions of the benefits of tubewell irrigation compared to those of improved water harvesting technology. In addition, *sailaba* irrigation accrues more water per unit of cropped area in micro-watersheds with higher net yields and economic benefits (Ahmad et al., 1998). Populations in the mountainous areas are less exposed to these exogenous factors. Thus, higher payoffs for research can be attained with lower population densities and higher yielding technology.

Most farmers in highland Balochistan are *khushkaba* and *sailaba* subsistence farmers. A relatively small group of farmers practice tubewell irrigation, mostly in the valleys. The poorest farmers practice *khuskhaba* agriculture and there is little option for improving the performance of rainfed agriculture, even with water harvesting techniques. Their communal grazing grounds in the foothills have been continuously overgrazed. *Sailaba* farmers, still poor, but better off than *khuskhaba* farmers, are more isolated in the mountainous environments, but have better chances to improve their livelihoods because their investments in landscape, designed to catch and convey torrential rains, result in more reliable water than in *khuskhaba* agriculture. Grazing lands are in better condition than in the valleys or foothills. Tubewell agriculturalists in the valleys are the wealthiest, market-oriented, with good land endowments, and only pay extraction costs for the very scarce groundwater.

Groundwater use in Aleppo, Syria

For the last 2 decades, a major part of Syria's agricultural investment has been devoted to the development of irrigation. Currently, 60% of its irrigated land is dependent on groundwater. The number of registered wells has increased from 45,000 in 1970 to 47,200 in 1980, and 143,000 in 1994 (ESCWA-FAO, 1996). This increase was encouraged through government loans for tubewell installation. The Syrian government has emphasized self-sufficiency in cereals as a means toward achieving food security. As a result, Syria became self-sufficient in wheat in 1994. In its quest for food self-sufficiency, Syria has seen a parallel decline in its groundwater tables, not necessarily because all water is allocated to wheat production, but because whenever a farmer has access to irrigation water, there are incentives to grow high-value crops in addition to cereals. Whether or not the country should use its limited groundwater to grow staple or high-value crops must be determined according to national priorities and policy objectives.

The study area is located in Aleppo province, in the northwestern part of Syria adjacent to Turkey. It comprises a cross-section of four out of five agricultural stability zones (Rodríguez, 1997; Ahmad and Rodríguez, 1998). Annual precipitation in the "high-rainfall" section of the study area exceeds 350 mm, and at least 300 mm in 2 years out of 3. The main crops are cereals, food legumes, fruits, vegetables, and summer crops. The "low-rainfall" part of the study area has 200-250 mm annual rainfall, and no less than 200 mm in 1 year out of 2. There is limited production of vegetables, food legumes, and wheat where irrigation is available. Because the area includes the outskirts of Aleppo City, it is affected by the agricultural product market there, which is continually growing to satisfy the higher and more diversified demands of urban dwellers. As one might expect, poverty is inversely related to the availability of water and arable land.

Farmers believe that “those who own wells are entitled to as much water as they want.” Wells are perceived as “land improvement”, and farmers believe “it is not proper to interfere with land use” (Rodríguez, 1997). Land tenure in this area determines access or exclusion and withdrawal rights to groundwater. In Islamic tradition, water is a gift from God and belongs to the community. However, value added as a result of investments in distribution or conservation may create a qualified right to ownership and thus permit appropriation and local water marketing (Aptekman, 1973; Mallat, 1995). In the drier areas, farmers suffer extreme water scarcity and well interference is evident. The simultaneous pumping of contiguous wells exhausts the water, making it necessary to wait for a few hours for the wells to recharge. This creates an endless cycle of competition for water extraction.

During discussions about the potential savings in pumping costs if irrigation scheduling were implemented, farmers raised the issue of cheating as a major concern and cited the inevitable limitations of such a system: “nobody will know whether someone is pumping water”, and the fact that monitoring costs would be prohibitive. Some pointed out that “if we could see the water in the channel, nobody could cheat”. Farmers are convinced that they will eventually return to the traditional barley-livestock systems. In the meantime, the race for more water is evident in the growing numbers of unofficial wells. Well-drilling is a risky endeavor, but one with which farmers in the drier areas are willing to live. The drier the land is, the higher the frequency of more than one well per farmstead (Mueller and Rodríguez, 1997).

In Zone 4, however, extended families comprising three or four households share a well for irrigation and domestic purposes in their farm premises, and cooperation in irrigation scheduling is more the exception than the rule. Recent work in the province (NRMP-DIWU, 1999) showed that 94% of the irrigators in Zone 4 were willing to share water for irrigation, and 69%-84% of the irrigators in other zones were willing to do so. As groundwater resources decrease, farmers may reconsider their right to appropriate water and their willingness to cooperate. There is a contradiction between what farmers genuinely believe about cheating and the cooperation they would like to see happening in the drier areas. Their real concern and a hypothetical willingness to cooperate are part of the perceptions on resource scarcity and management that need to be incorporated in the design sustainable policies.

Price incentives have induced farmers to adopt a cropping pattern that has pushed the agricultural frontier to the drier areas. Wheat is the dominant crop produced under rainfed and supplemental irrigation (SI) conditions in Aleppo (SI is defined as "the application of small amounts of irrigation to essentially rainfed crops normally grown at that location, to increase and stabilize yield levels"—ICARDA, 1995, p. 9). Of the 49,900 ha planted to wheat, 40% is under SI. The Directorate of Irrigation and Water Use (DIWU) and ICARDA have been collaborating to improve the water-use efficiency in wheat.

While rainfed wheat production is financially and socially profitable, wheat under SI is largely dependent on location (stability zone) and the level of irrigation (Table 1). When the social domestic resource cost (DRC) is accounted for, rainfed wheat cultivation uses resources efficiently (DRC values less than 1). Rainfed wheat in Zone 1 (350-mm rainfall) and Zone 2 (300-mm rainfall) are more efficient than rainfed wheat in Zone 3 (250-mm rainfall). There are two examples of scenarios under SI: one where rainfall is 350 mm (Zone 1), with 150 mm as SI; and the other where rainfall averages 200 mm (Zone 4), with 150 mm as SI. In the first example case, both private and social profitability are positive. In the second example, private profitability is positive, but social profitability is negative when domestic resources are fully paid. Supplemental irrigation (150 mm) in the lower rainfall areas (200 mm) had a DRC ratio well above 1.

Table 1. Economics of wheat produced under different types of water availability in Aleppo, Syria.

Water availability (mm)	Private profitability[a] (SL/ha)	Social profitability[b] (SL/ha)	Domestic resource cost
Zone 1 - Rainfed (350)	7,905	6,920	0.17
Zone 2 - Rainfed (300)	7,579	5,026	0.19
Zone 3 - Rainfed (250)	1,888	1,284	0.33
Zone 1a - Supplemental irrigation[b] (150)	16,496	8,200	0.54
Zone 4 - Supplemental irrigation[c] (150)	836	-3,643	1.62

a. SL = Syrian pound currency.
b. Rainfall = 350 mm.
c. Rainfall = 200 mm.

SOURCE: Ahmad and Rodríguez (1998).

Because the cost of the fuel is substantial (an average 20%-25% of variable costs), the response of social profitability in wheat to changes in the social price of diesel was examined. Four water regimes comprising different combinations of rainfall conditions and SI were plotted (Figure 1) according to six price variants for diesel (4, 6, ... 14 SL/L, with US$1 = 42.5 SL). These types of water regimes are commonly found in Aleppo province. As the price of diesel increases, the social profitability of wheat decreases at different rates. The steepest decline in social profitability occurs under 300-mm rainfall and 250-mm SI, with the second biggest drop at 300-mm rainfall and 150-mm SI. The decline in social profitability under (a) 200-mm rainfall with 200-mm SI, and (b) 250-mm rainfall with 150-mm SI is highly similar, but under the lowest rainfall, social profitability becomes negative when the social price of diesel was above 10 SL/L.

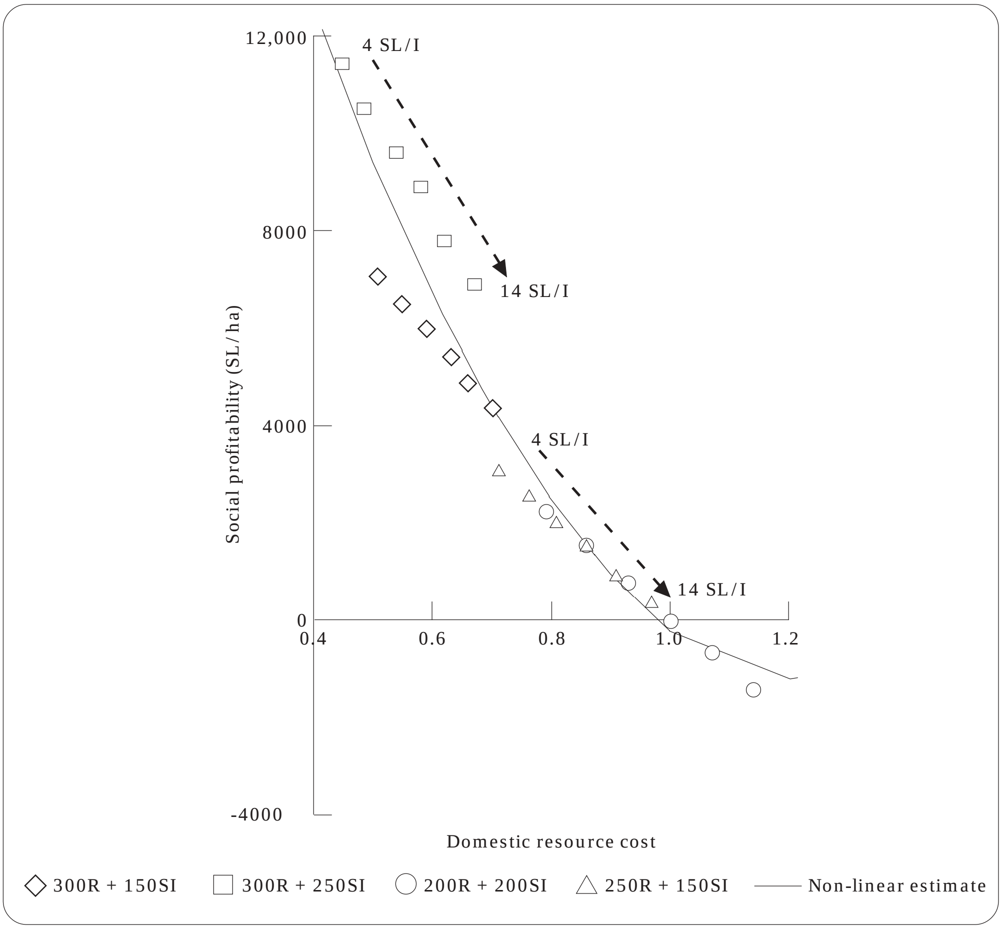


Figure 1. Social profitability of wheat with respect to domestic resource cost for alternative water regimens and prices of diesel in Aleppo, Syrian Arab Republic. Adapted from Ahmad and Rodríguez (1998). (R = rain in mm, SI = supplemental irrigation in mm, and SL = Syrian pound currency.)

Thus, increasing prices of diesel will not necessarily modify the unsustainable path of groundwater use. Private profitabilities, used by farmers to gauge the performance of a technology, are above the social profitabilities. For the policy analyst, the social profitability in Zone 2 with 250 mm SI at 14 SL/L is similar to that of 150 mm SI at 4 SL/L; in Zone 3, the social profitability is still positive for the range of diesel prices considered. For farmers who perceive that they could easily jump from one stability zone with less rainfall to another with more rainfall, using SI as a vehicle, the analysis of tradeoffs is not obvious. This is because SI is a highly noble technology (i.e., more yields with more water, farmers easily perceive benefits in terms of production levels). However, the largest share of groundwater use in Aleppo is in Zone 2 and only 20% is used for wheat under SI, the rest of the groundwater is used for high-value crops with larger gross margins per unit of water used (Rodríguez et al., 1999). Increasing costs of diesel alone is not enough to curtail groundwater use.

A sustainable groundwater policy requires strengthening the cohesion within the communities in order to perceive monitoring of water use and compliance of communal agreements for water extraction as a service to the community rather than as impinging the “rights” of individuals to water. Pricing of water, electricity, or diesel is necessary for farmers to realize the costs of these resources in the production process. Policy analysts could help to diffuse benefits and costs associated with rainfed and irrigated agriculture in different stability zones and help irrigators realize the competitiveness of different crops in the stability zones. Through their research, ICARDA and DIWU have realized that SI is only one aspect of farmers’ multiple use of groundwater that must be addressed in terms of resource sustainability. The DIWU is interested in evaluating irrigation practices in terms of net returns per cubic meter of groundwater, for each stability zone. Efforts to sensitize the technical staff about the environmental and economic value of water should complement efforts to promote viable options developed by policymakers and local institutions.

Wealth and resource degradation in the context of groundwater irrigation in northwest Syria is a fact that must be accepted for the long-term strategy of the agricultural sector. The resource-poor groundwater irrigators in stability Zone 3 or 4 are generating a negative externality, as measured by declining water tables. However, this is of considerably less magnitude compared to that of wealthy farmers in Zone 2 who are using 80% of their groundwater to produce high-value crops to feed the city of Aleppo. Undervalued or un-priced groundwater, weak institutions at the community level, and lack of sensitivity of the technical staff towards the economic and environmental value of water work together to form the unsustainable pattern of water use.

Rehabilitating mountain terraces in Hajja province, Yemen[1]

Abandonment of terraced agricultural land in the highlands of Yemen resulted in the degradation of productive land, historically constructed and sustained with indigenous knowledge and by cooperation within local communities. The dramatic social and economic changes of the last 30 years following the revolution, the oil boom in the Gulf region, road improvement, and increasing job opportunities in the rapidly growing urban centers as well as overseas led to the increasing migration of people

1. The work in this section is based on Aw-Hassan et al. (1997).

from the rural areas of Yemen. Thus, agriculture has become less important as a source of income as better opportunities emerge in urban centers and abroad. Reliance on the land for food supply has declined because of the availability of imported food grain, particularly wheat, and the restoration of many degraded terraces may not be economically feasible under the prevailing conditions. However, the good agricultural land that still remains on the mountain terraces could be sustainable if the institutional and economic environments favor land-use practices that yield long-term benefits.

Ownership of cultivated land comes through private, state, or endowment systems (*waqfs*). There is also communal land, which includes the vast mountain slopes used as rangelands. However, there is no agricultural land registration, and current statistics on land properties are only estimates. At the local (subdistrict or *Uzla*) level, a trusted person, locally known as an *amin,* keeps records of land transactions such as sales and tenancy arrangements. The Ministry of Local Administration encourages this system. Most (70%) of the private land is cultivated by owners, but it may also be rented out to tenants under sharecropping arrangements that depend on the crop, the agro-ecological zone, the availability of irrigation water, the cost-sharing arrangements, and terrace maintenance. Tenants under sharecropping cultivate both state and *waqf* lands.

Customary tenure systems in Yemen are flexible and accommodate investment in land improvement by tenants. However, this flexibility was developed with expectations of returns on investment. The customary rule on land improvement investment is more likely to apply where high-value crops such as *qat* and coffee (*Coffea* L.) are grown, and less likely where rainfed food crops are cultivated. Nevertheless, food crops were more frequently cultivated than *qat* or coffee on the reclaimed land over the last 5 years, financed mainly by farmers.

Farmers in the Hajja province ranked state land as the most degraded, followed by *waqf* (endowed) land. Private land was considered the least degraded. Furthermore, terraces cultivated by landowners had a lower number of broken walls per area than those cultivated by tenants under sharecropping arrangements. Even though the customary tenure system clearly defines the respective responsibilities of tenants and landowners for the maintenance and cost sharing of terraces, no effective mechanisms for enforcement exist. Farmers stated that proper enforcement of the customary rules would significantly increase investment in land improvement, particularly terrace maintenance. However, tenant farmers are in a relatively weak position to seek enforcement of these rules.

All farmers polled in the terracing study reported a high number of broken walls, with the number increasing over time. This indicates a need for research on the economic viability of land improvement in the mountain terraces, as well as an assessment of policy and/or technological measures that could enhance land improvement, particularly for food crops. Government support of local institutions is needed to strengthen land registration systems and documentation of sharecropping contracts, to increase agricultural credit services targeting land improvement, and to improve farmers' access to technology and information. Research suggests that if returns to investment increase, for example, through better price policy and/or improved agricultural technology, tenure systems will accommodate private investment in land improvement.

The Nature of Poverty and its Link with Environmental Degradation in these Three NRM Scenarios

Various aspects of poverty and environmental degradation within the context of the scenarios described above are included in Table 2. The effect of different degrees of each attribute under similar conditions is indicated for comparison. Because of the qualitative and quantitative variation reflected in these attributes, however, comparisons across countries cannot be applied.

Land and freshwater endowments are highly variable in highland Balochistan (Pakistan) and in Syria. Variations in location and altitude are closely associated with levels of rainfall. The ability to extract or divert water from another source, even if it is temporary, makes a great difference. In the Hajja province of Yemen, it is difficult to assess household resource endowment because many households own land distributed across different ecological floors, all with different attributes. The population growth in highland Balochistan and Aleppo is high; while in the Hajja province out-migration occurs.

Endogenous poverty is generated by environmental degradation, while exogenous poverty is caused by factors not related to such degradation (Duraiappah, 1998). Contrary to the generalized perception that poverty causes environmental degradation, Boyce (1994) states that this degradation is caused by a combination of economic power and the desire for short-term profits. Duraiappah proposes several relationships to explain the existence of a poverty situation that generates the extreme use of a natural resource. Economic power, greed, exogenous poverty, and the institutional and market failures constitute key factors for these relations. These factors, individually or interacting, determine the environmental degradation and therefore endogenous poverty. Poverty that is solely endogenous exists only in the *khushkaba* lands of the Quetta valley, where population growth and low resource endowment have been the major factors in the impoverishment process. It should be noted that many *khushkaba* farmers are also involved in semi-nomadic pastoralism in highland Balochistan, Pakistan, and in Afghanistan, where the incidence of endogenous poverty among pastoralists is high (Buzdar et al., 1989; AZRI, 1994).

Table 2. Poverty and environmental degradation[a] in selected natural resource management (NRM) scenarios in West Asia.

NRM scenario	Water							Land
	Highland Balochistan, Pakistan (1600 m) Types of agriculture[b]			Aleppo, Syria (300 m) Tubewell agriculture[c]				Hajja, Yemen (900-2600 m)
	Tubewell	*Sailaba*	*Khushkaba*	Zone 1	Zone 2	Zone 3	Zone 4	Rehabilitation of terraces
Resource endowment (land and water)	++++	++	+	+++	++++	++	+	low
Population growth	3%			3.2%				outmigration
Type of poverty	exogenous	endogenous and exogenous	endogenous	exogenous	exogenous	exogenous	endogenous and exogenous	exogenous
Poverty index based on estimated income	+	+++	++++	++	+	+++	++++	high
Market failure	+++	-	-	+++	++++	++	+	+ (land market could be improved)
Institutional failure	+++	-	-	+++				++ (encouraging evidence for improvement)
Livestock production	-	+	+	+	++	+++	++++	+
Collective action	-	+	-	-	-	-	-	+
Resource degradation	++++	+ strong interaction with overgrazing	- strong interaction with overgrazing	+++	++++	++	+ strong interaction with overgrazing	high considering the incidence of broken terraces

a. + = presence, - = absence.
b. *Sailaba* agriculture uses spate irrigation, *khushkaba* agriculture "harvests" water in the flatlands adjacent to the cropping areas.
c. Zone 1 = rainfed 350 mm, Zone 2 = rainfed 300 mm, Zone 3 = rainfed 250 mm, and Zone 4 = supplemental irrigation of 150 mm with rainfall of 200 mm.

SOURCES: Aw-Hassan et al. (1997); AZRI (1994); ESCWA-FAO (1996); NRMP-DIWU (1999); van Steenbergen (1997); Rodríguez (1997).

Exogenous poverty is not homogeneous among the people making a living from tubewell agriculture in Balochistan or in Zone 2 in Aleppo; many of them are laborers. The attributes of arable, available land in these areas vary greatly, skewing the distribution of agriculture benefits. Favorable terms of trade for the export of fruits and vegetables, or for small ruminants from the highlands to the lowlands, do not necessarily include the environmental costs of irrigation and grazing. In the long run, what appears to be an economic incentive actually represents a disinvestment in environmental capital (declining groundwater or loss of vegetation). In the Hajja province, incentives for the younger sector of the population to migrate to urban areas or overseas are very strong. Land availability is also a constraint in Hajja (much less so in Balochistan or Aleppo).

Allowing for average estimates of agricultural income, the poorest of highland Balochistan are the *khushkaba* farmers, followed by the *sailaba* farmers. A quantum decrease in poverty occurs for those practicing tubewell agriculture. Interestingly, the lowest level of poverty in Aleppo is in Zone 2, rather than Zone 1, which has conditions more favorable for agriculture. The difference is because of larger availability of land per household in Zone 2. The ability to extract water in Zones 3 and 4 decreases dramatically, increasing extraction costs, because of hydrogeological factors (Wagner, 1997). Care should be taken to avoid generalizations of the poverty levels in the NRM scenarios without considering the distribution of resources. For example, as cited previously, farmers in the Hajja province have land distributed across different floors of the altitudinal gradient. However, 41% of 2- to 5-ha landholdings belongs to 15% of the farmers, while 6% of the landholdings smaller than 0.5 ha belongs to 24% of the farmers (Aw-Hassan et al., 1997). Across the four stability zones in Aleppo, the highest inequality in land endowment and agricultural income occurs in Zone 2, the most prosperous zone in the province (NRMP-DIWU, 1999). While 75% of the agricultural land in Zone 2 is owned by 25% of the farmers in the rest of the zones, 50% of the land is in the hands of 25% of the farmers (Figure 2).

Market failure is based on environmental costs such as declining water tables, erosion, and other external costs in the agriculture and water sectors. These costs are not taken into consideration in markets in highland Balochistan and Aleppo. This includes time wasted chasing water and drilling deeper wells when the supply runs dry, and the associated inefficiency in irrigation, higher extraction costs, and the pollution of wells. Likewise, the long-term costs of downstream sedimentation, loss of soil fertility, and the domino effect of broken terraces caused by excess runoff are not included in the produce prices of farmers in the Yemeni mountain terraces.

This institutional failure is because of the lack of well-defined and tradable property rights, improper regulatory frameworks, unbalanced land tenure arrangements, and open access to undervalued water resources that encourage the depletion of groundwater. The fugitive nature of groundwater makes it extremely difficult to design effective monitoring systems, even if there is willingness to comply with hypothetical groundwater management policy. In the Yemeni case, the land tenure system could be improved so that the land markets would better reflect the future value of land investments and yield expectations.

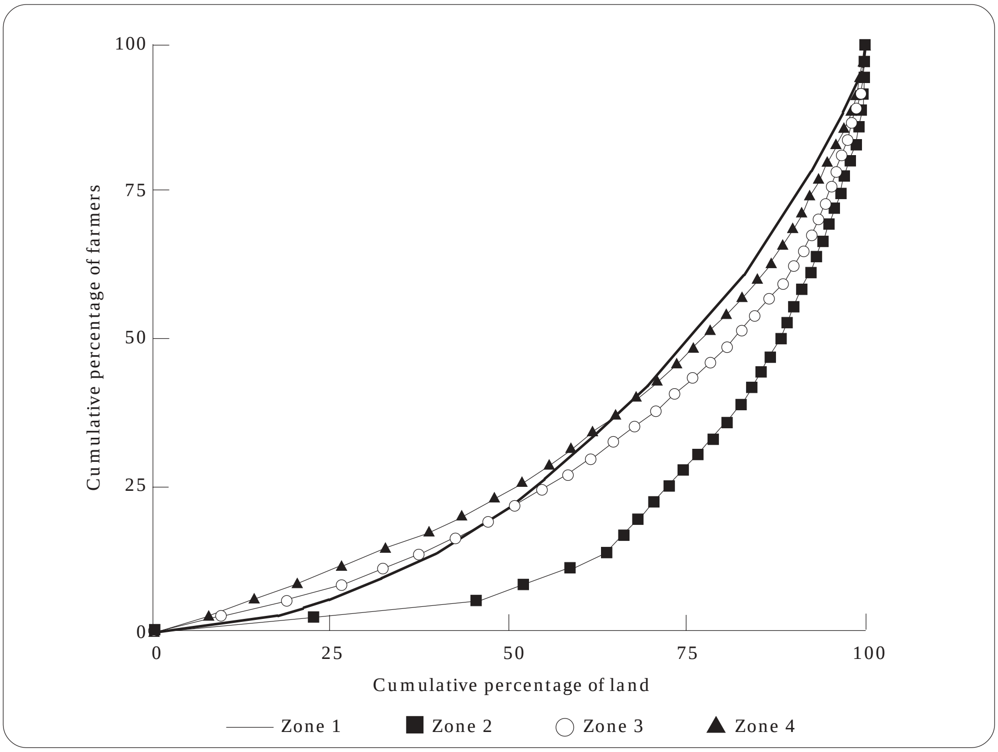


Figure 2. Distributions of agricultural land in the four different agricultural stability zones in Aleppo (from NRMP-DIWU, 1999).

Policy failure is attributed to price distortion, or under-pricing the resources needed to produce a commodity. Subsidized pricing for electricity and diesel discourages farmers from taking advantage of water-saving technologies. In addition, overvalued currency and price controls grossly bias the incentive structure within which farmers operate in Aleppo (ESCWA-FAO, 1996). While the economic value of water is acknowledged, no serious consideration is given to developing appropriate policies because of political instability and because tariff and pricing policies are not considered viable (Ahmad, 1996). Furthermore, the spontaneous emergence of alternative productive and non-productive uses of water and water markets in dry countries is not perceived as a phenomenon deserving attention in order to help reinforce policies and/or local and national institutions (Waughray and Rodríguez, 1998).

Collective action in *sailaba* agriculture and in the mountains of Hajja still plays a vital role in traditional irrigation and soil conservation systems and includes:

- Maintenance and repair of irrigation structures and terraces,
- System monitoring, and
- Compliance with customary rules.

Collective action and customary rules in *sailaba* agriculture minimizes “head-tail” asymmetries in agricultural income. The position of the command area with respect to the head or tail of the watercourse and the ownership of land were not significantly related with household agricultural income. This is because the rules for water allocation compensate for the position in the watercourse. Agricultural income was significantly related to the command area and number of livestock, differentiating the very small and small systems from the medium and large ones (Ahmad et al., 1998). However, the efficacy of collective actions across a section of NRM scenarios has not been quantified.

Tubewell irrigation has the highest contribution to resource degradation (i.e., declining water tables) in both highland Balochistan and in Zone 2 in Aleppo simply because of the large volumes of irrigation water used compared to the other zones. However, there is also a correspondence between resource degradation and contribution to the agricultural gross domestic product. Because of a combination of market, institutional, and policy failures, resource users are not encouraged to internalize the environmental costs; rather, the society as a whole is absorbing them. Strong interactions with overgrazing occur in *sailaba* and *khushkaba* agriculture in Balochistan and in Zone 4 in Aleppo. Because of the increasing number of broken walls in the terraces in Hajja and the associated downstream costs, there is a danger that the terraces will be lost as agricultural and cultural patrimony of the Yemeni highlands.

Although endogenous poverty is present in *khushkaba* agriculture, there is no apparent or documented on-site resource degradation. Off-site degradation is likely to be present through overgrazing and shrub uprooting for fuelwood. However, off-site transfer of degradation because of the impoverishment of *khushkaba* farmers has not been quantified. Low-input, micro-catchment water harvesting offers a moderate increase in gross margins and a modest decrease in its variability, but it is not a net yield-increasing technology. This is not enough incentive for subsistence farmers who also depend on extensive livestock production. In contrast, in situations where there is exogenous poverty, there is a high occurrence of in-situ resource degradation. Both the incentive structure and the associated institutions encourage resource degradation by the relatively wealthier farmers (i.e., fruit exporters in Balochistan or farmers in Zone 2 of Aleppo), who follow market signals closely. The evidence from Balochistan and Aleppo suggests that natural resource degradation is not directly linked with poverty. Rather, resource degradation is related to the quantity of natural resources accessed by the different sectors of the population without internalizing the environmental costs. Poverty, in turn, may or may not be related to environmental degradation. Market and institutional failures must be acknowledged to design incentives that could shift changes towards sustainable resource use.

Incentives

Other than *khushkaba* agriculture, few environmentally friendly technologies are higher yielding or higher income generating, and therefore suitable for low potential environments. What margin of gain makes a technology appealing to the poor? Subsistence farmers are more inclined toward higher and more stable yields than higher and more stable gross margins, but no cereal variety is better than the barley or wheat landraces already grown on *khushkaba* land. Livestock production, complementing *khushkaba* agriculture, occurs on overgrazed tribal rangelands with deteriorated grazing rights (Buzdar et al., 1989). Thus, the adoption of environmentally friendly water-management technologies needs to be coupled with improved livestock management, and the latter is largely limited by socioeconomic constraints.

Should resource degradation be attributed to the poor? In answering this question, it is useful to distinguish the effect of different income strata in the degradation process. For example, the highest mean income per household occurs in Zone 2 in Aleppo, but in terms of land distribution, this is the least egalitarian of the four zones. Depletion of fossil water from the deep aquifers (Wagner, 1998) is faster in Zone 2 than in Zones 3 or 4. This is not necessarily because of SI of wheat, but may also be attributed to the incentives to grow high-value crops with undervalued water in a system that lacks effective self-regulatory mechanisms for water extraction. Farmers take advantage of the failures of the system to avoid paying environmental costs. The most economically prosperous sector of the population is responsible for rapidly declining water tables and the pollution of wells. Market and institutional failures are in place in both cases.

In the context of terrace agriculture, what would it take to entice a young farmer to remain in Hajja as a steward of the terraces? Can agricultural options compete with those presented by urban and overseas migration? Even if a household is above the investment poverty line (Reardon and Vosti, 1995) and is willing to invest in land improvement, it would have to absorb the cost of increasingly scarce labor for the rehabilitation and maintenance of terraces. We need to achieve an understanding of the types of incentives required to encourage expatriates and urban dwellers to invest in rural environments. Households may decide to invest in education or small businesses rather than in land improvements.

In the hill torrent areas of Pakistan, available capital is used collectively to grant credit at competitive rates for productive and non-productive household investments, with a high rate of loan recovery. However, there is a need for better integration of existing incentives in the strategy for resource management interventions (Shahid Ahmad, personal communication, 1999).

Even though our NRM scenarios do not agree with the perception that poverty is related to resource degradation, this does not imply that options for improving the livelihoods of the lower income population or minimizing environmental degradation by the wealthier sector of the population should not be put forward. For the poor and the wealthy, net savings of household resources and higher yields or net benefits are incentives for improved resource management. The latter also should imply the identification of economic, institutional, or policy failures, and the design of mechanisms and practices to offset them.

