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An Ex-Ante Evaluation of Farming Systems Research in Northeastern Mali: Implications for Research and Extension Policy

by

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One component of the second phase of this cooperative agreement in Mali was an economic study of farming systems research in the Fifth Region of Mali. Specifically, the study aimed to establish the feasibility of expanding the work of the Farming Systems Research Division of the *Institut d'Economie Rurale* (DRSPR-IER) to the Fifth Region. Preliminary results from this research have already been published in Mali and the United States in the form of preliminary and final reports and a Ph.D. dissertation, most of which are cited in the bibliography.

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LIST OF ACRONYMS

CESA	Commission Nationale de Suivi et d'Evaluation de la Stratégie Alimentaire (Food Strategy Commission), Mali
CFA	Communauté Financière Africaine (Financial Community of Western and Eastern Francophone African states, except Guinea and Mauritania)
CFAF	CFA Francs (currency unit of the CFA Zone)
CMDT	Compagnie Malienne de Développement des Textiles (Malian Company for the Development of Textiles), Mali
CRD	Comité Régional de Développement (Regional Committee of Development)
DET/IER	Division des Etudes Techniques (Division of Technical Studies), IER, Mali
DNACOOP	Direction Nationale de l'Action Coopérative (National Direction of Cooperative Organizations), Mali
DPAER/IER	Division de la Planification Agricole et d'Economie Rurale (Department of Agricultural Planning and Rural Economy), IER, Mali
DRA	Direction Régionale de l'Agriculture (Regional Direction of Agriculture), Ministry of Agriculture, Mali
DRA/IER	Division de la Recherche Agronomique (Division of Agronomic Research), IER, Mali
DRC	Domestic Resource Costs
DRSPR/IER	Division de Recherches sur les Systèmes de Production Rurale (Farming Systems Research Division), IER, Mali
E&C	Extension and Credit
FSR	Farming Systems Research
FSR/E	Farming Systems Research/Extension Project, Mali
IARC	International Agricultural Research Center
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IER	Institut d'Economie Rurale (Agricultural Research Institute), Mali

IRR	Internal Rate of Return
ISNAR	International Service for National Agricultural Research
MRR	Marginal Rate of Return
MSU	Michigan State University, USA
NARS	National Agricultural Research System
NPV	Net Present Value
ODR	Opération de Développement Rural (Rural Development Agency), Mali
OHV	Opération Haute Vallée (Niger River Upper-valley Development Authority), Mali
OLS	Ordinary Least-Squares
OMM	Opération Mils de Mopti (Mopti Millet Organization), Mali
ON	Office du Niger (Niger River Irrigated Agricultural Development Agency), Mali
OPM	Opération Pêche de Mopti (Mopti Fish Organization), Mali
ORM	Opération Riz de Mopti (Mopti Rice Organization), Mali
ORS	Opération Riz de Ségou (Segou Rice Organization), Mali
OSR	On-Station Research
P	Policy
PV	Present Value
ROR	Rate of Return
SPAAR	Special Program for African Agricultural Research
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WARDA	West African Rice Development Agency
WB	World Bank

1. INTRODUCTION

The need for farming systems research in Mali emerged in the late 1970s, when it became clear that the technologies extended by the extension agencies (ODRs) were often inappropriate to the agro-climatic and socio-economic constraints faced by farmers and that the results of station research needed to be adapted to farmers' specific circumstances. In 1985, the main agricultural research institute, the Institute of Rural Economy (IER), decided to strengthen its institutional capacity to conduct FSR and expand gradually its farming systems research activities from Southern Mali to the other regions of the country. The United States Agency for International Development (USAID) supported IER's efforts by establishing a ten-year program of financial and technical assistance. The first phase of this program allowed IER to institutionalize its farming systems research division (DRSPR) and expand its activities from the Compagnie Malienne de Développement des Textiles (CMDT) zone in Southern Mali to the Opération Haute Vallée (OHV) zone. The second phase of this included a plan to expand the DRSPR to the Region of Mopti.

However, because the agroclimatic, socio-economic, and institutional constraints appeared more binding in the Region of Mopti than in the OHV zone, an in-depth study was thought necessary to examine the feasibility of this expansion. In particular, the climate of the Region of Mopti is semi-arid, with rainfall between 300 mm and 600 mm, which severely limits the production potential of the region. In addition, few technologies at the station level are available and appropriate for FSR to adapt and transfer to producers. Poorly developed infrastructure and institutions may further hamper the diffusion of new technologies. Finally, IER's ability to sustain an expanded FSR program in the near future is questionable.

As a result, a feasibility study of the expansion of the FSR division into the Region of Mopti was carried out in Mali from June 1987 to December 1988 (Henry de Frahan et al. 1989). This paper summarizes the results of analyses designed to evaluate the expected production impact of this FSR project, indicate the factors that would affect the returns to this project, and investigate alternative public investments to complement FSR (further details are provided in Henry de Frahan 1990).

The findings of these analyses shed some light on possible ways to orient the objectives and organization of agricultural research and FSR in Mali at a time when the government of Mali is concerned about how to reorganize and strengthen the national agricultural research system (NARS). The roles and organization of supporting rural institutions are also examined.

The results of this study also come at a time when FSR is criticized for having performed poorly in increasing farm productivity through technology development, particularly in Africa. Reasons generally given to explain the poor performance of FSR, such as the difficulties of institutionalizing FSR and the weaknesses of commodity and disciplinary research programs to back up FSR, suggest that more attention should be devoted to examining the pre-conditions necessary for FSR to stimulate farm productivity. Accordingly, this paper examines the conditions that would be needed for a possible FSR project in the Region of Mopti to have a significant production impact.

Section 2 of this paper presents the major constraints of the farming systems in the Region of Mopti. Section 3 identifies research priorities for the FSR project. Section 4 evaluates the technologies that FSR could develop, in terms of financial profitability, riskiness and economic efficiency. Section 5 estimates the potential impact of FSR on increasing farm production and ranks the major factors affecting the returns to FSR. Section 6 examines the production impact of diverse combinations of investments which complement FSR and the interactive effects between these investments and FSR to propose an investment strategy for the Region of Mopti. Section 7 explores the implications of the findings of this study for the roles and organization of agricultural research and extension in Mali and in Africa. The last section concludes with recommendations for using ex-ante evaluations for strategic resource allocation and conducting ex-ante evaluations of agricultural research.

2. CONSTRAINTS TO THE FARMING SYSTEMS IN THE REGION OF MOPTI

2.1. The Farming Systems

The Region of Mopti has a diverse agroecology: the seasonally-inundated inland delta of the Niger and Bani rivers, the Bandiagara plateau, and the broad Seno plain, which stretches from the Bandiagara cliffs to the border of Burkina Faso. The climate in the southern part of the region is sudano-sahelian, with a long-run average of 600mm of rainfall annually. In the North, the climate is sahelian with rainfall between 200mm and 400mm.

The Bandiagara plateau and the Seno plain are essentially agropastoral, where millet cultivation dominates (80 - 85% of crop area). The secondary crops of the millet-based farming system include cowpeas (generally intercropped with millet), groundnuts, sesame, fonio, and Bambara groundnuts. The northern part of the Seno plain also serves as a transhumance zone during the rainy season for livestock from the Delta and the cultivated parts of the Seno plain. The central and southern part of the Seno plain are considered the millet granary of the northern part of the country despite limitations in soil fertility and rainfall. On the plateau, about 20% of the total land available can be cultivated. However, the tributaries of the Yamé river and flooded low-lying areas provide numerous opportunities for dry-season vegetable gardens, particularly onions. Small ruminants are also raised.

The major farming systems in the Delta include the agropastoral, pastoral, and fish-based systems. The agropastoral system in the Delta actually comprises three overlapping sub-systems: the rice-based system, the rainfed crop-based system, and the flood recession crop-based system. Farmers are involved to different degrees in each of these sub-systems, depending on the geographic location of the farm. Rice cultivation, an ancient activity, is practiced under either natural or controlled flooding conditions. Controlled flooding enables the management of the floodwater rise after germination and the drainage of the polders by means of dikes, canals, and gates. This management is provided by the Mopti Rice Organization (ORM).[1] Rainfed crops - i.e. millet, sorghum, cowpeas, and groundnuts - are cultivated on the elevated land of the Delta. Flood recession agriculture is practiced in the northern, low-lying part of the Delta, which is also an excellent pastoral zone because of its dry-season pastures.

The pastoral system is based on the seasonal movement of livestock from wet-season to dry-season pastures. Following the recession of the flood, herders migrate to the dry-season pastures, which are made up of an herbaceous forage plant, called the "bourgou" (*Echinochloa stagnina*). During the Niger and Bani floods the herders return to the non-flooded areas, which provide wet-season pasture. Entrance to the "bourgou" area has been regulated by the Dina code, a set of rules instituted in the nineteenth century. This code is still actively enforced by the traditional authorities of the Delta, often in conflict with the 1969 governmental abolition of traditional water, land, and pasture rights. Fishing is principally practiced in the middle and upper parts of the Delta.

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[1]Like the natural flooding system, the controlled flooding system provides no guarantee against insufficient rain and flooding.

2.2. Bio-Physical Constraints to the Farming Systems

All production systems in the Region of Mopti dramatically suffered from the decline in rainfall and floodwater levels that characterized the period 1968-88. As a result, the regional contribution to national production in millet/sorghum fell from 24% over the period 1974-77 to 16% over the period 1985-88, and the regional contribution in rice declined from 38% to 28% over the same period. Similarly, the regional contribution to the national cattle herd fell from 25% (1980-82) to 20% (1985-87), while the proportion of small ruminants from the region remained at the same level (20%) over these two periods. The fresh fish catch fell at an annual rate of 3% from 1970 to 1987. These statistics indicate that the importance of the Region of Mopti declined in the mid- and late 1980s in these activities for which it has traditionally been competitive.

During the actual drought periods even the local short-cycle varieties of rainfed crops could not complete their cycle. *Oryza sativa* rice was not able to develop sufficiently before the arrival of the flood. Both perennial grasses and ligneous species in the wet-season grazing areas were not able to regenerate. The late arrival and weakness of the floods particularly affected natural flood and flood-control irrigation, recessional cultivation, recessional pasture, and the fish population. This climatological deterioration also exacerbated the disequilibrium which already existed between herd size and carrying capacity.

These climatological shocks on the production systems and other natural constraints to crop and livestock production revealed the fragility of these systems. Soil nutrient deficiencies in phosphorus, nitrogen, and organic matter in combination with low soil water retention limit yields of rainfed crops and the biomass of the wet-season pasture. Any significant increase in productivity would require the use of chemical fertilizer, manure, and water retention techniques. Strong winds and run-off water are additional natural constraints to rainfed agriculture in this area. Sand storms cover the seedlings in the Seno plain and fill some lakes in the lacustrine zone with sand. Run-off erodes arable land and removes fertile topsoil from the Bandiagara plateau and the peripheral areas of the Delta. Rainfed crops are subject to insect attacks both in the field and in storage. *Raghuva* headborer, in particular, frequently attacks millet, and other insects inflict serious damage on cowpeas in storage. Borers are also frequent on *Oriza sativa* rice. *Striga* is widespread in millet and cowpea fields, and wild rice species (*Oryza bartii* and *Oryza longistaminata*) are commonly found in rice polders. Termites, rodents, and granivorous birds are active pests on all crops. Parasitic diseases persist among transhumant cattle and small ruminants.

2.3. Labor and Market Constraints to the Farming Systems

In terms of input availability, seasonal labor scarcity is the most critical constraint to increasing agricultural output, particularly during the critical planting and weeding periods. As a result, animal traction has been well accepted among farmers (33% of the Seno plain mixed farmers and 40% of the ORM rice growers). However, the increased use of animal traction is hampered by unpredictable equipment supply, lack of agricultural credit, and difficulties in maintaining draft animals. In addition, during the cropping season, cash and food reserves are not available for hiring laborers and few laborers are actually in the labor market at this time. In contrast, rice growers more frequently are able to hire laborers from the rainfed areas for weeding, harvesting, and threshing because labor demand for rainfed crops is relaxed at this time.

In addition to variable and unpredictable rainfall, intra- and inter-annual crop price volatility discourages the intensive use of purchased inputs, primarily insecticides and chemical fertilizers. The absence of any profitable cash crops or other income-generating activities besides migration, and the head tax discourage investment in agriculture. As a result, input and product marketing infrastructure are not well developed, particularly in the rainfed area. Agricultural credit and input-supply facilities are inadequate for the minority of farmers who have an effective demand for modern inputs. Market outlets for livestock products are shrinking as a result of the decline in purchasing power among domestic consumers and the fall of import demand from coastal countries, particularly Côte d'Ivoire.

Important tenure conflicts over the use of arable land, pastures, forage, wells, and fishing areas are particularly severe in the Delta. These conflicts disrupt an optimal allocation of natural resources.

