Staff Paper

Progress and Problems in Promoting High External-Input Technologies in Sub-Saharan Africa: The Sasakawa Global 2000 Experience in Ethiopia and Mozambique

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Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

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howardj6@pilot.msu.edu maredia@pilot.msu.edu stepanek@pilot.msu.edu
crawfor5@pilot.msu.edu

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Abstract: Critics argue that high external input technologies are too costly for African farmers, and that pilot programs to promote them are economically unsustainable. This paper assesses Sasakawa-Global 2000 programs in Ethiopia and Mozambique; budgets, yield models and subsector analysis help explain the radically different country results and prognoses for sustainable adoption.

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Julie Howard and Mywish Maredia are Visiting Assistant Professors, Valerie Kelly is a Visiting Associate Professor, Julie Stepanek is a Ph.D. candidate, and Eric W. Crawford is a Professor in the Department of Agricultural Economics, Michigan State University, East Lansing, MI USA 48824-1039. Funding for this research was provided through the Food Security II Cooperative Agreement (PCE-A-00-97-00044-00) between the Department of Agricultural Economics at Michigan State University and the Office of Agriculture and Food Security in the Global Bureau of the United States Agency for International Development (USAID). Funding was also provided by the Africa Bureau's Office of Sustainable Development, Productive Sector Growth and Environment Division (AFR/SD/PSGE), USAID/Mozambique and USAID/Ethiopia.

Progress and Problems in Promoting High External-Input Technologies inSub-Saharan Africa: The Sasakawa Global 2000 Experience in Ethiopia and Mozambique[1]

Introduction

Sub-Saharan Africa's (SSA) cereal deficits are the largest in the world. The problem is exacerbated by rapid population growth and declining soil fertility. There is an urgent need to increase agricultural productivity but proposed solutions vary. Some propose labor-intensive, low-external-input technologies, while others argue that food security cannot be achieved without widespread adoption of high-external-input technologies (HEIT). Because many actors are expanding their support for HEIT despite arguments that these technologies (and the support systems they require) are too expensive for SSA, a review of these efforts is in order.

Research Objectives and Methods

This paper examines evidence from Ethiopia and Mozambique on progress and problems encountered in one of the most well-known efforts to bring HEIT to SSA—the Sasakawa Global 2000 program (SG). Working from the assumption that farmers' lack of awareness is the major constraint to technology adoption, SG (in collaboration with government extension services) promotes half-hectare, farmer-managed plots to demonstrate the superior performance of improved seed, fertilizer, and practices. Although SG has had notable success in boosting crop

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[1]This paper draws on research findings from two earlier papers: (1) Howard, Julie A., José Jaime Jeje, David Tschirley, Paul Strasberg, Eric W. Crawford, and Michael T. Weber. 1998. *What Makes Agricultural Intensification Profitable for Mozambican Smallholders?* MSU International Development Working Paper No. 69. East Lansing: Michigan State University and (2) Howard, J., Demeke, M., Kelly, V., Maredia, M., and Stepanek, J. 1998. *Can the Momentum be Sustained? An Economic Analysis of the Ministry of Agriculture/Sasakawa Global 2000's Experiment with Improved Cereals Technology in Ethiopia.* Department of Agricultural Economics Staff Paper No. 98-25. East Lansing: Michigan State University. José Jaime Jeje, Mulat Demeke and Ali Said led the field research on which these papers are based and contributed to the data analysis and writeup. We also thank Dr. David Tschirley, Dr. Michael Weber, and Dr. Duncan Boughton for their constructive comments on this paper.

yields, it has been criticized for using blanket rather than site-specific technical recommendations, and for failing to address non-agronomic factors (e.g., market development, subsidies). Also, farmers' input use often declines after program completion.

To better understand the potential for HEIT in SSA we examine the financial and economic profitability of SG packages for maize in Mozambique and Ethiopia. Analytical methods used are financial and economic budgets, econometric yield models, and subsector analysis based on survey data and crop cuts collected from more than 200 farmers per country in 1997 and 1998, plus key informant interviews with extension agents and input dealers.[2]

We first compare general characteristics of Ethiopia and Mozambique and their SG programs. Key research results are presented next, including the performance of the SG maize packages and factors contributing to yield and profitability differences. The paper concludes with a discussion of the implications of these results for HEIT expansion.