Implications

Three sets of conditions are critical for environmentally prudent behavior by the poor:

(1) Clear, secure, and tradable property rights to land and water, to ensure that expected future values of natural resources are realized.
(2) Less risky and higher income-generating options, to ensure a clear focus on the rewards associated with NRM interventions. This may require the integration of soil and water management actions with other resource management options, such as range and livestock.
(3) NRM practices that are gender-sensitive, developed according to previously identified intra-household decision-making processes (Griffin, 1996).

Complementing these conditions is the need to institutionalize NRM research in national programs through multidisciplinary and participatory approaches (Aw-Hassan and Saigher, 1996).

Often, efforts in NRM have been diluted by exogenous factors that affect economic efficiency (land tenure and water rights, overvaluation of currencies, subsidies in inputs and outputs, central planning, and international comparative advantages, among others). In this era of globalization, there is a need to identify what resource-poor farmers can produce better than other farmers in other regions of the same country or abroad. Policymakers and national research programs must nurture local solutions to local problems and encourage decentralized decision making, policymaking, and monitoring and evaluation of environmental impact.

The impact assessment of NRM interventions will remain complex because of various exogenous factors that determine how events unfold over a long enough period to show impact, (i.e., 5 to 10 years). Certain elements in a technology package can be adopted to impute indirect effects on the environment and direct effects on farmers' income. Baseline surveys and monitoring systems allow researchers to gauge changes in poverty indicators at the community or watershed level, and identify those factors that are most effective in poverty alleviation. Natural resource management research needs to be included in local and national development efforts to ensure demand-driven agendas with interventions that can be sustained long enough to generate visible results.

References

Ahmad, Mahmood. 1996. Sustainable water policies in the Arab region. Paper presented at the Symposium on Water Arab Gulf Development: Problems and Policies, University of Exeter, 11-12 Sept, GB.

Ahmad, Mahmood; Rodríguez, A. 1998. Groundwater policy issues in Syria: Competitiveness of agriculture in Aleppo. Regional Near East Policy–Food and Agriculture Organization (FAO), Cairo–International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, SY. (Working paper)

Ahmad, Mushtaq. 1990. *Karez* rehabilitation and improvement. *In*: Proceedings of the National Seminar on Water Resources Development and its Management in Arid Areas, 6-9 Oct, Quetta. Pakistan Council of Research in Water Resources and Water Resources Research Centre, Quetta, PK. p. 353-360.

Ahmad, Shahid; Rodríguez, A.; Shah, A.; Saddiq, N. 1998. Land and water rights in isolated spate irrigation systems (*sailaba* agriculture) in highland Balochistan. Water Resources Research Institute–National Agricultural Research Council, Islamabad, and International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, SY. (Working paper)

Aptekman, T. 1973. Syria. *In*: Caponera, D.A. (ed.). Water laws in Moslem countries. Food and Agriculture Organization (FAO) Irrigation and Drainage Paper no. 20, vol. 2, Rome, IT. p. 278-297.

Aw-Hassan, A.; Saigher, M. 1996. Participatory natural resource management research in the dry areas: Challenges and opportunities. *In*: New frontiers in participatory research and gender analysis. Proceedings of International Seminar on Participatory Research and Gender Analysis for Technology Development, 9-14 Sept, Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 251-259. (CIAT Publication no. 294)

Aw-Hassan, A.; Al-Sanabani, M.; Bamatraf, A. 1997. Impact of land tenure and other socioeconomic factors on mountain terrace maintenance in Yemen. Paper presented in the Workshop on Property Rights, Collective Action, and Technology Adoption, International Food Policy Research Institute (IFPRI)-International Center for Agricultural Research in the Dry Areas (ICARDA), 22-25 Nov, Aleppo, SY.

AZRI (Arid Zone Research Institute). 1994. Land and range resource management issues and food security in Balochistan. Pakistan Agricultural Research Council, Quetta, PK.

Boyce, J.K. 1994. Inequality as a cause of environmental degradation. Ecological Economics 11(3):169-178.

Buzdar, N.; Nagy, J.G.; Sabir, G.F.; Keatinge, J.D.H. 1989. Animal raising in highland Balochistan, a socioeconomic perspective. International Center for Agricultural Research in the Dry Areas (ICARDA), Quetta, PK. (Management in Agriculture, Research and Technology-Arid Zone Research, Research Report no. 50)

Duraiappah, A.K. 1998. Poverty and environmental degradation: A review and analysis of the nexus. World Develop 26:2169-2179.

ESCWA-FAO (Economic and Social Commission for Western Asia-Food and Agriculture Organization). 1996. Resource conservation policies and strategy for agriculture in the Syrian Arab Republic. ESCWA Agricultural Division-FAO, Amman, JO. (E/ESCWA/AGR/95/12)

Griffin, E. 1996. Gender analysis and international financial institutions. Natural Resour Forum 20:153-161.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1995. Project proposal: Ecoregional initiative-water in West Asia and North Africa. Unpublished draft. Aleppo, SY.

Kahlow, M.A.; Hamilton, J.R. 1996. *Sailaba* irrigation practices and prospects. Arid Soil Res Rehabil 10:179-191.

Mallat, C. 1995. The quest for water use principles: Reflections on Shai'a and custom in the Middle East. *In*: Allan, J.A.; Mallat, C. (eds.). Water in the Middle East. Legal, political and commercial implications. Tauris Academic Studies, London, GB. p. 128-136.

Mueller, R.A.E.; Rodríguez, A. 1997. Action research in irrigation institutions for supplemental irrigation. Unpublished draft. Department of Agricultural Economics, Christian Albrechts University at Kiel, Germany, and International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, SY.

NRMP-DIWU (Natural Resource Management Program-Directorate of Irrigation and Water Use). 1999. Socioeconomics of groundwater use in Aleppo, Syria. Unpublished draft report. NRMP, International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, and DIW, Syrian Ministry of Agriculture and Agrarian Reform, Damascus, SY.

Reardon, T.; Vosti, S.A. 1995. Links between rural poverty and the environment in developing countries: Asset categories and investment poverty. World Develop 23:1495-1506.

Rees, D.J.; Qureshi, Z.A.; Mehmood, S.; Raza, S.H. 1991. Catchment basin water harvesting as a means of improving the productivity of rain-fed land in upland Balochistan. J Agric Sci 116:95-103.

Rodríguez, A. 1997. Economic and institutional options in groundwater management in Northwest Syria. Paper presented at the Workshop on Property Rights, Collective Action, and Technology Adoption, International Food Policy Research Institute (IFPRI)-International Center for Agricultural Research in the Dry Areas (ICARDA), 22-25 Nov, Aleppo, SY.

Rodríguez, A.; Shah, N.A.; Afzal, M.; Mustafa, U.; Ali, I. 1996. Is water harvesting in valley floors available option for increasing cereal production in highland Balochistan, Pakistan? Exp Agric 32:305-315.

Rodríguez, A.; Salahieh, H.; Badwan, R.; Khawam, H. 1999. Groundwater use and supplemental irrigation in Atareb, Northwest Syria. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, SY. (ICARDA Social Science Paper no. 7)

van Steenbergen, F. 1997. Institutional change in local water resource management: Cases from Balochistan. Faculty of Geographical Sciences, Utrecht University, NL. (Neths Geog Studies no. 220)

Wagner, W. 1997. Hydrogeologic advice to ICARDA on sustainable development groundwater management in the dry areas. Report on Mission to the Syrian Arab Republic. Economic and Social Commission for Western Asia; Energy, Natural Resources and Environmental Division, Amman, SY. (E/ESCWA/TCD/1997/32)

Wagner, W. 1998. Supplementary investigations for the ICARDA programme on sustainable development groundwater management in northwestern Syria. Economic and Social Commission for Western Asia, Beirut, Lebanon, LB. (E/ESCWA/TCD/1998/32)

Waughray, D.K.; Rodríguez, A. 1998. Valuing water as an economic good in dryland areas–Balancing the need for food, environmental and financial security. Paper presented at the World Congress of Natural Resource Economists, Venice, June 24-27. Available in: http://inforumweb.umd.edu/WorkPaper/IOPAP/paperd~2.pdf

WRRI (Water Resources Research Institute). 1998. Water harvesting and conjunctive use of water for sustainable agriculture in dry areas of Balochistan, Pakistan. WRRI Annual Report 1997-98 of the On Farm Water Husbandry Ecoregional Initiative. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, SY.

CHAPTER 10

Enhancing Research-Poverty Alleviation Linkages: Experiences in the Semi-Arid Tropics

*Ma. Cynthia S. Bantilan**, *Devanathan Parthasarathy***, and *Ravula Padmaja**

Introduction

Evidence from literature shows that agricultural research has been instrumental in introducing improved technologies that have raised agricultural production, stimulated economic growth, and benefited the poor through lower food prices and higher incomes (Lipton and Longhurst, 1989; Tribe, 1994). However, there are legitimate concerns that research-led technological change in agriculture has favored wealthy farmers at the expense of poor producers and laborers (Pearse, 1980; Freebairn, 1995). Concerns regarding the environmental impact of new technologies have also been expressed. The relationship between poverty and environmental degradation is especially of importance in the world's semi-arid tropics (SATs). Peter Hazell and others have recently emphasized the importance of investing in less favorable, marginal, and resource-poor areas to achieve greater impact in terms of poverty reduction (Hazell and Fan, 2000). Discussion on related issues has led to work on the development of typologies for assessing and establishing research-technology-poverty reduction linkages (de Janvry and Sadoulet, 1996; de Janvry et al., 1997).

This paper shares the experience of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in understanding and assessing the linkages between research, technology adoption, and poverty alleviation, and the opportunities made to enhance these linkages for greater impact. We analyze impact studies with a view to understanding these linkages. Results from preliminary surveys of a project aimed at directly capturing the nature of these linkages are outlined.

* Economist and Scientific Officer, respectively, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India.
** Sociologist, Department of Humanities and Social Sciences, Indian Institute of Technology, Bombay, India.

Technology Adoption-Poverty Alleviation Linkages: Major Issues

Existing literature (Kerr and Kolavalli, 1999) in this area has identified several major issues of relevance for these linkages. Four major processes were identified that link agricultural research and development to poverty alleviation:

(1) Technology adoption,
(2) Agricultural intensification,
(3) Changing land relations, and
(4) Public investment and institutional arrangements.

This chapter is primarily concerned with the first process, technology adoption, which may sometimes result in the second, agricultural intensification, and thereby have an enhanced impact on poverty. The chapter also recognizes that the other factors act as facilitating conditions or intervening factors for adoption to result in positive impact. Studies (Bantilan and Joshi, 1994; Kerr and Kolavalli, 1999; World Bank, 1999) reveal that technologies generated through research may alleviate poverty by:

(1) Raising farmers' production income through increasing yields,
(2) Generating agricultural employment,
(3) Improving food security and accessibility,
(4) Reducing food prices,
(5) Reducing risk and increasing stability,
(6) Diversifying crops,
(7) Triggering economic growth in other sectors of the rural economy,
(8) Reducing inequalities at community and household levels, and
(9) Empowering different groups involved in agriculture.

Thus, agricultural innovations have the capacity to bring about welfare changes by improving productivity through improved crop and natural resource management (NRM) options and developing new sustainable systems of agriculture.

Advances in resolving the following issues or questions are important in understanding and enhancing the poverty impacts of agricultural technology.

(1) Are technologies not scale neutral, that is, do large-scale farmers benefit to a greater extent than do small-scale farmers, resulting in increasing inequalities?
(2) Is the knowledge regarding the typology of target households essential for generating and targeting appropriate technologies?
(3) Do gender differences and differential needs of social groups involved in agriculture have a bearing on adoption and impact?

(4) Does the development of appropriate technologies require analysis of agro-ecological and socioeconomic factors?

Studies on these aspects provide important feedback for the development of agricultural research strategies, especially with reference to desired characteristics or traits for specific target clientele, environment, and sector. Intervening conditions that influence adoption and impact are also important. These include:

(1) Government policies and interventions (infrastructure, subsidies, credit),
(2) Institutional factors (seed sector, markets, extension), and
(3) Other socioeconomic factors (human capital—age, education, health and nutrition; and asset base—ownership of land, resources, etc.).

Differential access to institutional support and information, and unequal distribution of assets, may constrain large-scale adoption of technologies and result in unequal impacts.

Types of Poverty Impacts

Depending on the way in which the enabling conditions influence technology effects, several types of poverty impact can occur. Impacts can be direct, that is, in terms of improved income, yield, and stability; or they can be indirect through their influence on markets, commodity prices, and general growth of the rural economy. Impacts can occur at different levels—household, village, social groups (women, marginal groups), and regional economy. First-level impacts, which can be easily measured and assessed, would include changes in income, yield, employment, and stability. Secondary changes deriving from these include health and nutrition, food security, equity, sustainability, and empowerment. Based on an analysis of existing literature as well as ICRISAT's past work, current research seeks to measure impacts through the indicators listed below that are related to human capital, assets and access, and that capture changes beyond, but inclusive of, improvements in yield and income.

Human capital

(1) Education and literacy.
    Rural literacy rates by gender.
    Rural schooling.
(2) Health, nutrition, and food consumption pattern.
(3) Rural total fertility rates.
(4) Rural sex ratios.

Assets

(1) Ownership of assets.
(2) Household assets.
(3) Farm investments (land, pump sets).
(4) Livestock.
(5) Vehicles (bicycle, scooter, tractor).
(6) Sanitation (toilets, drainage).
(7) Dwelling unit (houses, roofs, walls).
(8) Income, savings, purchasing power, liquidity.
(9) Electricity and electric appliances.

Access

(1) Improvement in infrastructure (roads, hospitals, schools, playgrounds).
(2) Access to credit.
(3) Social expenditure (marriage, pilgrimage).
(4) Geographical mobility.
(5) Dependence on patrons for employment, loans, and housing.
(6) Dependence on inferior/less preferred jobs.
(7) Energy use (wood fuel, biogas, fossil fuels).
(8) Water supply and availability.

In evaluating impact by measuring changes related to the above indicators, the question of attribution assumes importance. In positing causal linkage between research output and poverty alleviation, methodological advances are required to separate out the impact of technology from other intervening factors. It is observed that the specific process of adoption and enabling conditions influence the actual flow of benefits to different groups. (On this point, see ICRISAT's Impact Series, and Kolli and Bantilan, 1997). Analysis and feedback on this issue will therefore be useful in developing new research strategies.

Evidence of Adoption and Positive Impact

As of 1998, 405 improved cultivars developed by ICRISAT in collaboration with national agricultural research systems have been released throughout the world (Figure 1). Studies carried out by ICRISAT's Research Evaluation and Impact Assessment (REIA) team from 1994 onwards have clearly established large-scale adoption of several technologies that are products of genetic enhancement research as well as NRM research. The list on the next page presents a summary of adoption rates. Thus far, adoption of improved cultivars is restricted to South Asia and a few countries in southern and western Africa. Adoption of improved technologies has taken place for all five of ICRISAT's mandate crops.

Summary of adoption data generated from selected REIA studies

Region	***Crop/technology***	***Current adoption levels (%)***
India		Karnataka 59
Karnataka	Pigeon pea ICP 8863	Andhra Pradesh border 52
Andhra Pradesh	(Wilt endemic region)	Maharashtra border 59
Maharashtra		Maharashtra 18
Mali	Improved pearl millet and sorghum cultivars	Improved pearl millet cultivars 23 Improved sorghum cultivars 28
Cameroon	Sorghum variety S 35	Mayo Sava 49 Diamera 13 Mayo Danay 12
Chad	Sorghum variety S 35	Guera 39 Mayo Kebbi 25 Chari Baguermi 10
Zimbabwe	Pearl millet PMV2 Sorghum SV2	Improved pearl millet cultivars 26 Improved sorghum cultivars 36
India	Pigeon pea	
Western Maharashtra	(Short duration - ICPL 87)	Western Maharashtra 57
Maharashtra	Improved pearl millet cultivars	Maharashtra 89
Gujarat		Gujarat 95
Haryana		Rajasthan 56
Rajasthan		Haryana 86

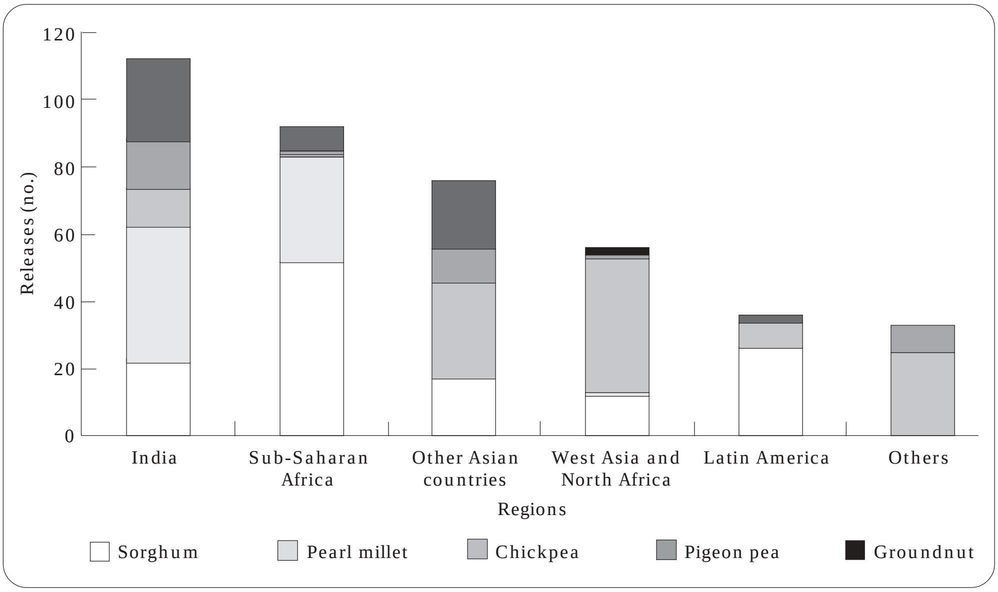


Figure 1. Releases of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)-national agricultural research systems (NARS) varieties, 1975-98.

Three kinds of impact resulting from research and development were identified:

(1) Output of ICRISAT breeding efforts/genetic enhancement research;
(2) Improved crop and resource management options; and
(3) Spillover effects of germplasm research.

The actual impacts observed and analyzed from technology adoption were mainly in terms of yield enhancement, unit cost reduction, income increase, high net present value (NPV), and internal rate of return (IRR), sustainability, and gender. Below, we present a summary; a brief discussion of the nature and kinds of impact follows.

(1) Impact on efficiency.
Wilt disease resistance research: pigeon pea (*Cajanus cajan* [L.] Millsp.).
60% adoption in wilt-endemic areas.
43% yield gains on-farm.
45% unit cost reduction (US$89 per ton).
$75 million NPV.
65% IRR.

(2) Impact on food security.
Early-maturing sorghum (*Sorghum bicolor* [L.] Moench) and pearl millet (*Pennisetum glaucum* [L.] R. Br.) for drought-prone areas of Africa allowing more stable yield.
Reduced risk of crop failures.
Savings in food aid far greater than the cost of research.

(3) Impact on sustainability.
Diversifying monocrop systems by introducing short-duration legumes as in the case of pigeon pea in drought-prone areas of India.
57% adoption.
Diffusion in five states.
New income from double cropping.
Improved soil fertility.

(4) Benefits to women.
Groundnut (*Arachis hypogaea* L.) production technology resulted in:
Easier weeding and harvesting.
Higher employment.
More involvement by women in decision making.

A study by Bantilan and Joshi (1996) on the impact and spread of ICP 8863, an improved wilt-resistant variety of pigeon pea, found that in comparison to the best cultivar previously available in the target zone, this new variety gave 57% higher yields, reduced unit costs by 42%, and matured slightly earlier. The total NPV of benefits from collaborative wilt research is about US$62 million, representing an IRR of 65%. The results, in addition to clearly quantifying the impact of wilt research, also provide important lessons for research and extension policy and for the formulation of future research priorities.

In a case study on impact assessment of groundnut production technology, Joshi and Bantilan (1998) found partial and step-wise adoption of different components of the technology that range from 31% to 84%. In comparison to the prevailing technology, the groundnut production technology gave 38% higher yields, generated 71% more income, and reduced unit cost by 16%. The technology also contributed in improving the natural resource base, and eased certain women-specific agricultural operations. The total NPV of benefits from collaborative research and technology transfer was more than US$3 million, representing an IRR of 25%.

A study by Bantilan and Parthasarathy (1999) established an important connection between farmers' concerns regarding sustainable farming and the adoption of improved technologies. Results from a formal on-farm survey and rapid rural appraisals conducted in a drought-prone area in central India revealed that:

(1) Farmers are well aware of the effects of intensive cultivation of cash crops, such as sugarcane (*Saccharum officinarum* L.) or cotton (*Gossypium hirsutum* L.) in irrigated tracts, in terms of reduced yields and increasing use of inputs;
(2) Appropriate crop/varietal adoption and management practices are consciously implemented to maintain long-term productivity levels for existing and desired cropping systems; and
(3) Farmers strive to increase or maintain soil fertility by including nitrogen-fixing legumes in crop rotations—in this case, short-duration pigeon pea.

Widespread adoption of short-duration pigeon pea (56%) made farming profitable in the short term (from higher yields and income) and helped sustain productivity in the long run via crop rotation to maintain soil fertility.

Kolli and Bantilan (1997) studied the gender-related impacts of a crop and resource management technology package in Maharashtra, India. The following indicators emerged with strong implications for gender because of the introduction of the technology:

(1) Labor-activity pattern and time allocation,
(2) Decision-making behavior of men and women with regard to resource use and utilization of crop products, and
(3) User perspective—differential perceptions of men and women with implications for technology development.

The study indicates that to ensure effective and committed involvement of men and women in agriculture, views and perceptions need to be incorporated of both genders of the farming communities during technology generation and development. A research and development agenda that incorporates analysis of gender-disaggregated farmer perspectives is likely to lead to a more appropriate and acceptable technology that will gain further and wider adoption.

Yapi et al. (1999) evaluated the impacts and research spillover effects of adoption of sorghum variety S 35, a pure line developed from the ICRISAT breeding program in India. It was later advanced in Nigeria and promoted and released in Cameroon and Chad. Farm-level impacts were found to be larger in Chad, where yield gain was 51% higher and cost reduction 33% higher compared to the best local varieties. The NPV of benefits from S 35 research spillover in the African region was estimated to be US$15 million in Chad representing an IRR of 95%, and US$4.6 million in Cameroon representing an IRR of 75%.

A study (Rorhbach et al., 1999) clearly showed that the high NPV of return from pearl millet variety Okashana 1 in Namibia resulted from the use of germplasm originally developed by ICRISAT, thus cutting the time and costs involved in variety development and testing. It was also found that early involvement of farmers in varietal selection, rapid release in response to farmer preferences, and government commitment to the rapid multiplication and dissemination of high quality seed were instrumental in the high level of return.

Thus, most of the REIA adoption and impact studies documented clear impact in terms of increased yield and income. The extents to which these impacts have actually translated into welfare changes are being documented by an ongoing project “Technological Innovations in SAT Agriculture and its Impact on Poverty in India.”

Adoption and impact studies were of crucial significance for ICRISAT by enabling researchers to learn lessons for providing feedback and identifying research priorities. These studies identified knowledge gaps especially in the research process-poverty alleviation linkages. Currently, knowledge gaps refer to these aspects:

(1) The process whereby technology adoption has consequences for poverty alleviation and reduction (there is also a question of attribution),
(2) Direct, indirect, and differential impacts of technology adoption, and
(3) The role of intervening factors/enabling conditions.

Existing literature, while opting for quantitative studies of impacts because of ease of measurability and comparability (of indicators such as income and yield), however, are unable to throw much light on the actual process by which adopters of agricultural innovations have benefited. Actual improvements in terms of empowerment, equitable distribution of benefits at the household level, access to institutions, and improvements in human capabilities have been especially difficult to assess. The current project aims to integrate quantitative and qualitative impacts in an integrated framework using different types of methods and techniques. Figure 2 illustrates the conceptual framework, showing the technology adoption-poverty alleviation linkages that were developed following an extensive survey of the literature.

Tracking Poverty Impacts—Case Studies from Maharashtra and Rajasthan

The poverty impact analysis covered a set of case studies covering NRM and germplasm innovations. Two case studies are underway:

(1) Groundnut production technology (GPT), an NRM package of practices introduced in Maharashtra, India. The GPT was specifically developed for cultivation of groundnuts in dry areas, especially to promote cultivation in summer using an improved package of practices that included improved cultivars, as well as soil, water, and nutrient management options.

(2) Participatory plant breeding and adoption of improved pearl millet (bajra) cultivars in Rajasthan, India. Rajasthan includes some of the most arid environments in India, and has the largest area under pearl millet in the country. Studies have shown widespread adoption of improved pearl millet cultivars developed by ICRISAT in collaboration with its national program partners. Research efforts here incorporated participatory varietal selection by farmers in some districts.

Results from preliminary surveys on these two technologies are presented in the following section.

Groundnut production technology

A benchmark survey in the early 1990s showed that adoption was reasonably widespread, but did not reveal an appreciable impact. However, significant changes were noticed with respect to the gender issue, especially the intra-household distribution of benefits, and changes in access to and control over different postharvest products.

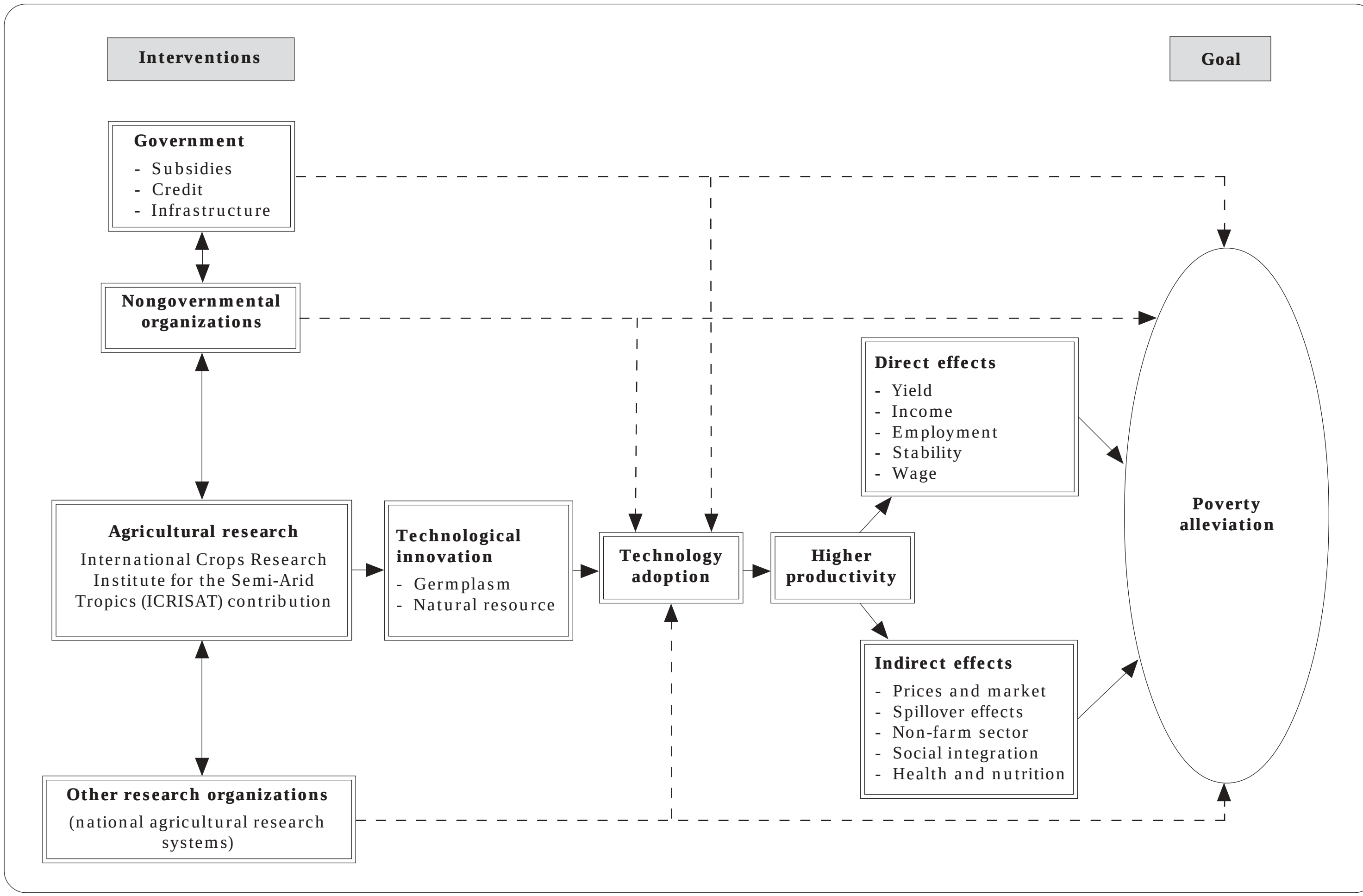
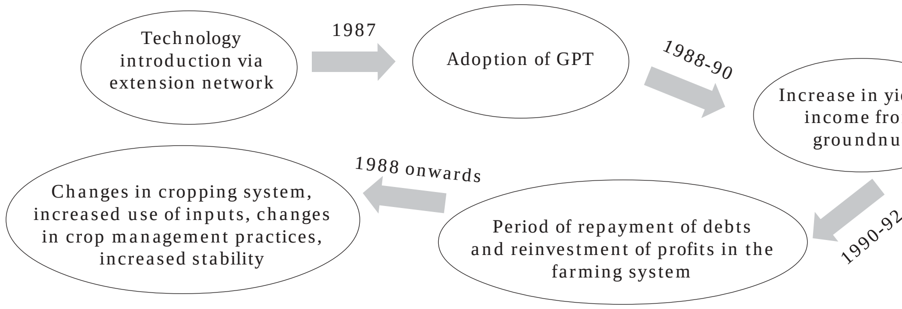


Figure 2. Technology adoption-poverty alleviation linkages: A conceptual framework.

Based on a pilot survey (1999-2000) almost a decade after the technology was introduced, it was found that technology adoption has contributed to welfare changes in direct as well as indirect ways. Rather than a particular path (of benefits) flowing from technology adoption there seems to be a stream of benefits flowing, each of which leads on to other changes in the agricultural system as is shown in Figure 3. Significant impacts on a number of indicators to diverse social groups were evident during the pilot surveys.

Using participatory rural appraisal (PRA) techniques and focused group interviews, we carried out a before and after analysis, which revealed that many welfare changes have occurred as a result of the adoption of the GPT that can be summarized as follows.