2.4. Sustainability at Risk

These factors, combined with an increased population pressure, endanger the sustainability of the production systems of the area. Without the means to invest in soil fertility, farmers are forced to neglect the traditional rotation system of long fallow periods and to cultivate marginal lands, all of which depletes soil, grazing, and timber resources. Farmers have also reacted to economic and environmental stress by diversifying their activities, which has worsened pressure on natural resources. As a consequence, tenure conflicts over the use of arable land, pastures, forage, wells, and fishing areas are mounting, particularly in the Delta area, while soil fertility, perennial and ligneous species, "bourgou" areas, and the fish population are endangered. Some producers have migrated to urban centers or more favorable agricultural areas, such as southern Mali. Traditional herd owners have became guardians for new livestock owners. These constraints to production in the Region of Mopti are daunting. Whether FSR can contribute to relaxing these constraints is the question that will be examined in the next sections.

3. RANKING RESEARCH PRIORITIES FOR FSR

In order to determine FSR's potential contribution to production in the Region of Mopti, research priorities are identified and selected according to an evaluation criteria approach. The first step in this approach is to rank commodities on which FSR should focus according to a set of criteria that reflect efficiency objectives but also equity, security, and sustainability objectives. The second step is to identify research areas and put them in order of priority according to the major constraints of the farming systems of the region and the technological components that are available from on-station research. In the final step, the research priorities are ranked by area of research within major commodity groups.

3.1. Commodity Priorities

The potential "efficiency" benefits from research depend partly on the relative importance of the agricultural commodities in terms of value of production, domestic consumption, and export opportunities. Table 1 reports estimates on the production value, the expected changes in domestic demand, and the market possibilities for the major commodities of the region. Using weights that reflect the relative importance given to each efficiency criterion, commodities for which data are available are ranked as follows: (1) millet, (2) sheep and goats, (3) cattle, (4) rice, and (5) wood.

FSR's distributional or "equity" objectives consist of increasing (1) the income of the rural population, which represents more than 90% of the regional population and (2) the well-being of the low-income rural and urban population. Increasing rural incomes is tantamount to giving a higher research priority to commodities that constitute the main source of income or consumption for the rural population. Increasing the well-being of the low-income population amounts to giving a higher priority to commodities that are basic foods. Table 1 reports values corresponding to these two equity criteria. Both equity criteria rank millet and rice as the first and second commodities, livestock as the third group of commodities, wood as the fourth commodity and fish as the fifth commodity.

To enhance the security impact of FSR, research should find ways to reduce the risk associated with the production of the main commodities produced in the region. Table 1 reports the degree of variability in producing these commodities across years. From the most to least variable, these commodities are rice, followed by millet, cattle, small ruminants, and fish.

Environmental sustainability of the production system can be fostered by developing techniques that (1) will augment the production of some commodities that have a positive impact on the conservation of the system or (2) will match the production level of some commodities to the sustainability level of the natural resource system. Wood and legumes are commodities that have a positive impact on the conservation of the system, while livestock production and fishing in the Region of Mopti appear currently to exceed the level of sustainability. Accordingly, techinques to increase wood and legumes production are ranked higher in table 1 with respect to sustainability

Table 1. Agricultural Research Priorities by Commodity

	EFFICIENCY CRITERIA					EQUITY CRITERIA			SECURITY CRITERIA			
	Total Annual Value of Production		Future Domestic Demand	Market Possibilities	Efficiency Rank	Percent Producers	Importance in Budget of Poor	Equity Rank	CV of Production	Security Rank	SUSTAINA-BILITY CRITERIA RANK	AGGRE-GATE RANK
COMMODITY	(Million CFA)	(%)	(1) (%)	(2)	(3)	(4) (%)	(5)	(6)	(7) (%)	(8)	(9)	(10)
Millet-Sorghum-Fonio	13380	31.9	14	North	1	47	1	1	40	2	medium	1
Cattle	10982	26.2	4	export	3	15	4	3	24	3	low	3
Sheep & Goats	5854	14.0	20	export	2	15	4	3	12	5	low	3
Paddy Rice	4900	11.7	40	local	4	23	2	2	70	1	medium	2
Wood (11)	2920	7.0	14	local	5	few	3	5	low	6	high	5
Cowpea	2420	5.8	NA	north	NA	47	2	NA	NA	NA	high	NA
Sesame	154	0.4	NA	export	NA	47	5	NA	NA	NA	medium	NA
Onion	1200	2.9	NA	export	NA	15	5	NA	NA	NA	medium	NA
Groundnuts	66	0.2	NA	local	NA	47	5	NA	NA	NA	high	NA
Maize	21	0.1	NA	local	NA	47	5	NA	NA	NA	medium	NA
Fish	NA	NA	NA	export	NA	10	5	NA	13	4	low	6
TOTAL	41898	100.0										

(1) Expected change in domestic demand over the next 5 years based on Ministry of Agriculture (1987, p. 87), Delgado and Staatz (1981, p. 349), and Shaikh (1985).
(2) Export for export market (rank = 1), North for northern Mali (rank = 2), and local for local market (rank = 3).
(3) For a weight distribution of 50% on annual value of production, 25% on future domestic demand, and 25% on market possibilities.
(4) Percent of farmers relying on different commodities as the major source of income.
(5) From 1 to 5 in decreasing importance.
(6) For an equal weight distribution between percentage of producers and importance in budget of poor.
(7) Period between 1974 and 1988 for the cereals, between 1977 and 1987 for livestock and between 1970 and 1987 for fish (Henry de Frahan 1990, App. 2-A).
(8) From the most variable to the least variable.
(9) With high (rank = 1), medium (rank = 2), and low (rank = 3).
(10) Weighing efficiency 40%, equity 20%, security 20%, and sustainability 20%.
(11) Values for wood are estimated from Shaikh (1985).
Source: Henry de Frahan 1990, p. 152.

than are techniques to boost livestock and fish production. Cereals, sesame, and onions are ranked between wood and legumes on the one hand, and livestock and fish on the other hand.

Ranking research priorities by commodity depends on the relative importance given by policy makers to efficiency, equity, security, and sustainability objectives. For example, if efficiency receives 40% of the weight and equity, security, and sustainability receive each 20% of the weight, research priorities should be given first to millet, then to rice, livestock, wood, and fish. Research on wood should, however, not be neglected because it contributes significantly to environmental sustainability and its increasing scarcity may eventually reduce national output in the long run, inducing a long-run efficiency effect. The likely payoffs to investment in research for a given commodity should also be considered in the ranking procedure. The following section examines that particular issue.

3.2. Priorities by Research Areas

Because of the number and complexity of the potential research areas for FSR and the limited human and capital resources available to the project, the potential research areas are placed in order of priority. Some research areas are highly complementary and must be grouped together to benefit from their large expected interactive effects. For example, a research area aimed at improving the use of a purchased input, such as a fertilizer or a pesticide, needs to be complemented by research on the accessibility of that input to farmers. The complementarity of the research areas is likely to be the strongest among research areas related to the same farming system. Therefore, in the following discussion the research areas are grouped by farming system and, within each farming system, complementary research areas are pooled together. Then, because each farming system is defined by its major commodity, the ranking of research priorities by commodity is used to rank these groups of research areas.

For the millet-based farming system, on-station research has developed several technological components to deal with rainfall variability and low soil fertility, the most limiting factors for increased productivity. These technological components include cropping patterns that increase plant density to facilitate water retention near the roots, use of moderate doses of chemical fertilizer (either soluble chemicals or rock phosphate), and use of legumes either interplanted or rotated with cereals. These technologies, however, need to be adapted and tested for the particular ecological and socio-economic environment of the Region of Mopti. This research work could be part of the FSR program. Another research area could include helping on-station research define its breeding objectives. To relax the labor constraints in the peak labor-demand periods, mechanized cropping techniques better adapted to local practices and crop and livestock activities need to be integrated in production activities. Research on the socio-economic feasibility of integrating anti-erosion and agroforestry techniques into the farming system and development and tests of improved food processing and storage techniques are also possible research areas.

To facilitate the transfer of these technologies to farmers, additional areas of research should include studies that identify the constraints to the production and delivery systems for inputs and to the credit system. Because the coarse grain market is volatile and is not a reliable source of cash income, special attention also needs to be devoted to cash crops and their potential to raise farm incomes and investment. Vegetables, cowpeas, and groundnuts for urban centers and sesame for export are possible sources of income.

For the rice-based farming system that is diversifying into rainfed crops, FSR could investigate the labor allocation problem. In addition, FSR could help on-station research define its breeding objectives for both *Oryza sativa* and *Oryza glaberrima* and test new rice varieties with a moderate level of management. To facilitate investment in animal traction, particularly for rice growers outside the ORM polders, FSR could develop solutions to improve the capital market. As the current large ORM threshing facility is not efficient and deserted by rice growers for smaller rice mills, an additional research area would be to look at the efficiency of alternate rice processing techniques with regards to labor and capital.

Besides research in the area of agriculture and livestock integration, no FSR interventions should attempt to increase the productivity of the pastoral system until more fundamental changes occur. These changes include the following: (1) resolving tenure conflicts over the use of arable land, pastures, forage, and wells; (2) developing infrastructure for eradicating parasitic diseases among transhumant cattle and small ruminants; (3) developing facilities for providing water in the dry areas; and (4) developing export market outlets by reducing administrative fees and export taxes. Likewise, FSR is limited in its capacity to increase the productivity of the fish-based system until tenure conflicts over the use of water are resolved and regulations that would guarantee fish replenishment are drafted and enforced.

The commodity ranking developed above can be used to rank the groups of research areas identified for FSR. Since millet is ranked first, the complementary research areas for the millet-based farming system is accorded a higher priority than those for the rice-based farming system. The groups of research related to rainfed agriculture will not only benefit the millet-based farming system but also the other systems of the region because of the current diversification of all the systems into rainfed agriculture. It is therefore proposed that in the short run FSR concentrate primarily on the research areas related to the millet-based farming system and secondarily on the research areas related to the rice-based farming system. The research areas identified for the intermediate run depend on the evolution of FSR and on-station programs, and the institutional and policy setting. Because in the short- and medium run the development of livestock and fisheries, the two other major resources of the region, depends more on infrastructure, market outlets, and resolving tenure conflicts over the use of pastures and bodies of waters than on contributions that might come from agricultural research, FSR on livestock and fisheries should not be given priority.

3.3. FSR Program

The proposed FSR program is comprised of the following research areas: studies relating to the marketing constraints for inputs and agricultural products, focussed surveys to obtain a better understanding of certain constraints and the means to alleviate them, tests of technical packages based on available or forthcoming results from station research, and cooperative programs with commodity researchers to identify technological solutions to certain agroclimatic constraints.[2] In the short run, FSR is expected to develop successfully several technical packages for rainfed agriculture. Involvement of FSR in flooded agriculture will depend on the remaining human and capital resources. In the intermediate run, FSR will develop additional technical packages incorporating improved varieties of millet and rice selected through on-station research.

Research for the flooded-crop-based farming system should be oriented towards (1) identifying the labor bottlenecks during the cropping calendar and developing labor-saving techniques, (2) identifying the most efficient rice processing techniques for rice growers, (3) fostering the collaboration with on-station research to collect local *Oryza glaberrima* germ plasm and define on-station objectives, (4) identifying the constraints to the capital market for rice growers outside the ORM polders, and (5) developing solutions.

The next section will show that FSR, by developing these research areas, may improve the comparative advantage of the region in groundnuts for local consumption, as well as in rice, millet, and cowpeas for the consumption markets of Mopti and Gao, and in sesame for export.

[2] For a more detailed discussion of how this proposed FSR program was determined, see Henry de Frahan et al. (1989).

4. TECHNOLOGY EVALUATION

In the short term, on the basis of the technological components currently available from station research, FSR could develop several technical packages for rainfed agriculture. Research areas on agronomy incorporating water retention techniques, moderate fertilizer levels, and improved varieties, mechanization and storage technology could result in four technical packages to be extended to farmers five years following the establishment of FSR in the region. These four technical packages include the following crop enterprises: millet-cowpea intercropping and cowpea, groundnut, and sesame mono-croppings. These technical packages are devised to reduce production risk under unfavorable agroclimatic situations but increase yields under favorable conditions. They pertain to approximately 60% of the population of the rainfed agriculture zones or 30% of the total population of the Region of Mopti.[3]

In the long term, FSR could develop additional technical packages to incorporate improved varieties of millet and rice emerging from on-station research. Because the development of these technical packages depends on additional investment in on-station research (OSR), these technical packages will be considered when a joint investment in FSR and OSR is evaluated below.

4.1. Financial Evaluation

Financial analysis looks at the attractiveness of the proposed packages to the farmers given the market prices he or she actually faces. The expected financial profitability and riskiness of the technical packages are first evaluated with respect to the current technologies for the three agroclimatic zones of the rainfed area (Northern Séno, Southern Séno, and Center Séno and Plateau together). Because capital and labor are the two most limiting factors of production for farm households in these zones, the marginal rate of return (MRR) and the marginal return per person day are estimated and used to eliminate unprofitable technical packages (tables 3-6 in appendix A).[4] After eliminating unprofitable or marginally profitable packages, MRRs in financial terms range between 41% and 175%, depending on the package, the zone and whether or not the potential adopter is mechanized (table 7 in appendix A). The marginal return per person day for these selected packages is between 453 and 9,271 CFA francs (using a 12% opportunity cost of capital), a figure generally higher than the present opportunity cost of labor.