Overview of Ethiopia and Mozambique and their SG Programs

Ethiopia has a much larger population (60.1 million) than Mozambique (18.3 million), and a greater land constraint (1 compared to 2.7 hectares per household). Ethiopians are better educated: 65% of Ethiopian adults are literate, compared to only 13% of rural household heads in Mozambique. Maize is a more important crop in Mozambique (36% of cultivated area) than Ethiopia (15%). Study areas in both countries are considered high potential, but agroecological conditions in Ethiopia (higher altitude and rainfall) are better suited for maize production. Ethiopian farmers have much more experience with HEIT: 30% of Ethiopian farmers have used

[2]Study areas in Mozambique were located in Manica (central) and Nampula (northern) Provinces. In Ethiopia we surveyed farmers from West Shoa and Jimma Zones (both in central-southwest Ethiopia).

fertilizer, compared with 7% in Mozambique. On average, Ethiopian farmers use 11.1 kg of NPK per hectare, compared to 1.8 kg/ha in Mozambique.

The SG program started two years earlier in Ethiopia, but otherwise the programs and technology packages are similar. Hybrid maize seed (which must be repurchased every year) is used in the Ethiopian program, while open-pollinated (OP) seed is used in Mozambique. The most striking difference between the two countries is the government response to the SG program. In Ethiopia, President Meles Zenawi has taken a personal interest in SG, and the Ministry of Agriculture is using SG principles as the model for its ambitious New Extension Program (NEP) to promote HEIT in a variety of crops, including maize, tef, sorghum and pulses. NEP's coverage is remarkable: while SG reached a maximum of 3,185 plots in 1995 and has now scaled back to 2,003 plots, NEP has grown from 32,046 to 600,634 demonstration plots between 1995 and 1997 and continues to expand. In Mozambique, by contrast, the SG program has remained small (1000 plots by 1997) and is one of several extension programs operated by the Ministry of Agriculture with assistance from donors and non-governmental organizations.

Performance of the SG Technology Packages

Methods

In Tables 1-6 we present maize yields and results of financial and economic profitability analyses under high- and low-input conditions. In Ethiopia, we collected yield and input data from current SG program participants and graduates as a basis for the analysis. For most current participants we also report yields and profitability results for a second maize plot where farmers were using "non-program" low-input practices. Because input use was not homogeneous within these categories, we also analyzed the data by level of fertilizer and type of seed used. For

Mozambique we collected data only for SG program participants in 1997 (in Manica and Nampula Provinces); in 1998 we limited our survey to Nampula Province but broadened the sample to include extension program participants (improved practices, local seed, no fertilizer) and farmers not participating in either program.

Yield Results

In Ethiopia, average maize yields across all survey plots (2.8-6.8 tons/ha) far exceeded national and regional averages of 1.9 and 2.1 tons/ha. Yields for HEIT plots were much higher than low-input plots. Farmers using the full HEIT package increased their yields by 71-74% compared to farmers using local seed with or without DAP (Table 1). In spite of these increases, smallholder HEIT maize yields are still only 62% of yields obtained on research stations.

Maize yields in Mozambique are much lower than in Ethiopia (Table 2): potential yields for improved varieties are 9-10 tons/ha compared with 5-6.5 tons/ha in Mozambique. Still, yield results for Mozambique SG program participants are promising: average SG yields (2.3 tons/ha)

Table 1. Maize Yields in Ethiopia

Year	SG	Grad.	Non-prog.	Local seed/ local seed + DAP	Imp.seed, DAP+ urea < rec. rate	Imp.seed, DAP, urea, >= rec. rate	Nat'l/ regional avg.[1]	Potential yields
1998 (tons/ha)	5.5-5.6	4.8-6.8	2.8	2.9-3.9	5.8-6.0	5.7-5.9	1.9/2.1	9-10
n	(161)	(96)	(47)	(81)	(103)	(118)		

[1]Average maize yield at the national level and for Oromiya Zone.