(1) Adoption of GPT has contributed directly to an increase in income and yields.
(2) Greater stability of the cropping system has been achieved.
(3) Indirectly, it has improved food availability, improved nutrition, led to crop diversification, and ownership of assets.
(4) Assets acquired for GPT are being used for other crops, and have enabled cultivation in other seasons.
(5) Initial benefits in the form of higher profits and income were reinvested in order to obtain long-term benefits and to stabilize the farming system.
(6) Stability of the farming system increases the freedom of farmers to take decisions regarding the cropping pattern (cash vs. subsistence crops or market vs. subsistence orientation, investing in production vs. investing in education, housing, household assets, etc.).
(7) Positive changes in the condition of labor. Out-migration of labor has been replaced by immigration of labor. Employment opportunities for women have risen.
(8) Credit rating has risen.
(9) Families and households have been enabled to fulfill social and family obligations (marriage of children, providing hospitality to household/village/community guests, increased capacity to perform traditional cultural activities, such as celebrating festivals, going for pilgrimages etc.).
(10) Government programs have enabled purchase of accessories; equally government programs have targeted the village after its “visibility” improved because of technology adoption and resultant impact.
(11) There have been general improvements relating to health, sanitation, housing, common facilities, etc., as also an improvement in the level of food security, especially for the marginalized groups in the village.
(12) A feeling of empowerment has shown—a general improvement in self-esteem, confidence, ability to innovate, etc. Empowerment is also reflected in an increased choice of crops that are cultivated, choice of investments, access to credit, information, and agents of various government bodies.



Flow of benefits

Women

- Employment opportunities for women have risen.
- Participation of female family labor in the cultivation process has increased.
- Wages paid to women labor for groundnut activities are higher.

Agricultural workers

- Increase in wages for agricultural workers.
- Increased availability of employment throughout the year.
- Positive changes in the condition of labor.
- Out-migration of labor has been replaced by immigration of labor.
- Improved choice of work and work place.
- Generation of permanent and semi-permanent assets, including land, livestock, etc.
- Changes in land holding pattern-some agricultural laborers have bought land, while marginal farmers have increased their landholding.
- Wider basket of commodities consumed by agricultural laborers (increase in consumption of pulses and oils, general improvement in nutrition).
- Reduced spending on food items.
- Increased capacity to support non-working family dependents.

Socially marginalized

- Socially marginalized sections (tribal, scheduled castes, agricultural laborers / marginal farmers), benefits accruing from agriculture to welfare gains.
- Greater food security, especially during lean season.
- Better integration into the larger community.
- Better educated; most of the children now go to school.
- Greater confidence, and ability to innovate.
- Improvement in social status vis-à-vis members of higher status groups.

Farmers

- Increase in yields.
- Increase in household income and profits.
- Assets acquired for GPT are being used for other crops, and have enabled cultivation in other seasons.
- Changes in cropping pattern—more diversified cropping system, larger basket of commodities.
- Bringing more land under cultivation (increased capacity to invest, more crop options).
- Increased area under cultivation during Rabi and summer.
- More area under irrigation (availability of sprinklers, pump sets).
- Reduced dependence on risky crops and crops requiring more inputs.
- Reduction of indebtedness.
- Easier availability of credit, both because of better overall credit rating, and because of the greater stability of the cropping system, particularly groundnut.
- Generation of permanent and semi-permanent assets, including land, livestock, pump sets, sprinklers, etc.
- Changes in land holding pattern—small and marginal farmers have increased their landholding.

- Government programs have targeted the village after its "visibility" improved because of technology adoption and resultant impact.
- General improvement in self-esteem, confidence, ability to innovate, etc.
- Increased capacity to fulfill social and family obligations.
- General improvement in common facilities.

Figure 3. Technology adoption and impact linkage: The case of groundnut production technology (GPT) in Central India.

(13) The social distance between groups of different social status has reduced; feelings of social isolation both within the community and with reference to the wider world have decreased. The community has become more socially inclusive, with greater interaction between members of different social categories. This is a direct consequence of GPT that made farmers more dependent on labor for a longer duration.

Participatory plant breeding and adoption of improved pearl millet cultivars in Rajasthan

Most earlier breakthroughs in pearl millet both from public and private sector agencies were in the form of hybrid varieties. These seeds need to be bought every year and need a higher level of inputs, which most poor households could not afford. Open-pollinated varieties developed and introduced by ICRISAT and its national program partners in Rajasthan provide yield increases without the disadvantages inherent in hybrids. Farmers can save and plant their own seed, and yield increases over local varieties are considerable, even without the use of yield-enhancing inputs. Many of these varieties were developed through farmer participatory trials and are therefore more suitable for local conditions.

Major benefits perceived by households in villages of western Rajasthan where large-scale adoption of ICRISAT-developed varieties have been adopted for over 10 years include:

(1) An improved choice of varieties to suit the weather; farmers are able to better manage risk arising out of climatic factors through the availability of varieties of different duration to suit the rainfall pattern.
(2) Reduction of risk has led to greater stability of the cropping system; farmers are able to plan better in advance and take decisions regarding the cropping pattern. More importantly, stability has led to long-term risk reduction, especially by building up grain stock for lean years.
(3) The cropping pattern has changed because of decreased risk and higher yields. Farmers choose an optimum mix of cash and subsistence crops to harvest grain yield for consumption, and cash crops for purchasing other necessities, and invest in inputs that lead to higher yields and productivity. In particular we observed land augmentation because of technology adoption—stable yields of pearl millet have enabled farmers to plant lesser area to millets and more to other, particularly cash, crops.
(4) The construction of “pucca” houses seems to be high on priority; most households first seek stabilization of their cropping system, and investment in productivity increasing ventures. Subsequently, they give importance to construction of a shelter to significantly improve their earlier “kuchcha” structures.
(5) Given the high-risk environment and extreme nature of economic backwardness in western Rajasthan, a premium seems to be placed on investing in community-level facilities. Thus, in several villages,

households pool resources to enhance their education and health facilities. Communities also invest in symbolic and non-tangible ventures, whose benefits are not increasingly apparent, but which enhance social status and have long-term benefits, such as temples, and “kabutarkhanas” (bird houses).

Lessons from Impact Studies: Some Essentials for Positive Impacts on the Poor

Based on the above preliminary findings, we are now developing a rigorous methodology to survey and quantify the observed impacts on a larger scale. At this point we wish to mention three distinct features that accompany the process of technology adoption resulting in poverty reduction. These we believe are essential for positive impacts on the poor.

(1) ***Asset generation.*** It is important to focus on increased productivity-related investments. Any on-farm investment that occurs after technology adoption points to positive impacts and is likely to result in sustainable, long-term development. Continuing on-farm investments are a key indicator of farmers’ self-reliance, leading to exit paths out of poverty. In general we observed that on-farm investments are in the form of purchase of land, investment in irrigation (pump sets, wells), motive power (livestock, tractors, power tillers, threshers), and land improvement measures. In Rajasthan, we also observed that, when income surpluses accrue or are sustained over a few years, one of the first items that farm households invest in is a pucca house. Shelter for the family as well as for farm animals comes across as most important for farm households.

(2) ***Improved access.*** Farmers practicing traditional agriculture, those using little inputs and local cultivars, are usually the more isolated ones who have less access to government agencies. They have less contact with extension agents; they are less integrated into various kinds of markets; and have little access to non-exploitative institutions, such as those for credit. In both Rajasthan and in Maharashtra, farmers reported increased visibility of their villages after technology adoption, and resultant improvement in their socioeconomic status. Their credit worthiness improved (among banks as well as input suppliers). Consequently, government programs targeted these villages, and they became better integrated with the larger community in a general way.

(3) ***Empowerment and human capital enhancement.*** A key feature of most villages where we carried out our pilot surveys was that, overall, farm households experienced an expansion of choice—choice of cropping pattern, choice of investment strategies, and choices to better manage risk and instability. Binding constraints were lifted to enhance economic decision making, which resulted in empowerment at the household and community level. For example, in Rajasthan where PRAs

were carried out among women and men, improved welfare after technology adoption was revealed through increased rates of schooling, especially for girl children, and community-level support for education. In the Maharashtra study also, literacy and education levels markedly improved, especially among marginalized (tribal) groups.

Conclusions

Much of the current debate on agricultural innovations and consequences for poverty essentially revolve around the nature and extent of positive or negative impacts on the poor, on inequality, and on the environment and its implications for larger economic growth. Methodological issues have mainly addressed measurement of these related impacts. Although issues such as risk and institutional constraints have also been the focus of studies, systematic analysis focusing on the nature of the linkages between research, technology adoption, and poverty and the actual process of impact have not been tackled adequately. This paper's primary focus is to seek an understanding of linkages and the actual process of benefit flows, and to establish a basis for confirming questions related to measurement of poverty impact in an adequate manner. This understanding provides feedback regarding the precise way in which a technological innovation effects improvement in welfare, and thereby helps in planning appropriate research strategies.

Participatory approaches enhance human capabilities, specifically those related to knowledge regarding innovations and the use of innovative techniques. Human capital enhancement in the form of knowledge regarding technological options expands choices available to farm households, and reduces risk. Expansion of choice reduces constraints on economic and social decision making. Technologies arising out of such approaches therefore are more likely to reduce poverty in the long run.

Poor people have few assets, and access to common property resources is also on the decline. It is therefore necessary to understand how technologies and intervening factors enable or constrain farm households in acquiring a wide range of assets and in gaining access to decision-making processes, resources, and markets, and benefit from them.

References

Bantilan, M.C.S.; Joshi, P.K. 1994. Evaluating ICRISAT research impact: Summary proceedings of a workshop on Research Evaluation and Impact Assessment. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 142 p.

Bantilan, M.C.S.; Joshi, P.K. 1996. Returns to research and diffusion investments on wilt resistance in pigeon pea. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 30 p. (Impact Series no.1)

Bantilan, M.C.S.; Parthasarathy, D. 1999. Efficiency and sustainability gains from adoption of short—duration pigeon pea in nonlegume-based cropping systems. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 24 p. (Impact Series no. 6)

de Janvry, A.; Sadoulet, E. 1996. Household modeling for the design of poverty alleviation strategies. University of California, Berkeley, California Agric. Exp. Station, Giannini Foundation of Agric. Econ. Berkeley, CA, USA. 17 p. (Working Paper no. 787)

de Janvry, A.; Key, N.; Sadoulet, E. 1997. Agricultural and rural development policy in Latin America—New directions and new challenges. Agricultural and Economic Development Analysis Division and Policy Assistance Division, FAO, Rome, IT. (FAO Agricultural Policy and Economic Development Series)

Fan, S.; Hazell, P. 2000. Should developing countries invest more in less-favored areas: An empirical analysis of rural India. Economic Political Weekly, April 22, 2000.

Freebairn, D.K. 1995. Did the green revolution concentrate incomes? A quantitative study of research reports. World Develop 23:265-279.

Joshi, P.K.; Bantilan, M.C.S.1998. Impact assessment of crop and resource management technology: A case of groundnut production technology. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 53 p. (Impact Series no. 2)

Kerr, J.; Kolavalli, S. 1999. Impact of agricultural research on poverty alleviation: Conceptual framework with illustrations from the literature. International Food Policy Research Institute (IFPRI), WA, USA. 197 p. (Environment and Production Technology Division Discussion Paper no. 56).

Kolli, R.D.; Bantilan, M.C.S. 1997. Gender-related impacts of improved agricultural technologies: Identification of indicators from a case study. Gender Develop 1:371-393.

Lipton, M.; Longhurst, R. 1989. New seeds and poor people. Johns Hopkins, Baltimore, MD, USA. 473 p.

Pearse, A. 1980. Seeds of plenty, seeds of want: Social and economic implications of the Green Revolution. Clarendon Press, Oxford, GB. 262 p.

Rohrbach, D.D.; Lechner, W.R.; Ipingi, S.A.; Monyo, E.S. 1999. Impact from investments in crop breeding: The case of Okashana 1 in Namibia. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 43 p. (Impact Series no. 4)

Tribe, D. 1994. Feeding and greening the world: The role of international agricultural research. CAB International in association with the Crawford Fund for International Agricultural Research, GB. 274 p.

World Bank. 1999. India: Towards rural development and poverty reduction. Vol. 1 and 2, Rural Development Sector Unit, South Asia Region, World Bank, WA, USA. (World Bank Report no. 18921-IN)

Yapi, A.M.; Debrah, S.K.; Dehala, G.; Njomaha, C. 1999. Impact of germplasm research spillovers: The case of sorghum variety S 35 in Cameroon and Chad. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), IN. 30 p. (Impact Series no. 3).

CHAPTER 11

Formal System and Farmers' System: The Impact of Improved Maize Germplasm in Southwest China

*Yiching Song**

Introduction

The need for increasing sustainable crop yields continues to grow with increasing population and environmental limitation. This is especially true in the case of China, which is the most populated country with the most limited amount of arable land per head in the world. China is a country probably occupying one of the highest positions on the international food security agenda in the coming century. However, food security is a complex and debatable issue. Food productivity and availability do not necessarily equate with food security for all. Poverty is a major determinant of chronic food insecurity. In this chapter, the impact of agricultural research on food security, at both national and household levels, and on poverty alleviation is addressed through the impact study of the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) Program in the context of China. Southwest China hereon refers to this CIMMYT Program area, including three provinces—Guangxi, Yunan, and Guizhou.

In collaboration with the Chinese Academy of Agricultural Science (CAAS), CIMMYT initiated a maize (*Zea mays* L.)-breeding program in southwest China. The general objective was one of poverty alleviation at the end of the 1970s. The maize-growing area in China can be roughly divided into two distinct parts, the northern plain and the southwest. The former is relatively similar to the Corn Belt of the USA in soil types and climatic conditions. Maize production there is mainly for feed. The southwest is a remote mountainous area with a tropical and subtropical climate. The 25 million poor farmers who reside in this area basically depend on maize for their staple food, but production circumstances are quite different from the northern "Corn Belt", as are the socioeconomic conditions.

* Postdoctoral Research Fellow, Department of Communication and Innovation Studies, Wageningen Agricultural University, the Netherlands.

The present chapter, which is based on the impact study, intends to address the interrelated national and household food security and poverty alleviation issues by assessing the impact of the Program and analyzing the capabilities of public research and farmers' indigenous knowledge to deal with these issues at different levels. It concludes by suggesting that China will benefit from a combination of a modern technology-oriented approach and a participatory approach. Collaboration between the formal and farmers' knowledge systems are highly necessary for the design of agricultural research projects that could better address the challenges to be faced in poverty alleviation, food security, and natural resource conservation.

Changing Context and Confronting Challenges

China turned to the power of modern agricultural technology to solve the problems revealed by the great famine at the end of the1950s to the early1960s. The most noteworthy development was the establishment of the public agricultural research and extension systems for modern varieties. Some 30% or so of Chinese food security since then is attributable to the development and rigorous promotion of improved planting materials, especially hybrid wheat, rice, and maize (Fan and Pardey, 1997; Lin, 1998). China was the first country in the world to plant significant areas of genetically modified crops in the early 1990s. But the modern technology approach cannot work in all areas or for all farmers. Besides, the social context and natural environment are rapidly changing, and the poor, with limited resources, are the most fragile group to adapt to the changes.

The Chinese rural economy has experienced a rapid growth since the adoption of a broad program of rural economic reforms beginning in 1978, and China is widely recognized for its achievements in reducing absolute poverty since then. Nevertheless, about 60 million people still live under the absolute poverty line, and they comprise most of the food-insecure population. They are mainly farmers cultivating in resource-constrained, remote upland areas, where the agro-ecologically diverse, resource-poor, and risk-prone regions in southwestern and northwestern China are located. These small-scale subsistence farmers have an average land size of less than 0.2 hectares. Although these poor have land use rights, in most cases the land itself is of such low quality that subsistence levels of crop production cannot be achieved. Consequently, most poor consume grain and other subsistence foods beyond their own production levels, and are negatively affected by price increases for these products after reforms (UNDP, 1995; World Bank, 1995). Minority peoples are known to represent a highly disproportionate share of the rural poor.

Feminization of agriculture is strong; women constitute more than 80% of the agricultural work force because of male out-migration (Gao, 1995; Song, 1998). This is especially true in the remote and upland communities, where most of the male farmers have migrated to urban and economically booming areas for income earning opportunities. Women, who were left behind in agriculture, were overburdened with low or non-profit agricultural activities as unpaid laborers within the household. There were fewer opportunities for women-headed households to adopt modern varieties (MVs) because of their limited access to resources and services (Ashby, 1985; Jiggins, 1986; Song, 1998). These poor, women-headed households are facing problems of food insecurity, and poor access to basic health and education services and other public services. They comprise the poorest group of the poor.

Meanwhile, when we discuss food production and security, especially with respect to the rural poor, the issues of environment and biodiversity conservation also should be addressed. Some researchers argue that poverty and environmental degradation are closely linked, often in a self-perpetuating negative spiral in which poverty accelerates environmental degradation, which in turn results in, or exacerbates, poverty. Continuing to neglect these less-favored, vulnerable areas where many of the poor live will make degradation worse and perpetuate poverty. Continuous exploitation is guided by the state's single-minded aim of targeting only yields to ensure national food security since the Green Revolution era. With little regard for the chaotic variation in environment and emerging changes in social contexts, this exploitation has tended to degrade natural resources and agro-ecology. For example, the wide adoption of MVs was accompanied by the disappearance of indigenous varieties, by soil erosion resulting from overuse of chemical fertilizer, and by insect resistance because of overuse and repeated use of pesticide. This, in turn, has tended to destroy the resilience of the ecosystem and the sustainable livelihood of farmers, particularly the poor, and mainly women.

In China, rice (*Oryza sativa* L.), wheat (*Triticum sativum* Lam.), and maize have long been the three traditional main food crops. Each of these grains accounts for roughly 100 million tons of the 340 million tons annual grain harvested. However, rice and wheat are now the two national staples, with rice dominating in the south and wheat in the north. Maize used to be the staple food in the northeast, southwest, and northwest. Maize is now the most important feed crop (about 70% of harvest used as feed [Dong, 1995]) and the third most important food crop in China. More importantly, it is the main staple food crop for the rural poor in the remote upland areas in the northwest and southwest. The latter is an agro-ecologically diverse area and the major source of maize genetic diversity in China. Previous research revealed that the narrow genetic base is a main technical constraint in maize plant improvement in China (Li, 1990). Recent studies and evidence further show that these local varieties and landraces are disappearing at a rapid rate. Genetic base broadening and biodiversity enhancement have a crucial role to play in sustainable food production and food security in China.

Under such circumstances, research questions arise such as: what has happened in areas where environmental resource endowments are too variable and marginal for modern technology strategies to succeed? What are poor farmers in these areas looking for in improved planting materials? And how have their needs been met? What can agricultural research, in our case plant breeding, do to better address the confronting inter-linked issues of food security, poverty alleviation, and natural resource conservation in a sustainable and equitable way? The impact study intended to answer these questions by assessing the impact of the MVs and analyzing the capabilities of public research and farmers' indigenous knowledge to deal with the food security and poverty alleviation issues at different levels.

The Impact of Improved Maize Germplasm in Southwestern China

The impact study was made at five levels (i.e., state, province, county, village, and farmer household), by using exploratory qualitative methods and quantitative formal survey methods. The impact assessment (at both macro and micro levels) and the comparative analysis of formal and informal breeding with in-depth case studies provide a comprehensive view of the Program.

The Program's general impact is impressive. A farmer survey and in-depth case studies in the region revealed that 65% of the total maize area is covered by MVs (46% hybrids and 19% improved open pollinating varieties [OPVs]), while the rest are landraces. About 957,000 hectares are planted to the CIMMYT-related materials every year, comprising about 43% of the total maize area in the three provinces. Of the total local releases, 73% has been based on improved germplasm during the period from 1980 to 1996. Of the MVs currently used, about 87% are CIMMYT-related materials. The total adoption of improved germplasm has been growing for both favored and less-favored areas during the implementation of the Program in the last 15 years. There is little doubt that the wide adoption of MVs has contributed significantly to the continuous increment in maize production and productivity over that period (Figure 1).

Despite the impressive achievement at the macro level, further in-depth case studies and participatory observation have revealed great variation among regions and differentiation among farmers in coping with the MVs. A farming-level study showed that the types of materials adopted are obviously different in different environments. Improved OPVs are adopted mainly by farmers in environmentally harsh and rainfed areas. For instance, the three improved populations from CIMMYT (Tuxpeño 1, Tuxpeño P.B. C15, and Suwan 1) have had an annual adoption of 310,000 hectares, comprising about 15% of the total maize area since the early 1980s. They are mainly cultivated by poor farmers in the marginal and environmentally less-favored areas with difficult and complex maize farming systems. The three improved populations, which were held and directly used by farmers, have become dominant varieties and contributed significantly to household food security and poverty alleviation in the rocky mountainous areas in the southwest. Although this is not reflected in the state's statistic of modern technology (mainly hybrid) adoption, great impact through farmers' informal systems has contributed considerably to the realization of the general objective of the Program for poverty alleviation. In the environmentally favored areas, top-cross and three-way cross hybrids are widely accepted and dominant, such as Guangxi Top-cross 1 to 5, which have dominated in the relatively favored areas in Guangxi for about 10 years. These are CIMMYT-related hybrids. The adoption of the government-recommended, single-cross F_1 hybrids is limited despite the large number of releases available at the public breeding institutions and with strong government recommendation and intervention.

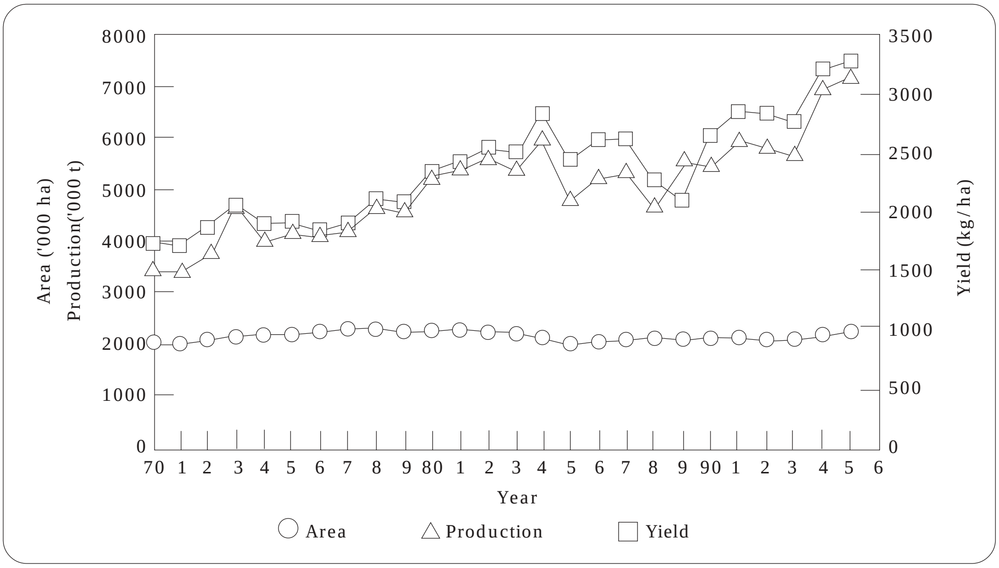


Figure 1. Maize production trends in Guanxi, Yunan, and Guizhou provinces, China 1970-95. (From Song, 1998.).

A large gap exists between (1) farmers' heterogeneous needs and interests, and (2) the formal breeders' single-minded pursuit of yield and their profit incentive in hybrids. Most public efforts went into the development and diffusion of several uniform, high-yielding hybrids. As a result, the formal knowledge system largely neglects regional variation and user differentiation in terms of gender. This has resulted in the activation of the farmers' indigenous system for OPV improvement, landrace maintenance, and seed exchange, because few public efforts were made to distribute and improve these varieties as a result of the public seed system's low interest in OPVs.

Consequently, the impact of CIMMYT's maize germplasm is actually being achieved through both the formal system and farmers' systems. The macro-level impact is mainly achieved through the public breeding efforts, and is reflected in the adoption of CIMMYT-related hybrids and yield increments, which, however, have limited benefit for resource-poor farmers in marginal rainfed areas. The considerable impact of the improved maize germplasm on the household food security and poverty alleviation of the poor and women farmers is achieved through the informal system, which has assured the wide distribution of CIMMYT's improved populations through farmers' own systems.

The Formal System, its Policy Orientation and Hybrid Bias

The great famine in China in the late 1950s to early 1960s, and the poor socioeconomic situation of agriculture at the time, stimulated the construction of a modern technology-oriented approach. Since then, national food security via food self-sufficiency has been the central government's number one goal for agriculture. Government policy started to emphasize modern inputs in terms of MVs, fertilizers, and irrigation schemes. The most noteworthy development was the establishment of an agricultural research and extension system for MVs. The development and distribution of MVs for the three main staples (rice, wheat, and maize) has been the core task and first priority for this system from the very beginning. F_1 hybrid breeding has become a universal tool for the formal plant breeding system to achieve the overall goal of national food security.

In 1990, the government started to reform its agricultural research funding policy. The government reduced its fiscal appropriation for agricultural research, shifted funding from institutional supports to competitive grants, and encouraged research institutes to commercialize their technologies, using part of the proceeds to subsidize their research (Lin, 1998). The agricultural research institutes have had to become more profit driven either through their research or other activities. For this reason, hybrid breeding and hybrid seed production have drawn more attention and effort than ever before. This has resulted in a strong public sector focus on several profitable hybrids and neglect of non-profitable OPVs needed by farmers in unfavorable marginal areas.

Unlike the situation in other developing countries, in China, CIMMYT's breeding material goes entirely through the dominant public system(s) (Figure 2). Obviously the formal system's program followed a top-down linear technology transfer process, through which CIMMYT's breeding materials made their way to farmers. With the single purpose of increasing productivity to ensure national food security, most public efforts went into the development and distribution of several uniform high-yielding hybrids, particularly single-cross F_1 hybrids.

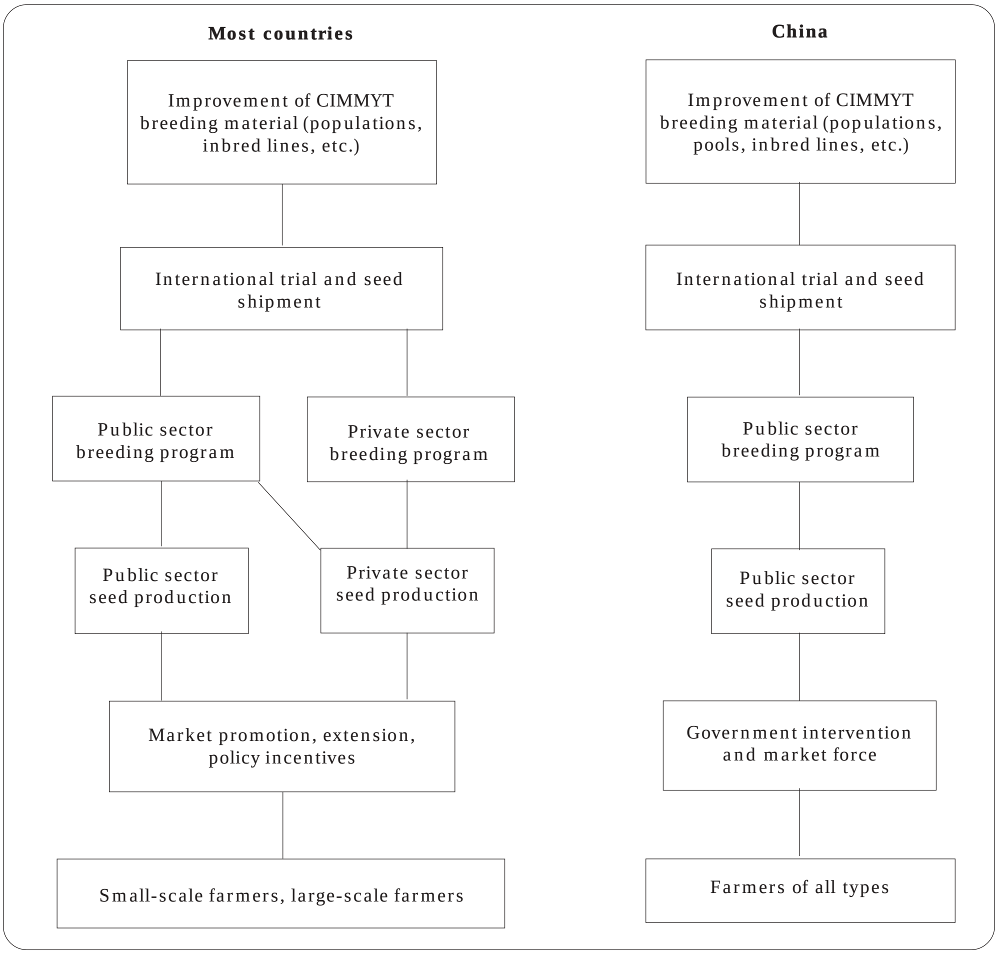


Figure 2. Flow chart of Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) breeding material in most countries (left) and in China (right). Adapted from Song (1998).

This is especially true after the 1990 policy reform. The formal breeding and seed distribution system has increasingly been forced to commercialize its operations, leading to an increasing focus on hybrid breeding and seed production and to an increasing neglect of OPVs and the deterioration of the quality of hybrid seed.

Fieldwork revealed that 48 maize varieties released by the formal breeding system in the southwest from 1980 to 1996 consisted of 39 hybrids and only nine OPVs (Table 1). Within the 39 hybrids, 31 are combined with one parent line from CIMMYT. The study also shows that CIMMYT germplasm has been playing an increasingly dominant role in formal, mainly hybrid, maize breeding (Figure 3).

Table 1. Trend in public maize breeding in southwestern China, 1980-96.

Maize types	Period			
	1980-85	1986-90	1991-96	1980-96 (total)
Hybrids	18	14	7	39
Open pollinated varieties	5	4	0	9
Total release	23	18	7	48

SOURCE: Song (1998).

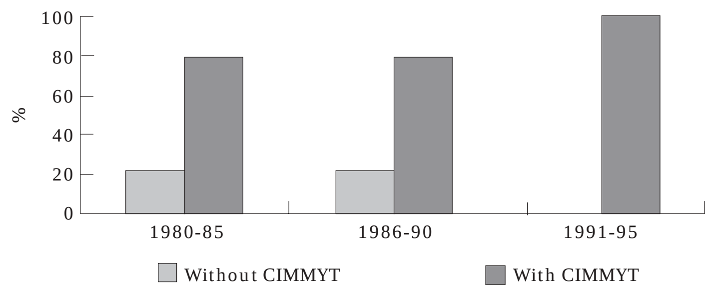


Figure 3. Releases with and without Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) breeding material in southwestern China, 1980-95. (From Song, 1998.)

However, Table 1 also illustrates the worrisome trend for the total number of releases by public breeding to decrease considerably after 1985, especially after the 1990s. This is mainly because of the government's reduced funding for public research resulting from structural adjustment and privatization. As a result, the hybrid policy together with the reduced funding situation and the inadequate profit incentives led the formal seed system to provide fewer and more limited options for farmers.

The Farmers' System, its Initiatives, and Efforts

Geographical variation is a major characteristic in Chinese agriculture. Regional variability in farming systems and differentiation among users are increasing as a result of the changes that emerged after the recent reforms (e.g., the development of rural industry, the commercialization of agriculture, and the feminization of agriculture). Farmers dependent on varied farming systems with diverse patterns of usage of maize have quite different and heterogeneous needs for, and interests in, technology and genetic diversity. The big gap between the breeders' limited supply and farmers' diverse needs led to the activation and development of indigenous knowledge systems through which farmers work on the neglected improved OPVs and landraces to meet their own needs. Owing to the feminization of agriculture and other socioeconomic factors, women mainly do the local seed selection and breeding.