Sensitivity analysis reveals the degree of instability of the technical packages with regard to changes in output prices, yields, or costs of production and, hence, the degree of riskiness in adopting these technical packages (table 8 in appendix A). Most of the selected packages are unstable given a 10% to 20% change in prices, yields, or costs of production. Adoption of these

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[3]For details about these technical packages, see Henry de Frahan (1990).

[4]The MRR is the ratio of the incremental net income to the incremental costs and reflects the additional net income earned by the additional capital and labor invested in the new practice. The marginal return per person day is the incremental return to the incremental person-days of labor used in the new package. It isolates the effect of additional labor from other factors of production, such as capital and land.

technical packages would, therefore, be difficult if agricultural input and product markets as well as the yields of the proposed packages are not stabilized. Given the likelihood of such changes and farmers' risk aversion, this instability implies that the current agricultural input and product market conditions and current technological development at the research station level severely limit the capacity of FSR to develop technical packages appropriate to actual farming conditions. On the other hand, this instability also indicates that a relatively small decrease in input costs or increase in output prices or in yield performance would have a relatively large effect on the profitability of these technical packages. These effects would, however, induce technical change only if farmers perceived these changes as fairly stable.

4.2. Economic Evaluation

Financial budgets are converted into economic budgets by removing all transfers due to subsidies, taxes, or interest rate and exchange rate controls. This conversion allows the testing of the economic efficiency of producing selected commodities under the current and the proposed technologies. This conversion is also used in the next section to estimate the rate of return to FSR in economic terms.

To identify farm enterprises for which agricultural research could most likely improve economic efficiency for a specified market, the domestic resource cost ratios are calculated.[5] Estimating these DRCs with the current technologies indicates the areas in which the Region of Mopti currently has a comparative advantage while estimating these DRCs with the technologies that agricultural research could develop indicates the areas in which the Region of Mopti could potentially improve or gain a comparative advantage. With the current technologies, the areas in which the Region of Mopti has a comparative advantage are millet, cowpeas and rice for the consumption markets of Mopti and Gao (table 9 in appendix B). For these consumption markets, the Region of Mopti is more competitive than the other producing areas of the country. Agricultural research may improve the comparative advantage of the region in these commodities for the same markets (table 10 in appendix B). The proposed technical packages for groundnuts and sesame appear efficient for local consumption and for exports respectively. Producing sesame for exports is, however, no longer efficient with a simulated 20% decrease in world market FOB prices. With a 50% overvaluation of the CFA franc instead of 33% in the base case, producing millet for Bamako becomes efficient with the current technologies but not with the proposed technical packages. Though it is efficient to orient agricultural research to millet and cowpeas, groundnuts, sesame, and rice, the Region of Mopti may not completely benefit from its comparative advantage in these areas because of current market distortions such as the overvalued CFA franc, import taxation and export disincentives.

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[5]The domestic resource cost (DRC) ratio is an efficiency indicator that contrasts the economic cost of the domestic factors used in producing a commodity (i.e. the net costs for primary factors) with the cost of importing the equivalent of those domestic costs from abroad (i.e. the value added for tradables).

5. FSR PROGRAM EVALUATION

The proposed FSR program is evaluated in three steps: (1) determining the extent to which the technical packages developed by FSR would be adopted in the Region of Mopti, (2) evaluating the expected production and income impact of these technical packages, and (3) analyzing the factors that would most likely affect the expected impact.

5.1. The Expected Diffusion Paths

To aggregate farm benefits at the regional level, one important element is the estimation of the expected diffusion paths of the technical packages across the area. The parameters of these expected diffusion paths are estimated on the basis of diffusion paths that have occurred for animal traction in the Region of Mopti. This estimation is carried out in two steps (see appendix C for more details). First, the diffusion paths for animal traction are estimated with an ordinary least-squares (OLS) regression, using a logistic function representing the cumulative growth in the percentage of farmers who have adopted animal traction from 1966 to 1987 in the three agroclimatic zones of the rainfed area.[6] Second, a relationship between the values of the parameters estimated for animal traction's diffusion and factors of adoption is sought to extrapolate the results to the diffusion of the proposed technical packages. Once the parameters of the expected diffusion paths are estimated, the cumulative growth in the percentage of farms that would adopt the proposed packages is converted into area terms, using the field survey's results and National Statistics' estimates of cultivated areas.

5.2. Production Impact

To simplify the use of an economic surplus approach, some assumptions are made about the structure of the regional supply and demand curves.[7] Producers in the Region of Mopti are

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[6]The logistic function has been used to describe diffusion paths of innovations (Rogers 1957; Griliches 1957; Feder, Just, and Zilberman 1982; Thirtle and Ruttan 1986) and to estimate ex-post the return to FSR in Panama (Martinez and Saín 1983). This function is characterized as follows:

$$P(t) = K/[1+e\text{-}(a+bt)]$$

where K is the long-run upper limit on diffusion; the slope 'b' is a measure of the rate of acceptance of the innovation; and the intercept 'a' reflects aggregate adoption at the start of the estimation period and thus positions the curve on the time scale.

[7]The economic-surplus approach estimates returns to investment by measuring the change in consumer and producer surplus arising from a shift to the right in the supply curve due to technological change. In practice, this approach can be implemented using a benefit-cost analysis, as commonly used by international organizations such as the World Bank, UNIDO, USAID. Put simply, benefit-cost analysis of a research program compares the time-valued estimate of the net returns from the innovations generated by the research program as farmers adopt them, with the time-valued costs of the research program. Similar to the economic surplus approach, it estimates an average rate of return to agricultural research in contrast to the production function approach which provides a marginal rate of return by using econometric techniques.

considered "price takers", facing a perfectly elastic demand curve for cereals and oilseeds. It is not expected that FSR would be able to reverse the food situation in the Region of Mopti from net deficit to net surplus for agricultural products such as millet, rice, cowpeas, and groundnuts. Moreover, it is assumed that, in conjunction with the development of sesame production in the area, efforts would be made to integrate local markets for sesame with export markets, so that producers would face a perfectly elastic demand for sesame. Consequently, the evaluation is conducted with fixed output prices.

Supply curves, on the other hand, are highly inelastic in the short run. First, fixed inputs such as land and farm labor are fully employed. Second, the crops included in the economic analysis are those already employing most of the available resources. Consequently, estimated price elasticities of production for rice and millet-sorghum in the short and long run are low for Mali (USDA 1985). In sum, the postulated regional supply-demand structure for crops is one of a perfectly elastic demand curve facing a perfectly inelastic short-run supply curve. Therefore, the change in total economic surplus is roughly equivalent to the change in producer surplus, all the more so because a significant proportion of household cereals production is consumed by the household.

The main incremental net benefits consist of the increased net incomes accruing to farm households as a result of the transfer and adoption of new technical packages developed and tested by the FSR project (see appendix D for the estimation procedure). With a 12% discount rate, the present value (PV) of the incremental farm net benefits amounts to $US 0.94 million while the PV of the FSR project costs amounts to $US 2.80 million. This results in a negative net PV of $US 1.86 million and a low internal rate of return (IRR) of 2%. The economic value of the FSR project is, however, undervalued by this measure because some research areas that the FSR might develop are not included in the economic value of the project. Some possible external effects of the project are not included in the economic value of the project, particularly the reduction of food aid and outmigration from increases in farm income. In sum, the ex-ante evaluation of FSR indicates that if FSR were limited to adapting and transferring new technological components currently available from station research and if it were the only major new public investment in the Region of Mopti, it would have a low return.

5.3. Sensitivity Analysis

Sensitivity analysis is used to rank the major factors affecting the return to FSR. The IRR of the project is very sensitive to variations in project costs, yields, and prices of agricultural products. To a lesser extent, the time taken to complete research, the incremental farm costs, the diffusion parameters, and the life of the innovation also affect the stability of the project's economic value. This implies that the following set of conditions are critical to making FSR profitable: (1) the performance of on-station research in generating improved technological components from which FSR can draw, (2) the performance of the marketing system in reducing marketing margins and seasonal price variations for inputs and outputs, and (3) the conduciveness of the institutional setting to transferring technological innovations. An improvement in only one of these conditions would not likely be sufficient to make FSR profitable.

However, these restrictive conditions for implementing an FSR project do not mean that FSR has no role to play in the Region of Mopti. The economic return provided by the ex-ante evaluation captures the effects of only one FSR function, namely that of diagnosing on-farm problems and adjusting technologies currently available from station research to the particular set of problems faced by farmers. Other important FSR functions excluded from the evaluation are (1) improving the relevance of research efforts through a better conveyance of information about farmers' needs to the research system and (2) informing policy-makers and planners about measures that could generate and transfer improved technologies. Because the production impact of these two important linkage functions also depends on strengthening commodity and disciplinary research and on measures to facilitate the transfer of improved technologies, the impact is evaluated as the result of complementing FSR with additional on-station research and improving the marketing, institutional, and policy environments. The possibility and the potential impact of developing more appropriate technological components at the agricultural station level and improving the marketing system and institutional environment in the Region of Mopti are presented in the next section.

6. INVESTMENTS COMPLEMENTARY TO FSR

The ex-ante evaluation of FSR in the Region of Mopti indicated that if FSR were limited to adapting and transferring new technological components currently available from station research and if it were the only major new public investment in the Region of Mopti, it would have a low return. Hence, it is hypothesized that the FSR project would have a larger economic impact if more appropriate technologies were developed at the agricultural station level and if the market and institutional environment improved.

Three public investments that would complement FSR are analyzed in this section. First, the complementary investments are defined and evaluated individually. Second, scenarios combining the three public investments and FSR are evaluated in terms of their potential economic impact. Third, the best scenarios are identified and ranked.

6.1. Returns to Investments which Complement FSR

The three complementary public investments considered were restricted to those that might directly affect farm productivity, namely investment in additional on-station research (OSR), investment in the extension and credit system, and investment to promote improvements in the marketing of agricultural products and fiscal policy reforms.[8]

Based on the finding that on-station research has been unsuccessful for semi-arid environments without on-farm research components (Matlon 1985), returns to OSR are only estimated when FSR is associated with OSR. To estimate the returns to a joint investment in FSR and additional on-station research, enterprise budgets of the technical packages that FSR could develop are first adjusted to include the new technological components that on-station research, according to interveiws of scientists, could generate in the near future with an incremental investment (in particular millet and deep floating rice varieties). Second, the expected diffusion paths of these new technical packages are adjusted to reflect the change in profitability resulting from the complementary investments, and the other factors affecting adoption. The expected returns to this joint investment are then calculated on the basis of the increased net incomes accruing to farmers as a result of the transfer and adoption of these new technical packages, taking into account the additional research costs and leadtime of on-station research. Joint investment in FSR and additional on-station research yields an IRR of 14%, much higher than the IRR to FSR alone (2%).

To estimate the returns to improvements in extension, input delivery and credit supply, it was assumed that the major benefit of these improvements would be a greater adoption of the technology currently extended with lower input costs and higher yields. First, enterprise budgets of the manual and currently extended technology were modified to include a 10% reduction in input costs due to organizing farmers' associations to contract purchases, a 50% reduction in the

[8]Although this third type of investment involves two separate types of reforms, they are considered together to reduce the number of simulations.

interest rate due to access to formal credit by these farmers' associations, and a 5% increase in yields for the currently extended technology due to extension demonstration.[9] Second, the expected diffusion paths of the currently extended technologies were adjusted to reflect their increased profitability due to the changes in extension, input delivery, and credit supply. Third, the expected returns to these improvements are calculated on the basis of the increased net incomes accruing to farmers as a result of a greater adoption of a less costly and more efficient technology, taking into account the additional extension costs. The additional costs per hectare of improving the extension and credit are evaluated at half the costs of the fairly well developed extension agency for cotton and cereals in Southern Mali, the CMDT.

The returns to improving extension, input delivery and credit supply are lower than the costs of improving the technology transfer system, unless the yield effect due to extension increased to 14%, which is an over-optimistic expectation. Because the expected gains from extending current technologies are low relative to the costs of agricultural extension, investment in extension should be delayed until the research system can generate improved technologies. In contrast, improvements in the input and credit supply functions are likely to yield positive returns.

To estimate the returns to an improvement in the agricultural product marketing system and a reform of fiscal policy, it is assumed that prices received by farmers would increase by 10% and that all taxes, subsidies and duty administrative fees on agricultural inputs and outputs would be removed.[10] First, these changes are incorporated into the enterprise budgets for both the manual and currently extended technologies. Second, the expected diffusion paths of the current technologies are adjusted to reflect the changed profitability of these technologies and the other factors affecting adoption. Third, the expected returns to these improvements are calculated on the basis of the increased net incomes accruing to farmers as a result of a greater adoption of the current technology with lower input costs and higher agricultural product prices.

Promoting improvements in the agricultural product marketing system and fiscal policy results in an IRR of 18%, which is higher than the IRR of 14% reached by the joint investment in FSR and additional on-station research. But, because the joint investment in FSR and additional on-station research yields a net present value (NPV) three times larger with an IRR higher than the opportunity cost of capital, it should receive priority over promoting improvements in the agricultural product marketing system and fiscal policy. The returns to the promotion of these improvements are, however, underestimated since direct and induced effects of these

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[9]Because of the uncertainty in the yield effect due to extension, a sensitivity test is carried out on the yield increase.