Table 2. Maize Yields in Mozambique

Year	SG	Extension Program	Non-program	Regional average[1]	Potential yields
1997 (tons/ha)	2.3			0.4-1.3	5-6.5
n	(143)				
1998 (tons/ha)	1.3-2.7	1.3-2.0	1.1-1.7		5-6.5
n	(79)	(71)	(58)		

1998 optimal conditions (tons/ha)	4.1	2.8	2.5
n	(11)	(11)	(10)

[1]Averages for districts and provinces covered in the DNER/SG program for 1994/95-1996/97.

exceeded regional average yields (0.4-1.3 tons/ha) by a wide margin in 1997. In 1998, yields on the SG (1.3-2.7 tons/ha) and Extension Program (1.3-2.0 tons/ha) plots were higher than yields on non-participants' plots (1.1-1.7 tons/ha), but there was no statistically significant difference between SG and Extension Program yields (Table 2).

The impact of improved seed and fertilizer in Mozambique is reduced by late input delivery in both study years. The absence of an effective private input distribution system resulted in a 2-5 week delay in planting for most SG program participants. For 1998 we also present yield data for an "optimal conditions" scenario—in this case, for sample farmers in the highest yield tercile in one district (Monapo/Meconta) where inputs were delivered on time and weather conditions were favorable. These yields under "optimal conditions" were 4.1 tons/ha, 46% higher than yields obtained by Extension Program farmers (2.8 tons/ha). Non-program farmers in the highest yield tercile obtained yields of 2.5 tons/ha (Table 2).

Yield Determinants

Econometric models were developed to identify the most important factors affecting yields. In Ethiopia, we found that the use of improved seeds and fertilizer is strongly associated with higher yields. Farmers using less than the recommended rates of DAP and urea (on average, 25-28% less) did as well as those using higher rates, however, signaling the possibility of reducing the fertilizer applied and increasing profits. These results were obtained primarily by program graduates, suggesting the existence of a learning curve with farmers becoming more proficient in applying and adapting improved techniques over time.

In both countries there was considerable yield variability across fields within a given technology type. Although insufficient variability and high multicollinearity across key variables made it impossible to isolate the yield impact of seeds, DAP, 12-24-12, and urea, we could identify several specific environmental and management factors that affected yields. In Ethiopia, for example, a farmer can increase yields by 0.4-1.5 tons/ha if he plants on red soils, and farmers plowing four or more times before planting can increase yields by 550 kg/ha. Late planting reduces yields by 200 kg/ha per week; and incorrect row or plant spacing reduces yields by 280-315 kg/ha. Failure to weed on time results in average losses of about 200 kg/ha.

In Mozambique, increased planting density had a positive and significant effect on yield, as did labor availability and participation in an extension group. As in Ethiopia, yields were higher when maize was planted in red soils. Damage caused by termites and rats, and climatic problems such as drought, field-level flooding and high winds, significantly reduced yields.

Financial Analysis

Ethiopia. The use of improved maize technology was extremely profitable for Ethiopian farmers under a range of output prices (Table 3). Profits for farmers using HEIT and selling output in January (soon after harvest) ranged from $314 to $463/ha, 45-59% higher than for farmers who used local seed or local seed plus DAP ($157-$346/ha). Since farmgate prices rose sharply over time, HEIT users could increase their profits by one-third ($447-$541/ha) by holding maize until August. If these farmers reduce storage losses by one-half by using storage insecticide, profits increase by 45-50% over January levels. Profits from HEIT use are very robust: net income is positive even if output prices decline by 25-50% from January levels. Returns per labor day from maize production were much higher than average daily wage rates for all farmers: returns for low-input users were double and for HEIT farmers as much as six times the average daily wage rate. Program graduates who adapted technology packages by applying less fertilizer than recommended (and using fewer labor hours) achieved higher profits than farmers who used the full fertilizer rate.

Table 3. Financial Profitability, Ethiopia, 1997/98

	SG	Grad.	Non-prog.	Local seed + or - DAP	Imp.seed+ DAP+urea < rec. rates	Imp.seed+ DAP+urea >=rec.rates
Net income/ha (USD)						
January price	305-415	380-403	154	157-346	337-463	314-412
August price	449-486	431-599	246	256-370	499-541	447-515
August with insecticide	496-534	472-658	270	289-412	561-609	508-582
Net income/labor day (USD)						
January price	2.3-2.6	2.0-2.7	1.7	1.7	3.0	2.0-2.5
August price	2.8-3.6	2.1-4.3	2.7	1.8-2.8	3.2-4.7	2.6-3.2
August with insecticide	3.1-4.0	2.3-4.7	2.9	2.0-3.1	3.6-5.3	3.0-3.6
Avg. daily wage rate	0.4-0.9	0.4-0.9	0.4-0.9	0.4-0.9	0.4-0.9	0.4-0.9