The two cases below of Zhichen and Wenteng villages represent the two contrasting environmental and economic conditions of maize farming in southwestern China. Zhichen represents the poorest remote mountainous communities, which use maize for subsistence food production, while Wenteng represents relatively better off communities in the valleys and flat areas that use maize as pig feed. Zhichen villagers considered improved OPVs and some landraces as appropriate technologies to meet their needs in their harsh environment, whereas Wenteng villagers used to cultivate hybrid maize. However, most of them recently have shifted to improved OPVs, mainly because of the decreasing quality of government-supplied hybrid seed. As a result, Tuxpeño 1 has now become the dominant variety in both villages.

The experience of Tuxpeño 1 in southwestern China

Tuxpeño 1 (local name Mexican 1) is an improved population that CIMMYT developed from a landrace that originated from Tuxpau, Mexico. Tuxpeño 1 was introduced in southwest China in 1978, originally as a constituent for variety improvement and hybrid combination. However, it was rapidly disseminated through the three provinces, mainly through informal seed exchange. Because of its broad adaptability and stability, and strong tolerance to stress, especially lodging resistance, it became particularly popular with farmers in difficult farming systems in the remote mountainous areas. It has contributed significantly to household food security and poverty alleviation in the last two decades in those areas. Meanwhile, because of the poor quality of government-supplied hybrid seed, farmers in relatively favorable areas have increasingly adopted Tuxpeño 1. However, because maize is an out-breeding crop, without improvement effort from formal breeding, Tuxpeño 1 has degenerated greatly by out-crossing, resulting in decrease of yield, increase in plant height, and loss of stress-resistant characteristics to a certain degree. Farmers requested the government to assist them to improve the material, but no government attention was received. This led to significant efforts by local women farmers to engage in regeneration of Tuxpeño 1 (see under Wenteng case below).

The two case studies below illustrate women farmers' initiatives and methods in maintaining and improving Tuxpeño 1 and three landraces in two villages.

The Wenteng case. Wenteng has a relatively favorable environment, people are better off, educated, and integrated into the market economy. Maize used to be traditional staple food, but is now mainly used as pig feed. Pig raising is the main source of income for most villagers.

Because of the lack of institutional support, and the popularity of Tuxpeño 1, women in Wenteng village have organized themselves to maintain and improve the variety since the late 1980s. An innovative woman, who had tried to maintain Tuxpeño 1 since its adoption, initiated this activity. The crop development methods used by the women include spatial separation through use of plots at different locations, temporal isolation, and seed selection. These methods are critical for population maintenance. The women explained that because of the popularity of Tuxpeño 1 and the women's initiative in selection, it is easy to organize women farmers to grow the variety in adjoining fields, isolated from other varieties. The main selection method the women farmers use is mass selection in field and postharvest. In breeding terms, it is stabilizing selection for population maintenance. The three steps in seed selection are:

(1) Select best plants in the field (ideal phenotypes with big ears and other preferred agronomic traits in the middle of the field);
(2) Then select best ears (based on cob size, length, and number of seed rows); and
(3) Then select best grains (from the middle part of the ears, seeds are selected for kernel size, shape, quality, and color).

The women farmers claimed that their skills mainly have been passed on for generations, because they have also used similar techniques for the maintenance of landraces. They also added that some of their selection knowledge and techniques are gained from barefoot scientists[1] (breeders) in Mao's period by their parents or by themselves. As a result, the quality of Tuxpeño 1 in Wenteng village has been maintained and even improved in the sense that it is better adapted to the local conditions than before. Most villagers now consider it a local variety rather than a foreign one. It is not surprising that the improved Tuxpeño 1 has spread rapidly to the neighboring areas through farmers' informal seed exchange systems. Now Wenteng has become a source for quality Tuxpeño 1 seed for a large area.

The Zhichen case. Zhichen has a harsh and rugged environment. Farmers plant maize in minute pockets of soil on steep mountain slopes and between rocks in flat fields. There are no roads, and access to markets is very limited. Maize is produced for consumption. It has been a traditional staple crop in the area, which has a diversity of maize landraces. For instance, waxy maize is considered to have originated from this area (Liu, 1991; Zhang, 1995; Song, 1998).

Tuxpeño 1 was introduced in Zhichen at the end of the 1970s and quickly became the dominant maize variety. In Zhichen, 90% of the

1. During the Cultural Revolution, Mao emphasized technicians and scientists participation in the everyday life and work of farmers. It was revealed by the case study that a few breeders worked in Wenteng and other neighboring villages in the late 1960s and early 1970s.

farmers surveyed in this study said that resistance to lodging and higher yield are the most important criteria for their selection. Other preferred characteristics include white kernels, a good stalk with strong root system, relatively short plant stature, wide adaptability, and little external input (e.g., seed and fertilizer). In the last 3 to 4 decades, the cultivated landraces have been disappearing. From 20 local maize varieties planted in the 1960s, Zhichen villagers now only plant Tuxpeño 1 along with three local varieties (Local Sticky, Duan 1, and Local White). However, Tuxpeño 1 has degenerated greatly in Zhichen, as have the three landraces, as a result of outcrossing.

In contrast to Wenteng farmers, Zhichen villagers did little to maintain Tuxpeño 1 themselves; instead they maintain preferred landraces. Zhichen villagers feel that Tuxpeño 1 has degenerated beyond their skills to improve it. They hope that the government will improve the variety, because they consider this a government or foreign variety rather than a local one. Yet, they also know that they have to maintain their local varieties because no outside help will ever bother to do so. The farmers chose to maintain and improve the three local varieties based on their complex farming system and livelihood. Some farmers maintain the local white variety for its sweet stalks, which children enjoy chewing like sugarcane (*Saccharum officinarum* L.). Local sticky is a waxy variety used as a specialty food for local festivals. Almost every household maintains a small plot in its vegetable garden, despite low yield. Duan 1, an OPV improved by the county extension station in the 1960s, is maintained because of its strong drought resistance. Despite its low yield, farmers grow the variety in the second cropping season in the autumn, when no other variety survives the severe drought. The methods used by women farmers to maintain the three local varieties include spatial isolation (grown in isolated gardens or separate valleys) and postharvest seed selection for the best ears and then best kernels. Zhichen villagers also claim that their ancestors passed on this knowledge. Compared with the women farmers in Wenteng, farmers in Zhichen have less access to the outside world and less influence from external knowledge, and they maintain more diversity for risk management.

Comparison of the two cases. Wenteng has maintained and improved Tuxpeño 1, while Zhichen has chosen to maintain local landrace varieties. The different choices made by the two villages offer insights into farmers' selection strategies. Given the fact that maize is their staple food crop, Zhichen farmers strategically chose maize varieties that reflect their risk-aversion strategies. Despite the agronomic popularity of Tuxpeño 1, for Zhichen farmers in subsistence agriculture and risk-prone environments, other varieties were maintained and improved because of a combination of nutritional value, cultural practices, and reliable supply in the most adverse environmental conditions. The poorer villagers chose to maintain more diversity for managing risk. On the other hand, in Wenteng, Tuxpeño 1 fits the requirements for a commercial crop. The surplus in production extends the readiness of Wenteng's women to take risks. In addition, their more advanced knowledge and skills in varietal improvement and seed selection also reflect their greater external influence and better access to information and education compared with Zhichen, where women farmers live in isolation and often are illiterate.

Farmers' contrary adaptive strategies towards Tuxpeño 1 in the two cases show that their selection priorities and objectives reflect their environmental conditions, market and institutional relations, socioeconomic positions, and risk management.

The case studies also illustrate farmers' potential capability in selection and their benefit from exotic varieties such as this one. Some questions arise from the case studies. Why has Tuxpeño 1 such broad adaptation and why is it well accepted by farmers? Can the formal system pay more attention to these types of varieties by bringing more appropriate germplasm for the needs and interests of the poor farmers as well as for genetic base broadening in the agro-ecological diverse, remote, and resource-poor upland areas? What should international organizations and Chinese national agricultural research systems do to enhance the local process that already exists and to expand the base that farmers already have genetically and institutionally?

Conclusion: Facilitate Interaction and Collaboration between the Formal and Farmers' Systems

The impact study has clearly shown that agricultural innovation and the diffusion of new technologies are important factors in addressing food security (both at national and farmer household levels) and poverty alleviation. This is especially true with the case of maize, which is often grown in less favored areas and remote uplands, and is usually the primary base for diets in these areas. However, farmers adopt an innovation only if it will work in their fields. The modern technology approach in China, which has contributed considerably to the national food security, does not work in the remote, resource-poor, upland area. And the uniform MVs, mainly hybrids, are not sufficient to meet the heterogeneous needs of farmers, especially the poor and women in the marginal areas. In order to address the food security issues and to attack poverty and hunger, it is critical to direct agricultural research to cover these marginal areas and reach the un-reached poor populations by developing appropriate technology to meet their needs and interests.

An abundance of evidence and cases found in the research suggests that the real causes for the failure of the formal breeding program to address the variation of farming systems and to respond to the heterogeneous needs of farmers in marginal areas are institutional rather than technical constraints. These institutional constraints are related mainly to the research priority and focus and partially to the inefficiency and ineffectiveness of the formal system. Some technical factors, such as variety characteristics and environmental conditions, are responsible for the failure at first sight. However, technical constraints can be overcome by breeding varieties with desired traits for target areas (CIMMYT, 1996).

The impact study provides us with a comprehensive picture of the great impact achieved through the public system and farmers' indigenous system and the operation and functioning of the two systems at different levels. The study also revealed a wide and growing gap between farmers' diverse needs in terms of stability, quality, yield, and other agronomic and postharvest characteristics, and the formal system's single interest in yield increase through F_1 hybrid breeding and distribution. This resulted in the initiatives of farmers and the activation of their indigenous system to meet their own needs and interests.

The experience of Tuxpeño 1 shows the impact of CIMMYT material on household food security and poverty alleviation and the potential role of CIMMYT through the farmers' informal system. When CIMMYT's technologies reached the limit of success in terms of reaching the poor through the formal system, their impact continued through the farmers' system. This implies an urgent need for better institutional linkage and collaboration between the farmers' and formal systems in crop improvement in order to explore local dynamics and potential farmer capability.

The impact study also revealed that the "feminization of agriculture" is an impressive phenomenon in the remote upland areas. Women there are playing a predominant role in subsistence agriculture and food security. Seed maintenance and selection is carried out entirely by women based on their own knowledge. However, the women's access to resources and public services is much more limited than that of men. A gender analysis and involvement of women's participation and their expertise in technology design and development is vital in technology design and development to meet their specific needs and interests. This could substantially contribute to reduce poverty and ensure food security at the farmer household level (Jiggins, 1986; Quisumbing et al., 1995; Song, 1998).

Considering the main policy issues arising from the impact study, and given the specific situation in China, a twin-truck approach (i.e., a combination of the present modern technology-oriented approach and participatory approaches) can be an alternative to address food security and poverty alleviation. It could also enhance the sustainable use of genetic resources and biodiversity. In the same way, a combination of traditional technologies from the farmers' indigenous level and modern technologies from the scientific level might provide a great opportunity for additional food production and productivity gains while conserving natural resources. Farmer's indigenous knowledge systems have a close relationship to the complex natural ecosystem and diverse farming systems. Farmers know their farming system best and scientists have the knowledge of scientific principle and biotechnology. A cooperative and complementary relationship between the two systems, rather than a separated and conflicting one, is a logical combination to meet both the state's need for national food security at the macro level, and the farmers' diverse needs and interests in different areas at the micro level.

China should certainly take the technological high road in uniform and well-favored environments to insure national food security. In addition, reconsideration and adoption of the Chinese traditional ecological knowledge and indigenous farming practice are highly necessary to maintain land productivity and minimize the negative side of the modern technologies on the environment and natural resources. But, in the more remote and difficult regions, research on more location-specific technologies is needed to produce a wider range of technology options tailored to diverse environments and complex and fragile ecosystems.

Decentralization of the formal systems and involvement of farmers, mainly women, in the technology design and development process is necessary and essential to stimulate collaboration between the two systems through mutual communication and understanding. The informal sector needs to know more about the complexity of biotechnology, while the formal system needs to know more about the complexity of poor farmers' farming systems and their livelihoods. For instance, the importance of farmers' knowledge of landraces and their understanding of the micro-variations in the environment could become the basis for local-level breeding or location-specific breeding. Through farmers' participation and cooperation, breeders can gain new insight into the criteria, objectives, or evaluation techniques of farmers and the differentiation between regions and types of farmers (in terms of gender). As a result, appropriate varieties within a wide range of options can be produced to meet the heterogeneous needs resulting from regional variation and user differentiation.

We can conclude that interaction and collaboration between formal and informal knowledge systems through participatory methods and gender analysis is critical, not optional, in the design and development of agricultural technology that could better meet the needs and interest of the poor and of women farmers. In return, it could substantially contribute to reduce poverty and ensure food security.

References

Ashby, J.A. 1985. Women and agricultural technology in Latin America and the Caribbean. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 41 p.

CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo). 1996. Developing drought- and low-N-tolerant maize: Proceedings of a symposium. MX.

Dong, L. 1995. Maize improvement and utilization in China. *In*: Crop Science no. 46, August issue. Chinese journal by Chinese Academy of Agricultural Science, Beijing, CN.

Fan, S.; Pardey, P.G. 1997. Research, productivity and output growth in Chinese agriculture. J Dev Econ 53:115-137.

Gao, Xiaoxian. 1995. Economic reform and rural women. *In*: Women and, development in China: Status, health and employment. Proceedings of the First International Seminar on Chinese Women and Development, Tianjing Normal University. Henan People's Press House, CN. p. 102-136.

Jiggins, J. 1986. Gender-related impacts and the work of the International Agricultural Research Centres. World Bank, WA, USA. (Consultative Group on International Agricultural Research [CGIAR] Study Paper no. 17)

Li, Jingxiong. 1990. Maize growing under stress environments in China. *In*: De Leon, C.; Granados, G.; Read, M.D. (eds.). Proceedings of Fourth Asian Regional Maize Workshop, 21-28 Sept 1990, Pakistan. Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), MX.

Lin, J.Y. 1998. How did China feed itself in the past? How will China feed itself in the future? Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) Economics Program, Second Distinguished Economist Lecture. MX. 38 p.

Liu. 1991. (ed.) Maize in China. China Southern Press, Guangzhou, CN. (In Chinese)

Quisumbing, A.R.; Brown, L.; Feldstein, H.; Haddad, L.J.; Peña, C. 1995. Women: The key to food security. International Food Policy Research Institute (IFPRI), WA, USA. 22 p. (Food Policy Report)

Song, Y. 1998. "New" seed in "old" China: Impact study of CIMMYT's Collaborative Program on Maize Breeding in Southwest China. Thesis (Ph.D.). Wageningen Agricultural University, NL. Available in http://www.cimmyt.cgiar.org/research/economics/Index.htm

UNDP (United Nations Development Programme). 1995. Human development report. Oxford University Press, NY, USA.

World Bank. 1995. Staff appraisal report: China Southwest Poverty Reduction Project. Agricultural Operational Division China and Mongolia Department East Asia and Pacific Regional Office, World Bank, WA, USA. 106 p. (Report no. 13968-CHA)

Zhang, Shihuang. 1995. Some suggestions for maize genetic base broadening by a systematic utilization of exotic germplasm and landraces. Chinese Academy of Agricultural Science, Beijing, CN. (Draft working paper)

CHAPTER 12

Analysis of a Cassava Integrated Research and Development Approach: Has it Really Contributed to Poverty Alleviation?

*María Verónica Gottret** and *Melanie Raymond***

Introduction

Cassava (*Manihot esculenta* Crantz) is an important crop throughout the tropical world for small-scale farmers with access to marginal lands. Its high tolerance to seasonal low rainfall, high temperatures, and intermediately fertile soils makes it an essential source of food security and cash income in areas where few alternatives exist. For example, small-scale farmers of the semiarid North Coast of Colombia obtained 40% of their cropping income by marketing cassava (Janssen, 1986). The crop represented an important food source for the farmers and their families as well as an employment generator, creating about 7.3 million wage-days per year. Despite cassava's socioeconomic significance, the quick deterioration of cassava roots rendered its marketing difficult. During the 1970s and 1980s, farmers in Latin America had limited marketing outlets for their cassava production; most of the production was for on-farm consumption and sold on fresh markets. A marketing channel made up of several intermediaries ensured the supply of roots from the farm gate to the urban consumers. The short shelf life of harvested fresh roots made marketing cassava a risky business; losses were high and fluctuations of daily price were large.

Market alternatives were needed. CIAT identified dried cassava chips for the animal feed industry as a potential market alternative. The Integrated Cassava Research and Development (ICRD) Project, 1981-1989, was set up to widen market opportunities for small-scale farmers, secure a price floor for cassava, and thus provide a sustainable source of income for the farmers. The program's strategy was to link small-scale farmers with the expanding market for animal feed concentrates (Best et al., 1991). The project targeted small landholders and tenant farmers working farms

* Economist, Impact Assessment Project and Rural Agro-enterprise Development Project, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

** PhD Student, Agricultural and Resource Economics, University of California at Berkeley, USA.

of less than 20 hectares. The project's main hypothesis was that with secure and profitable markets, cassava farmers would be more likely to adopt improved production technologies that were cost reducing, thus improving their cassava production and, consequently, their incomes.

We evaluate the main hypothesis driving the ICRD Project and its overall impact on poverty. To determine whether the project reached its goal, we focus on assessing the project's impact on participating communities in terms of poverty alleviation within them. We also aim to identify the avenues by which the project brought about these changes. Thus we analyze:

(1) The emergence of cassava drying organizations, and the expansion of cassava drying capacity in the region;
(2) The short-run, intermediate effect of the new alternative market developed for cassava roots;
(3) The new market influence on the adoption of modern varieties;
(4) The contribution of the ICRD Project to poverty alleviation; and
(5) The sustainability of the impact after the project ended and after the national economy opened up to international competition.

Lessons learned from the project's experience indicate that interinstitutional partnerships played an important role in reaching the targeted population and implementing the project and that the market alternative created by the drying agro-industry stimulated the adoption of new technology.

The Challenge

In the early 1980s, the Colombian cassava market experienced particularly depressed prices, partly a result of an intensification of cassava production. Taking advantage of a credit program offered by the Colombian government's Integrated Rural Development Program (DRI, the Spanish acronym), cassava farmers increased their production in the late 1970s (Janssen, 1986). By 1981, cassava production was extremely high and unable to find buyers; many farmers plowed their crops without harvesting.

With prices falling below production costs, problems of massive credit default appeared. Limited markets for cassava belied the DRI's basic premise that production increases would improve the income of small-scale farmers. After the 1981 debacle, farmers were afraid to increase cassava production. Small-farm development in the North Coast region clearly did not depend on production increases alone, but also on marketing. The DRI therefore began searching for alternative markets for cassava.

In the same period, CIAT was concerned that, constrained by lack of markets, cassava farmers in Latin America were not adopting improved production technologies developed during the 1970s. The Center therefore studied alternative uses for cassava to identify markets with growth potential, the most promising of which was the use of dried cassava chips as an energy component in animal feed concentrates (Pachico et al., 1983). This industry was originally developed in Asia, where millions of tons of dried cassava chips had been produced for export. After conducting economic studies, CIAT initiated an integrated approach to cassava research and development to introduce this market opportunity to South America (Cock, 1985; Lynam and Janssen, 1988).

The Intervention

For the DRI, also facing the challenge of finding alternative markets for cassava, CIAT was a natural partner because it had already identified such possibilities. The Center had also begun developing appropriate cassava processing technology, and conceptualizing the ICRD strategy. In 1981, together with the DRI Program, the ICRD Project was implemented through an integrated set of institutional, organizational, and technological interventions designed to link small-scale cassava farmers to expanding markets, thus to stimulate their demand for improved production technology with potential to improve their income and welfare.

To establish an agro-industry based on drying and chipping cassava roots required the construction and operation of small-scale processing enterprises, owned and managed by small farmer associations. The technology was brought from Asia, but was tested, adjusted, and diffused with small-scale farmers' participation. This low-cost and appropriate technology consisted of chipping cassava roots, which were then spread on cement floors and sun dried. The North Coast region of Colombia was chosen to elaborate the project because of the importance of the cassava crop to the region. In the early 1980s, the region grew 35% of the country's total cassava production. Moreover, the region had a high proportion of small-scale farmers, with 80% of farms of 20 hectares or less representing less than 10% of the total farmland (DANE, 1974). The North Coast region featured all the characteristics desirable to develop and implement the ICRD.

The ICRD Project was coordinated by the DRI, in collaboration with other decentralized public and private institutions. Each institution assumed an agreed set of responsibilities in accordance with their own mandates and capacity (summarized in Table 1). The ICRD Project was executed in four phases (Best et al., 1991).

Experimental phase: 1981-82

The project began with a group of 15 farmers, selected from the municipality of San Juan de Betulia, Department of Sucre. A pilot plant was built, the processing technology was evaluated and adapted, and an operational scheme was developed for local conditions. Seven tons of dried cassava chips were produced and distributed to several animal feed firms to obtain feedback on their potential interest in buying the product and the price they would pay. As a result, one firm committed itself to buying the entire production of the next cassava season.

Table 1. Private and public institutions and their responsibilities in the Integrated Cassava Research and Development (ICRD) Project, North Coast, Colombia, 1981-89.

Institution[a]	Responsibilities
CIDA	Finance the Project's experiment and demonstration phases, and the first 2 years of the replication phases.
ANPPY	Marketing of dried cassava chips.
Caja Agraria	Provide credit for cassava production.
CIAT	Develop production and processing technology, provide technical assistance and training to national personnel, conduct socioeconomic and market studies, and monitor and evaluate the project's progress.
CECORA	Provide technical assistance in processing, marketing, and management.
CORFAS	Provide technical assistance in processing and marketing, investment and working capital credit, and credit advice.
Cooperatives[b]	Provide labor for constructing the drying plants and participate actively in the whole project.
DANCOOP	Provide legal advice to cooperatives.
DRI	Provide institutional coordination and financing in DRI areas (municipalities where farms are smaller than 20 hectares).
ICA	Develop and adjust production technology and provide technical assistance.
INCORA	Provide technical assistance on production and processing, and credit for land reform beneficiaries.
PMA	Provide credit for the construction of drying plants, using funds obtained through sales of food aid, which were channeled through CORFAS.
PNR	Provide institutional coordination and financing in PNR areas (municipalities with social and violence problems).
SENA	Assist in community organization and provide business management training, including permanent consulting services.

a. See List of Acronyms (p. 265).
b. Organized communities for cassava-drying activities.

Demonstration phase: 1982-83

The pilot plant became semi-commercial, with the farmers taking full responsibility for its management. This period provided reliable data on the plant's operation and consolidated the market for the product. A technological and economic feasibility study was conducted, and its positive results prompted the DRI to create a line of promotional credit for establishing additional drying plants. The pilot plant expanded its capacity and was used as a demonstration and training model for other farmer groups interested in building drying plants in their communities.

Replication phase: 1983-89

Drying plants were replicated at other sites in the North Coast. At the same time, the development and validation of production technologies were intensified, and a methodology of farmer participation was incorporated into technology development. By 1989, small-farmer cooperatives were managing 39 drying plants, and five plants were privately operated. As dried cassava chips production reached 5600 tons, the product had to be promoted among a larger number of buyers. The National Association of Cassava Producers and Processors (ANPPY, the Spanish acronym), an association of small-farmer cooperatives, was created and took responsibility for marketing the dried cassava chips. In 1989, the ICRD Project ended as a formal interinstitutional activity.

Reduced institutional support phase: 1989-93

By 1993, 138 processing plants for drying cassava were operating. Small-farmer cooperatives managed 101 plants, while private individuals who had adopted the processing technology, but not the organizational model, built the remaining 37. The total drying capacity of all 138 plants was 179,715 m^2, of which private entrepreneurs installed 28% (Figure 1). The rapid growth in private investment occurred mainly during this phase, when the technology was completely adapted to local conditions, the market already established, and the economic feasibility of the investment proved. The private entrepreneurs therefore assumed a lower risk. In 1993, dried cassava production reached 35,000 tons, valued at US$6.2 million, and requiring 90,000 tons of fresh roots. This volume represented 10% of total cassava roots marketed in the region. Probably 36% of small-scale cassava farmers in the region were selling cassava roots to the dried cassava agro-industry, and 15% of all small-scale farmers were members of a cooperative.

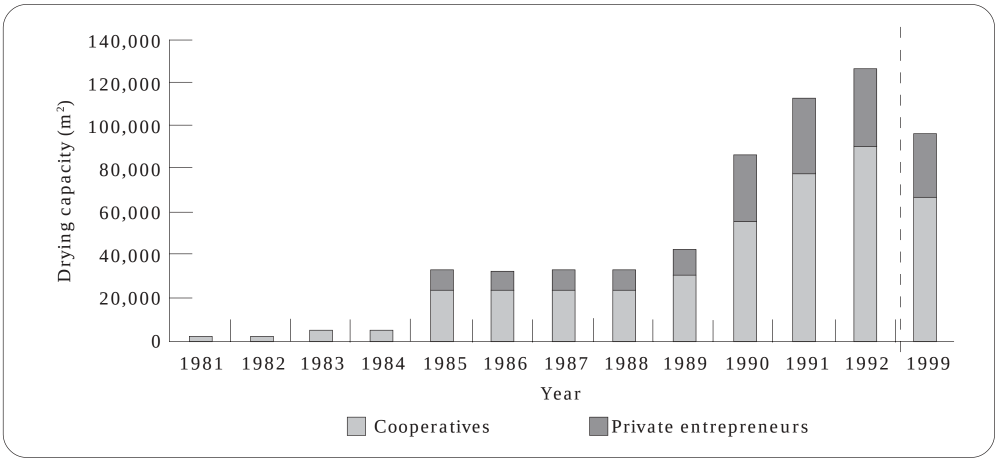


Figure 1. The emergence of the cassava drying agroindustry in the North Coast of Colombia, 1981-92. (Data were obtained from the Integrated Cassava Research and Development [ICRD] Project monitoring and evaluation system.)

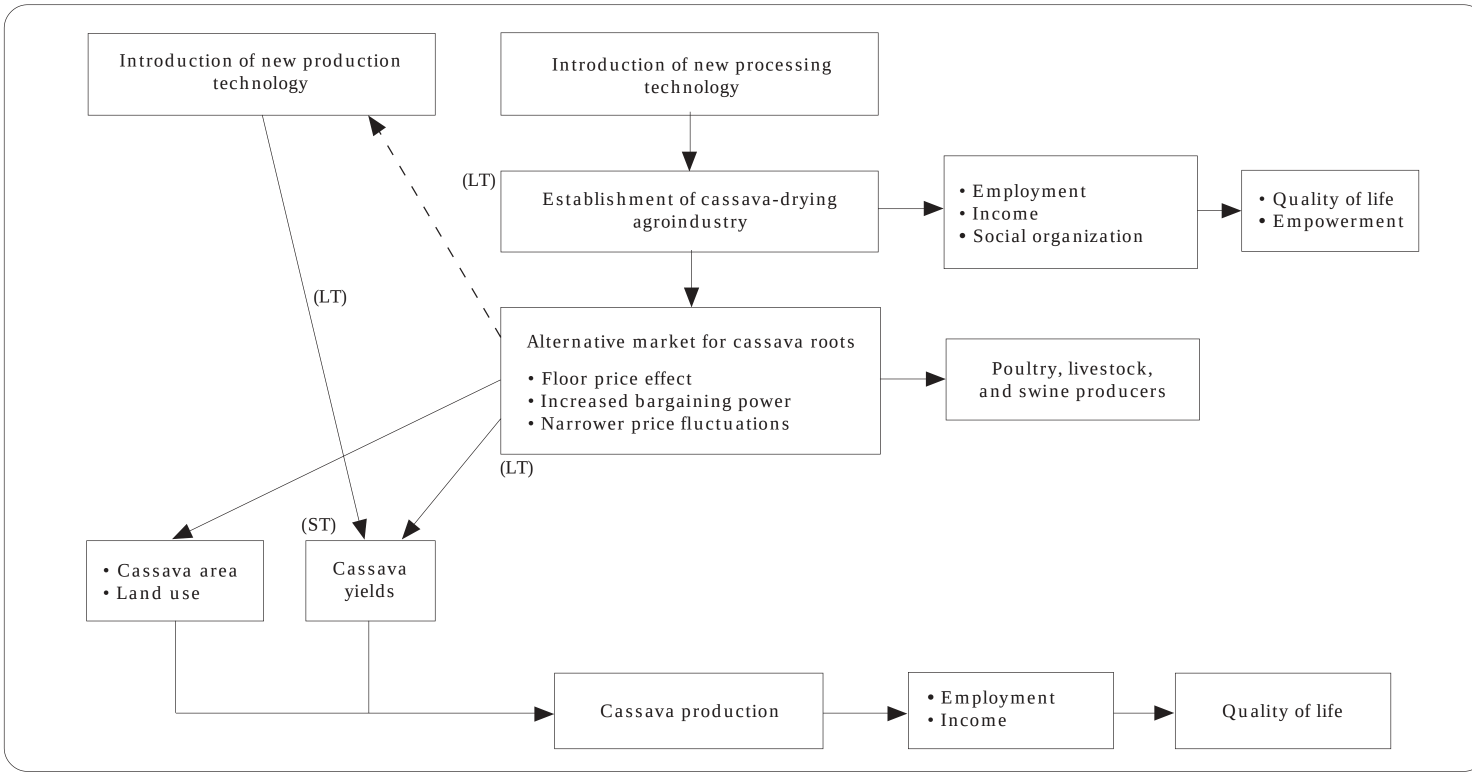


Figure 2. Conceptual framework for the expected impact of the Integrated Cassava Research and Development (ICRD) Project, North Coast, Colombia. (ST = short-term and LT = long-term effect on cassava production.)

Hypothesis on the Impact of the ICRD Project

Figure 2 illustrates the conceptual framework of the ICRD Project, its expected impact, and its links with the adoption of cassava production technology. The promotion of small-scale, cassava-based, drying firms was expected to create an alternative market for cassava roots that would contribute to establish a price floor for the product in the fresh market, narrow price fluctuations, and enhance farmers' bargaining power. These changes in demand and prices should thus reduce market risks faced by cassava farmers and create an incentive to increase cassava production.

Over the short term, cassava farmers would increase their production by expanding the area planted to cassava. The reduced market risk, over the longer term, would stimulate the adoption of improved cassava production technology, therefore improving productivity. Cassava production in the region would be reflected by increased cassava area and crop productivity.

Hence, the changes in prices and production, hypothesized as being brought about by the technological changes in the region, would be translated into changes in consumer, processor, and producer surpluses. Income would be raised and employment would be generated, not only as a consequence of increased cassava production in the region, but as a result of the established agro-industry. The increased income and additional employment opportunities for small-scale and landless farmers in the rural communities would be expected to encourage overall community development, foster social organization, and reduce poverty levels in the population.

Methodology

To assess the impact of the ICRD Project, we break down the analysis into five levels. First, we model the emergence of the drying plants to understand the conditions that favored the implementation of the program. Then we evaluate if the drying plants contributed to securing a floor price for cassava. We examine the adoption response to the new market alternative followed by the impact on poverty alleviation within the community. Finally, we discuss the sustainability of the program. We analyzed the emergence, technology adoption, and impact on poverty using regression techniques. The framework used for each is explained below.