[10]Three areas for market improvement are considered to increase prices received by farmers and, thereby, stimulate technology transfer and adoption. First, the elimination of export restrictions and costly licensing procedures as well as the promotion of new agricultural outlets would prevent producer prices from falling precipitously during surplus periods. Second, supporting farmer associations and a market information system would give farmers greater collective bargaining power. Third, encouraging the participation of farmer associations in assembly operations and reducing market uncertainties would lower marketing margins and, hence, increase the prices received by farmers and the quantity traded.

improvements on other areas of the agricultural sector and on other sectors of the regional economy are not considered.

The economic returns from promoting these marketing and fiscal improvements suggest that removing tax-related transfers from the input and output marketing system has a direct economic impact as well as a financial impact. As the financial costs of marketing are reduced by removing transfers, prices received by farmers for their products increase and prices paid by farmers for farm inputs decrease. These changes in market prices stimulate adoption of new technologies, which results in real economic growth. However, because removing such transfers is a one-time measure, the economic growth that it stimulates will tend to diminish unless other types of improvements, such as in the road network and marketing infrastructure, follow. In contrast, investing in agricultural research provides the infrastructure to increase productivity on a long-term basis. Agricultural research has, however, a longer leadtime than removing tax transfers. Which investment should be given priority is further discussed in the next sections.

6.2. Returns to Investment Combinations

Because investment in on-station agricultural research, farming systems research, technology transfer, and promoting marketing and fiscal improvements are expected to have strong interactive effects, scenarios which combine these investments are simulated. Table 2 gives the results of the simulations in terms of the present value: (1) incremental net benefits accruing to the target population, (2) public investment costs, (3) net benefits of the public investments, (4) the IRR of the public investments, (5) the interactive effects, and (6) the incremental rate of return.[11] The scenarios are ranked by increasing project net benefits.

FSR must be associated with additional public investment to be profitable. Among the two-by-two combinations of FSR with another public investment, the combination of FSR with either additional on-station research or improvements in the technology transfer system have similar net benefits. The combination of FSR and marketing and fiscal improvements has lower net benefits. The high returns to combining FSR with other public investments as well as the large interactive effects estimated between FSR and the other investments reinforces the finding that the production impact of FSR depends on the performance of complementary institutions in the agricultural technology system and on the marketing and policy environments.

[11]The interactive effect is first estimated for a combination of two investments according to the simple rule that the interactive effect due to a combination of two investments is equal to the net benefits of the combination of the two investments taken together less the net benefits generated by the two investments taken alone. In the same way, the interactive effects are successively estimated for combinations of three and four investments. It is assumed that the interactions of additional on-station research with improvements in the technology transfer system or with improvements in the marketing system and fiscal policy are nil on the basis that OSR needs to be complemented by FSR to have some impact.

Table 2. Economic Values of the Scenarios

Scenario (a)	Incremental Farm Net Benefit (b)	Public Investment Costs (b)	Project Net Benefits (b)	IRR (%) (c)	Interactive Effects (b)	Incremental Rate of Return	Rank on the B-C Function (e)
FSR	940	2804	-1864	2	NA	dominated (d)	
E&C-P	4423	6246	-1823	NA	-497	dominated	
E&C	2039	3596	-1557	NA	NA	dominated	2
P	1345	1114	231	18	NA	21	1
FSR-P	4365	3918	447	14	2080	dominated	
FSR-OSR	4370	3628	742	14	2606	20	3
FSR-E&C	4743	3860	883	15	4304	61	4
FSR-OSR-E&C	10140	7406	2734	18	-755	dominated	
FSR-E&C-P	11013	5718	5295	24	2598	dominated	6
FSR-OSR-P	10381	4742	5639	22	2586	539	5
FSR-OSR-E&C-P	18773	9433	9340	26	-392	79	7

(a) FSR = Farming Systems Research
E&C = Extension, credit, and input supply
P = Marketing and fiscal policy
OSR = On-station research
(b) Present value in thousands of $US at a 12% discount rate.
(c) IRR is undefined when the annual incremental net benefits are negative every year of the project life.
(d) A scenario is dominated if it incurs higher investment costs but no additional net benefit.
(e) The ranking is based on additional incremental farm net benefits for additional investment costs.
Source: Henry de Frahan 1990, p. 291.

Whether FSR should first be complemented with additional on-station research or with improving the technology transfer system depends on the time preference. When long-term objectives are favored over short-term objectives by selecting a lower discount rate, the returns to joint investment in FSR and additional on-station research are larger than the returns to joint investment in FSR and improvements in the technology transfer system. This suggests that, in the short run, existing constraints in the technology transfer system are more important than the lack of station research results. Without FSR, however, improvements in extension, input supply and credit supply yield a loss.

Among the three-by-three combinations of FSR with other public investments, the combinations that include FSR and improvements in the marketing system and fiscal policy have the highest net benefits. These combinations reveal large interactive effects, suggesting that even if other investments have already been made, there remain large potential gains from improving the marketing system and fiscal policy. The combination that includes additional on-station research in addition to FSR and marketing and fiscal improvements has higher net benefits and IRR than the combination that includes the technology transfer improvements (the IRRs are 22% and 18% respectively). This difference is amplified when preference is given to long-term objectives over short-term objectives.

The scenario combining FSR with additional on-station research, technology transfer improvements, and promoting marketing and fiscal improvements (FSR-OSR-E&C-P) yields the highest net benefits ($ US 9.34 million). When the scenarios are considered mutually exclusive, this scenario is the best investment.

The marginal analysis carried out on the twelve scenarios confirms that the FSR-OSR-E&C-P scenario is the best investment. The incremental rate of return (incremental ROR) is estimated for non-dominated scenarios of incremental cost and reported in table 2.[12] Using an incremental rate of return threshold of 50% to take account of risk, three scenarios are economically attractive: a combination of FSR and improvements in the technology transfer system (a 61% incremental ROR); a combination of FSR, additional on-station research, and promoting marketing and fiscal improvements (a 539% incremental ROR); and a combination of this second scenario and improvements in the technology transfer system (a 79% incremental ROR). Among these three scenarios, the scenario combining all four investments generates the highest net present value together with an acceptable incremental ROR. Therefore, this scenario is considered the best scenario.

Figure 1 shows the relationship between benefit and cost among the eleven scenarios. A frontier benefit-cost function is graphed. It is an envelope curve that includes those scenarios for which additional investment costs generate higher additional farm net benefits when the scenarios are ranked according to increasing investment costs. Seven scenarios meet this criterion and

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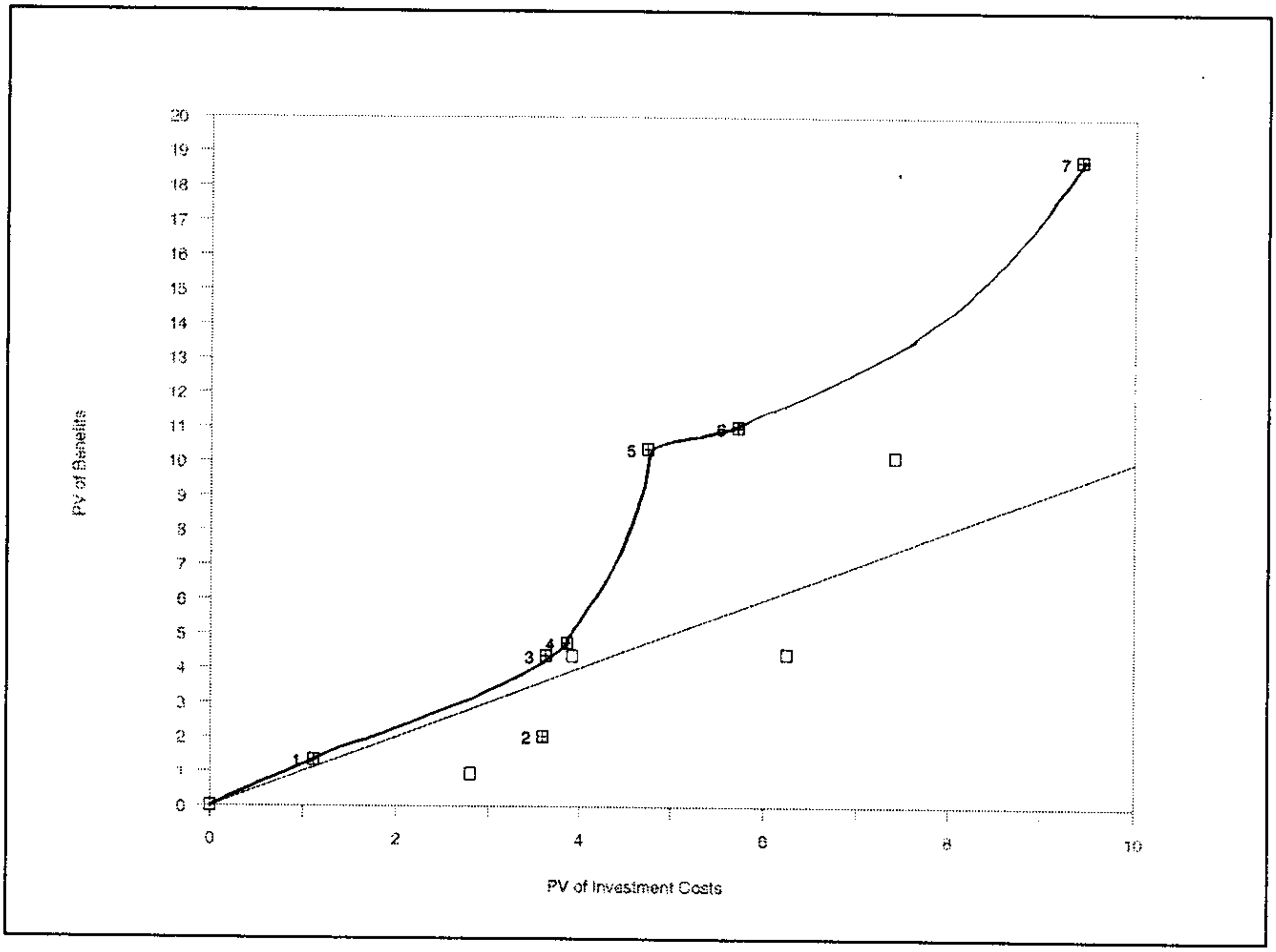
[12]In marginal analysis, any scenario that has net benefits less than or equal to those of a scenario with lower costs is said to be dominated, and therefore eliminated from the marginal analysis. Because the marginal analysis carried out in this section does not refer to infinitesimal incremental changes, the "incremental rate of return" expression is used instead of "marginal rate of return."

Figure 1. Frontier Benefit-Cost Function



Note: Numbers refer to the scenarios listed in table 2.

determine the frontier benefit-cost function. All but one scenario are above a 45° line representing the threshold at which the potential benefits of scenarios just cover the incurred costs at a 12% economic discount rate. Yielding an IRR above 12%, these six scenarios are possible alternative investments.

The scenario combining all four investments is, however, probably not feasible given current human and financial resource limitations in Mali and the political implications of, for example, fiscal reforms. The investment costs of the best scenario are more than three times the costs of the initial FSR project. Human resources for conducting the FSR, additional on-station research, market and policy analysis, and extension called for in this alternative are not currently available. Recurrent costs of these four components exceed the level at which the Government of Mali is able to sustain its contribution. Marketing and fiscal improvements call for a ban of export and import taxes and elimination of export restrictions, which may be politically unacceptable.[13] Under these limitations, second-best scenarios should be considered. Based on these economic returns and interactive effects, the following investment strategy is proposed.

6.3. Best and Second Best Investment Strategies

Assuming that human and financial resources might gradually increase over time, the possibility of staggering public investments should be considered. If improving the functioning of the agricultural product marketing system and reforming fiscal policy is politically acceptable in the short run, these should be the first changes implemented because of their large and immediate impact. Because market conditions would facilitate technology transfer and adoption, investing in FSR would be an advisable second step. The third step in this series would be to invest in additional on-station research to take advantage of the strong complementarity between FSR and commodity and disciplinary research.[14] This third step should be taken as soon as human and financial resources are adequate because of the long leadtimes in research. However, FSR could already begin adaptive research on the results already available from on-station research and the collection of information and data that could improve the relevance of on-station research efforts. The last step in the investment series would be to invest in the technology transfer system. Improving the input and credit supply functions could come earlier in the sequence of investments, but improving the extension function should be delayed until the research system is able to generate improved technologies ready for extension.

If marketing and fiscal improvements are politically unacceptable in the short run, FSR with either additional on-station research or improvements in the technology transfer system should begin the sequence, depending on the time preference of the decision maker.[15] An alternative first step would be to improve the input and credit functions with or without FSR. The second step would be to promote improvements in the marketing system and fiscal policy. Then, depending on the previous investments, additional on-station research or improvement of the technology transfer system could follow. However, it is possible that the improvements in input and credit supply could come earlier in the sequence of investments.

Although the staggering of investments is not simulated, the IRR for the first series of investment is expected to range between 18% and 26%.[16] For the second series of investments, the IRR is

[13]Export taxes were removed in 1990.

[14]The interactive effect between FSR and additional on-station research is three times larger than the additional investment in on-station research. This large interactive effect underscores the importance of associating additional on-station research with FSR.