Table 4. Financial Profitability, Mozambique, 1996/97 and 1997/98

	1996/97	1997/98		
	SG	SG	Extension Program	Non-program
Net income/ha (USD)		(numbers in parentheses are negative)		
September-October price	66	(6)-105	111-144	90-125
November-December price	196	58-197	175-216	142-185
Net income/labor day (USD)				
September-October price	.64	(0.1)-1.4	0.9-1.2	0.7-0.9
November-December price	2.0	1.0-2.6	1.3-2.0	1.0-1.4
Avg. daily wage rate	1.22	1.1-1.5	1.1-1.5	1.1-1.5
Under optimal conditions				
Net income/ha (USD)				
September-October price		225	216	209
November-December price		366	311	295
Net income/labor day (USD)				
September-October price		2.7	1.4	1.1
November-December price		4.4	2.0	1.5

Mozambique. Farmgate prices for maize in Mozambique ($90-$150/ton) and Ethiopia ($81-$140/ton) are similar, but the use of improved maize technology is far less profitable for Mozambican farmers (Table 4). Earnings for high-input farmers selling in September-October (soon after harvest) ranged from a loss of $6/ha to a profit of $105/ha, compared to $111-$144/ha for farmers in the extension program, and $90-$125/ha for non-program participants. If farmers sell early, returns per labor day are below the average daily wage rate for all three groups of farmers. If farmers hold maize until November, profits for SG farmers increase by 158-196% ($58-$197/ha) and by 52-53% for extension ($175-$216/ha) and non-program farmers ($142-$185/ha). Returns per day (for November sales) exceed the average daily wage by 31-38% for SG and extension group participants.

In general, profits from the use of SG technology are not significantly higher than low-input technologies (after farmers pay their input loans) and the use of HEIT is riskier than low-input technologies. The data presented in the tables are means from the different survey areas, and mask the fact that in 2 of the 3 districts SG farmers in the lowest yield tercile lost $21-$45/ha.

As noted earlier, in two districts SG farmers planted 2-5 weeks late because of tardy input delivery. Under optimal conditions—on-time input delivery, good management, good weather—represented by the highest yield tercile in Monapo/Meconta District, profits from high-input plots ($225/ha) were slightly higher than for the extension group ($216/ha) and non-program participants ($209/ha), if farmers sell in September. HEIT maize is slightly more attractive if farmers hold maize for sale in November. Farmers earn $366/ha from the SG plots, 18% more than extension plots ($311/ha) and 24% more than non-program plots ($295/ha).

Economic Analysis

In this section we summarize the results of the economic analysis, which considers profitability from the viewpoint of society instead of the individual farmer. We address three questions: (1) If the alternative to increased domestic production is to import grain at commercial rates, is society better off producing maize locally using improved technologies instead of importing? (2) If grain is produced for export, is society still better off producing maize with improved technology? And (3) does the benefit of programs to facilitate technology adoption outweigh their costs to society?

Ethiopia. If the alternative to intensified domestic production is importing grain, payoffs to intensive maize production are high from society's perspective. Profits are high and stable even when world fertilizer prices are high. Economic gains from the use of HEIT are $914-$1005/ton, 59-71% higher than gains from using local seed or local seed/DAP ($458-$700/ton) (Table 5). Our analysis looks quite different if we assume that HEIT maize will be exported. Whether intensified maize produced for export is economically profitable depends on the prevailing export price. Table 5 shows the minimum export prices (CIF Mombasa) needed in order for the investment in technology to break even. Break-even export prices range from $133-$157/ton for farmers using local seed and no fertilizer and from $140-$160/ton for farmers using HEIT. This finding raises questions about whether Ethiopia can compete with lower-cost producers supplying the regional market. For example, the 1996-98 average US FOB price was $124/ton. Shipping and insurance costs are about $37/ton, so US producers could supply maize CIF Mombasa at $161/ton or less. Subsector marketing and transport costs will have to fall if Ethiopian maize is to compete effectively on regional markets. Transport costs between the farmgate and port represent 40-57% of the export (CIF Mombasa) maize price and add 22-68% to the imported price of DAP and urea (CIF Assab).