Cooperatives emergence analysis

Using the Colombian municipality as our definition of a community, we first model the farmers' decision to enter the market of dried cassava chips, that is, to build one or more cassava drying-plants in the community. Farmers will decide to build a plant if the profits from its operations outweigh the fixed costs involved in organizing the cooperative and building the plant. They first determine what the profits will be, which directly depends on the quantity of cassava chips they can produce, or the total drying capacity. A desired drying capacity will be determined given the cassava roots production, the transaction costs, and the demand for fresh cassava in the municipality. This desired drying capacity is such as to maximize the profits from the drying activities. Let DC^* for municipality k represent this desired drying capacity, then:

$$DC_k^* \mid f(S_k, D_k, TC_k^{coop}, TC_k^{fresh}) \qquad (1)$$

The vector S_k represents the factors affecting the potential supply of fresh cassava roots, that is, the land available for growing cassava, the productivity of farmers, and the farm size found in the municipality. The greater the potential supply of cassava to the drying plants, the greater the total drying capacity needed in the municipality. The more land that is available to grow cassava (from increases in cropped land or substitutions of other crops for cassava), the greater is the potential supply of roots to the drying plant, and thus the desired drying capacity. Similarly, higher productivity suggests greater potential supply. Three measures of productivity are used: the percentage of farmers treating their seeds, the percentage of farmers using pesticides, and the average experience at growing cassava. The last factor affecting potential supply is farm-size distribution in the municipality. Traditionally, small-scale farmers grow cassava as a cash crop, large-scale farmers growing it only as feed for their cattle. Thus, a smaller average farm size and a more uniform distribution of small farms should indicate greater potential supply to the drying plants.

The variable D_k represents the demand for fresh cassava roots in the municipality. The greater the demand for fresh cassava roots, the less the alternative market of dried cassava chips is needed as an income generator. The desired capacity should therefore be lower with a higher demand.

The TC_k^{coop} and TC_k^{fresh} variables capture the transaction costs of selling the cassava to the drying plant and to the fresh urban markets. The higher the transaction costs of selling cassava roots to the drying plant, the lower the farmer's profits for their sale. A lower potential cassava supply to the drying plants is implied and, as such, less drying capacity will be needed. On the other hand, the higher the transaction costs in selling the roots to fresh urban markets, the greater the potential cassava supply for the local market, including a drying plant. The distance to the urban markets dictates transport costs and thus the transaction costs, which increase with distance. To capture the expected transaction costs to the drying plant, the average distance from the farm gate to the municipality center is used, while the distance to the department capitals proxies the costs to the large fresh urban markets.

Once the profits are determined, the farmers compare them to the fixed costs of building the plant. The group of farmers will decide to build the desired drying capacity if the net benefits are positive. This comparison can be represented by a net benefits index function:

$$NB_k^* \mid NB(S_k, D_k, TC_k^{coop}, TC_k^{fresh}, F_k) \qquad (2)$$

$S_{k,}$ D_k, TC_k^{coop}, and TC_k^{fresh} capture the profits just as in desired drying capacity (Equation 1). The organizational costs, F_k, are the fixed costs of building the drying capacity. The vector F_k consists of variables that affect the organization of the cooperative and building of the plant specifically. These are the previous experience with local community associations, presence of institutions in the municipality, average formal education level of cassava farmers, and commitment of farmers to the community as represented by the percentage of farmers who own land in the municipality. The institutions include CIAT and Instituto Colombiano Agropecuario (ICA) research programs on cassava-production technology, and extension activities of ICA, Instituto Colombiano de la Reforma Agraria (INCORA), and Caja Agraria (see Table 1). The first three F_k variables capture the human and social capital found in the municipality. Previous experience with associations, measured by the number of community associations, and average formal education indicate the capacity and ability of the community to organize itself and how its members can work together. The presence of institutions involved in the innovation and diffusion of cassava technology encourages and helps provide the social and human capital necessary to organize a cooperative.

The cassava-drying capacity of a municipality will equal the desired capacity if the benefits index is greater than zero. The complete decision process can be summarized:

$$DC_k \mid \begin{cases} DC_k^* & \text{if} \quad NB_k^* \} 0 \\ 0 & \text{if} \quad NB_k^* \, \Omega 0 \end{cases} \qquad (3)$$

A two-part model allows the econometric implementation of this decision. In the first stage, a probit over the presence of cooperatives in the municipality will estimate whether the benefits NB_k* were positive. Then, using the prediction on the probability of organizing a cooperative, the amount of drying capacity built will be estimated by an ordinary least square regression. The econometric system is therefore:

$$\begin{aligned} Pr(C \} 0) &\mid f(S_k, D_k, TC_k^{coop}, TC_k^{fresh}, F_k) \\ DC_k &\mid f(S_k, D_k, TC_k^{coop}, P\hat{r}(C \} 0)) \end{aligned} \qquad (4)$$

All the variables are measured as of 1985, thus prior to any drying plant operating. This system answers questions such as: Did the project successfully reach the targeted population of small farms? And what were the community's characteristics that drove, or refrained from, the implementation of a drying plant, and how much capacity was built?

Production technology adoption

To analyze the long-term impact of the ICRD Project on the adoption of modern varieties requires a conceptual framework of the individual adoption decision. The farmer can adopt a new variety and yet decide to continue planting some of his cassava area to a traditional variety. His decision consists therefore in choosing the proportion of cassava area to plant to modern varieties (M_i). To make this decision, the farmer will consider the factors directly affecting its production, opportunity and transaction costs, and the availability of information about the new varieties and their seed.

Factors affecting production include the farmer's productive assets, such as the amount of land owned and farmed, formal education, experience in growing cassava (Z_i), and the availability of credit and technical assistance (Z_k). Off-farm work constitutes an opportunity cost for a farmer (C_k), and will influence all his cropping decisions, including whether to plant modern cassava varieties. It is captured by the agricultural wage in the municipality. The transaction costs to the fresh market will also influence the adoption of the new varieties, because intermediaries and consumers prefer the old varieties. The distance to the large urban market thus enters C_k.

The presence of community organizations and public institutions will influence adoption by providing information and planting material of the new varieties (I_k). Drying plants also provided information and planting material to farmers, and to capture this diffusion channel, two variables will be included in the analysis: the distance to the drying plant and the presence of a drying plant. The distance to the drying plant also captures the transaction costs the farmer must bear to sell his production to the drying plant (included in the C_k vector for purposes of estimation). The actual presence of drying plants in the municipality cannot be used directly because of possible correlation with the farmer's and his land's unobservables that influence the adoption decision. A farmer who is technologically inclined will both show interest and get involved in creating and operating a drying cooperative in the community, and will adopt more readily new production technology. The past involvement of the farmer in setting up a drying plant or actual involvement in operating it are not observed. Additionally, the past and present quality of land influences the production of the farmer and his need for and interest in a market alternative, and thus for a drying plant in his community. Using the predicted probability estimated in the previous step ($Pr(C \geq 1)$ avoids the introduction of a possible bias in the estimation. The farmer's adoption decision will be a function of all these factors:

$$M_i = g(Z_i, Z_k, C_k, I_k, \hat{\Pr}(C_k \geq 0)) \qquad (5)$$

Because the decision is measured as a percentage, truncated at 0 and 1, a tobit regression will be estimated. Such a framework will allow us to answer questions such as, did the presence of drying plants influence the adoption of new cassava varieties? Did the implication of both local and national institutions influence the diffusion and adoption of the new varieties?

Impact on poverty

Ultimately, the interest of this analysis lies in whether the project helped reduce poverty within the participating communities. To measure this contribution, we used changes in poverty levels from 1985 to 1993 at the community level. The presence of cooperatives in the communities ($Pr(C > 0)$ and the adoption of modern varieties (M_i) should partially explain these changes in poverty. These two parts of the ICRD Project will be included as the predictions from the previous calculations, because these contain the full information about the different decision levels. Community associations may also have a direct impact on poverty reduction (*Ca*). Therefore, they should be included as an aggregate to the analysis. Finally, poverty levels can be affected by diverse factors other than the project. To capture these external effects, we include variables meant to characterize the municipality. These are the rate of urbanization (*U*), the distance to the department capital to measure economic opportunities (*Km*) and average family size (*Fa*) to measure poverty at the family level. Equation 6 summarizes the quantitative analysis performed.

$$Pov_k^{1993} - Pov_k^{1985} = f(\hat{\Pr}(C_k > 0), \overline{\hat{M}}_i, Ca_k, U_k, Km_k, F\overline{a}_k) \quad (6)$$

The analysis will be carried out on two measures of poverty: the percentage of households with unsatisfied basic needs, which measures the percentage of people below the poverty line, and the percentage of households living in absolute poverty.

Data sources used in the analysis were a 1991 survey on adoption among cassava-farmer households conducted by CIAT (Henry et al., 1994), 1985 and 1993 census data from the Colombian Department of Statistics (DANE), and a 1981 national household survey conducted by DANE and DRI (Sanint et al., 1985).

Reaching the Poor: Cooperative Emergence Analysis

Table 2 shows that cooperatives emerged in communities with higher potential production surplus, and higher social and human capital. With respect to cassava supply conditions, cassava drying plants tended to emerge in municipalities with cassava cropping land of higher potential, and with more productive farmers (see $Pr(C \geq 1)$ column, Table 2). The productivity of farmers is captured by the treatment of seeds, the extent of pesticide use, and the average experience growing cassava. The negative sign on the pesticide use contradicts intuition about productivity. A possible explanation may be that pesticide use may have a double purpose: to enhance productivity and to improve the appearance of the roots for fresh consumption marketability. The average experience growing cassava is also another proxy for productivity. It suggests, like the treatment of seeds, that communities with higher productivity are more inclined towards creating a drying cooperative. Existing local demand for cassava also had a negative impact on the establishment of cassava-drying plants. Hence, these results indicate that dry cassava agro-industries did tend to emerge in communities with higher potential cassava production and lower fresh demand.

Table 2. Community-level regression estimates of the cooperative emergence and cooperative size in small-scale farming communities participating in the Integrated Cassava Research and Development (ICRD) Project, North Coast, Colombia.[a]

	Marginal effect for $Pr(C \geq 1)$	Total drying capacity (m^2 of drying floor)
Supply conditions (S_k)		
Potential cropping land (km^2)	0.0060 (0.001)	0.06 (0.993)
Average farm size (ha)	-0.0212 (0.112)	-65.01 (0.636)
Farm size ratio of large to small farms	0.0170 (0.570)	-400.02 (0.088)
Farmers who treated their seed in 1985 (%)	0.1550 (0.000)	-4.06 (0.964)
Farmers who used pesticides in 1985 (%)	-0.0166 (0.016)	263.50 (0.009)
Average experience (years)	0.0795 (0.014)	336.43 (0.230)
Fresh cassava demand (D_k)		
Cassava consumption (tons in the municipality per year)	-0.0003 (0.002)	0.43 (0.447)
Transaction costs to cooperative and fresh market (TC_k)		
Average distance to municipality center (km)	-0.0355 (0.073)	-90.32 (0.415)
Distance to department capital (km)	0.0021 (0.180)	-4.53 (0.788)
Factors influencing fixed costs (F_k)		
Number of community associations in 1985	0.0010 (0.974)	
Institutional presence (dummy)	-0.2078 (0.478)	
Interinstitutional interaction	0.0567 (0.020)	
Average formal education (years)	0.4949 (0.000)	
Land tenure (% farmers owning land)	0.0023 (0.549)	
Constant		723.76 (0.910)
Inverse mills ratio		-906.92 (0.787)
Number of observations (municipalities)	43	17
Log likelihood	-12.6	
Pseudo R^2	0.56	
R^2		0.81

a. Marginal effects calculated at the sample means using probit estimates are presented for the cooperative emergence (middle column), while regression coefficients are presented for cooperative drying capacity (right column). Values in parentheses are the *P*-values, which indicate the level of significance of the variables. The errors are estimated using the robust White-Huber estimator.

Human capital played an important role in the emergence of cooperatives as captured by the average education of farmers in the community. Human capital influenced the capacity that the community had for becoming organized and asking for institutional support to build a processing enterprise. Although the public and community associations did not influence the cooperative emergence individually, their interaction and cooperation stimulated the creation of the drying plants. Through cooperation with local associations, research and public institutions can reach more effectively the targeted population by taking advantage of the infrastructure already in place. The local association can serve as intermediary for diffusion purposes of new technologies or for provision of complementary technical assistance and other type of services.

The results show the importance of community associations, institutions, and education to the establishment of the dried-cassava agro-industry. Technology development institutions and community organizations jointly influenced the project's implementation, suggesting that research institutions should work in partnership with local community organizations to enhance the probability of project success. For the communities that created one or more cooperatives (see right-hand column, Table 2), the built capacity was mainly determined by the productivity of farmers as captured by the extent of the pesticide use. It indicates that communities with more productive farmers, and thus with a greater potential cassava supply, built more drying capacity.

Short-Term Effect of the New Alternative Market for Cassava

As was hypothesized by the ICRD methodology, the development of the dried-cassava agro-industry in the Colombian North Coast created an alternative market for cassava roots. A price floor for cassava was established and over the short term, farmers reacted by increasing their cassava area. As shown in Figure 3, prices for fresh roots rose between 1983 and 1993 at an annual rate of 2.5%. Also, the price paid for cassava roots by the cassava-drying industry started to provide a price floor, which provided a secure market for cassava farmers. If the price of fresh cassava roots fell under the price floor or the quality of the roots was not acceptable to the fresh market, farmers had the option of selling their product to a cassava-drying plant. Cassava farmers of Socorro (at San Juan de Betulia in 1993) expressed it thus:

> "I remember when I was child, some producers were left with their cassava...there were no markets for the product." And "... of course, it's the cooperative that has practically given life to cassava cropping in this region. Before, some years nobody would buy the cassava, there was no market, and the roots were completely lost." By linking farmers to expanding markets, the cassava market situation was improved. "...Now, we have different market alternatives, the fresh

market, the drying plant, and the new starch plants that are being built. If the fresh market offers a better price, then farmers try to sell their roots to this market, but when things become complicated, farmers sell their crop to the drying plant".

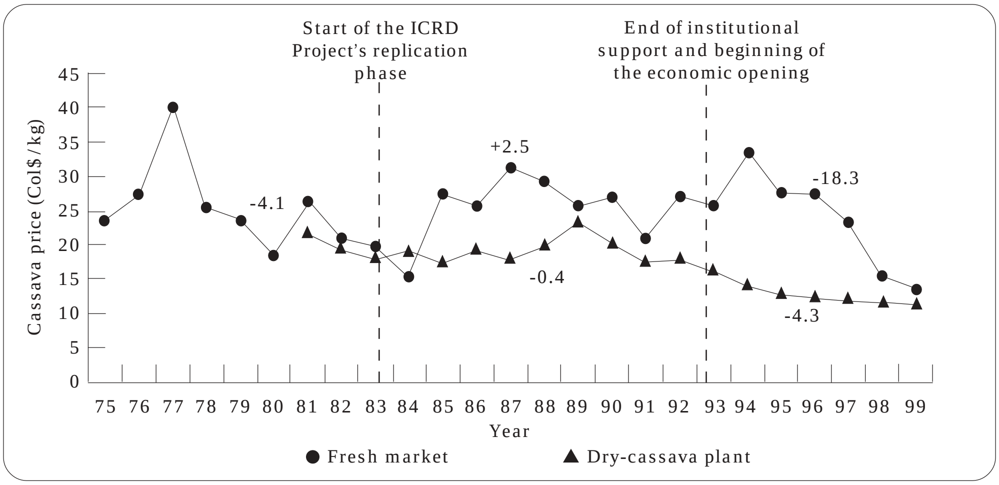


Figure 3. Trends in cassava prices for small-scale farmers in the North Coast of Colombia, 1975-99, showing the impact of the Integrated Cassava Research and Development (ICRD) Project (1981-89). Prices are based on the 1990 Colombian peso. Data were obtained from the ICRD Project monitoring and evaluation system. Values in the field indicate price trends in percentages.

Over the short term, this new market alternative created an incentive to increase the area planted to cassava. As shown in Figure 4, the area under cassava in the Colombian North Coast increased at an annual rate of 7% between 1983 and 1993. Results from a 1991 cassava-farmer survey show that about 43% of cassava farmers increased their area planted to cassava between 1983 and 1991. Of farmers who responded that their cassava area was increased, 50% said it was because the market for cassava had improved, 22% said that land availability had increased, 12% had substituted yam for cassava because of the incidence of a serious yam disease, and 5% received credit for cassava cropping. Alvaro Meza, cassava farmer and cooperative associate of Sabanas de Beltrán, Los Palmitos, Sucre describes this short-term effect of the project:

"The construction of the drying plant was a major achievement of this community, and the changes in the standard of living are obvious. The association has improved the market for cassava. Before, farmers only planted a quarter or half a hectare with cassava... mainly for home consumption. Now, farmers plant 2 to 3 hectares of cassava because they have a secure market. The drying plant pays members and nonmembers in cash, therefore they increase their cassava cropping area, and this means a higher income."

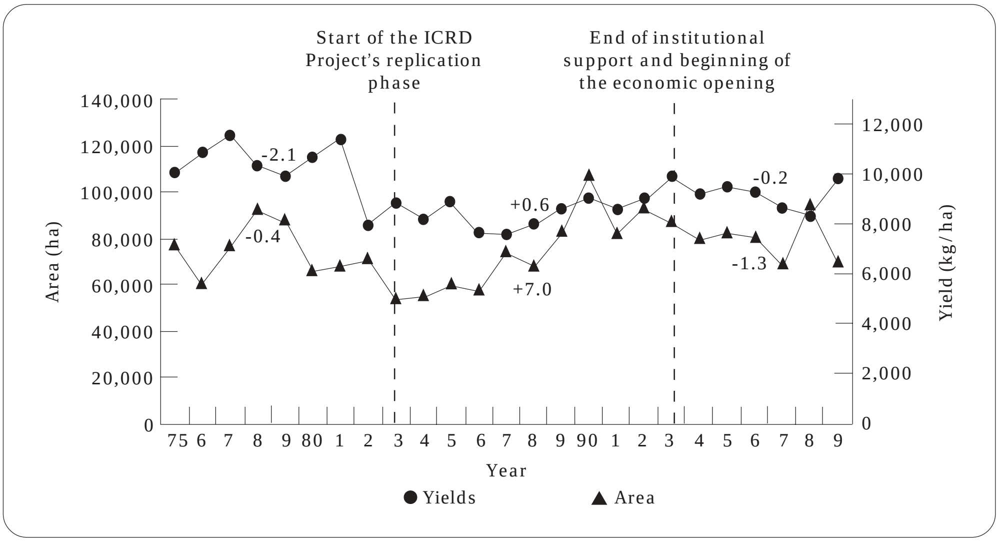


Figure 4. Trends in cassava area and yields in the North Coast of Colombia, 1975-99, showing the impact of the Integrated Cassava Research and Development (ICRD) Project (1981-1989). Data were obtained from the Colombian Ministry of Agriculture. Values in the field indicate trends in percentages.

Cooperative Impact on Adoption

The long-term impact of the new agro-industry was hypothesized to foster the adoption of improved production technology, such as new varieties to increase cassava yields. The results in Table 3 validate this hypothesis. About 77% of cassava farmers in the region adopted the variety Venezolana, and 5% the variety MP-12. On the average, cassava farmers also planted 82% of their cassava area to modern varieties. First, the existence of a drying plant in the community modestly encourages the adoption, by increasing the area planted in modern varieties out of the total cassava land by 0.4%. More importantly, the proximity of the farmer's field to the nearest drying plant has a positive impact on the adoption of modern varieties, with an increase of about 4% of the total cassava land in modern varieties for every 10 km closer to the drying plant. On the average, farmers have to travel over 40 km to bring their roots to the drying plant. This result captures two possible effects of the drying plant on technology adoption. The first is related to the new market alternative and more stable fresh prices as discussed previously. As such, farmers have more incentive to increase their production by either increasing the area planted or adopting new technology to increase yields. The other effect of the drying plant is to enhance technology diffusion in three ways. First, technological programs found cassava-drying cooperatives to be natural partners for technology diffusion, by allowing them to reach more farmers. Cassava farmer associations also foster farmer-to-farmer networking, which in previous adoption studies was found to be a major source of technology diffusion (Henry et al., 1994). Further, a major constraint to adoption—availability of planting material—was partially overcome by the cooperatives' establishing of seed multiplication plots.

Table 3. Individual decisions on the adoption of modern cassava varieties in small-farming communities participating in the Integrated Cassava Research and Development (ICRD) Project, North Coast, Colombia.[a]

	Percentage of cassava land under modern varieties[b]
Percentage of farmers planting modern varieties	
Venezolana	77
MP-12	5
Average cassava area with modern varieties (%)	82
Productive assets (Z_i)	
Land owned (ha)	0.0023 (0.554)
Formal education (years)	-0.0278 (0.207)
Experience (years)	-0.0013 (0.807)
Help for production (Z_k)	
Credit availability (% farmers receiving credit)	0.0005 (0.865)
Technical assistance availability (% farmers receiving technical assistance)	0.0015 (0.512)
Transaction and opportunity costs (C_k)	
Agricultural wage (Col$ / day)	-0.0012 (0.000)
Distance to drying plant (km)	-0.0036 (0.028)
Institutional and communitary presence (I_k)	
Institutional presence (no technology programs)	0.6177 (0.000)
Number of community associations in 1985	-0.0049 (0.194)
Presence of a drying plant, $Pr(C \geq 1)$	0.0035 (0.051)
Constant term	2.9839 (0.000)
Number of observations (farmers)	481
Pseudo R^2	0.18

a. Tobit estimates for the percentage of cassava land planted in new varieties.
b. Values in parentheses are the *P*-values, which indicate the level of significance of the variables. The errors are estimated using the robust White-Huber estimator.

The presence of technology development projects implemented by cassava research institutions in their municipality also influenced the adoption decision. The percentage of cassava area planted to modern varieties was therefore higher when at least one technology project was active in the municipality. Finally, the opportunity costs of working off-farm that farmers faced also had an impact on the adoption. The higher the agricultural wage in the municipality, the lower is the importance of cassava cropping as an income generation activity for the farmer. Consequently, farmers will grow cassava mainly for on-farm consumption, and will have fewer incentives to increase cassava yields by adopting new varieties.

This analysis allows us to conclude that the cassava-drying agro-industry influenced the adoption of modern varieties both directly and indirectly through the transportation costs that farmers faced in marketing their cassava. It also provided a more secure market and a platform for diffusing technology and planting material. Adoption was also encouraged by the presence of technology research projects in the communities. Therefore, the presence of institutions and the presence of and access to drying plants each played an important role in the adoption of modern varieties.

Making a Difference for the Poor

In the early 1980s, the Colombian North Coast was characterized by poverty levels that were higher than the national ones: 76% of the population had unsatisfied basic needs compared with 64% at the national level, and 55% were living in absolute poverty compared with 36% at the national level (DANE, 1985). The small-scale farmers targeted by the ICRD Project were therefore among the poorest populations of the region, already poor by national standards. Can a project like the ICRD help alleviate poverty?

Table 4 shows the impact of the ICRD Project on poverty reduction. Changes in the “absolute poverty” levels (measured as the percentage of households living in conditions of absolute poverty) and in the unsatisfied basic needs show that the ICRD Project contributed to poverty reduction. It did so, not directly through the emergence of cassava-drying cooperatives, but through the provision of new production technology and its diffusion as captured by its adoption. The higher the percentage of cassava area planted to modern varieties in a municipality, the greater was the reduction in poverty. An increase of 10% cassava area under modern varieties will reduce the percentage of households living under the poverty line by 0.8% and of those living in absolute poverty by 1%.

An economic surplus model applied to the ICRD Project by Gottret et al. (1994), which shows the distribution of returns among the different groups of society, supports the above results. The study concluded that the direct benefits generated by the processing technology were US$1.6 million for the 1984-91 period (8.5% of total benefits). However, it was the indirect impact of the agro-industry on the adoption of improved cassava production technology that generated most of the economic surplus, estimated at US$18.6 million.

Beyond what these results can explain, the project had other direct impact on poverty in the communities that built drying plants. It created employment and stabilized incomes. As a focus group in Socorro expressed:

> “There’s been a big change since the drying plant was built. Before, labor was only used for cassava cropping (planting, weeding, and

harvesting). Now things are different, and see the income that the crop generates for the community! A farmer eats from cassava if he harvests it, transports it to the drying plant, works in the drying plant, processes it, grinds it, sells it, or even owns the truck that takes it to the feed plant. This is a source of employment and income…"

Table 4. Impact of the emergence of processing plants and adoption of modern cassava varieties on poverty reduction in small-scale farming communities participating in the Integrated Cassava Research and Development (ICRD) Project, North Coast, Colombia.[a]

	Change in absolute poverty level[b]	Change in unsatisfied basic needs[b]
Emergence of a cooperative (predicted $Pr(C \geq 1)$)	-0.021 (0.528)	0.037 (0.136)
Adoption rate of modern varieties (average of predicted M_i)	-0.118 (0.013)	-0.079 (0.064)
Number of community associations in 1985 (*Ca*)	0.043 (0.545)	0.053 (0.335)
Urbanization level (% of municipality population living in urban areas) (*U*)	0.266 (0.000)	0.030 (0.677)
Distance to department capital (km)	0.006 (0.609)	0.004 (0.722)
Family size (*Fa*)	-2.626 (0.002)	-1.832 (0.096)
Constant term	-6.198 (0.344)	1.827 (0.836)
Number of observations	43	43
Adjusted R^2	0.053	0.465
Root mean square error	6.629	6.718

a. Ordinary least square coefficients on the changes in poverty. The dependent variables are the change in the percentage of households from 1985 to 1993 living under the conditions indicated. The unsatisfied basic needs indicator represents the poverty line.
b. Values in parentheses are the *P*-values, which indicate the level of significance of the variables. The errors are estimated using the robust White-Huber estimator.

The plants also provided some informal credit, with which farmers could buy durable goods or face health needs.

"… a few years ago, in my house there was no television, no refrigerator, or stove. I didn't have money to buy shoes for my children or send them to school. Now, I don't have that much money, but if I need some, I can go to the drying plant manager and ask him to give me some in advance in exchange for cassava, and he will lend me the money."

Moreover, income generated from cassava cropping has been used as a means to accumulate capital goods such as cattle, which most farmers aim to own. As expressed by farmers in Socorro:

"… farmers planted 4 to 5 hectares of cassava, and with what was left they would buy a cow… of course, with the profits obtained from cassava."

The following testimony by Don Carlos, a cassava farmer and cooperative member of Segovia, Sampués, Sucre, validates the findings of the econometric model on the contribution of the ICRD Project to poverty alleviation.

> "Before, our situation was critical. We only had one pair of pants each; we were all day workers. For example, we didn't eat three meals a day… if we had breakfast; we didn't have lunch. And now… I said that there was a change. If you walk around the village, you can see that almost all the houses are built of brick and cement. The village has a water supply and part of the village has a sewage system, and all of this we got with the little we earned. We don't live in adobe houses anymore, where you could see the beds from outside. The hammocks used to be made with jute, and now we have at least a more comfortable bed. Now we have money to send the children to school and to dress them, to buy shoes and socks, and we have enough to eat three meals too… and well… sometimes we even have enough to buy some beers…" He laughs.

In conclusion, the ICRD Project directly and indirectly reduced poverty by creating an alternative income-generation activity through selling roots, creating employment, and reducing production costs through improved production technology. The organization of communities around a tangible activity that generates income and employment also fostered existing levels of social and human capital and therefore further empowered the communities.

ICRD Project Sustainability

Four years after the project officially ended, some institutional support for cassava continued in the region, but this terminated after 1993. At the same time, the Colombian Government moved toward a neoliberal system by opening up the economy to international competition (economic opening) and decreased its presence, both in size and intervention. Figure 5 shows that, after 1993, prices of both dried cassava, paid by the agro-industry, decreased at annual rates of 5.5% and of fresh roots at 4.3%. These steep decreases in prices were a result of Colombia importing grains for animal feed at lower prices, which were at that time particularly low, reducing to almost zero the profit margins received by cassava-drying organizations. During the same period, the collapse of institutional support eliminated the availability of credit at low interest rates for use as working capital. These two shocks, combined with the lack of accumulation of working capital by most associations, forced 28% of the cassava drying plants to stop processing between 1992 and 1993. Eight cassava associations also closed down because their members were displaced by violence in their communities. Hence, dried cassava production dropped from 35,000 tons in 1993 to only 7,000 tons in 1994.

In 1999, even though cassava farmers had faced these two major shocks to the dry cassava agro-industry, 56 cassava-drying plants were still operating. Of these, 43 belong to small farmer cooperatives although 15 rent their plant to individual entrepreneurs. Figure 5 also shows that dry-cassava production is starting to increase again as grain imports are becoming more expensive because of the recent devaluation of the Colombian peso. These results show that the sustainability of the program is highly dependent on the macroeconomic environment, which directly affects the viability of the developed marketing alternative.

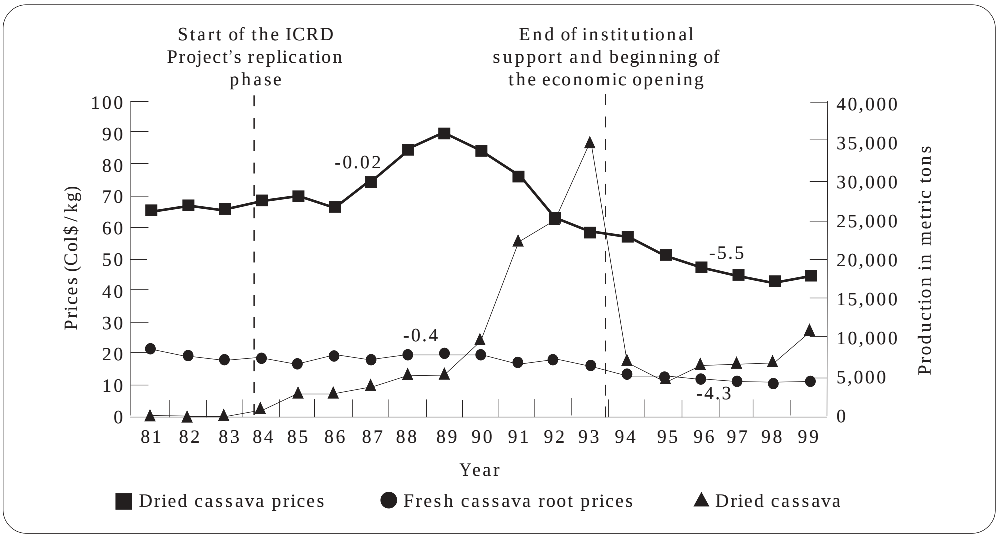


Figure 5. Trends in cassava prices and dried cassava production in the North Coast of Colombia, 1981-99, showing the impact of opening up the country's economy to international competition (economic opening). Prices are based on the 1990 Colombian peso.