[15]With the change of government in March 1991, the potential acceptability of such reforms appears to have increased markedly.

[16]Because the flow of the expected benefits will be slower when the four investments are staggered over time than when all four investments are made simultaneously as proposed in the best scenario, the returns to the two series of staggered investments are expected to be lower than those for the best scenario. However, because several

expected to range between 14% and 26%. These expected returns should be confirmed by simulating the staggering of investments. In addition, since there are uncertainties in key variables that are combined in the final rate of return estimate, risk should be assessed for each proposed investment and series of investments by using, for example, a Monte Carlo simulation procedure.

In sum, the major finding of this rate of return analysis is that FSR alone is not the most effective means to increase farm productivity in the Region of Mopti. Improving the functioning of the agricultural marketing system and reforming fiscal policy appear to be the most important pre-conditions for positive and significant returns to FSR. Investments in FSR, additional on-station research and the technology transfer system could then follow sequentially. If these pre-conditions cannot be met in the short term, then an alternative pattern of investments would be first investing simultaneously in FSR and additional on-station research, then promoting improvements in the marketing system and fiscal policy, and lastly strengthening the technology transfer system with the possibility of improving the input and credit supply earlier in the sequence of investments.

These alternative investment strategies have important implications for both the role and organization of agricultural research and extension in Mali and in the Region of Mopti. These implications are examined in the following section.

investments are made over time, these returns are expected to be higher than the returns to the first investment in the series taken alone.

7. IMPLICATIONS FOR THE ROLE AND ORGANIZATION OF AGRICULTURAL RESEARCH AND EXTENSION

7.1. Agricultural Research Strategy in Mali

Results from the ex-ante evaluation are used below to outline a long-term research agenda in the Region of Mopti and to suggest an appropriate method and organization for conducting agricultural research. These issues are particularly important since the Malian agricultural research institute (IER) recently drafted a long-term research plan with the International Service for National Agricultural Research (ISNAR) and is re-structuring its organization.

7.1.1. Long-Term Research Objectives

Long-term agricultural research objectives should be consistent with the major production potentials and constraints of the farming systems. For rainfed agriculture in the Region of Mopti, the agricultural research system should develop technologies that are not highly intensive in purchased inputs, as long as the profitability of purchased inputs is low and variable and input marketing is not improved. These technologies should be designed to increase water retention and soil fertility to improve the agronomic environment of the production systems. For the areas with a more stable environment, plant breeding should develop varieties for moderate management levels, focussing on yield improvement, quality characteristics, and resistance to disease (mildew), insects (*Raghuva*) and weeds (*Striga*). For the more variable areas in the region, plant breeding should continue to emphasize both drought resistance at the critical early and post-flowering phases, and a relatively long growing cycle to avoid the peak swarming period of the boring caterpillars. Plant breeding should, however, de-emphasize programs on short growing season varieties because these varieties are particularly subject to damage from grain-eating birds and insects on the heads. Screening the best performing local varieties for drought, and insect resistance, stable yield and taste is also recommended to provide farmers with a greater diversity of varieties to cope with a variable bioclimatic regime. Other research objectives include (1) adapting mechanized cropping techniques to farm circumstances, (2) improving the integration of crop and livestock activities, (3) developing anti-erosion and agroforestry techniques, (4) diversifying crop enterprises, and (5) developing food processing and storage techniques.

For the flooded agriculture of the Region of Mopti, the research objectives should include (1) developing peak-labor-saving technologies (such as a multiple-purpose agricultural implement adaptable for both lowland and upland cropping operations), (2) screening the best performing local rice varieties grown under natural submersion to improve yields and production stability under traditional or moderate management level, and (3) improving rice varieties grown under controlled submersion to improve yields and production stability under moderate management level rather than high management level. For flood recession agriculture, a diagnostic survey should be carried out to identify the research objectives.

Input from economics and other social-sciences should be incorporated early in the development of these technologies. In addition, the constraints to capital markets, to the production and delivery systems for inputs, and to the agricultural product marketing system should be identified. Means to alleviate these constraints should be investigated. Sources of income from cash crops and food processing should also be examined as part of a strategy to sustain increased agricultural production. Institutional constraints such as those imposed by the rigid enforcement of the forestry code on wood access and by the fiscal regulations on farmers' revenues should also be investigated.

No research objectives are proposed for livestock and fisheries. Resolving tenure conflicts, developing infrastructure for eradicating parasitic diseases and facilities for providing water in the dry areas, and developing market outlets should be given priority over animal research to rehabilitate livestock in the Region of Mopti (Diakité and Kéita 1988). Greater priority in the short run needs to be given to resolving conflicts over the use of water and to developing regulations to guarantee fish replenishment rather than to hydrobiological research. These objectives for agricultural research in the Region of Mopti have important implications for the research methodology and organization of the Malian agricultural research system.

7.1.2. Research Methodology for the Malian Agricultural Research System

Although the Malian agricultural research system is one of the largest systems in terms of research personnel in francophone sub-Saharan Africa, its very limited financial resources prevent researchers from being fully operational. Its estimated 337 person-years of scientists may in fact be reduced to approximately 145 full-time person-years due to limited operating funds (ISNAR 1990). Domestic financial resources are expected to continue to limit agricultural research because, under tight budget restrictions, the government will be unable to increase its total contribution to agricultural research in the near future.[17] Therefore, because of its limited financial resources, the Malian agricultural research system cannot sustain large applied research programs without external funding.

With 145 person-years of full-time scientists, the Malian agricultural research system could meet domestic human resource requirements to perform adaptive research programs effectively. Financial resources in Mali for adaptive research could be increased by reallocating the budget from personnel expenses to operating and equipment expenses. Since June 1987, the government has facilitated the departure of government personnel by giving severance bonuses or advancing the retirement period. The government's savings in research personnel expenditures should be reallocated to operating research budgets to sustain adaptive research.

While concentrating on adaptive research and on-farm tests, the Malian agricultural research system should devote a relatively large share of its limited resources to activities involving external linkages with International Agricultural Research Centers (IARCs), policy-makers, extension services, and farmers, on the one hand, and to domestic research focussed on collection,

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[17]The total 1986 annual research budget supported by the national budget was 0.4 % of the agricultural gross domestic product and 44% of total agricultural research expenditures. The budget covers 90% of the 350 person-years of scientists (10% are expatriate researchers) but only 28% of the recurrent and capital costs (ISNAR 1990).

analysis, and interpretation of data and research results, on the other hand. Some applied research could be conducted domestically on very selective issues critical to development efforts when imported options are not available. One example is a program of varietal improvement by radiation to reduce the shattering of the *Oryza glaberrima* species. Other examples are the INTSORMIL physiology research to understand the critical factors required for drought resistance in sorghum and millet and the TROPSOILS/INTSORMIL soil research to determine the factors causing soil toxicity.[18] This applied research should, however, not divert large human and financial resources from adaptive research.

For most of the applied research, however, the Malian agricultural research system should rely heavily on regional centers, such as the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center and West African Rice Development Agency (WARDA), and on larger national agricultural research centers (NARS) of the same agroclimatic region. In addition to carrying out selected applied research activities, each regional center could be more involved in coordinating applied research in its areas of expertise among the NARSs of the region. A collaborative regional research network could be developed on the basis of the comparative advantage in agricultural research of each individual NARS and have its research activities jointly determined by the NARSs' leaderships and each regional center's director through regular review and planning sessions. These regional centers could play additional roles in strengthening NARSs' scientific and institutional capacity to conduct adaptive research and applied research on selected research areas. Probably with ISNAR, they could provide the training and methodologies required to conduct adaptive and applied research and help design the appropriate research strategy for each individual NARS. These regional centers could also play an active role in mobilizing external funding to complement national programs in their efforts to establish a sustainable research system. The option currently being examined by the Special Program for African Agricultural Research (SPAAR) group of implementing an additional regional center to coordinate agricultural research among the Sahelian countries and to strengthen their scientific and institutional research capacity should be carefully assessed. The coordination function of this additional center may duplicate that of the existing regional centers and place additional administrative burdens on the NARSs' personnel. The existing regional centers are better suited to provide technical support and train researchers in their respective areas of specialization. ISNAR, which has gained experience in assisting developing countries to improve the effectiveness and efficiency of their NARS since 1980, could concentrate its efforts in the Sahelian sub-region on improving communication among the individual NARSs and between the NARSs and the regional centers.

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[18]INTSORMIL (International Sorghum/Millet) and TROPSOIL (Tropical Soils Collaborative Research Program) are two initiatives of the Collaborative Research Support Program (CRSP) developed by the Board for International Food and Agricultural Development (BIFAD), an Advisory Board of the US Agency for International Development.

7.1.3. Agricultural Research Organization of the Malian Agricultural Research System

Because the cost effectiveness of adaptive research largely depends on strong internal and external linkages and on-farm research activities, emphasizing adaptive research has important implications for the organization of the Malian agricultural research system. Currently, this system is inadequately structured to conduct adaptive research. Many studies on the Malian agricultural research system report poor internal communication between biophysical and social disciplines and, to a lesser extent, between commodity/disciplinary and systems research (Coulibaly 1987; Henry de Frahan et al. 1989; Staatz 1989; USAID 1989; ISNAR 1990). Weak external linkages with policy-makers, extension agencies, and farmers are also documented. The recent reorganization of IER has addressed some of these problems.

The simulation results of this study confirm the need to pay more attention to the internal and external linkages to research. First, the strong complementarity between FSR and additional on-station agricultural research calls for removing institutional and training barriers between on-station researchers and FSR practitioners. Second, the strong complementarity between marketing improvements and policy reform, on the one hand, and agricultural research, on the other hand, confirms the need to incorporate economics and other social-science input into the agricultural research process. Third, the strong complementarity between improvements in the technology transfer system and agricultural research calls for strengthening linkages between the regional development agencies that handle extension, input marketing and credit, and agricultural research.

Several proposals for restructuring research to foster effective linkages internal and external to the agricultural research system have been suggested in Mali. One, which is currently being implemented, involves decentralizing agricultural research by reinforcing or creating research centers that serve homogeneous agroecological zones (ISNAR 1990, pp. 87-88). These regional research centers will conduct multidisciplinary research programs, concentrating on a few important commodities in their immediate agroecological zone and receiving national responsibilities for their commodities. Such decentralization will likely result in greater interaction of researchers with both extension staff and farmers and in reduction of the risk that on-farm programs evolve independently from on-station agricultural research programs.

To foster greater interaction between biological and social scientists within the research institutions, each regional research center could add one economist or social scientist to the commodity and disciplinary technical scientist team (Staatz 1989, p. 19). The economists or social scientists would specialize along commodity lines and be responsible for investigating selected issues in the commodity subsector, from production to processing and marketing. This appointment would create formal and informal opportunities for technical and social scientists to interact with one another and respond to the need to incorporate economics and other social-science input into the agricultural research process, particularly earlier in the design of the technologies themselves. The head of the regional centers would coordinate the research activities between technical scientists and social scientists.

Other economists and social scientists would specialize on issues that cut across subsectors, such as production and delivery of agricultural inputs, agricultural credit, land tenure, and price and trade policy. This team would be based in Bamako and be responsible for contacts with policy-makers and external institutions, such as the International Agricultural Research Centers (IARCs) and donors. Coordination of the research efforts between these two groups of social scientists would need to be strong and facilitated by adequate travel funds. The head of the Bamako-based social scientist team would primarily be in charge of this coordination. In addition, he or she would regularly consult the Bamako-based technical scientists to strengthen coordination between biological and social sciences.

Like in Senegal, FSR units could be placed at the regional research centers, where the bulk of commodity and disciplinary researchers would be located. Because they would be located at the same site, on-station research and FSR could be coordinated by the head of the regional center and, hence, benefit from close linkages. For example, joint field visits between the farming systems and commodity or disciplinary researchers become easier to organize, providing commodity or disciplinary researchers with direct and regular contact with farmers. FSR's ability to channel relevant information from farmers' points of views to station-based research priority-setting would improve.

In sum, the decentralization of research activities across the country in several regional research centers would facilitate effective linkages between research and development institutions, between on-station research and FSR, and between technical and social scientists. The regional research centers would include (1) technical scientists specialized along commodity or disciplinary areas, (2) social scientists specialized along commodity lines, and (3) FSR practitioners specialized in problem solving research. In Bamako, the social scientists would specialize in issues that cut across commodity subsectors and the technical scientists would support and coordinate the biophysical research activities carried out in the research centers. The two Bamako-based teams would be responsible for the contacts with the other national research institutions, educational institutions, the government (Ministry of Agriculture, Ministry of Planning, Ministry of Finance and Trade, Ministry of Education, etc.), the IARCs, and with donors. The heads of each Bamako-based team would be responsible for coordinating research activities within their own team and between the regional center-based scientists and the Bamako-based scientists. Interdisciplinary interactions would, therefore, be stimulated at the regional center level and at the national center level.

7.2. Integrating FSR into the Research Process

To ensure effective linkages between on-station researchers and FSR practitioners, the research organization suggested above would place the FSR units at the regional research centers, where the bulk of commodity and disciplinary researchers would be located. However, by separating the FSR team from the commodity and disciplinary team, there is still the danger of poor linkages between them, even when both are at the same research site. In addition, implementing this type of organization for each agroecological zone is probably not feasible in the short term in Mali given the financial and human limitations of the research system.