In the economic analysis, net income represents the residual return to factors that facilitate crop production but are not explicitly costed out in the analysis. As a result of fertilizer market liberalization the **price** of fertilizer is no longer directly subsidized by the government, but the government and donors are still facilitating farmer access to fertilizer in other ways, i.e., through intensive extension and credit programs. These program costs are not recovered through the prices farmers currently pay for fertilizer. We estimate the cost of extension and credit program administration to be $126 per program farmer. Accounting for these costs reduces the economic profitability of improved technology use, but if maize is considered an import substitute, the relative costs are low, reducing net gains to society by only 11-15% (Table 5). If intensive maize will be exported, accounting for program costs raises the break-even export parity price by 13-14% to $161-180/ton, further reducing the competitiveness of Ethiopian maize.

Mozambique. Mozambique's geography greatly influences the international competitiveness of its maize. The large consumption centers of Maputo and Beira are located in the far south, close to South Africa, while the major maize producing areas are located in the central and northern parts of the country, 1100 and 2150 km from Maputo. If there is a maize deficit in Southern Africa, maize from Mozambican producers competes with maize imported from the U.S. Table 6 shows that under these conditions, net gains to society range from $25-$156/ton if HEIT maize is supplied to Maputo from central Mozambican provinces. In most cases it is not economically profitable to ship maize to Maputo from northern Mozambique except for higher-altitude zones where farmers obtained average yields of 2.9 tons/ha in 1996/97.

When the region has a maize surplus, it is very difficult for Mozambican farmers to compete with South African producers because of their closer proximity to the main Mozambican markets. Table 6 shows that under most conditions it is not economically viable to supply maize to Maputo from either central or northern Mozambique. However, as regional trade barriers have come down neighboring Malawi has become an increasingly important market, and there is evidence that maize is also being exported to eastern Zambia. Farmers in northern Mozambique can export maize to Malawi at very competitive prices, given the proximity and low-cost rail link, and the market may be relatively stable because of Malawi's structural deficit in maize. Break-even prices (FOB Malawi border) range from $87-$245 per ton. US producers could supply maize to Malawi at approximately $185/ton, but these varieties are likely to be less preferred by consumers. In the future it may also be possible for northern Mozambican farmers to export to

Table 5. Economic Analysis Results for Ethiopia

	Program Type			Input Level		
Zone/Budget Item	MOA/ SG	Tradi- tional	Graduate	Local seed + DAP	Imp. seed + DAP+ urea < rec. rate	Imp. seed + DAP+ urea >= rec. rate
Net Income (USD/ha)						
a. Import Parity Hi Fert Price	863-923	443	832-1093	458-700	972-1005	914-925
b. Import Parity Lo Fert Price	885-945	447	840-1114	463-700	991-1023	939-951
c. Import Parity Hi Fert Price incl. Program Costs	737-797	n/a	706-967	n/a	847-879	788-799
d. Import Parity Lo Fert Price incl. Program Costs	759-820	n/a	714-988	n/a	865-897	813-825
e. Import Parity Hi Fert, 50% Prog.	800-860	n/a	769-1030	n/a	909-942	851-862
f. Import Parity Lo Fert, 50% Prog.	822-883	n/a	777-1051	n/a	928-960	876-888
Break-Even Export Prices (USD/ton)						
g. Hi Fertilizer Prices	147-157	157	140-153	133-157	140-153	151-160
h. Hi Fertilizer Prices+ Prog.Costs	169-179	n/a	167-170	n/a	161-172	172-180
i. Hi Fert.+50% Prog. Costs	159-168	n/a	154-162	n/a	151-162	161-169