Conclusions and Lessons Learned from the Project

As the analysis shows, the emergence of the cassava-drying agro-industry encouraged both directly and indirectly the adoption of modern varieties, which, in turn, contributed to poverty alleviation. The central hypothesis of the ICRD Project methodology was therefore validated: if agricultural research institutions want to make a difference for the poor they should not concentrate uniquely on production technology development, but also on postharvest and market research. Such process requires agricultural research to be based on a broader, demand-led development process. This integrated approach allows (1) better identification and articulation of farmers' needs in terms of production and postharvest technology and market research; (2) development of an accordingly more complete set of technology; and thus (3) a more efficient contribution to poverty alleviation.

The interinstitutional partnership among local, national, and international institutions involved in technology research and rural development contributed to the success of the ICRD Project. As the cooperative emergence results show, the interaction of the different organizations helped to reach the targeted population and to implement the project. The partnership allowed the conduct of demand-led research that was articulated to a multipurpose support system. Such cooperation among institutions led to the inclusion of a broader range of services, such as technical assistance on production, processing, marketing, management, and organization, as well as credit. Coordination with other governmental programs such as land reform was also possible. The partnership built around the needs of targeted groups permitted the consortium to respond adequately and directly to the communities' demands and needs and then feed back to them with solutions.

The experience of the ICRD Project in the Colombian North Coast shows that agricultural research can contribute tangibly to poverty alleviation. However, it requires three highly important components. First is the integration of market and postharvest research and development into the production technology research agenda. Second is the use of interinstitutional partnerships, where each institution provides its own expertise, comparative advantage, and mandate to respond to the demands of community organizations and individuals. Third is the fostering of an intimate networking among institutions and local social organizations and individuals, building on existing local social and human capital.

Acknowledgements

The authors express their heartfelt gratitude to Alain de Janvry and Elizabeth Sadoulet, professors at the University of California at Berkeley, for their invaluable contributions to developing the conceptual framework and the econometric model for analyzing the impact of the ICRD Project on poverty alleviation in northern Colombia.

Rupert Best (Leader) and Christopher Wheatley (Agribusiness Specialist) of the Rural Agro-enterprise Development Project at CIAT, and Bernardo Ospina, Executive Director of CLAYUCA[1], provided valuable information on the ICRD Project, thus improving our understanding of the intervention; they also made helpful comments on the paper.

A special recognition goes to all those cassava farmers and their families in the North Coast of Colombia who were interviewed and who freely collaborated with their time. Without them, this study would not have been possible. The United Nations World Food Program provided the funds for the fieldwork conducted in 1999 to interview cassava-drying cooperative members.

Other people and institutions who also deserve special thanks for their contributions to our data collection are Rafael Vergara from the Federación

1. CLAYUCA = Latin American and Caribbean Consortium to Support Cassava Research and Development based at CIAT, Colombia.

Nacional de Productores, Procesadores y Commercializadores de Yuca (FEDEYUCA) and Eusebio Ortega, who helped update the ICRD Project's monitoring and evaluation system. Alberto Fernández from the Colombian Ministry of Agriculture and staff of the Secretariats of Agriculture for the Departments of Sucre, Córdoba, Atlántico, Bolívar, Magdalena, and Cesar provided updated data on cassava production and prices. From the Corporación Colombiana de Investigación Agropecuaria (CORPOICA) regional offices, Antonio José López (in Montería) and Alvaro Tolosa (in Valledupar) provided information on the agro-ecological zones of the North Coast of Colombia.

References

Best, R.; Sarria, H.; Ospina, B. 1991. Establishing the dry-cassava agro-industry on the Atlantic Coast of Colombia. *In*: Pérez-Crespo, C.A. (ed.). Integrated cassava projects. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 112-127. (Working Document no. 78)

Cock, J.H. 1985. Cassava: New potential for a neglected crop. Westview Press, CO, USA. 205 p.

DANE (Departamento Administrativo Nacional de Estadística). 1974. Censo Nacional Agropecuario. Santafé de Bogotá, CO.

DANE (Departamento Administrativo Nacional de Estadística). 1985. Censo Nacional. Santafé de Bogotá, CO. 13 p.

DANE (Departamento Administrativo Nacional de Estadística). 1993. Censo Nacional. Santafé de Bogotá, CO. 16 p.

Gottret, M.V.; Henry, G.; Mullen, J.D. 1994. Returns of the Integrated Cassava Research and Development Project in the Atlantic Coast of Colombia. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. (Unpublished working paper, available from the authors)

Henry, G.; Izquierdo, D.; Gottret, M.V. 1994. Proyecto Integrado de Yuca en la Costa Atlántica de Colombia: Adopción de tecnología. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 79 p. (Working Document no. 139)

Janssen, W.G. 1986. Market impact on cassava's development potential in the Atlantic Coast region of Colombia. Thesis (Ph.D.). Agricultural University of Wageningen, NL. 369 p.

Lynam, J.K.; Janssen, W. 1988. Methodology development for the planning and evaluation of integrated cassava development projects. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 32 p.

Pachico, D.; Janssen, W.; Lynam, J. 1983. Ex-ante analysis of new technology: A comparison of cassava for feed and fresh markets in Colombia. Agric Syst 11:131-142.

Sanint, L.R.; Rivas, L.; Duque, M.C.; Seré, C. 1985. Análisis de los patrones de consumo de alimentos en Colombia a partir de la encuesta de hogares DANE/DRI de 1981. Rev Planeación y Desarrollo XVII:38-68.

Chapter 13

Impacts of the Use of Market- and Subsistence-oriented Bean Technology on Poverty Reduction in Sub-Saharan Africa: Evidence from Uganda

Soniia David, *Roger Kirkby*, and *Sarah Kasozi**

Introduction

The common bean (*Phaseolus vulgaris* L.) plays a paramount role in human nutrition and market economies throughout rural and urban areas of eastern Africa. While beans are considered a low status food, the "meat of the poor", they provide the second most important source of protein after maize (*Zea mays* L.) and the third most important source of calories after maize and cassava (*Manihot esculenta* Crantz) (Pachico, 1993). Beans are also highly valued by the poor because all parts of the plants can be consumed: the grain is eaten fresh or dried, the leaves are used as vegetables, and the stalk is used to make soda ash.

This chapter explores the contribution of bean research to poverty alleviation in eastern Africa by asking three basic questions in the context of a specific community in Uganda: can modern bush bean varieties improve the welfare of small-scale African farmers, and if so, how, and to what extent? We examine the impacts of market- and subsistence-oriented bean technologies on household income, on food security and consumption patterns, and on gender relations.

The field study used in this chapter is set in the maize-based farming system of eastern Uganda in Mbale District, Nabongo Parish, the study community. This parish was selected to represent high-potential areas of the country where small-scale farmers grow beans both for food and sale.

Bean Research and Poverty Reduction in Uganda

Uganda represents both an anomaly and a representative case for assessing the research-poverty linkage in eastern Africa. Nearly 15 years of civil strife up to 1986 resulted in the destruction of the economy,

* Sociologist, Coordinator CIAT-Africa, and Scientist, respectively, Centro Internacional de Agricultura Tropical (CIAT), Pan African Bean Research Alliance (PABRA), Kampala, Uganda.

including the agricultural research system. Uganda in the 1990s is acclaimed as a development "success story" because of macroeconomic stabilization, sustained economic growth over a decade, relative socio-political stability, modest gains in social provision, and progress towards achieving democratic governance. Although recent evidence shows modest declines in absolute poverty (UNDP, 1999), Uganda remains a poor country.

In 1995-96, 50% of 16 million rural Ugandans were poor, meaning they could not meet their food requirements (UPPAP, 1999). Nationally, 26% of the population could not obtain sufficient food or non-food essential requirements (e.g., shelter, clothing, health care, and basic education). The main material indicators used by local people to measure poverty are: lack of sufficient food and income, lack of livestock, inability to educate children, insufficient or lack of land, and poor housing and clothing (UPPAP, 1999). Non-material indicators included poor health, idleness, having no one to help with problems, and a sense of helplessness. Despite improved statistics on poverty, a recent study reports that local people feel that poverty is increasing (UPPAP, 1999). According to the UNDP (UNDP, 1999), the major causes of poverty in Uganda can be grouped into four categories:

(1) Institutional constraints (lack of social and economic infrastructure such as favorable marketing facilities, inappropriate structural organizational systems),
(2) Lack of requisite resources (land, credit, agricultural inputs, etc.),
(3) Political instability, epidemics, and natural disasters, and
(4) Socio-cultural practices and belief systems that retard human development.

In the 1960s, Ugandan health officials identified a high incidence of malnutrition among children (Fina Opio, personal communication, 1999). The Ministry of Agriculture responded by initiating bean research at Kawanda Research Station. The bush variety K20, released in 1968, was the first product of bean research activities and is currently widely grow in Uganda, Kenya, and Tanzania (Grisley, 1994) for its marketability and yield stability. In 1994, 26 years after the release of K20, the Uganda National Bean Program released two CIAT bred lines: K131, a red-mottled seed type beige variety similar to K20, and K132, a beige, small-seeded type red variety, previously unknown in Uganda. In the remainder of this chapter we will refer to K132 as Kawomera or the red variety and to K131 as Kabalira or the beige variety. An important point worth noting is that Kawomera is highly marketable, while Kabalira is shunned by traders in most parts of the country because of its small seed size.

No precise figures are available on the amount of seed distributed by formal institutions, but estimates suggest 450 tons of Kawomera and 600 tons of Kabalira by 1999 (PABRA, 1999). Adoption studies show and predict modest uptake of the red variety in most parts of the country (ADC-IDEA, 1996; David, 1997), but low adoption of the beige variety in the south and central regions (David, 1997; Kato, 2000). However, observation suggests a higher rate of adoption for the beige variety in the east and north. In the absence of nationwide adoption studies, extrapolations based on seed sales and knowledge about diffusion offer estimates of impact for the two varieties (PABRA, 1999). By 1998, the red variety was sown on an estimated 4100 hectares with a production increase of 290 tons valued at US$87,000 (farmgate price). The beige variety was sown on an estimated 45,000 hectares with a production increase of 6303 tons, having a farm value of US$1,891,000.

The Field Study

In 1994, K20 was the major variety sown in Nabongo, accounting for 74% of the 40 hectares of beans sown by surveyed households. In Nabongo, beans may be grown both on household plots and on plots belonging to individual men or women. Women provide much of the labor in field and postharvest activities, but male participation in field activities (both on household and personal plots) and sales has increased with commercialization (David, 1999).

Seed distribution and research activities concentrated on three neighboring villages (Bwighonge, Bunywaka, and Bumulaha) between 1995 and 1999. To achieve rapid adoption, nearly 400 kg of seed of both varieties were sold in the study sites over three seasons (1995-1996) through women's groups and individual sellers. The seed was priced at Ush 600-800 per kg and buyers were limited to purchasing 1 kg per variety. The rate of exchange was US$1 = Ush 960 in 1994, and US$1 = Ush 1265 in 1998. Seed was sold at the official price set by the Uganda Seed Project.

The impact of new bean varieties was assessed through a longitudinal study using a combination of quantitative and qualitative data collection methods. This chapter mainly draws on results from a 1998 survey of 100 adopters (henceforth the impact sample), although reference is made to baseline surveys conducted in 1995 and 1996 (David, 1999), a 1998 adoption study conducted in three non-study villages (henceforth the adoption sample), and a 1998 food security survey. Most respondents in the impact and food security surveys were women or farm couples. The reference period for yield, income, and other quantitative data is the first season (A) of 1994 and 1998. The discussion provides both a cross-sectional and historical perspective of change in bean production on both household and personal plots between 1994 and 1998 by drawing on baseline data collected in 1995.

Characteristics of survey respondents

A predominant proportion of the sample was drawn from average (42%) and poor (44%) households, while the rich represented 4%, and those above average, 10%. Table 1 summarizes the main wealth indicators identified by key informants. A resident male headed 81% of households; female-headed households (14% of the sample) were disproportionally drawn from the average and poor wealth groups. The mean age of heads of households was 46 and household size ranged from 4-7. Although all households regularly cultivated beans, 44% considered it their highest source of crop income. It is significant that a relatively higher proportion of poor households (51%) compared to wealthy (43%) and average (38%) households depended on beans as a principal source of crop income. Poor, bean-growing households in Nabongo face a classic dilemma—low production due to small farm size, labor, and other constraints, few cash crop options and a high dependence on beans as a source of protein. Yet these households sell a high proportion of their bean harvest compared to better off households that tend to have more diverse income generating opportunities and therefore sell a lower proportion of their bean harvest.

Table 1. Summary of wealth indicators for Nabongo Parish, Uganda.

Wealth indicators	By ranking			
	Rich	Above average	Average	Poor
Amount of land owned (ha)	3+	0.4-1.6	0.1-0.4	≤ 0.1 or landless
Average bean area (ha)	0.69	0.57	0.39	0.27
Number of cattle	10+	2-3	0	0
Type of house	Brick / permanent	Tin roof	Grass thatch	Grass thatch, often homeless
Education of children	All children in school	All children in school	Educate up to primary, some to secondary level	Unable to send children to school
Occupation / source of income	Salaried employment, trader, sells major crops	Trade and petty business	Sells major crops	Works as hired labor
Other comments	Eats meat regularly, owns ox-plow, hires labor	Owns ox-plow, hires labor	May have to buy food after selling food crops	Not self-sufficient in food, some are drunkards, not married

An important demographic difference worth noting between adopters and non-adopters in the food security survey is that poor and female-headed households comprised a larger proportion of the sample of non-adopters compared to adopters.

Adoption pattern and productivity of the new varieties

Households in both the impact and food security surveys preferred the red variety: 98% of the households sampled in the impact sample and 100% in the food security sample sowed the red variety in 1998—compared to 47% in the impact sample and 43% in the food security sample sowing the beige variety. High adoption rates in neighboring non-study communities

(72% for Kawomera and 22% for Kabalira) suggest that the introduction of the varieties as part of a research activity did not artificially stimulate adoption, but adoption is clearly higher in the study communities. Adoption was influenced by wealth. Poor and average households were more likely to adopt only one variety (usually the red variety) and a higher proportion of wealthy households (64%), compared to average (43%) and poor (45%) households, adopted the beige variety. The preference for marketable varieties can be explained by the greater dependence of poorer households on beans as a source of income, as mentioned earlier. Nearly all farmers who discontinued growing a new variety (51%) dropped the Kabalira mainly because of lack of market (67%).

Only seven seasons after introduction, the two bean varieties accounted for 74% of the total bean area sown on household plots by surveyed households (Table 2). The total bean area, and the area planted to both new varieties, differed significantly by wealth because a few wealthy households sowed 1 acre or more of the new varieties (Table 3). Seasonal differences in area sown (hectares) to the new varieties (15.4 in 1997B, 16.7 in 1998B, and 23.1 in 1998A) show that farmers expect a better performance in the first season (A).

Table 2. Area (ha) sown to specific bean varieties on household plots in 1994 and 1998, Nabongo Parish, Uganda.

Variety	1994		1998	
	Area (ha)	Total (%)	Area (ha)	Total (%)
Kawomera (red)	–	–	19.3	62
Kabalira (beige)	–	–	3.8	12
All modern varieties	–	–	23.1	74
Kanyebwa	5.2	13	5.4	17
K20	30	75	2.3	7
Other local varieties	4.8	12	0.5	2
All local varieties	–	–	8.2	26
Total	40	100	31.3	100

Table 3. Area (ha) sown to bean varieties[a] on household plots by wealth status, first season 1998, Nabongo Parish, Uganda.

	All bean varieties		Kawomera		Kabalira	
	Mean	Range	Mean	Range	Mean	Range
Mean area	0.36	0.03-1.2	0.23	0.01-0.69	0.13	0.01-0.85
Wealthy	0.61	0.17-1.2	0.39	0.14-0.69	0.44	0.03-0.85
Average	0.39	0.01-0.93	0.26	0.03-0.57	0.06	0.02-0.13
Poor	0.27	0.03-0.61	0.17	0.01-0.61	0.11	0.01-0.28
Significance level for differences among wealth groups	N.S.	–	0.001	–	0.001	–

a. Kawomera = red variety, Kabalira = beige variety.

The farmgate value of production in the first season of 1998 was US$2833 for the red variety and US$287 for the beige variety. In most cases, both varieties were intercropped with maize. It is also notable that the total bean area among the households surveyed in 1998A was 5% larger compared with 1994A, although the average bean area was 0.36 hectares, a decline from 0.49 hectares in 1994A (David, 1999). A major factor that could account for the decreased bean area in 1998 were cattle raids that occurred in April, interrupting the planting and causing many farmers to flee their villages. A few adopters also reduced the amount of bean seed sown because of better germination (nine cases), the need to sow the red variety at a wider spacing (seven cases), and the higher yields of the new varieties (three cases).

Mean yields (Table 4) were high for intercropping. The lower than expected yields of the beige variety (11% less than the red variety) may have been because of a mid-season dry spell that depressed yields of this longer maturing variety. The yield advantage of the two modern varieties over the dominant local varieties indicates that they brought about significant productivity increases on farms where they were adopted.

Table 4. Comparison of mean yields of Kawomera (red variety) and Kabalira (beige variety) with local cultivars, first season 1998.

	Mean yield (kg/ha)	Percentage increase over local cultivars	
		K20	Kanyebwa
Kawomera	680	38 (n = 14)	35 (n = 48)
Kabalira	724	79 (n = 5)	69 (n = 14)

Farmer opinions showed that the performance characteristics that encouraged adoption of the red variety included high yields (100%), marketability (92%), fast cooking time (93%), high grain density (85%), drought tolerance (83%), and taste (80%). The major disadvantage of the variety mentioned by 71% of adopters was the need to plant at wider than normal spacing to discourage common bacterial blight. Resource-poor households more frequently mentioned this problem, together with late maturity (20%) and susceptibility to diseases (13%). The beige variety was appreciated for its high yields (93%), taste (89%), and drought tolerance (54%); but it was disliked because its grain stays whole when cooked (83%) and it has a limited market (70%). Disadvantages of the new varieties specifically mentioned by women are discussed later.

The adoption of modern varieties is often accompanied by a change in the cropping system. In Nabongo, over half (55%) of adopting households stopped growing one or more local varieties or earlier generations of improved bean varieties. The most frequently discarded variety was K20 (95%), showing the new improved varieties displacing this earlier generation. Low yields (56%) and poor drought tolerance (55%) were the major reasons for dropping a variety. We recorded seven varieties compared with eight in 1994, suggesting that, at the community level, bean varietal diversity had not changed. Notably, however, compared to 1994, fewer households sowed minor landraces and areas sown had reduced.

Of adopters that sowed the new varieties on household plots in 1998 (n = 86), 66% have changed some aspect of bean cropping or agronomic practice since 1995. In 75% of cases, the higher productivity and market value of the red variety motivated increased bean production and hired labor (number and frequency). Reasons for the reductions in seed rate were mentioned earlier.

Impact on income

Of those adopting the red variety, 88% reported income gains because of higher productivity and price. Middle category households perceived increased income as most important, whereas a higher proportion of the poorest and wealthiest households emphasized the food security and health benefits of the red variety, despite their greater dependence on beans as a source of income. Traders quickly accepted the red variety, and by 1997 it had captured the market for Calima-type beans, commanding a premium price of Ush 150-500 per kg in 1998, Ush 50-100 above the price of K20. Kanyebwa fetched the highest farmgate price for beans (Ush 200-700 per kg). Bean farmgate prices did not change between 1994 and 1998.

On the average, in 1998A, adopters sold 92 kg of the red variety at a farmgate value of Ush 26,169, compared with 48 kg for all other bean varieties combined, valued at Ush 17,400. The red variety provided 90% of bean earnings in the major season of 1998. It is unclear why, despite its higher productivity, mean average bean sales were significantly lower in 1998 compared to 1994 (97 kg compared to 137 kg). In both years, there was a statistically significant relationship between bean sales and wealth. But, whereas wealthy households had the highest sales in 1994 ($P \leq 0.02$), in 1998 households of average wealth sold the most beans—208 kg compared with 170 kg for the wealthy and 129 kg for the poorest group ($P \leq 0.06$) (Table 5).

Because of lower bean sales in 1998 compared with 1994, no income gains show among adopters overall. In fact, bean earnings showed a slight drop in actual value and a significant drop in 1994 values. It is significant, however, that only the average wealth group recorded income gains, a finding corroborated by farmers' perception of impact, although not by their ranking of income sources.

Table 5. Quantity of beans sold (kg—all varieties) in the main season of 1994 and 1998, by household wealth status.

Household wealth status	1994	1998
Wealthy	212	170
Average	140	208
Poor	96	129

Farm families used income gains from the red variety for both short-term consumption and productive investments including household items (soap, paraffin, candles, sugar, and salt—88%), food (69%), medical expenses (68%), clothes (66%), personal items (e.g. bicycles and radios—39%), school fees (28%), livestock (23%), renting land (18%), hiring farm labor (17%), building materials (e.g., iron sheets) to improve or expand houses (14%), and paying taxes (11%). Household items were the most important area of expenditure for the poor (44%) and average (49%) wealth groups, while school fees topped the list for wealthy households. Food was the second most important area of expenditure for all wealth categories.

Impact on household food security and consumption patterns

Beans, eaten fresh or dried, are an important and highly valued protein source in Nabongo Parish because few households regularly consume animal protein. Groundnuts (*Arachis hypogaea* L.) and an assortment of domesticated and wild vegetables (including bean leaves) are the other major sauce ingredients that accompany the principal staples of maize, cooking bananas (*Musa* spp.), and sweet potatoes (*Ipomoea batatas* [L.] Lam.). Food consumption patterns differ significantly by wealth and season, with the poor eating fewer meals than better-off households eat at certain times of the year, particularly January to April and September to December (David, 1999).

Improved food security and health were important benefits mentioned by adopters of both varieties, although the relative importance varied by wealth, variety, and season. Wealthy and poor adopters of Kawomera were more likely to mention food security and health benefits, while households of average wealth stressed financial benefits. The major benefit of Kabalira for all wealth groups was improved food security. As expected, more farmers reported impact on food security in the dry season compared to the rainy season for both varieties. Adopters reported various improvements in food security (Table 6). The beige variety had a greater impact on bean availability, especially during the dry season, while a significant number of red variety growers were able to diversify their diet in the dry season with sale earnings and increased bean consumption.

Both quantitative and qualitative data confirm higher bean consumption from 1995 levels among adopters. Change was greatest in the dry season, normally a time of food shortage. Compared with non-adopters, adopters across all wealth categories were more likely to have a larger amount of beans in store and consume more during periods of food shortage (Table 7). On the average, households growing the new varieties ate beans at five meals per week during the dry season compared to two for non-adopters, and they prepared mixture dishes (which require larger quantity of beans) more often. Increased frequency of bean consumption during the dry season was reported by 48% of red variety growers and 71% of beige variety growers. Since bean availability and consumption may be determined by a multiplicity of factors not related to production (e.g., food choices made by individuals, marketing vs. consumption decisions, and emergency situations forcing a household to sell much of their harvest), attributing change among adopters exclusively to the introduced varieties is implausible. However, four factors strongly suggest that the varieties contributed directly and significantly to improving food security among adopters—improvements across wealth groups, the varieties' higher productivity, limited opportunities to market the beige variety, and anecdotal evidence.

Table 6. Impact of Kawomera (red variety) and Kabalira (beige variety) on bean availability and food security by season[a] (percentage).

Impact of bean availability	Kawomera (n = 98)		Kabalira (n = 49)	
	Dry season	Rainy season	Dry season	Rainy season
Have beans in store, had none before	24	1	57	0
Eat more beans per meal	26	62	55	51
Eat beans more often	48	36	71	35
Use earnings to buy other food	45	35	0	0

a. The dry season is a time of food shortage in the area.

Table 7. Availability of beans among adopters and non-adopters of new varieties, April 1998 (percentage), Nabongo Parish, Uganda.

Bean availability	Adopters (n = 21)	Non-adopters (n = 22)	Significance level
Beans in storage[a]	76	54	_
Amount of beans in store (kg)	33	13	0.35
Stored beans sufficient for >3 months	31	0	_
Consumption (g per capita per meal)	222	220	0.001

a. With the exception of one case, all stored beans were harvested on farm.

At 214 g, the median value for per capita bean consumption in September 1998 (a period of moderate bean insecurity) was significantly higher than the 166 g recorded among non-adopters in September 1996 for all wealth groups. A significant proportion of adopters reported increased bean consumption (Table 8), although the largest consumption gains appear to have gone to the wealthy and average groups. Increased bean consumption is expected to contribute to improved nutrition and health, although measuring nutritional impact was beyond the scope of the study. Farmers' perceptions of health benefits provide some evidence of impact.

Table 8. Bean consumption by household wealth status in September 1996 and 1998 (median values), Nabongo Parish, Uganda.

Household wealth status	Bean consumption (g per capita)	
	September 1996	September 1998
Wealthy	151	243
Average	152	224
Poor	192	200
Overall median	166	214

The increased yields of both varieties meant that women spent less time foraging for wild vegetables during the dry season. This shows an important impact on food security. Significantly, a higher proportion of poor households mentioned a reduction in foraging as a secondary benefit of growing modern varieties. However, no quantitative data are available on the amount of time saved, a positive impact for women, with potentially negative nutritional implications. Although both varieties improved bean availability, fewer opportunities for selling the beige variety meant that it was more likely to be stored during the dry season. In response to an open-ended question regarding impact, 30% of beige variety adopters surveyed in September, compared to 21% of red variety growers, reported spending less time foraging for wild vegetables. About half of the farmers interviewed for the food security survey had reduced the time they spent foraging since using the new varieties. A higher proportion of households growing the beige variety (13% compared with 5% of those growing the red variety) stopped foraging altogether.

Impact on gender relations

The introduction of higher yielding varieties of beans, a traditional "female crop", had both beneficial and negative impacts on the organization of production and gender relations. We expected that women would show greater interest than men in sowing Kabalira on personal plots because of its food security value. Women noted an increase in their workload caused by three factors associated with growing Kawomera: increased bean area, the need for more careful weeding to avoid diseases, and frequent redrying of seed to reduce weevil infestation. Most adopters sowed both varieties only on household plots, but, contrary to expectation, more women than men sowed both varieties on personal plots each season during the study period. In 1998A, women farmers sowed a larger total area than did men to all bean varieties and to the red variety (Table 9). But, contrary to our expectation that women would show a stronger interest in the beige variety, mean areas for it were similar for both sexes (0.25 for men and 0.23 for women), with men sowing a larger total area to that variety. In 1998A, the red variety covered 60% of bean area sown by women and 61% by men, while the beige variety covered 19% of women's bean area and 17% of men's. We discuss three areas of gender-related impact: changes in women's and men's personal production between 1994 and 1998, differences between men's and women's bean incomes, and increased conflict over bean earnings.

Table 9. Area sown to new varieties[a] on men's and women's personal plots, and income earned from sales first season of 1998, Nabongo Parish, Uganda.

Area sown and income earned	Men's personal plots (n = 12)	Women's personal plots (n = 15)
Total bean area (ha)	4.4	5.3
Total area sown to Kawomera (ha)	2.7 (n = 11)	3.2 (n = 14)
Total area sown to Kabalira (ha)	1.0 (n = 3)	0.76 (n = 4)
Mean income from Kawomera (Ush)	67,577	29,475
Mean earnings from beans (Ush)	80,633	27,120

a. New varieties: Kawomera = red variety, and Kabalira = beige variety.

Since 1995, some important changes have occurred in women's and men's personal production of beans. Women sowed larger bean plots in 1998 compared to 1996: a mean of 0.4 hectare compared to 0.2 hectare in the major season. Farmers indicated that much of this expanded production was in direct response to the new varieties. Half of the independent women farmers (n = 20) increased the amount of beans sown, mainly in response to the higher productivity of the varieties, while half of the male farmers (n = 14) sowed more seed and increased the number of plots. As a result, the significant gap observed in 1994-96 in mean area sown to beans on men's and women's plots was less apparent in 1998. Both new varieties represented similar proportions on men's and women's personal plots.

What are the implications of increased independent female bean production? Although the data do not allow us to quantify impact from this development, we infer some plausible outcomes. Because women farmers grow beans on personal plots to meet both food security and income objectives, whereas men concentrate more on the latter (David, 1999), increased female production is likely to result in higher household consumption as well as higher earnings, both of which contribute to improving household welfare. This conclusion is supported by the finding that while most men and women farmers used the red variety grown on personal plots in the major season of 1998 to feed their families, women were more likely than men to use a larger amount for home consumption. Yet, surprisingly, men and women sowed the same area to the beige variety, which has limited market value. The gender implications of higher earnings are discussed below.

Although, on the average, bean area between men and women showed little difference, in 1998A, men's sales and earnings from beans generally, and from Kawomera, were significantly higher than women's (Table 9). Men sold a mean of 276 kg of beans of all varieties and 214 kg of Kawomera; women sold an average of 110 kg of beans and 99 kg of Kawomera. Average bean incomes increased significantly for men and women over 1994-96 figures: by 103% for men and 63% for women (1994 values). The gender division of responsibility might account for gender differences in bean sales and earnings. Women's greater responsibility to provision their households means that a higher number (six out of 14 compared to two out of 11 men) did not sell Kawomera in 1998A. Gender differences in the proportion of the harvest sold were noted above.

Informal discussions, rather than formal surveys, proved more appropriate for exploring other impact areas of concern to women, notably the extent of income-related marital conflict caused by the new varieties. Some women complained that higher bean earnings encouraged their husbands to take greater control over income from both household and personal bean plots. An impact diagram drawn by farmers shows that increased income from the red variety caused more drinking among both men and women, which led to more domestic violence, divorce, and sexual infidelity, and ultimately an increase in the incidence of Acquired Immunodeficiency Syndrome (AIDS). Conversely, a perceived benefit of the beige variety was the absence of marital conflict over earnings.

Conclusions

This chapter provides evidence of the significant contribution, in just 4 years, of two modern bean varieties to food intake, nutritional status, and health in a rural Ugandan community. Our findings suggest, however, that modern bush bean varieties are likely to bring about modest, but important, impact in the areas discussed. Although the data drawn from one season did not show income gains over the baseline reference season, the higher price and productivity of the red variety plus farmers' reports of higher earnings suggest that adopters received significant financial gains. Additional economic benefits, from reduced labor requirement and lower use of firewood among others, were not quantified in this study. This case study showed that, although the varieties were appreciated for different reasons, better-off households were more likely to grow both, and sowed a larger proportion of total bean area to the beige variety. Households in the average and poor wealth categories were less likely to cultivate the beige variety or sowed small amounts. Although impact of the new varieties was wealth neutral, the evidence nevertheless suggests that the greatest benefits went to households of average wealth. Probably because of lack of land, labor, and other resources, the poorest households were unable to increase production significantly. Women farmers were as likely as men to adopt the varieties, and overall, both appear to have bettered women's lives by improving household welfare, increasing both household and personal income and reducing their labor, despite the negative implications of expanded bean area and increased marital conflict reported by some households.