A possible solution to this problem is the integration of a farming systems perspective into the traditional discipline-oriented and commodity-based research programs. All scientists of the regional research center could carry out both on-station and on-farm research related to the center's commodity or specialization. In particular, agronomists could take on most of the on-farm and technology transfer responsibilities. Social scientists could reinforce the research programs. In addition to operating at the farmer level, they would examine the marketing issues elsewhere in the subsector if no other institutional arrangement is set up. This way of integrating a farming system perspective into the research programs reduces the risk of compartmentalization of research and fosters more direct and rapid communication between research and extension (Stoop 1988). For example, this organization would facilitate the feedback function, which channels relevant information to station-based research priority-setting, and this feedback increases effective farmer participation in the research process. As a result, research efforts are better coordinated vertically, from farmers' needs to the research station. This option requires little institutional change or management reorganization, but a change in the incentive structure facing researchers.

Given the current limited human and financial resources of the Malian agricultural research system, the integration of a farming systems perspective into the traditional research programs is appealing, at least as a short-run solution. Several disadvantages to this option, however, suggest that a separate FSR unit closely linked to the commodity and disciplinary team is probably better in the long run (Collinson 1986). The pre-determined focus of the team members into commodity or discipline inhibits the introduction of a systems perspective. Therefore, this option might not help prioritization efforts across commodities and disciplines, a major contribution from a full systems perspective. Horizontal coordination across farmers' problems, commodities, or disciplines is hardly possible in the traditional organization. The team members' primary concern with a commodity or discipline is incompatible with an area-oriented extension organization and, hence, may hinder the development of linkages with extension. Lastly, a single team of researchers is unlikely to overcome effectively the complexity of an adaptive research program. An adaptive research program basically involves two broad sets of research activities that require different research skills. For example, the development of improved varieties requires, on the one hand, disciplinary or commodity researchers to concentrate their research activities on identifying promising local varieties, searching other varieties that can be transferred from other areas with little adaptation, adapting these materials to the local farm circumstances and executing collaborative programs with other research institutions. On the other hand, adaptive research requires subject-matter researchers (such as agricultural economists and agronomists) to concentrate their research activities on collecting, analyzing, and interpreting socioeconomic and agricultural production data and research results with a view to guiding the screening process, assessing the potential performance of the newly developed varieties, and providing feedback to the commodity researchers.

In addition to the need to generate appropriate new technologies for farmers, the ex-ante evaluation indicated the need to improve the agricultural marketing system and reform fiscal policy. In that area, research topics specific to the Region of Mopti could include (1) the comparative advantage of the region in processing raw products for new markets, (2) the domestic market outlets for raw products produced in the region (millet, rice, cowpeas, groundnuts) and export possibilities for sesame, (3) the appropriate measures to reduce marketing margins in the region, (4) the type of support that farmer associations need to manage marketable surplus, negotiate input purchases, and manage formal credit programs, and (5) the incentives to stimulate the production and delivery of animal traction equipment, pesticides, and other inputs. Land tenure as well as herding, fishing, and water drawing rights in the Delta area of the region could be an additional research area.

Social scientists based at the proposed regional research center of Mopti could conduct research on these issues. In case research decentralization is delayed, an independent study on market improvements and policy reforms for the Region of Mopti could be very useful in light of the high economic returns to improvements in the agricultural marketing system and fiscal policy found by this study. Because a close association between the researchers of the proposed study and the policy-makers would facilitate the communication of the recommendations for market improvement and policy reforms, the Department of Agricultural Planning and Rural Economy (DPAER) of IER is probably the right choice to house the study. The DPAER has frequent and direct contact with the Ministry of Planning and the Food Strategy Commission (CESA). To facilitate the field work and close contacts with the different regional institutions, the members of the study could work closely with the regional Office of the Ministry of Planning in Mopti. This regional Office is a member of the Regional Committee for Development (CRD), where regional development policy is regularly discussed under the chairmanship of the Governor of the region. With the new democratically elected government of Mali, which took power in 1992, the government decision making in the country tends to be decentralized.

Another alternative would be to include an agricultural economist with experience in these broader policy and marketing issues in the FSR team. This agricultural economist would be primarily responsible for identifying marketing outlets for raw and processed products, constraints to rural financial market development, and constraints to production and delivery systems for inputs. Within the FSR team, a second agricultural economist would specialize in farm management and be responsible for identifying production constraints at the farm level and evaluating promising technologies. The FSR project would need two agronomists, one specialized in the agronomy of semi-arid rainfed crops and the other specialized in flood irrigation (natural and controlled) and recessional cultivation. The project would also need a livestock specialist to integrate crop and livestock activities and a sociologist to study the possibility of grouping farmers in village associations. In the long run, the skills of the FSR team members will probably need to include experience in transhumant herding and fishing once the tenure conflicts are solved in these areas.

7.3. Ranking the Technology Transfer Functions

Since 1988, the Ministry of Agriculture, with World Bank support, has been conducting a program to test and improve extension methods. These extension methods follow the organizational and pedagogic principles of the training and visit (T & V) approach. Extension by training and visit assumes that technology is available for farmers and that the critical constraining factor is the organization of clear extension messages and methods for delivering them. As a result, the extension workers exclusively concentrate on advice and promotional work related to agricultural production and are not involved in other activities that would distract them from their extension tasks (Benor and Harrison 1977).

In Mali, a pilot extension program started in 1988 with three ODRs, including ORM, and expanded in 1989 to include an additional ODR and three Regional Directions of Agriculture (DRA), including the DRA of Mopti, in 1989. The ODRs participating in the pilot program, however, continue to be involved in the organization and supply of farm inputs (including credit) and the marketing of produce, while the DRAs, due to insufficient operating funds, are only involved in extension work and collection of agricultural statistics. Given the difficulties of obtaining farm inputs and formal credit in the area covered by the DRA of Mopti and the lack of improved technologies ready for extension for both the areas covered by ORM and the DRA of Mopti, the benefit of strengthening extension is questionable.

Moreover, in a situation of static technology, extension cannot achieve significant production gains by training farmers to make better use of their available resources because, as Schultz (1964) argues, farmers are likely to use already their available resources in an efficient manner. The constraints to increased productivity are likely to be reduced or removed only if there are technological breakthroughs, if farmers' resource base can be expanded through, for example, credit availability or new market opportunities, or if both occur. Based on the findings of this study and preliminary reports of the pilot extension program, intensifying extension through a T & V system is premature in the Region of Mopti. In addition to technology development, access to farm inputs and formal credit should be given priority over extension.

7.3.1. Priority among the Technology Transfer Functions

For the rainfed area of the Region of Mopti, the production and delivery of inputs and the supply of agricultural credit are currently the most poorly performed technology transfer functions. For example, farmers surveyed reported that the lack of quality equipment and formal agricultural credit prevent them from adopting animal traction. The lack of information and training to use the available technologies efficiently was never mentioned. Even though training farmers to use available technologies could improve efficiency, the gain in efficiency would need to be relatively large to cover the costs of extension. In the case of animal traction, the major innovation for the rainfed agriculture in the Region of Mopti, the simulation results showed that extension must increase yields by 14% to offset its costs. Given farmers' existing resource constraints, such an impact on yields is unlikely. Although further research should study the productivity disparity among farmers and how to narrow it through technical advice, the information and teaching functions of technology transfer should probably not be given top priority at this time. In contrast, the availability of farm inputs and formal credit are essential ingredients for effective technology transfer. For example, advice given in the rainfed area on plowing, manuring, planting, thinning, and weeding fail to take into account farmers' difficulties in obtaining and investing in equipment and draft animals, their labor constraints and objectives to minimize risk. Ineffective organization of stable-yielding seed production and distribution in the rice area means that farmers cannot secure a minimum level of production during dry or low flooding years. Information on market opportunities for both producers and traders is another critical service that should be encouraged.

Furthermore, the current lack of improved technology to extend to farmers supports the view that focussing extension on offering technical advice to farmers for crop improvement is premature. Apart from the technologies already known by farmers, such as animal traction, fungicide, improved varieties, and some cultural practices, the agricultural research system in the region has no newly improved technology to offer that is appropriate for farmers of either the rainfed or the flooded areas. The simulation confirmed that improving the quality and relevance of agricultural research is a prerequisite for extension work on crop improvement.

The T & V approach in the Region of Mopti is not currently feasible for two additional reasons. First, in marginal, dryland farming areas where many farmers are primarily concerned with subsistence crops and where labor and soil fertility may vary greatly from farm to farm, it is critical that extension agents be trained in giving farm management advice rather than conveying technical information. The development of such skills implies a large investment in training that is probably more costly than the farm benefits that we might expect given the current state of technology. Second, the recurrent costs of supporting a highly intensified extension agency - one extension agent for 400 farmers - are certainly beyond a sustainable threshold for the government of Mali, particularly in areas where the market for cash crops is limited. Although the T & V approach can be instrumental in improving extension staff performance and in refocussing the attention on agricultural production extension, it is not currently appropriate for the Region of Mopti.

7.3.2. Organization of the Technology Transfer Functions

The organization of the supply of farm inputs and formal credit should receive priority over extension in the Region of Mopti. This section proposes some general principles to organize the supply of farm inputs and formal credit, and concludes with some recommendations to organize extension.

The distribution and supervision of farm credit should be removed from the duties of the extension agents of the ODRs and standardized under the same system. The involvement of the extension agents of the ODRs in filling out loan applications and collecting debts in addition to their training responsibility has the disadvantage of diluting their extension tasks and confusing the farmers about the precise role of the extension agents, who can be mistaken for debt collectors instead of agricultural advisors. Therefore, giving the responsibility for all credit distribution to the Cooperative Organization, DNACOOP, would be more consistent with its mandate. The Cooperative Organization also has a long experience in organizing producers in village associations. These village associations could play an important role in extending formal credit and assuring access to inputs for small households through a system of collective guarantee (Dioné 1989, p. 361). In the longer run, these local associations could help mobilize local savings as well as provide credit, improving the functioning of rural financial markets.

In addition to the collective management of agricultural loans, these village associations could also negotiate farm input purchases and manage their marketable surplus. The participation of village associations in the collection of agricultural products and distribution of farm inputs would increase the volume of individual market transactions, thereby providing some economies of scale. This, in turn, would facilitate a greater participation of the private sector in agriculture provided that the ODRs gradually discontinue the provision of farm inputs and the commercialization of farm production, on the one hand, and the government eases trade regulations and taxation, on the other hand. Following the example of the *Office du Niger*, the private sector could progressively handle the distribution of farm equipment and chemicals and the processing and marketing of rice. Seed production and delivery, however, would still require the intervention of the ODRs.

The emergence of village associations and the greater involvement of the private sector in agricultural and financial markets will be particularly critical when newly improved technologies become available from the agricultural research system and ready for diffusion since these technologies will require additional resources such as seeds for the new varieties, fertilizers, pesticides, and farm equipment. At that time, the extension agency may need to expand, reorganize, or upgrade through training to communicate to farmers about the recommended improved technologies. In addition to providing technical advisory services for agricultural production, the extension agency may also need to provide market information to farmers and traders and to communicate farmers' problems back to the agricultural research and policy-making systems. The simulation exercise indicated that these extension functions are highly complementary to research. Therefore, a broader approach to the problem of technology transfer to increase agricultural productivity would probably be better than an extension program that is a-priori restricted to crop improvement alone. A systems approach allows more flexibility in strengthening a given aspect of the transfer system, be it extension, input supply, credit, or marketing.

The contact farmer/farmer group approach promoted by the T & V system is likely to exclude other farmers from advice and services and result in poor technology transfer and increased inequity among farmers (Howell 1982, p. 10). Instead, the "target group strategy", which aims at organizing the rural population into groups by taking into account the diversity among farmers (i.e. gender, degree of mechanization, access to land, capital, and labor) would fit into the network of village associations that are eventually involved in input purchases, credit and marketing (Stoop 1988, p. 24).

To take maximum advantage of the complementarity that exists between research and extension, mechanisms of different types exist (SPAAR 1987; Ewell 1989; Stoop 1988). At the organizational level, a research-extension coordinating unit could be created within the research and extension institutions and filled by liaison officers. Joint planning committees could regularly meet at national and regional levels. They could also include representatives from the public administration and the farmers' community and those responsible for input and credit supply and marketing to enhance the coordination of the different functions of the technology transfer system. At the program level, the participation of the extension personnel in the early stages of and throughout an on-farm research effort will be more effective than trying to establish linkages for technology dissemination later. Early participation allows extension to contribute to the planning of research and hence increases the likelihood that research will be relevant to farmers' needs. Consequently, structures and procedures for technology transfer will be already in place when they are needed. Upgrading extension through better education and training and more joint appointments with research are advisable, too.

Even with a stronger linkage between extension and research and with improved input distribution and marketing systems, the impact of extension will still be limited in the Region of Mopti. The complexity of the farming systems, the riskiness of the physical environment, the poorly developed infrastructure, the dispersion and inaccessibility of villages, the shortage of trained personnel, and a lack of a profitable and well-developed cash commodity are all factors that will continue to hamper extension efforts.