Table 6. Economic Analysis Results for Mozambique DNER/SG Program, 1996/97

	Central (Manica)	North (Nampula)
SG Yields (tons/ha, 1996/97)	2.1-2.5	0.8-2.9
Maize Deficit in Southern Africa	(numbers in parentheses are negative)	
a. Net Income: Import Parity Hi Transport Cost ($/ha)	25-80	(131-50)
b. Net Income: Import Parity Lo Transport Cost ($/ha)	75-156	(74)-142
c. Break-Even Export Price Lo Trans. (FOB Malawi) ($/ton)		87-245
Maize Surplus in Southern Africa		
a. Net Income: Import Parity Hi Transport Cost ($/ha)	(63-25)	(193-165)
b. Net Income: Import Parity Lo Transport Cost ($/ha)	(13)-34	(109)-0
Break-Even Export Price ($/ton)		
a. Break-Even Export Price Lo Trans. (FOB Malawi) ($/ton)		87-245
b. Break-Even Export Price Lo Trans. (CIF Mombasa) ($/ton)		140-285

Kenya and Tanzania, which have different weather and crop production trends. Our analysis indicates that the break-even export price to Kenya (CIF Mombasa) will be $140-$285 per ton. Lower-cost producers in Mozambique could compete with U.S. maize ($161/ton CIF Mombasa). In general, developing the regional market will reduce the risk of adopting HEIT by increasing the probability of remunerative prices even during years of regional surplus.

Information on program costs for Mozambique was not available, but assuming that per-farmer costs are similar to Ethiopia's ($63-$126), investing in programs to encourage maize intensification given the current technology and institutional conditions results in net losses for society under most scenarios.

Implications for the Expansion of HEIT

The contrasting experiences of Ethiopia and Mozambique clearly demonstrate the importance of a country- and crop-specific approach to the introduction and expansion of HEIT programs. Many factors affect the performance of technology packages. Most basic are the yield potential of the technology and input/output price ratios. If maize is sold within 3 months of harvest, Mozambican HEIT users must produce 950-2074 kg of maize to pay for one hectare of inputs (48-104% of average yield) vs. 913-1189 kg (17-22% of average yield) in Ethiopia. Because maize varieties are so responsive in Ethiopia, farmers can repay their inputs and start to make money even with relatively mediocre yields. In Mozambique, HEIT users who get average yields risk losing money; profits for those who get excellent yields may not be significantly higher than profits from well-managed low-input plots.

For countries now considering HEIT programs, Mozambique offers a fundamental lesson: focus on technology packages that are profitable at the farm level, improving technical assistance, and reducing the costs of input and output marketing. A major rethinking of Mozambique's HEIT approach is needed. First, HEIT needs to be promoted within an institutional context that will permit the improvement of research, extension and marketing services at a reasonable cost. Formal collaboration that began in 1998/99 between SG, the extension service, input companies and farmer organizations may help strengthen the institutional environment for technology adoption and deserves close monitoring. Second, researchers and extensionists should alter current maize recommendations. In higher altitude areas, farmers are already using higher-yielding hybrid maize varieties from Zimbabwe. In these areas it may be possible to use high levels of fertilizer profitably--but further analysis is needed. Elsewhere it will also be important to better match varieties to local conditions and look at the impacts of (a) decreasing fertilizer; (b) using complementary organic practices to increase soil fertility; and (c) improving crop management practices. Third, researchers and extensionists should look at the profitability of HEIT for alternative crops. Fourth, more attention needs to be given to the impact of HEIT at the whole-farm level. If HEIT enables farmers to produce maize (or another crop) for consumption or sale on a smaller area and devote more land and labor to other more profitable crops, the use of HEIT may be profitable at the farm level (but not for the specific crop). Similarly, if there are spillover effects for fertilizer used on maize so that continuing soil fertility benefits are captured by maize or other crops in subsequent years, these benefits should be accounted for.

Because of its relative stability, strong research and extension institutions, high literacy rates, and farmer experience with HEIT, Ethiopia is starting from a higher place on the HEIT learning curve. Our results suggest that Ethiopia has made good progress on “getting the crop and technology package right” but now faces a different set of challenges. Profitability can be improved and risk reduced by fine-tuning recommendations (as program graduates are already doing), but the key challenges now for Ethiopia (and other countries with a successful bank of technologies) are institutional, centering around how to scale up the current successful program, especially (1) expanding NEP *extension* coverage to a wider base of farmers without (a) diluting the quality of the extension message and (b) increasing program costs; (2) finding low-cost, financially sound ways of administering *input credit*; and (3) developing a transparent and responsive *input supply* system (with special attention to the weak seed system) that can function independently of the NEP and provide all farmers access to low-cost, high-quality agricultural inputs.