We pose two related questions of broad theoretical importance: What factors reduced or enhanced the positive impacts of the new varieties? Is this impact success story likely to be replicated elsewhere in Uganda? Income benefits from the new varieties were reduced by low farmgate bean prices, while food security benefits were lessened by farmers' high dependence on beans as a cash crop, which results in a selling-rebuying cycle. Appropriate solutions to the pricing dilemma could include direct sale of crops by farmer trading cooperatives to traders rather than through middlemen, improving farmer access to information on markets, and communal level interventions that promote crop storage until prices are higher, while providing farmers with a cash advance. The introduction of high-value cash crops would also improve bean availability at the household level.

We maintain that three major factors enhanced the impact of the new varieties in the study community:

(1) Access to markets. Location on a main highway (being tarmacked at the time of writing) makes Nabongo highly accessible to traders from both Uganda and neighboring Kenya. Elsewhere in Uganda, access to markets varies considerably.
(2) High yields per hectare. Because of moderate to high soil fertility, Nabongo farmers realized yields of both new varieties comparable to on-station yields even when they were intercropped. In much of Uganda, soil fertility is moderate to low compared to Nabongo.
(3) Access to seed and seed quality. In a situation where farmers, especially the poor, find it difficult to retain bean seed, a reliable seed supply system enhances adoption and consequently impact. In response to continued high demand for seed and to improve seed supply and quality, a group of four farmers in Nabongo set up a business on their own initiative to produce good quality seed of both new varieties. For small-scale farmers elsewhere in the country, regular access to good quality seed of new bean varieties at an affordable price continues to be problematic.

Some mechanisms and avenues for strengthening the agricultural research-poverty linkage include improvement of the extension system, use of non-traditional approaches and channels for technology dissemination, stronger linkages between agricultural and health care institutions, policy changes, microenterprise development and credit facilities, improvements in farmer access to information on local, regional, and export markets, and development of appropriate organizational structures, among others.

Acknowledgements

The Canadian International Development Agency (CIDA), the Swiss Agency for Development and Cooperation (SDC), and the United States Agency for International Development (USAID) provided financial support for research reported in this chapter. This research builds on earlier varietal development and dissemination activities by Uganda's National Agricultural Research Organisation (NARO). We are indebted to the people of Bwihonge, Bumulaha, and Bunywaka villages for their hospitality and willingness to put up with our numerous questions and surveys. Nathan Mayeku and Harriet Nafuna, in particular, assisted the research team in many ways over the years. We express our sincere appreciation to the survey enumerators for an excellent job: Alex Jigga, Harriet Nafuna, Kate Nafuna, James Makoba, Delphine Nadunga, and Angela Ayo. We also wish to thank Charles Wortmann for comments on an earlier draft.

References

ADC-IDEA (Agribusiness Development Center-Investment in Developing Export Agriculture). 1996. A seed usage survey of maize and beans in six districts of Uganda. Kampala, UG. 42 p.

David, S. 1997. Dissemination and adoption of new technology: A review of experiences in bean research in Eastern and Central Africa, 1992-1996. Network on Bean Research in Africa, Centro Internacional de Agricultura Tropical (CIAT), Kampala, UG. 27 p. (Occasional Publications Series no. 21)

David, S. 1999. Beans in the farming system and domestic economy of Uganda: A tale of two parishes. Network on Bean Research in Africa, Centro Internacional de Agricultura Tropical (CIAT), Kampala, UG. 44 p. (Occasional Publications Series no. 28)

Grisley, W. 1994. The bean revolution. Ceres 149:27-30.

Kato, E. 2000. A socio-economic analysis of factors affecting adoption of K131 bean variety by women farmers in Luuka County, Iganga District, Uganda. Thesis (M.Sc.), Makerere University, UG. 52 p.

PABRA (Pan African Bean Research Alliance). 1999. Current and projected impact of some new bean varieties in Eastern Africa. Draft document. Kampala, UG. 3 p.

Pachico, D. 1993. The demand for bean technology. *In*: Henry, G. (ed.). Trends in CIAT's commodities. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 60-73. (CIAT Working Document no. 128)

UNDP (United Nations Development Programme). 1999. Uganda human development report 1998. Kampala, UG. 94 p.

UPPAP (Uganda Participatory Poverty Assessment Project). 1999. Briefing for the plan for modernisation of agriculture. Kampala, UG. 41 p.

CHAPTER 14

The Impact of Crop Improvement on Rural Poverty: An Analysis of Bean Varieties Resistant to Bean Golden Mosaic Virus in Honduras

*Nancy Johnson** and *Justine Klass***

Introduction

Honduras is one of the poorest countries in the Americas. Per capita income is less than US$2000 per year and nearly half the population lives on less than US$1 per day (UNDP, 1998). Most of the population and much of the poverty is rural. Beans (*Phaseolus vulgaris* L.) are one of the two most important crops in Central America in terms of both production and consumption. They are a traditional part of the diet in Central America and, along with maize (*Zea mays* L.), often form the main food source of the poor.

Therefore, when the bean golden mosaic virus (BGMV) began to spread through Central America in the 1970s, it posed a threat to a particularly vulnerable population. Controlling BGMV became top priority among bean breeders in the region, and by the late 1970s their efforts had resulted in the release to farmers of a first generation of virus-resistant bean varieties, which were quickly and widely adopted. By 1996, an estimated 40% of the bean area in Central America was planted to resistant varieties, often reaching as high as 80% in BGMV-affected regions (Viana Ruano et al., 1997; Viana Ruano, 1998). The success of this effort is widely recognized. In 1984, CIAT was awarded the King Baudouin Prize for its work on BGMV in Central America. The cumulative value of the increased production that resulted from the new varieties has been estimated at over 200 million US dollars in 1998 (value in 1990 US$) (Johnson et al., 2003). In 1998 alone the impact was estimated at over US$17 million.

Although these benefits are large, they probably underestimate the impact of the new varieties, especially their impact on poverty. One reason for this is that the economic estimation was based on the varieties' capacity to increase yields rather than to avoid losses. The total benefits of the

* Senior Research Fellow, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.
** PhD candidate, Leverhulme Unit for Population Biology and Biological Control, National Environment Research Council (NERC), Centre for Population Biology, Imperial College, UK.

varieties would be higher if the benefits of losses avoided could be measured. They are particularly relevant for poverty alleviation. First, because many of the benefits accrue to poor farmers. Second, because the nature of the innovation—risk reducing versus yield enhancing—directly addresses a main characteristic of poverty, namely the inability to manage risk and to cope with a crisis such as crop loss.

This chapter analyzes the impact of BGMV-resistant bean varieties on poverty, taking into consideration recent conceptual and empirical advances in our understanding of both the impact of innovations and the nature and location of poverty. The case chosen for analysis is Honduras, where a lot of agricultural, climate, and poverty data is available that permits a multi-perspective, multi-method analysis. First, the magnitude and distribution of the economic benefits of the resistant varieties were estimated using the results of a climate-based technique of geographic information systems (GIS) for creating BGMV risk maps. These estimates were then compared against poverty maps to assess to what extent the benefits were realized in areas of significant poverty. The results of participatory poverty assessments that go beyond monetary and material measures to develop a series of locally relevant indicators of poverty were identified. They were used to draw a closer causal link between the impact of the innovations of resistant-bean varieties and any changes in human well-being.

Poverty in Honduras

How to define poverty has become an important research question both conceptually and empirically. Traditional measures such as income or expenditure are increasingly being criticized as inadequate indicators of human welfare. Although such monetary measures have advantages in terms of comparability across space and time, they often fail to capture non-monetary aspects of the standard of living—highly important in many developing countries. Such measures can also be difficult to estimate reliably because individuals are reluctant to reveal how much they earn. Alternative methods are being developed to more accurately identify and understand poverty.

In recent years, Honduras has been the focus of several different exercises to measure poverty at country level. Oyana et al. (1998a) used census data to create a national poverty map that ranks each village according to the degree to which residents' basic needs were satisfied. Ravnborg et al. (1998) focused on identifying and understanding local people's perceptions of poverty. Although this study does not provide a national map of poverty, it does provide a more nuanced definition of poverty and indicators of well-being that are clear and easy to observe. Because the poverty indicators are in terms of local people's activities, assets, and livelihoods, they make it possible to relate the impact of technical interventions, such as new crop varieties, directly to changes in poverty.

Where are the poor? The material standard of living and the unsatisfied basic needs approach

In 1996, CIAT undertook a project to measure and map poverty in Honduras based on census data (CIAT, 1997; 1998; Oyana et al., 1998a). The data come from the 1988 Honduras Population Census and are calculated at the *aldea* (village) level (SECPLAN, 1991). The approach was called the Unsatisfied Basic Needs (UBN) method and involves selecting criteria of basic needs and identifying measurable indicators of the level at which these needs are satisfied (Boltvinik, 1996). In the case of the CIAT study, the basic needs identified were housing quality, access to basic services, ownership of non-land assets, and education. For each of these, several measurable indicators were also identified. In the case of housing quality, for example, the measurable indicators were the materials used in constructing the walls, floor, and roof. In the case of basic services, measurable indicators were water source, use of latrine, presence of electricity, and fuel source (Oyana et al., 1998b).

After selecting the criteria and indicators, minimum standards and level of nonsatisfaction were identified. Communities were rated according to their average level of satisfaction with the minimum standards. Five levels of poverty were identified. Level 4, the so-called threshold level, includes communities that on the average meet the minimum requirements. Figure 1 shows the distribution of statistically significant areas of poverty in Honduras according to the UBN criteria.

Who are the poor? Participatory poverty assessments

In 1996, the Inter-American Development Bank (IDB), Danish International Development Agency (Danida), and CIAT carried out a participatory poverty assessment (PPA) in the states of El Paraíso, Yoro, and Atlantida in Honduras (Ravnborg et al., 1998). The poverty index identified by the PPA has 11 components (Table 1). The components of this index were statistically validated and can be considered representative of the larger population that the sample communities represent. Some indicators, such as income, housing quality, and asset ownership, are also elements of more conventional poverty measures. However, according to the PPA, local people complement these measures with others such as the ability to contract day laborers, degree of involvement with agricultural output markets, access to health and health care, participation in financial markets, and food security. It is also interesting to note what potential indicators did not turn out to be significant in the PPA well-being index. In terms of agricultural production, the production of basic grains alone was not a distinguishing factor between rich and poor households. This is probably because most households were producers of basic grains. Identifying the poorest farmers will require going beyond crop choice.

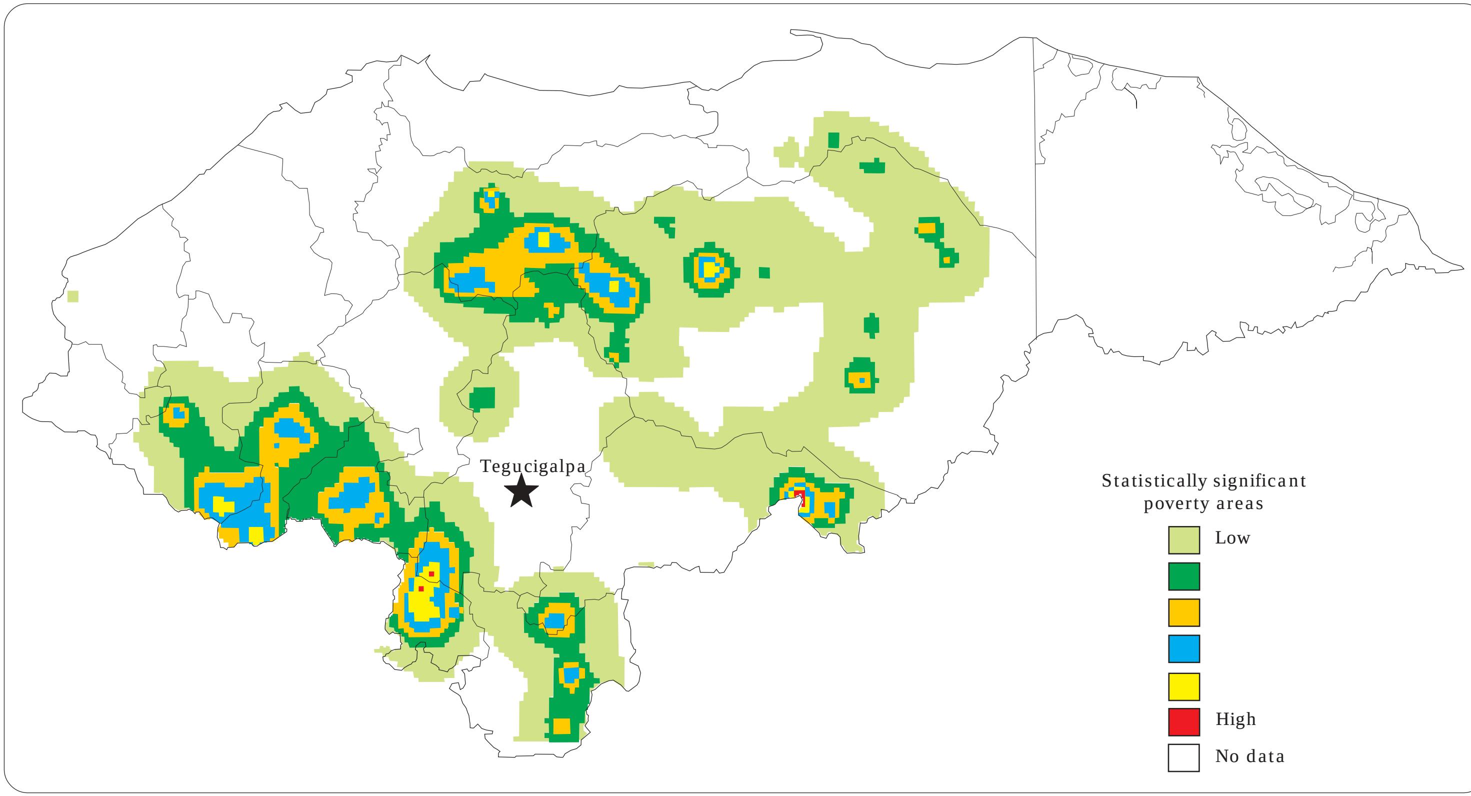


Figure 1. Distribution of statistically significant areas of poverty in Honduras.

Table 1. Components of the participatory well-being index used in a participatory poverty assessment in El Paraíso, Yoro, and Atlántida, Honduras, 1996.

Variable	Well-being level	Condition of household
Land ownership	Highest	Owns 4 mz[a] or more, or has land in pasture or gives land in rent to others.
	Middle	Owns land, but less than 4 mz and has no land in pasture or land in rent to other farmers.
	Lowest	Owns no land or only owns the house and the land upon which it stands.
Sell day labor	Highest	Nobody works as a day laborer and the housewife does not do housework for other families nor prepare food to sell.
	Middle	Someone works as a day laborer, but either for less than 9 months per year, or for more than 9 months, but less than three times per week.
	Lowest	Someone works full-time for more than 9 months per year as a day laborer, or the housewife does housework for other families, or sells prepared food.
Income	Highest	Someone is a professional, a businessman, or a merchant, or children or other relatives send remittances.
	Middle	Someone is a skilled worker, but no one in the household is a professional, businessman, or merchant, and the household receives no remittances.
	Lowest	No one is a professional, businessman, merchant, or skilled laborer, and the household receives no remittances.
Hire day labor	Highest	Contracts day labor.
	Middle	Does not contract day labor.
Cattle	Highest	Has cattle.
	Middle	Does not have cattle.
Animals	Highest	Owns horses, pigs, or oxen.
	Middle	Owns chickens, but not horses, pigs, or oxen.
	Lowest	Owns no animals or poultry.
House	Highest	Owns house of good quality.
	Middle	Owns house, but not of good quality.
	Lowest	Owns house, but of very poor quality, or does not own house.
Market participation	Highest	Grows coffee or cacao, or does not buy basic grains and sells half or more of its production of basic grains.
	Middle	Does not grow coffee, but both buys and sells basic grains, or does not buy basic grains and sells less than half of its production.
	Lowest	Does not grow coffee or cacao and buys basic grains in addition to using all of its production for home consumption.
Money	Highest	Has a savings account or makes loans to others.
	Middle	Does not save nor make loans.
Health	Middle	No one in the house was ill, or if someone were ill s/he paid for adequate health care either with own money or by selling assets.
	Lowest	Someone in the household has health problems and was treated by asking relatives for money, borrowing money, or by going to the herbalist, or was untreated for lack of money.
Food security	Middle	Has not experienced a food shortage, or did so for less than 1 week and solved the problem without having to ask others for food or money, reducing number of meals, or sending the wife or children out to work.
	Lowest	Experienced a food shortage for more than 1 week, or for less than 1 week, but had to solve the problem by asking for food, borrowing money, or sending wife and children out to work.

a. 1 mz (*manzana*) = 0.704 hectares.

SOURCE: Adapted from Ravnborg et al., 1998.

In a companion study for three Honduran watersheds (Saco River in Atlántida, Cuscateca in El Paraíso, and Tascalapa in Yoro) aimed at understanding the relationship between poverty and natural resource management (NRM), residents were surveyed about agricultural and NRM practices (Leclerc et al., 1999). Their answers were later classified according to well-being level, as determined by the participatory index described above. The analysis finds no significant difference between well-being levels in terms of land use or production practices, as measured by land preparation, use of chemical inputs, or use of crop varieties. Rich and poor in these watersheds do not use different agricultural technologies or practices, at least not in the production of basic grains such as maize and beans. Although this finding is encouraging in the sense that it shows that improved technologies are not being appropriated just by richer farmers, it also means that we cannot use production practices to distinguish between rich and poor farmers.

Bean Production and Producers in Honduras

Honduras is the third largest bean producer in Central America after Nicaragua and Guatemala. In 1998, 83,000 hectares were sown to beans, slightly more than in 1970, but less than the high of nearly 120,000 hectares planted in 1994 (Figure 2). Production has been similarly variable. During the period 1970-98, the area planted increased by 16% and production increased by 18% with the difference caused by small increases in yield. In 1997, per capita consumption was reportedly between 9 and 21 kg per year, however it varies greatly depending on the economic level of the consumer (Viana Ruano et al., 1997). Within the category of basic grains, beans are second only to maize in area planted, and they are the top source of farm income (Viana Ruano, 1998).

The main bean production area is in the central and central-eastern part of the country, producing about 60% (Martel and Bernsten, 1995). A 1993 study by the Bean-Cowpea Collaborative Research Support Project (CRSP) conducted in this zone found that one third of Honduran farmers planted beans. The farms were generally small—average area planted to beans was 1.08 hectares—and were considered non-commercial in the sense that their production was primarily for home consumption, although surpluses were sold on the market. The degree of market participation of bean farmers has grown over time (Schoonhoven and Pachico, 1998). In the past, most farmers produced primarily for their own consumption, however, according to the survey, in 1993 only 13% of farmers neither bought nor sold beans. Half reported selling, and 37% were net buyers.

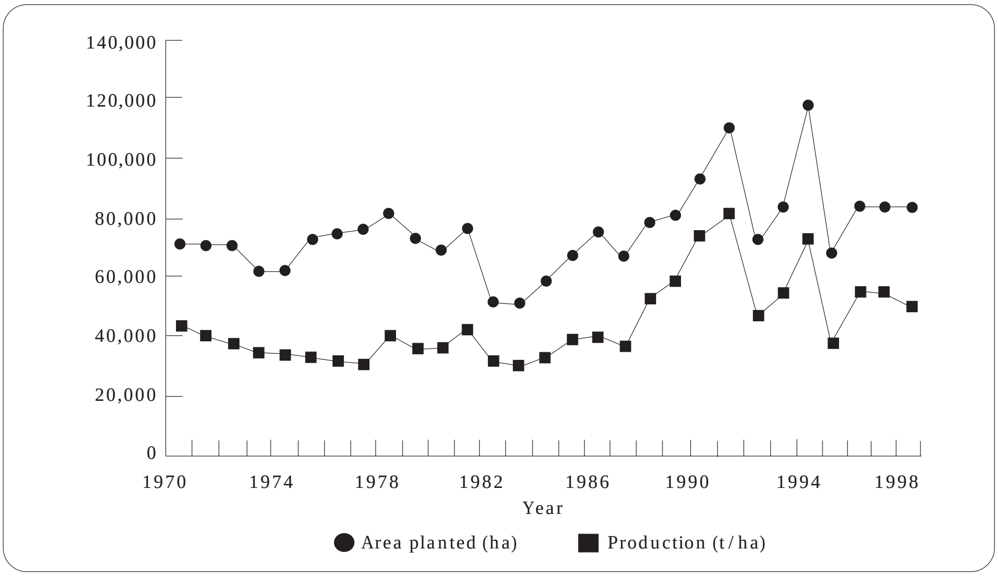


Figure 2. Bean area and production in Honduras, 1970-98 (adapted from FAOSTAT [http://apps.fao.org//]).

The survey also found that smaller-scale farmers plant relatively more beans than do larger-scale farmers. Large-scale farmers are more commercially oriented, but the income earned from beans is relatively more important to the small-scale farmers because it makes up a greater portion of their income. In terms of production practices, chemical use does not differ between small- and large-scale farmers (Martel and Bernsten, 1995).

The main production constraint in the region is BGMV (Martel and Bernsten, 1995). The virus arrived late to Honduras, where the first reported incidence was in 1985. In 1989, severe outbreaks occurred with crop losses ranging from 10% to 100% (Rodríguez et al., 1994). Whiteflies cause extensive crop damage. Specific whitefly species act as a vector of plant pathogens and transmit plant diseases, such as *Bemisia tabaci*, which transmits BGMV in a semi-persistent manner. This means the virus needs time to be acquired and transmitted (Morales, 1994).

The first resistant variety, Dorado, was released in 1990 and several others soon followed The varieties spread quickly, and by 1996 adoption rates were as high as 80% in some areas (Martel and Bernsten, 1995; Viana Ruano et al., 1997). No association was found between the adoption of Dorado and farm size, suggesting that small- and large-scale farmers are equally likely to adopt the variety (Martel and Bernsten, 1995). This is logical because resistant varieties, unlike some high-yielding ones, are not dependent on costly chemical inputs or optimal growing conditions to make them perform. They can be adopted without significant changes to the production system. Martel and Bernsten (1995) find an association between farm size and adoption of another improved variety, the high-yielding but non-resistant Catrachita, which was released in Honduras in 1987. This may also reflect greater risk aversion on the part of small-scale farmers because it appears that yield alone is more attractive to larger- than to smaller-scale farmers.

In terms of yield, which variety is highest yielding depends on many factors, and is therefore highly variable. Honduras has two growing seasons, the *primera,* or first growing season, from May to September, and the *postrera* or second growing season, from September-October to December-January with the latter being the main production season. Martel and Bernsten (1995) found that Catrachita is highest yielding during the *primera* and Dorado during the *postrera* season. These results are consistent with the fact that the virus is only a problem in the *postrera*. Dorado offers no significant advantage over traditional varieties in the *primera*, but does in the *postrera*. The fact that the resistant variety appears to offer a yield advantage only in the virus season supports the idea that it is not the variety's yield potential, but rather its reduced yield variability, that makes it valuable to farmers. In Honduras, yield advantage of BGMV-resistant varieties has been observed to be between 0% and 38%, averaging about 18% (Martel and Bernsten, 1995; Viana et al., 1997; Viana, 1998).

In terms of price, traditional varieties generally sell for higher prices than improved varieties. This reflects the fact that farmers have selected traditional varieties over generations to exhibit the desired production, processing, and consumption characteristics of the region. Improved varieties must often sacrifice certain desirable characteristics in order to obtain high yield or disease resistance. In the case of beans in Honduras, for example, Dorado does not have the light red color that is most valued in the region, and is also reported to have some undesirable cooking characteristics. This accounts for the improved variety's lower market price relative to the traditional variety.

The Economic Impact of Virus-Resistant Varieties: Getting the Counterfactual Right

The impact of an agricultural technology is generally measured in terms of its ability to increase yields. In the case of varieties whose main advantage is a high yield, the comparison between traditional and improved varieties may be appropriate because the observed yield increase is the main benefit of the variety. In the case of resistant varieties, however, observed yield differences may not tell the whole story. The value of a resistant variety may not be that it obtains higher yields than were possible with traditional varieties, but rather that it maintains its yield in the presence of pests and diseases.

The benefits of disease-resistant varieties cannot be easily measured using farm-level production data on observed yields (Otsuka et al., 1994). In trials conducted to rigorously compare varieties, plots are either selected randomly or are chosen with great care to ensure that different varieties are grown in similar conditions to be able to compare the results. We would not expect farmers to make planting decisions based on either of these methods. Farmers decide what to plant where, based on their own criteria, among them how to obtain the highest output. If the location of the field or choice of cropping pattern affects the expected damage from BGMV, then we would expect farmers to take this information into consideration.

For example, one would expect areas where the likelihood of virus damage is high to be planted to resistant varieties, whereas areas where the probability of virus damage is low may be planted to the higher priced traditional varieties. In a sense, what farmers are trying to do is minimize the observed difference between traditional and improved varieties, planting traditional varieties where possible and improved varieties where necessary. Therefore we can say that if certain conditions exist then the observed yield difference between traditional and resistant varieties will underestimate the true production benefits of the resistant varieties. The conditions are that farmers have a choice between traditional and improved varieties, that probability of virus is not random, but rather correlated with farm characteristics, and that farmers maximize profit.

One way to more accurately estimate the benefit of improved varieties would be to use data from trials that control for the biases described above (Morris et al., 1994; Smale et al., 1998). A sample of data for Honduras shows that the resistant variety (Dorado) has a yield advantage of between 0% and 59% over the traditional local varieties (Oswaldo Voysest, personal communication, 1999). Caution must be used in interpreting results of experimental trials because observed yields are generally much higher than in farmers' fields. However, the results of the trials do suggest that in areas where disease pressure is high, the benefits of improved varieties may be greater than what we observe in the field.

If information is available about the determinants of disease incidence and intensity, it may be possible to estimate what production would have been in the absence of new varieties. This provides another way of estimating the benefits of improved varieties. Klass et al. (1999) describe several methods for predicting the probability of virus occurrence based on the geographical and climatic characteristics of an area. The dynamics of BGMV are complex and are determined by many factors; however, virologists consider geographical and climatic conditions to be significant determinants of virus occurrence. Therefore statistical analysis can be used to predict the probability of occurrence based on where the virus has been observed in the past. It should be noted that this GIS model will be expanded to include other factors that affect BGMV, perhaps most importantly the cropping pattern in the area. Figure 3 shows the results of the analysis for Honduras. Klass et al. (1999) test several techniques for predicting the occurrence of BGMV in Central America. For the case of Honduras, the most accurate appears to be a Fourier transform with principle components analysis, a process developed to help scientists and other plant collectors identify likely areas for finding specific plant species (Jones et al., 1997; Jones and Gladkov, 1999).

Using this information we can calculate the expected value of production with and without improved varieties, allowing us to estimate the full benefit of improved varieties, including crop losses that did not occur because resistant varieties were available. For the calculation, we need data on yields and on damage from the virus. In terms of virus damage, observed crop losses caused by the virus range from 10% to 100% in Honduras. In the absence of information on the geographical determinants of virus intensity, we analyze for different levels of crop damage, and compare the results.

Table 2 presents the other parameters used in the simulation. For simplicity, we will only consider the cases of one traditional variety, Rojo de Seda, and one improved variety, Dorado. Because in the *primera*, traditional and improved varieties show no yield differences, we use yield from that season as base estimates of yield potential of the variety. As discussed earlier, the price of traditional varieties is generally higher than resistant varieties because of their market characteristics. In this case, the traditional variety sells for 19% more than the resistant variety.

In the absence of resistant varieties, we can estimate the total expected value of production as:

$$3_p\ [(1-p)*(Y) + p(Y)(L)]*H_p * P$$

where p is the probability that the virus occurs, Y is yield of the traditional variety, L is loss caused by virus, H_p is the number of hectares with probability p, and P is the price of the traditional variety.

Take the case where farmers have the choice to plant either improved or traditional varieties. If each farmer wants to maximize the expected value of production, then we can determine aggregate production by determining the threshold probability above which no one will plant the traditional variety.

The analysis was done for bean-producing areas of the states of Francisco Morazán and El Paraíso. Tables 3 and 4 present results. As shown in Table 3, depending on the level of crop damage associated with the virus, the production gain with improved varieties ranges from 7% to 58%, which is above the range of field observations and in line with what experiment data suggest.

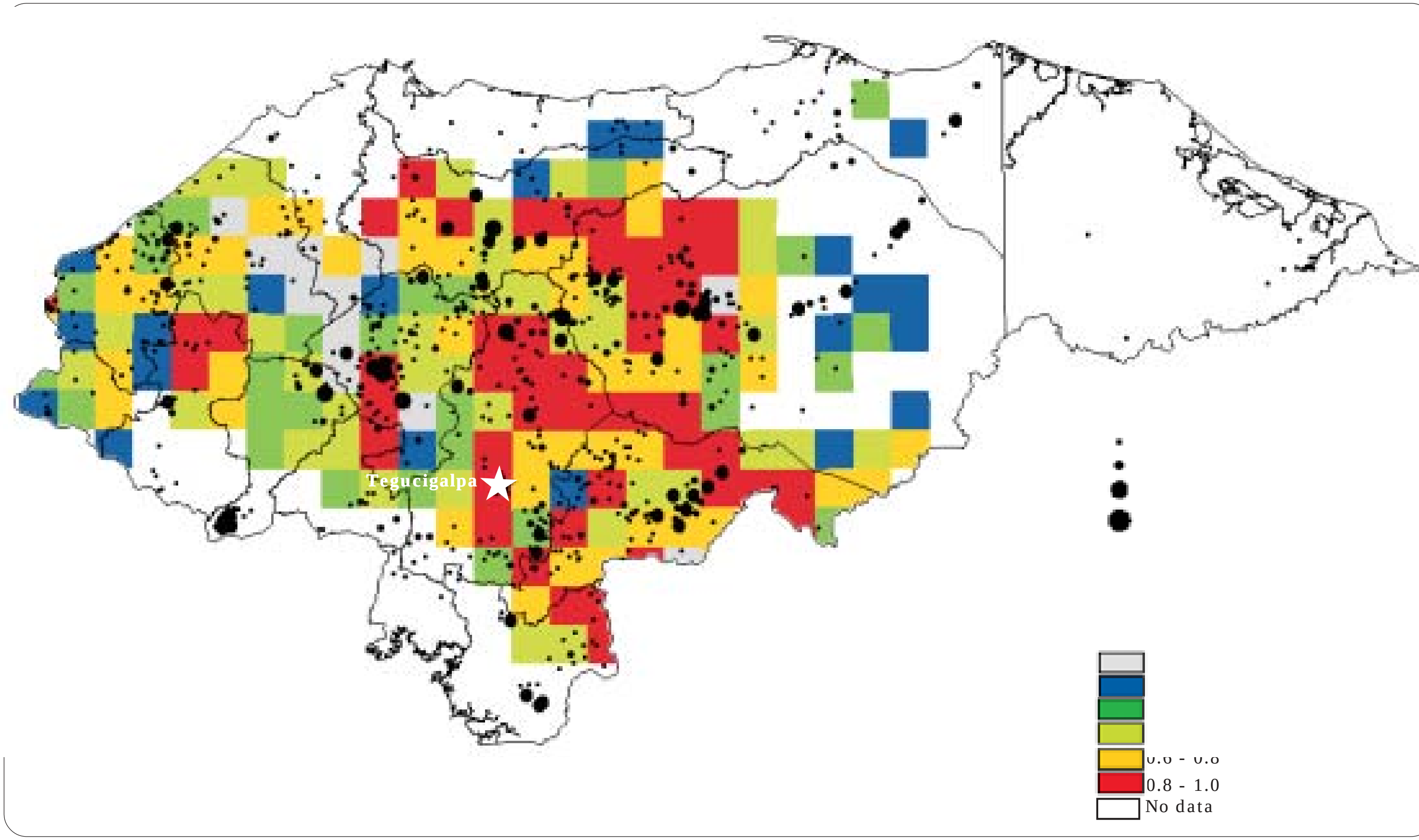


Figure 3. Probability distribution of bean golden mosaic virus (BGMV) in Honduras.