7.4. Implications for the Organization of Agricultural Research and Extension in Africa

For countries like Mali, with limited human and financial resources, the most cost-effective research strategy is to invest in adaptive research and rely on regional centers and larger foreign NARSs for most basic and applied research. For these countries the Mali case study shows that the NARSs of these countries should be structured to facilitate (1) internal communication between disciplines; (2) external communication with policy-makers, extension agencies, and farmers; (3) coordination with regional centers and other NARSs; and (4) on-farm research activities. Decentralizing the agricultural research activities of these countries by establishing or reinforcing research centers for each of the major agroecological zones of the country would be one method of organizing research to use scarce resources better.

In addition, a form of research organization that facilitates internal and external communication and promotes on-farm activities could yield large benefits. Activities within research institutions (e.g. on-station research and on-farm research), and between these institutions and institutions external to the research system (e.g. extension, input delivery, formal credit, government) would be better coordinated. The Mali case study demonstrates that the degree of synergism among concerted actions is higher than among poorly concerted actions.

FSR provides a useful framework for adaptive research because it is specifically designed to link the problems of production systems to on-station research and other institutions. The more variable and complex the farming systems, the greater the potential contribution of FSR in terms of research prioritization and appropriate technology development. Two organizational issues that must fit the specific circumstances of the country are the manner in which FSR is incorporated in the national research system and the composition of the FSR team. Where human and financial resources are limited and/or where there is strong internal resistance to re-organizing the national research system, integrating a farming system perspective into the traditional disciplinary or commodity-oriented research programs is one option. However, integrating FSR in this way is likely to lead to several problems: (1) horizontally examining farmers' problems, (2) communicating research results to extension agents, and (3) recruiting researchers that are skilled in both on-farm and on-station research. Therefore, this form of integration probably needs to evolve into a separate FSR unit within the national agricultural research system as resources for research are made available. The skills of the FSR team members must reflect the research priorities identified for FSR. These research priorities and skills should be identified during the FSR feasibility study.

Before investing in extension, it is important to identify carefully the constraints to technology transfer. In many cases, the inappropriateness of recommended technologies to farm circumstances rather than the lack of technical advice is the main reason adoption is slow. The low profitability and high yield variability of the recommended technologies, uncertain access to the recommended inputs, and shortages in labor or capital are all factors that may inhibit technical change. In these cases, strengthening extension is inappropriate since the relevant problems go beyond merely the communication of technical advice. Extension agents can do more than convey technical information to increase farm production; they can also (1) help farmers interpret market information from an eventual national marketing information system and make short-term forecasts, (2) help develop and promote possible income-generating activities, such as crop processing and handicrafts, (3) guide farmers in the allocation of their resources among different farm enterprises, and (4) help organize farmer associations for bulk purchasing of inputs to become eligible for formal credit and to market their agricultural surplus more efficiently. In order to promote these roles for extension, however, extension agents must be specifically trained in giving farm management advice.

8. CONCLUSIONS ABOUT CONDUCTING EX-ANTE EVALUATIONS OF AGRICULTURAL RESEARCH

8.1. Using Ex-ante Evaluations for Strategic Resource Allocation between Agricultural Research and Complementary Investments: Potential and Limits

In contrast to an ex-post evaluation, an ex-ante evaluation of an agricultural research program must try to predict advances in technology, forecast market conditions, and determine potential institutional support for technology transfer. Because these predictions are subject to large estimation errors, the estimated value of any rate of return to agricultural research is highly uncertain. Therefore, the most useful information to come out of an ex-ante evaluation is, by far, a better understanding of the factors that affect the return to research rather than the rate of return figures themselves. Ranking these factors according to their impact on the return to research allows decision-makers to determine the most important constraints to the return to research. Furthermore, simulating improvements in the institutional or policy environment shows to what extent benefits from research depend on these improvements and, consequently, indicates which actions ought to be taken to complement investment in agricultural research. These simulations are also used to estimate incremental rates of return and interactive effects between different types of investment. The incremental rate of return reflects the additional net gains earned by the incremental investment costs. The interactive effect reflects the strength of complementarity between investments and, hence, to what extent investments ought to be considered together. As a result, an ex-ante evaluation of a research program can guide the strategic allocation of resources between agricultural research and complementary investments. For countries where institutions and infrastructure are particularly weak, using ex-ante evaluations for this purpose is much more relevant and useful than limiting the evaluations to a quest for a rate of return figure.

In ex-ante evaluations of investment in agricultural research, the most important stage is to identify the research program that will most effectively relieve the constraints faced by the target groups. Most of the parameters of the economic analysis are derived from the identification of the research program. For example, giving research priority to rainfed crops over rice or livestock has the most dramatic impact on the return to the research program. In contrast to ex-post evaluations where the research program is known, this stage in ex-ante evaluations requires in-depth knowledge of the constraints faced by the target groups and of how these constraints might be relaxed. Because such an investigation calls for extensive interaction with target groups, researchers, extension agents, traders, policy-makers, and others and for the diagnosis of complex situations, this stage of the evaluation requires a multi-disciplinary approach and is particularly time-consuming.

In ex-ante evaluations, the parameters of the diffusion paths of the technologies that the research program is expected to develop are the most uncertain. While these parameters can be estimated relatively easily with a field survey in an ex-post evaluation, the estimation of these parameters in an ex-ante evaluation is subject to a large degree of subjectivity. Because the parameters of diffusion paths depend on many uncertain variables (input and output price level and variability, yield level and variability, input and credit access, extension, etc.), these parameters are in turn increasingly uncertain. Obtaining an accurate estimation of these parameters is, however, less critical to the benefit-cost analysis in cases where sensitivity analysis reveals that economic results are not very sensitive to these parameters, as in this study. Otherwise, one solution to the problem of uncertainty is to disaggregate the parameters of diffusion into their major uncertain components and identify the probability distributions for these components. If these probability distributions and the correlations among them can be estimated, the problem then becomes how to estimate the appropriate relationship between the parameters of diffusion and their components. Historical data on technology diffusion are helpful in estimating this relationship, but a great degree of uncertainty remains, as future conditions of technology diffusion may be quite different from past conditions. Sensitivity analysis can be used to handle the problem, and in some instances, when the preceding methods are not possible, it is the only method available to deal with uncertainty and subjectivity.

In the semi-arid areas, such as the Region of Mopti in Mali, output prices and yield levels may be uncertain for a given year but their range of variability can be fairly well estimated from historical records (price variability from secondary data and yield variability from on-station and on-farm trials). Based on past research programs, leadtimes for agricultural research and research costs are probably the least uncertain variables of an ex-ante evaluation.

In most cases, ex-ante evaluations of investment in agricultural research must begin by identifying (1) the target groups' production constraints (and eventually the constraints to processing and marketing), (2) the proper research program, (3) the expected outputs of this program, (4) the expected diffusion paths, and (5) the expected effects (at the farm level and at higher levels) before proceeding to the economic analysis per se. As a result, comprehensive ex-ante evaluations require more skill, time, and data than ex-post evaluations. However, they are only feasible for a specific research program (such as FSR in one particular area), not for large research programs that include many different commodities for diverse agroclimatic areas.

8.2. Recommendations for Conducting Ex-ante Evaluations of Agricultural Research Programs

8.2.1. For an FSR Program

This study demonstrates the need to estimate carefully the potential production impact of FSR and to identify the conditions necessary for FSR to succeed. The limited number of successes FSR has had in increasing productivity for resource-poor farmers underscores this need (Tripp et al. 1990). If the rapid prospective economic analysis reported in the USAID project paper (1985, Annex C) had led to an expansion of the FSR program to the Region of Mopti, the results of this study indicate that the decision would have been wrong. The analysis in the project paper assumed that (1) the extension services deliver the information about the technologies to an adequate number of farmers, (2) that inputs are available and the terms of trade between inputs and products are favorable, and (3) that product markets are not completely inelastic or shrinking. Based on these optimistic assumptions, the prospective analysis shows that the costs of the FSR program could be covered by the gains resulting from the introduction of new technologies with reasonable adoption rates and yield increases (ibid., C-4).[19] Yet, this study indicates that the first two critical assumptions do not hold true in the Region of Mopti and that, consequently, the project would have a low rate of return. Therefore, evaluators should not overlook the institutional and economic environments in which an agricultural research program will be implemented. Because time and financial resources are, however, generally limited for carrying out in-depth feasibility studies, this section reviews the important questions to address in rapid ex-ante evaluations of the potential returns to research.

The first question to address in the evaluation process is whether the lack of an FSR approach in the national agricultural research system actually constitutes the binding constraint to increased farm productivity. Starting the feasibility study with this question facilitates the investigation of alternative solutions to farmers' problems. For example, changes in the policy environment, or improvements in the marketing system or in the financial market may yield higher payoffs than investment in FSR. To address this question the evaluators must carefully investigate the production, processing, and marketing constraints of the farming system. In addition to reconnaissance surveys, interviews with researchers, extension agents, civil administrators, and policy-makers are all helpful sources of information to identify these constraints. These informants can also provide information as to the factors that have affected the adoption of previous technologies in the project area to help specify these constraints. The evaluators can also use these interviews to explore the potential ways of relaxing these constraints. If an informant cites stimulation of agricultural research to develop improved technologies as a major solution, the evaluators can ask him or her to outline an agricultural research program that would contribute to removing farm constraints. The informant's outline of the research program also gives the evaluators an idea of which functions of the agricultural research system need to be strengthened and, consequently, how relevant an FSR approach would be to the resolution of the situation.

After the constraints at farm level and at higher levels (i.e. village, region, country) and the need for an FSR approach are identified, the next critical step is to draft a research program for FSR. The elaboration and the peer review of the FSR program are the most intensive activities of the field work. Although the evaluation criteria approach suggested by Norton et al. (1989) for the Gambia were designed to set research priorities for an entire NARS, this approach is helpful for ranking FSR priorities in terms of commodities and research areas. The research program is then designed according to the identified constraints, the relative importance of the research functions of FSR, the technological components available to date or in the near future at the experiment station level, and the available human and financial resources. The first two elements frame the objectives of the study, while the last two elements determine how realistically these objectives can be pursued.

To speed up the identification process of the research program for FSR, the evaluators can rely on the views expressed by the informants in the previous stage of the evaluation process. It is,

[19]For the Region of Mopti, yield increases would have to be around 2% per year on about 25% of the cultivated millet land from project year 8 to year 20 in order to provide a net benefit in excess of project costs, discounting the net benefit at 10% (USAID 1985, C-4).

however, likely that a second round of interviews will be necessary to specify the FSR program as well as the expected outputs of the program. Sub-contracting some components of the program identification, as was done for this study, saves time and also bring into the identification process expertise that may be lacking among members of the original evaluation team. Researchers and research administrators can estimate the expenditures, research staff, and leadtime that are necessary to accomplish a specific on-station research activity. In turn, this information can be used to indicate when the technological components will be available to FSR. Ex-post evaluations of similar FSR projects in the country or in neighboring countries are also sources of information for estimating the research budget, staff, and leadtime of the FSR program. Historical data on adoption of previous technologies in the project area can indicate the likely diffusion paths of the technologies that the FSR program will develop.

The usefulness of a formal survey, in addition to a reconnaissance survey, in contributing additional information for designing an FSR program and evaluating its potential production impact is questionable. In this study the formal survey confirmed some of the findings of the reconnaissance survey, particularly those related to the organizations of the farming systems and the identification of production constraints. The formal survey also permitted to the quantification of many farm parameters. In retrospect, however, the formal survey would have been more useful had it been planned later in the evaluation process and had it focussed on verifying the validity of the FSR program components rather than the production constraints. Some parameters were missing for a proper analysis of some of the FSR program components both in financial and economic terms and these parameters could have been estimated with a formal survey conducted later in the study. In addition, the questionnaires should have included more specific questions on factors affecting the adoption of available technologies (e.g. animal traction and fungicide) and on input and output marketing. Since formal surveys are expensive and time-consuming, evaluators faced with the decision to conduct a formal survey in addition to a reconnaissance survey should, therefore, consider (1) the types of new information they want to collect in addition to the information already collected by the reconnaissance survey and (2) the proper timing of the formal survey within the evaluation process. Although there is some pressure within the research community to conduct a formal survey to add credibility, rigor and systematization to the evaluation process, a formal survey should be more than a validation or verification exercise because of its relatively high costs. A formal survey cannot replace a well-conducted reconnaissance survey which puts evaluators in direct contact with farmers.

Evaluators should not underestimate the data required to identify the areas in which investment in research would improve the comparative advantage of the region and to estimate the project's worth. Fortunately, secondary data on the shadow exchange rate, taxes and subsidies on goods, traded and non-traded components of goods, opportunity costs of labor and capital, and marketing costs are often available and, hence, facilitate these economic analyses.

An estimate of the FSR project's worth is likely to be incomplete for those responsible for deciding whether to invest in FSR. If the rate of return to FSR is low and unstable, these decision-makers will want to consider alternative investments or the additional investments which must accompany FSR. If the rate of return is attractive and stable, decision-makers will want to know the best institutional setting for FSR and related institutions (e.g. on-station research, extension, input, and credit supply). Since donors and policy-makers are increasingly concerned about the sustainability of new institutions, evaluators should address this concern explicitly in the evaluation process.