Table 2. Simulation parameters used in the simulation of probability distribution of bean golden mosaic virus in Honduras.

Parameter	Unit	Value(*s*)
Yield of traditional variety in *primera* (Y_T)	t/ha	0.43
Yield of resistant variety in *primera* (Y_R)	t/ha	0.43
Price of traditional variety (P_T)	US$/kg	0.51
Price of resistant variety (P_R)	US$/kg	0.42
Crop loss caused by virus (L)	%	90, 75, 50, 25

SOURCE: Martel and Bernsten, 1995.

Table 3. Estimated quantity and value of increased production caused by disease-resistant bean varieties with different levels of disease intensity[a].

Production factors	L = 90%	L = 75%	L = 50%	L = 25%
Production with improved variety (t)	5736	5714	5744	5595
Production without improved variety (t)	3620	3991	4609	5227
Total production (t)	9356	9705	10,353	10,882
Percentage change in production	58	43	25	7
Adoption rate (%)	61	56	55	30

a. L = crop loss caused by virus.

SOURCE: FAOSTAT (http://apps.fao.org//).

Table 4. Estimated bean yield changes under different scenarios and virus intensities [a].

	L = 90%	L = 75%	L = 50%	L = 25%
Scenario 1: Non-resistant varieties only:				
$Yield_{TT}$ (t/ha)	0.27	0.29	0.34	0.38
Scenario 2: Resistant varieties available (this is important because not everyone in this scenario is actually using resistant varieties):				
$Yield_{TR}$ (t/ha)	0.41	0.41	0.41	0.40
$Yield_R$ (t/ha)	0.43	0.43	0.43	0.43
$Yield_A$ (t/ha)	0.42	0.42	0.42	0.41
Yield advantages				
$Yield_R$ over $yield_{TR}$ (%)	5.0	5.4	4.0	6.5
$Yield_A$ over $yield_{TT}$ (%)	58.5	43.2	24.6	7.0
Magnitude of difference	11.6	7.9	6.2	1.1

a. L = crop loss caused by virus, R = resistant, A = average of traditional and resistant, TT = traditional when no resistant available, TR = traditional when resistant was available.

SOURCE: FAOSTAT (http://apps.fao.org//).

According to the simulation results, the level of adoption of the new variety ranged from 61% when crop damage was 90% to only 30% when crop damage was 25%. Actual adoption of improved varieties is about 73%, with 50% of that area devoted to Dorado (Viana Ruano, 1997). Given that some of the improved varieties are not resistant, the actual adoption level of resistant varieties is slightly lower, in the range of 65%. These results suggest that, if the model is accurate, the expected crop damage from BGMV is quite high.

Table 4 reports the average yields with and without resistant variety. When we use data from farmers' fields, we are comparing yields between traditional varieties ($Yield_{TR}$) and improved varieties ($Yield_{R}$) under scenario 2. Under this scenario, in which improved varieties are available, the average traditional yields were between 5% and 6% higher than the average improved yields. However, when we compare the traditional yield under scenario 1 ($Yield_{TT}$) with the average yield under scenario 2 ($Yield_{A}$), we see that the latter is up to 11 times greater than the former, depending on the level of crop damage. If the level of crop damage is low, then $Yield_{TT}$ and $Yield_{A}$ show little difference, but when crop damage is high, the difference is very large.

These results clearly demonstrate that appropriate specification of the alternative scenarios—with and without the technology—can be potentially highly significant in estimating the impact of a new technology. Both the experiment data and the simulation results suggest that estimates based on observed data underestimate the total impact of resistant varieties because an important part of their contribution is to maintain yields.

Impact of Resistant Varieties on Poverty

The previous section demonstrates that the total magnitude of the benefits is likely to have been much larger than previous estimates suggested. This sections looks at what those benefits imply for poverty alleviation. We can first determine where the benefits occurred, something that can be done given that the analysis was spatial. Overlaying the poverty map and the bean production map reveals a significant area of overlap. Adding the virus map reveals that the target area for disease-resistant varieties also coincides with areas of moderate to extreme poverty. Because the poverty map is from 1988, before the release of the first resistant variety, it can be interpreted as the "before" picture unaffected by the impact of the release of resistant varieties. According to the results of the analysis in the previous section, 40% of the total economic benefits from new varieties occur in areas of statistically significant poverty.

Although the geographical coincidence of poverty and economic benefits from a new technology is certainly suggestive of an impact on poverty, it alone does not guarantee that poverty was reduced in those areas; nor does it mean that poverty was not reduced in other areas.

To address these issues, we need to know more about what happens at the individual and household level as a result of the technology adoption. This is the type of information we can obtain through an analysis of the results of the PPAs, which provide links between household characteristics, economic activities, and the underlying determinants of poverty. Conventional welfare analysis equates an increase in production, other things being equal, to an increase in welfare. The PPA helps make the link between aspects of agricultural production and poverty explicit for the case of beans in Honduras.

A key result of the PPA is that production practices in basic grains do not differ significantly between rich and poor households. Past empirical evidence has suggested that technologies such as fertilizers and varieties are divisible and scale neutral, making them adoptable by both rich and poor (Ruttan, 1977). The results of the PPA confirm this for the case of beans in Honduras, and allow us to assume that if varieties were adopted in a region, they were as likely to be adopted by poor as by rich households.

The local poverty indicators offer several ways in which increases in production can be linked not only to increased economic well-being, but also to poverty alleviation. First, experiencing food shortage is an indicator of poverty; if an increase in production reduces the chance of food shortage, then it contributes directly to poverty reduction. Another component of the PPA well-being index has to do with market integration, particularly with respect to basic grains (maize and beans). Self-sufficient producers and net buyers are considered to be less well off than net sellers. Increases in production mean that net buyers moved closer to self-sufficiency, while self-sufficient producers and net sellers increased their incomes. According to the PPA index, this change would represent an improvement in producers' well-being. Third, to the extent that producers increase their cash income as a result of the new variety, the index offers several avenues for linking increased cash income to well-being, for example, improving housing quality, purchase of animals, or savings.

Beyond production increases, disease-resistant varieties can also contribute to poverty reduction by reducing the risk associated with production. A vast literature is available on the relationship between risk aversion, wealth, and agricultural production, in particular on how risk affects small farmers (Moscardi and de Janvry, 1977; Dillon and Scandizzo, 1978; Binswanger, 1980). Both theory and empirical evidence suggest that small-scale, poor farmers are risk averse, which means that they would be willing to trade gains in average yield for reduction in variability of yield. A technology such as a disease-resistant bean variety, whose main benefit is to reduce the probability of a large, negative outcome such as crop loss, would be particularly beneficial to small-scale, poor farmers.

Several of the indicators in the participatory well-being index directly link reduction of economic risk to increases in well-being. In the indicators concerning health and food security, what distinguishes the non-poor from the poor is their ability to cope with a crisis such as an illness or a food shortage. Those who have the resources to handle these problems on their own without having to seek help from others are considered to be much better off than those who have not. One way in which people handle these crises, according to the index, is by using savings or by selling assets such as land or livestock. Therefore the value of these assets—in themselves indicators of well-being—is also related to risk reduction. Selling the assets allows households to smooth their consumption in the face of highly variable production and income.

The importance that poor people place on security and independence—on not having to ask for money, food, or employment from family and friends—appears to be a highly important aspect of well-being that is not captured by conventional poverty measures (Ravnborg, 1999). Eight of the 11 participatory indicators (land ownership, selling day labor, income, cattle, animals, money, health, and food security) have some element of risk coping or reduction, reflecting the truly profound role that risk plays in determining the well-being of poor households in Honduras. Disease-resistant bean varieties contribute to the reduction of uncertainty and dependency by maintaining yields and reducing variability associated with bean production. Thus they contribute significantly to poverty alleviation.

Conclusions

This chapter demonstrates the importance of disease-resistant bean varieties in Honduras, both in terms of their economic impact and their impact on poverty alleviation. By taking into account both the production increases observed and the losses that were avoided, we arrive at a significantly higher estimate of the economic contribution made by the disease-resistant varieties.

The results have several lessons for research and for policy. The first is that accurate impact assessment requires accurate definition of the "with" and "without" situations. Often the appropriate counterfactual is difficult to identify, and even harder to measure. More attention must be paid to measuring the benefits of varieties that are pest and disease resistant, rapidly maturing, low input, or easy to process. Often, in impact assessment, non-yield characteristics still are not accorded the importance of increased yields simply because there is no easy way to measure their benefits. Empirical implementation of these studies will also require new data collection and methods of data analysis.

The second conclusion is that targeting research towards poverty alleviation appears to be possible by mapping poverty and areas of impact. In this analysis, the overlaying of bean production, virus incidence, and poverty accurately identified some critical areas. Adoption studies show that these areas were in fact where impact occurred. Because agricultural research affects poverty through many mechanisms, the geographical coincidence may not be necessary for a project to be well designed and successful. However, if the goal of the technology is to benefit producers directly, then this type of spatial analysis can be valuable. The increasing availability of data and sophistication of analytical tools is making this work much more efficient and effective.

Finally, in having an impact on poverty, the way a technology works may be as important as where it works. The more detailed and dynamic definitions of poverty that are resulting from recent research on well-being and poverty can be highly useful in identifying which types of technologies will most benefit poor farmers and why. In the case of beans, the fact that varietal selection was not something that was systematically related to wealth suggests that crop improvement may be an appropriate way to target agricultural technology to poverty. Similarly, technologies that reduce risk rather than simply increase average yield may be particularly beneficial to the poorest farmers because they reduce the chance that these farmers will face an agricultural or economic shock with which they are ill prepared to cope. These concepts of risk aversion and biasing technologies towards small-scale, poor farmers are by no means new (Pachico, 1983). What **is** new is our better understanding of poverty and our better ability, via new empirical methods, to identify specific characteristics of poverty in specific environments with sufficient precision that they can be useful in the process of developing agricultural technologies that contribute to the reduction of poverty.

Acknowledgements

We are grateful to Francisco Morales, Oswaldo Voysest, Steve Beebe, Matthew Blair, and César Cardona for providing valuable insights and inputs. Their help has significantly improved the paper; whatever errors remain are our own.

References

Binswanger, H. 1980. Attitudes towards risk: Experimental measurement in rural India. Am J Agric Econ 62:395-407.

Boltvinik, J. 1996. Poverty in Latin America: A critical analysis of three studies. Int Soc Sci J 148:245-260.

CIAT (Centro Internacional de Agricultura Tropical). 1997. Information Systems–GIS Annual Report 1996-97. Cali, CO. 70 p.

CIAT (Centro Internacional de Agricultura Tropical). 1998. PE-4: Land Use Studies: Reconciling the dynamics of agriculture with the environment. Annual Report 1998. Cali, CO. 146 p.

Dillon, J.; Scandizzo, P. 1978. Risk attitudes of subsistence farmers in Northeast Brazil. Am J Agric Econ 60:425-435.

Johnson, N.L.; Pachico, D.; Wortmann, C.S. 2003. The impact of CIAT's genetic improvement research on beans. *In*: Evenson, R.E.; Gollin, D. (eds.). Crop variety and its effect on productivity: The impact of international agricultural research. CAB International, Wallingford, Oxon, GB. p. 257-274.

Jones, P.; Gladkov, A. 1999. FloraMap Beta Version. CD-ROM with 87 p indexed manual. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 1 CD.

Jones, P.; Beebe, S.E.; Tohme, J.; Galwey, N.W. 1997. The use of geographical information systems in biodiversity exploration and conservation. Biodivers Conserv 6:947-958.

Klass, J.; Leclerc, G.; Morales, F.; Wellens, J. 1999. Using GIS techniques to aid in predicting a plant virus in beans. Paper presented at the 25th Annual Conference and Exhibition of the Remote Sensing Society, 8-9 Sept, GB.

Leclerc, G.; Ravnborg, H.; Nelson, A.; Barbier, B.; Couillaud, P.; Oyana, T.; Knapp, E.B.; Ashby, J.A. 1999. Human welfare in Honduras and natural resource management: The search for the missing link! CIAT Internal Seminars Series. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 8 p.

Martel, P.; Bernsten, R.H. 1995. Food markets, policy and technology: The case of Honduran dry beans. Bean/Cowpea Collaborative Research Support Project (CRSP) of United States Agency for International Development (USAID). (Mimeographed. Available from chapter authors)

Morales, F.J. (ed.). 1994. El mosaico dorado del frijol: Avances de investigación. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 193 p.

Morris, M.L.; Dunin, H.J.; Pokhrel, T. 1994. Returns to wheat breeding research in Nepal. Agric Econ 10:269-282.

Moscardi, E.; de Janvry, A. 1977. Attitudes towards risk among peasants: An econometric approach. Am J Agric Econ 59:710-716.

Oyana, T.; Couillaud, P.; Leclerc, G.; Knapp, E.B.; Bell, W. 1998a. Census data: A means of understanding spatial complexities. A case study—Honduras. GIS Unit, Centro Internacional de Agricultura Tropical (CIAT), Internal Document. Available from PE-4, CIAT, Cali, CO. 38 p.

Oyana, T.; Couillaud, P.; Leclerc, G.; Knapp, E.B.; Bell, W. 1998b. Processing social indicators at individual and household level, and their aggregation at different scales. Internal document. Available from PE-4/GIS, Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 66 p.

Otsuka, K.; Gascon, F.; Asano, S. 1994. Second generation MVs and the evolution of the green revolution: The case of Central Luzon, 1966-1990. Agric Econ 10:283-295.

Pachico, D. 1983. Bean technology for small farmers: Biological, economic and policy issues. Agric Admin Int J 15:71-86.

Ravnborg, H.M. 1998. The different faces of poverty—What conventional poverty measures do not tell. Internal Document, mimeo, available from PE-3 Documentation Center, Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 17 p.

Ravnborg, H.; Escolán, R.; Méndez, M.A.; Mendoza, F.; Urbano, P. 1998. Scaling up from local perceptions of poverty to regional poverty profiles—developing a poverty profile for Honduras. Internal Document, mimeo, available from PE-3 Documentation Center, Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 29 p.

Rodríguez, F.; Diaz, O.; Escoto, N.D. 1994. Situación actual del mosaico dorado del frijol en la América Central: Honduras. *In*: Morales, F.J. (ed.). El mosaico dorado del frijol: Avances de investigación. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 45-50.

Ruttan, V. 1977. The green revolution: Seven generalizations. Intern Dev Rev 19: 16-23.

Schoonhoven, A. van; Pachico, D. 1998. Rice and beans in Latin America: A summary report of the economic impact of improved varieties. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. 13 p.

SECPLAN (Secretaría de Planificación, Coordinación y Presupuesto). 1991. Precenso y censo de población y vivienda 1988. Información básica de los municipios de Honduras. Tegucigalpa, HN. 41 p.

Smale, M.; Singh, R.P.; Sayre, K.; Pingali, P.; Rajaram, S.; Dubin, H.J. 1998. Estimating the economic impact of breeding nonspecific resistance to leaf rust in modern bread wheats. Plant Dis 82:1055-1061.

UNDP (United Nations Development Programme). 1998. Human development report 1998. Oxford University Press, NY, USA.

Viana Ruano, A. 1998. Flujo de germoplasma e impacto del PROFRIJOL en Centroamérica: Período 1987-1996. Proyecto Regional de Frijol para Centro América, México y el Caribe (PROFRIJOL), GT. 48 p.

Viana Ruano, A.; Rodríguez, F.; Escoto, D. 1997. Adopción de la variedad Dorado región Centro-Oriental de Honduras, 1996. Dirección de Ciencia y Tecnología Agrícola, Programa Regional de Investigación en Frijol (DICTA-PROFRIJOL), HN. 17 p.

Epilogue

*Rodney D. Cooke**

I was asked to actively participate in a session on **Donor Perspectives**, at the International Conference on Impacts of Agricultural Research and Development, "Why Has Impacts Assessment Research not Made more of a Difference?", 4-7 February 2002, San José, Costa Rica. During the rich discussion in that session, several important issues emerged, of direct relevance to this book.

Here, I would like to briefly recapitulate my summary, for further thinking and debate on some of the concerns expressed by we Donor Representatives at that Session.

At the outset, an underlying observation was that if we do not care about the impact of agricultural research and development "we are dead in the water". In other words, we must be concerned about demonstrating cost-effective interventions with widespread impact on rural poverty, arising from donor investments in pro-poor research. Donors are anxious to find out the extent to which proven technologies (from the research communities' standpoint) are accepted and adopted by those for whom such technologies were intended and, indeed, the change such adoption has brought about in the livelihoods of the adopters. Responses to the former question are not adequately reassuring in the context of public goods research. A major reason for this has been the lack of investment in types of research to develop technologies that are more in consonance with the actual needs of targeted communities. There is a long-standing perception among the more discerning donors that even applied, adaptive research, seemingly targeted to poor farming community requirements, has been often based on top-down governance structures. This is often accompanied by disconnected phases of adaptive research followed by extension, which can also lead to difficulties in subsequent "take-up" or sustained adoption on the part of the intended "recipients".

* Director, Technical Advisory Division, International Fund for Agricultural Development (IFAD), Rome.

Among the many issues related to agricultural research and poverty reduction discussed in this book is the dominating fact that the research community has not given adequate attention to clearly demonstrating the impact of their otherwise fruitful research outcomes on rural poverty. The authors examine various aspects of the technology system, including policy formulation and decision making, research and generation of new technology, the transfer of new techniques and, most importantly, their utilization. They attempt to analyze the production-technology relationship and proffer arguments highlighting different aspects that may impinge on the ready adoption of proven techniques.

A major problem for the support of agricultural research and development (R&D), however, has been the declining support for rural development as a whole, across national governments and the donor community. The rural poor depend primarily on agriculture (directly or indirectly). The commitment of the International Fund for Agricultural Development (IFAD) to reverse the trend of declining support for agricultural R&D relates to the observation that 75% of the world's poor people live in rural areas. The proportion of Official Development Assistance for agriculture fell from 20% in the 1980s, and remains only at around 12% today. The recent Monterrey Financing for Development International (FfD) Conference and the Johannesburg Earth Summit provided platforms for expression of a strong recommitment to the agricultural sector, as an engine for sustainable development. Despite this fact, and the international community's Millennium Development Goals (MDG) pledge, which focuses so sharply on the livelihoods and welfare of the poorest communities, we have yet to see significant movement in global support to agricultural R&D. The MDG pledge was reconfirmed strongly, most recently at IFAD's 25th Anniversary Governing Council, 18-19 February 2003, and it is hoped that we will see some positive movement in investments targeting pro-poor R&D.

A number of International Financial Institutions are attempting to reverse this decline through engagement in a series of policy dialogues and in making a case to the international community. IFAD's Rural Poverty Report was published in 2001, in partnership with the World Bank and others to reverse the declining support for rural development. The report is being complemented by increased funding for agricultural research for development, for example, for the Consultative Group on International Agricultural Research (CGIAR), which itself amounts to over US$110 million in the past 2 decades. Investment in agricultural research is exposed to the pressures described by most donor representatives, in other words, it is a long-term investment with a risky reputation, or—as others see it—a blunt instrument for change often involving capacity building with returns foreseeable only in the longer term. For these reasons, IFAD has been a financial supporter of the Impact Assessment and Evaluation Group (IAEG; now Standing Panel for Impact Assessment, SPIA) in order to further clarify the advantages of targeted, effective, R&D

programs, and to develop innovative ways of helping demonstrate the impact of such investments.

Agricultural research leading to the adoption of improved technology may reduce rural poverty in many ways. Thus, we must get away from the too simplistic internal rates of return analysis based on adoption of high-yielding varieties. These ways can include a range of benefits:

- Higher on-farm yields,
- Expansion of farm employment opportunities and higher wages,
- Growth of non-farm activities,
- Lower food prices,
- Reduced vulnerability to crop and other risks, and
- Empowerment of the poor and of their organizations.

I emphasize the last item, **Empowerment**, as an important outcome in itself that has gained increasing attention in recent years. Unless the poor have the power to participate in deciding which technology to use, they are unlikely to benefit from it. In other words, better farm technology will most benefit the farmers who are active partners in setting priorities of R&D and in the conduct of the research itself, contributing their own knowledge and wisdom to formal science.

IFAD has supported the SPIA in the CGIAR system as part of the contribution to the reform and refocusing of the international agricultural research system.

One of the most relevant aspects of this San José conference was the SPIA program itself, which has been looking at methods for evaluating the impact of agricultural research on poverty in the context of different agricultural technologies and within different country, social, and institutional settings. Several interesting case studies from all the developing regions were presented. Key aspects of the framework include:

- Expanding the understanding of the dimensions of poverty and how to measure it;
- Emphasis on vulnerability to natural phenomenon, market shocks, and trends (this also relates to livelihood strategies);
- Examination of the five asset types (Sustainable Livelihoods framework) and how people combine these in livelihood strategies; and
- Understanding how the institutional environment at the micro and macro levels influences these livelihood strategies.

Future Developments

These relate to three areas. The first lies in matching Impact Assessment (IA) outputs to decision makers' priority needs. Second, IA outputs must be made more credible, plausible, and understandable, without losing rigor in the process. Third, methods need to be improved, particularly in terms of developing a set of impact indicators for a broader array of impacts beyond the traditional economic ones.

In terms of these three areas, there exist various needs and opportunities. Major user groups consist not only of funders of research (an accountability function mainly), but also of the planners and decision makers who are shaping future programs, that is they want ex post and ex ante IAs as input in making decisions about such programs.

The results of IA need to be effectively publicized and disseminated. All the disparate information on IA being generated by the centers need to be brought together at the system level. For example, a Web page “IA in the CGIAR”, could serve as (a) a central repository of credible impact information (peer reviewed); (b) a channel for exchange of information; (c) a means of reporting results to users; and (d) other functions as needed.

Attempting to attribute impacts separately to each research partner may not be feasible. In fact, it can be counterproductive to attempt such attribution since it can threaten good working relations within the partnership. This point needs to be understood, particularly by funders and decision makers who promote partnership as a means of making research more effective and efficient.

The IAs should not be limited to success stories. Honest attribution of project shortcomings as well as benefits is required. Recognition of risk and uncertainty associated with successes must be transparent in order to gain the confidence of those who use IAs.

Impact Assessment needs to be fully institutionalized as a management function (e.g., for priority setting, resource allocation, feedback to program planning). In many research organizations, it is often carried out in response to external demands rather than as an integral part of planning.

A set of realistic strategic guidelines should be formulated for future ex-post IA in the CGIAR, highlighting good, credible studies as models to follow (e.g., IA of soybean technology).

Finally, more resources should be devoted to developing methodologies/procedures for:

- Multidisciplinary IA based on a problem-driven approaches;
- Upscaling and synthesizing (of case studies, smaller studies);
- Rapid, low-cost data collection, as long as it results in acceptable levels of accuracy;
- Modeling adequate counter-factual estimates; and

- IA and evaluation methods for capacity building, NRM, and other areas that have proven elusive in terms of application of existing IA methods.

I am pleased to share some of the collective thinking of IFAD, and of other donor-partners supporting international agricultural research for development, on the subject of poverty impact of their research investments. These are, by no means, to be considered an exhaustive list of issues but are meant here, at the end of this book, as a collection of thoughts for further reflection as we contemplate future support to the important area of pro-poor technology development.

List of Acronyms and Abbreviations Used in Text

Acronyms

ADC	Agribusiness Development Center, Uganda
AIDS	Acquired Immunodeficiency Syndrome
ANPPY	Asociación Nacional de Productores y Procesores de Yuca (*National Association of Cassava Producers and Processors*), Colombia
ARET	Agricultural Research and Extension Trust, Malawi
ASARECA	Association for the Strengthening of Agricultural Research in Eastern and Central Africa
AZRI	Arid Zone Research Institute, Pakistan
CAAS	Chinese Academy of Agricultural Sciences
Caja Agraria	Caja de Crédito Agrario, Industrial y Minero (*Agrarian, Industrial, and Mining Credit Bank*), Colombia
CECORA	Central de Cooperativas de la Reforma Agraria Ltda. (*Federation of Agrarian Reform Cooperatives Ltd.*), Colombia
CGIAR	Consultative Group on International Agricultural Research
CIDA	Canadian International Development Agency
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (*International Maize and Wheat Improvement Center*), Mexico
CLAYUCA	Consorcio Latinoamericano y del Caribe para la Investigación y el Desarrollo de la Yuca (*Latin American and Caribbean Consortium to Support Cassava Research and Development*), based at CIAT, Colombia
CORFAS	Corporación Fondo de Apoyo de Empresas Asociativas (*Fund for Support to Member Enterprises Corporation*), Colombia
CORPOICA	Corporación Colombiana de Investigación Agropecuaria (*Colombian Corporation for Agricultural Research*)
CRSP	Collaborative Research Support Project of USAID
DANCOOP	Departamento Administrativo Nacional de Cooperativas (*National Administrative Department of Cooperatives*), Colombia
DANE	Departamento Administrativo Nacional de Estadística (*National Administrative Department of Statistics*), Colombia

Danida	Danish International Development Agency
DARTS	Department of Agricultural Research and Technical Services, of MOALD, Malawi
DFID	Department for International Development, UK
DICTA	Dirección de Ciencia y Tecnología Agrícola (*Directorate of Agricultural Science and Technology*), Honduras
DIWU	Directorate of Irrigation and Water Use, Syrian Arab Republic
DRI	Fondo de Desarrollo Rural Integrado (*Fund for Integrated Rural Development*), Ministry of Agriculture, Colombia
ECART	European Consortium for Agricultural Research in the Tropics
ECOSOC	Economic and Social Council of the United Nations
EPTD	Environment and Production Technology Division, of IFPRI
ESCWA	Economic and Social Commission for Western Asia, of the FAO
EU	European Union
FAO	Food and Agriculture Organization, Rome
FCND	Food Consumption and Nutrition Division, of IFPRI
FEDEYUCA	Federación Nacional de Productores, Procesadores y Comercializadores de Yuca (*National Federation of Cassava Producers, Processors, and Traders*), Colombia
FfD	Financing for Development International Conference
FGT	Foster, Greer, Thorbecke class of poverty measures
GoM	Government of Malawi
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (*German Technical Cooperation*)
HIE	Household Income and Expenditure Survey
IA	Impact Assessment
IAEG	Impact Assessment and Evaluation Group, IFPRI
ICA	Instituto Colombiano Agropecuario (*Colombian Agricultural Institute*)
ICARDA	International Center for Agricultural Research in the Dry Areas, Syria
ICCDR	International Centre for Diarrheal Disease Research, Dacca, Bangladesh
ICRAF	International Centre for Research in Agroforestry, Kenya
ICRD	Integrated Cassava Research and Development Project of CIAT
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics, India
IDB	Inter-American Development Bank
IDEA	Investment in Developing Export Agriculture, Uganda
IFAD	International Fund for Agricultural Development, Italy
IFPRI	International Food Policy Research Institute, USA
ILO	International Labor Organization, Geneva
INCORA	Instituto Colombiano de la Reforma Agraria (*Colombian Institute of Agrarian Reform*)
IRRI	International Rice Research Institute, Philippines
ISNAR	International Service for National Agricultural Research, Neths
KARI	Kenya Agricultural Research Institute
MDG	Millennium Development Goals

MIDDA	Model for Innovation Development, Diffusion and Adoption
MoALD	Ministry of Agricultural and Livestock Development, Malawi
NARO	National Agricultural Research Organisation, Uganda
NERC	National Environment Research Council, UK
NRMP	Natural Resource Management Program of ICARDA
NSSA	National Sample Survey of Agriculture, Malawi
OECD	Organization for Economic Cooperation and Development
PABRA	Pan African Bean Research Alliance
PMA	Programa Mundial de Alimentos (*World Food Program*)
PNR	Plan Nacional de Rehabilitación de la Presidencia de la República (*National Rehabilitation Plan of the Presidency of the Republic*), Colombia
PRGA	Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation of the CGIAR
PROCAMPO	Programa de apoyos directos al Campo (*Farmers' Direct Support Program*), Mexico
PROFRIJOL	Programa Cooperativo Regional de Frijol para América Central, México y el Caribe (*Regional Collaborative Bean Program for Central America, Mexico and the Caribbean*)
REIA	Research Evaluation and Impact Assessment team, ICRISAT
SDC	Swiss Agency for Development and Cooperation
SECPLAN	Secretaría de Planificación, Coordinación y Presupuesto (*Secretariat for Planning, Coordination, and Budgeting*), Honduras
SENA	Servicio Nacional de Aprendizaje (*National Learning Service*), Colombia
SOFA	State of Food and Agriculture series of FAO
SPIA	Standing Panel for Impact Assessment
TAC	Technical Advisory Committee of CGIAR
UBN	Unsatisfied Basic Needs method
UN	United Nations
UNDP	United Nations Development Programme
UNIFEM	United Nations Development Fund for Women
UPPAP	Uganda Participatory Poverty Assessment Project
USAID	United States Agency for International Development, WA
WIRFS	Women in Rice Farming Systems, of IRRI
WRRI	Water Resources Research Institute
WTO	World Trade Organization
ZOPP	Zielorientierte Projekt Plannung (*Objectives-oriented Project Planning*) of GTZ, Germany

Abbreviations

BGMV	bean golden mosaic virus
CAP	common agricultural policy
DRC	domestic resource cost
GAM	geographical analysis machine
GDP	gross domestic product

GIS	geographic information systems
GMs	genetically modified crops
GNP	gross national product
GPT	groundnut production technology
IPM	integrated pest management
IRR	internal rate of return
LDCs	less developed countries
LT	long-term effect on production
MVs	modern varieties
NARS	national agricultural research systems
NGO	nongovernmental organization
NPV	net present values
NRM	natural resource management
OPVs	open pollinating varieties
PPA	participatory poverty assessment
PRA	participatory rural appraisal
R&D	research and development
RHS	right-hand side
RNFS	rural non-farm sector
SATs	semi-arid tropics
SI	supplemental irrigation
SL	Syrian pound currency
SSA	sub-Saharan Africa
ST	short-term effect on production

CIAT Publication No. 335

IFAD/CIAT Impact Assessment Project and CIAT's Communications Unit

Editing:	Annie L. Jones
Editorial assistance:	Gladys Rodríguez
Production:	Graphic Arts, CIAT Oscar Idárraga (layout) Julio César Martínez (cover design)
Printing:	Imágenes Gráficas S.A., Cali, Colombia