8.2.2. For a Research Program in General

The same recommendations for ex-ante evaluations of FSR apply to adaptive and applied research programs. However, the less applied and the more basic the research program, the less clear are the potential effects of the program at the farm level. Again, the most important issue to address throughout the evaluation process is to what extent investing in agricultural research will solve farmers' problems and what the investments needed to complement agricultural research are. The identification of a research program using informal surveys, secondary data, and an evaluation criteria approach is also a critical step in the evaluation.

To reduce the time needed for the financial and risk analyses of the technologies that the research program is expected to develop and the economic analysis of the research program, only the most promising technologies and agroclimatic areas can be selected to estimate the economic value of the research program. This selection can be made using expert opinions. Information about the diffusion of previous technologies can then be used to estimate the expected diffusion paths of these technologies. Because these shortcuts reduce the reliability of the estimated economic value of the research program, sensitivity analysis can be used to provide a range of possible economic values rather than a point estimate. As with the more detailed and comprehensive ex-ante evaluations, the most useful information from this quicker analysis is the ranking of the factors affecting the stability of the economic value of the research program rather than the numerical estimates of the economic value itself. A careful interpretation of the sensitivity analysis can substitute for the simulation of alternative market, institutional and policy conditions. However, in this case, only cautious non-quantitative judgments about the impact of improving these conditions can be made.

APPENDIX A

TECHNOLOGY EVALUATION

Table 3. Marginal Analysis of the Technical Packages for Farms in the Northern Zone (Financial Analysis)

TECHNICAL PACKAGE (1)	Net Income (CFAF)	Total Cost (CFAF)	Marginal Net Income (CFAF)	Marginal Cost (CFAF)	MRR (%) (2)	Average Rate of Return % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	30739	20226	6256	6483	96	60
Improved M-C cropping pattern	24484	13743	1616	6118	26	42
M-C interc. transitional practice	22867	7624	3602	6389	56	56
M-C intercropping manual practice	19265	1235				
2nd year of M-M-M trans. practice	15626	7079	1321	6384	21	21
2nd year of M-M-M manual practice	14305	695				
Improved sesame cultivation	8238	10503	dominated (5)			
B) MECHANIZED FARM:						(4)
Improved M-C intercropping	21283	20226	5600	6483	86	54
Improved M-C cropping pattern	15683	13743	1152	6124	19	19
M-C interc. transitional practice	14531	7619				
2nd year of M-M-M trans. practice	9421	7079	dominated (5)			
Improved sesame cultivation	1387	10503				

(1) M-C: Millet-Cowpea.
M-M-M: Millet-Millet-Millet rotation.
Transitional practice: Mechanized practice with no other external inputs.
Manual practice: Non-mechanized practice with no external inputs.
(2) From preceding to following, e.g. from manual to transitional practice or from transitional to improved practice.
(3) From manual practice.
(4) From transitional practice.
(5) A technical package is dominated if it incurs higher costs but no additional net income.
Source: Henry de Frahan 1990, p. 205.

Table 4. Marginal Analysis of the Technical Packages for Farms in the Center and Plateau Zone (Financial Analysis)

TECHNICAL PACKAGE (1)	Net Income (CFAF)	Total Cost (CFAF)	Marginal Net Income (CFAF)	Marginal Cost (CFAF)	MRR (%) (2)	Average Rate of Return % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	40560	26538	9466	18112	52	58
M-C interc. transitional practice	31094	8426	5231	7289	72	72
Improved M-C cropping pattern	29673	19042	dominated (5)			
M-C intercropping manual practice	25863	1137				
Improved G-M-G rotation with TRP	23308	18924	7582	4849	156	48
Improved G-M-G rotation w/o TRP	15726	14075	1092	6122	18	9
M-M-M rotation transitional practice	14634	7952	91	7295	1	1
M-M-M rotation manual practice	14543	657				
Improved sesame cultivation	19483	13896	3573	5944	60	31
2nd year of M-M-M trans. practice	15910	7952	567	7295	8	
2nd year of M-M-M manual practice	15343	657				
B) MECHANIZED FARM:						(4)
Improved M-C intercropping	27916	26538	7398	18105	41	41
M-C interc. transitional practice	20518	8432				
Improved M-C cropping pattern	17701	19042	dominated (5)			
Improved G-M-G rotation with TRP	17574	18924	7570	4849	156	80
Improved G-M-G rotation w/o TRP	10004	14075	1156	6122	19	
M-M-M rot. transitional practice	8848	7952				
Improved sesame cultivation	12946	13896	3299	5944	55	55
2nd year of M-M-M trans. practice	9648	7952				

(1) M-C: Millet-Cowpea.
G-M-G: Groundnut-Millet-Groundnut rotation.
M-M-M: Millet-Millet-Millet rotation.
TRP: Tilemsi Rock Phosphate.
Transitional practice: Mechanized practice with no other external inputs.
Manual practice: Non-mechanized practice with no external inputs.

(2) From preceding to following, e.g. from manual to transitional practice or from transitional to improved practice.

(3) From manual practice.

(4) From transitional practice.

(5) A technical package is dominated if it incurs higher costs but no additional net income.

Source: Henry de Frahan 1990, p. 206.

Table 5. Marginal Analysis of the Technical Packages for Farms in the Southern Zone (Financial Analysis)

TECHNICAL PACKAGE (1)	Net Income (CFAF)	Total Cost (CFAF)	Marginal Net Income (CFAF)	Marginal Cost (CFAF)	MRR (%) (2)	Average Rate of Return % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	36041	38545	2187	11668	19	37
Improved M-C cropping pattern	33854	26877	7357	19443	38	45
M-C interc. transitional practice	26496	7434	4146	6384	65	65
M-C intercropping manual practice	22350	1050				
Improved G-M-G rotation w/o TRP	14619	13083	400	6099	7	7
M-M-M rot. transitional practice	14220	6984	520	6384	8	8
Improved G-M-G rotation with TRP	13944	17933	dominated (5)			
M-M-M rotation manual practice	13700	600				
Improved sesame cultivation	26303	12985	11027	6001	184	96
2nd year of M-M-M trans. practice	15276	6984	876	6384	14	
2nd year of M-M-M manual practice	14400	600				
B) MECHANIZED FARM:						(4)
Improved M-C intercropping	26566	38545	1443	11668	12	28
Improved M-C cropping pattern	25123	26877	7357	19443	38	38
M-C interc. transitional practice	17766	7434				
Improved G-M-G rotation w/o TRP M-M-	8861	13083	145	6099	2	2
M rot. transitional practice	8716	6984				
Improved G-M-G rotation with TRP	8179	17933	dominated (5)			
Improved sesame cultivation	19988	12985	10472	6001	175	175
2nd year of M-M-M trans. practice	9516	6984				

(1) M-C: Millet-Cowpea.
G-M-G: Groundnut-Millet-Groundnut rotation.
M-M-M: Millet-Millet-Millet rotation.
TRP: Tilemsi Rock Phosphate.
Transitional practice: Mechanized practice with no other external inputs.
Manual practice: Non-mechanized practice with no external inputs.

(2) From preceding to following, e.g. from manual to transitional practice or from transitional to improved practice.

(3) From manual practice.

(4) From transitional practice.

(5) A technical package is dominated if it incurs higher costs but no additional net income.

<u>Source</u>: Henry de Frahan 1990, p. 207.

Table 6. Average Return to Labor and Marginal Return per Person Day with an Opportunity Cost of Capital of 12% (Financial Analysis)

TECHNICAL PACKAGE (1)	Gross Value of Production (CFA F)	Total Cost (CFA F) (2)	Return to Labor (CFA F)	Labor Input (Day)	Incremental Labor Day (Day)	Average Return to Labor (3) (CFA F/Day)	Marginal Return to Labor (CFA F)	Marginal Return Per Peron Day (4) (CFA F/Day)
A) NORTHERN ZONE:								
Improved M-C intercropping	46000	22754	23246	36.0	5.0	646	7432	1486
M-C intercropping manual practice	20500	1353	19147	48.5	17.5	395	dominated (5)	
Improved M-C cropping pattern	31275	15461	15814	31.0	3.5	510	2236	639
M-C interc. transitional practice	22150	8571	13579	27.5		494		
2nd year of M-M-M trad. practice	15000	782	14218	41.5	18.0	343	5682	316
2nd year of M-M-M trans. practice	16500	7964	8536	23.5		363		
Improved sesame cultivation	16500	11816	4684	35.0		134	dominated (5)	
B) CENTRAL AND PLATEAU ZONES:								
Improved M-C intercropping	62600	29855	32745	47.5	4.4	689	11917	2708
M-C intercropping manual practice	27000	1279	25721	57.5		447	dominated (5)	
Improved M-C cropping pattern	42250	21422	20828	43.1	9.1	483	1364	150
M-C interc. transitional practice	28950	9486	19464	34.0		572		
Improved G-M-G rotation with TRP	42240	21290	20951	51.0	0.7	411	6490	9271
M-M-M rotation manual practice	15200	739	14461	50.3	3.6	287	1735	482
Improved G-M-G rotation w/o TRP	28560	15834	12726	46.7	16.4	272	4872	297
M-M-M rot. transitional practice	16800	8946	7854	30.3		259		
Improved sesame cultivation	31500	15633	15867	43.0	14.0	369	7213	515
2nd year of M-M-M manual practice	16000	739	15261	49.0		311	dominated (5)	
2nd year of M-M-M trans. practice	17600	8946	8654	29.0		298		

Table 6. (cont'd.)

TECHNICAL PACKAGE (1)	Gross Value of Production (CFA F)	Total Cost (CFA F) (2)	Return to Labor (CFA F)	Labor Input (Day)	Incremental Labor Day (Day)	Average Return to Labor (3) (CFA F/Day)	Marginal Return to Labor (CFA F)	Marginal Return Per Person Day (4) (CFA F/Day)
A) SOUTHERN ZONE:								
Improved M-C intercropping	68300	43363	24937	46.0	7.0	542	3174	453
Improved M-C cropping pattern	52000	30237	21763	39.0		558		
M-C intercropping manual practice	23400	1181	22219	64.0		347	dominated (5)	
M-C interc. transitional practice	25200	8363	16837	39.0		432	dominated (5)	
M-M-M rot. manual practice	14300	675	13625	50.0	4.0	273	1819	455
Improved G-M-G rotation w/o TRP	26525	14718	11806	46.0	16.0	257	3963	248
Improved G-M-G rotation with TRP	31560	20175	11385	49.3		231	dominated (5)	
M-M-M rot. transitional practice	15700	7857	7843	30.0		261		
Improved sesame cultivation	39000	14608	24392	49.0	19.0	498	15749	829
2nd year of M-M-M manual practice	15000	675	14325	50.0		287	dominated (5)	
2nd year of M-M-M trans. practice	16500	7857	8643	30.0		288		

(1) M-C: Millet-Cowpea.
G-M-G: Groundnut-Millet-Groundnut rotation.
M-M-M: Millet-Millet-Millet rotation.
TRP: Tilemsi Rock Phosphate.
Transitional practice: Mechanized practice with no external inputs.
Manual practice : Non-mechanized practice with no external inputs.
(2) Labor cost excluded, but including a 12% opportunity cost of capital for the cropping season.
(3) Return to labor divided by total labor days.
(4) Marginal return to labor divided by the incremental labor day.
(5) A technical package is dominated if it incurs more labor input but no additional net benefit.
Source: Henry de Frahan 1990, pp. 209-10.

Table 7. Technical Packages Included in the Sensitivity Analysis

Zone and Level of Technology	Technical Packages (1)			
	P1	P2	P3	P4
Northern Zone				
Non-mechanized	X			
Mechanized	X			
Center and Plateau Zones				
Non-Mechanized	X		X	
Mechanized	X		X	
Southern Zone				
Non-mechanized	X		X	X
Mechanized	X		X	X

(1) P1: "Millet-cowpea intercropping."
P2: "Millet-cowpea mono-cropping."
P3: "Groundnut-millet-groundnut rotation."
P4: "Sesame cultivation."
Source: Henry de Frahan 1990, p. 213.

Table 8. Sensitivity Analysis for the Marginal Rate of Return for Technologies for the Center and Plateau Zone

TECHNOLOGIES (1)	PRICE OR YIELD -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	dominated	25	38	52	67	182	237
Transitional	4	48	60	72	82	91	116
Traditional							
Improved G-M-G Rotation with TRP	dominated	23	132	156	180	205	277
Traditional M-M-M Rotation							
Improved G-M-G Rotation w/o TRP	dominated	dominated	0	18	31	45	98
Transitional M-M-M Rotation	dominated	dominated	dominated	1	7	13	27
Improved Sesame Cultivation	dominated	5	37	60	85	113	219
2d Year of Trans. M-M-M Rotation	dominated	dominated	1	8	14	20	36
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	dominated	18	29	41	53	66	220
Transitional							
Improved G-M-G Rotation with TRP	8	111	133	156	179	202	270
Improved G-M-G Rotation w/o TRP	dominated	4	11	19	28	37	74
Transitional M-M-M Rotation							
Improved Sesame Cultivation	dominated	20	37	55	76	99	185
2d Year of Trans. M-M-M Rotation							

TECHNOLOGIES (1)	COSTS -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	383	205	69	52	39	27	2
Transitional	145	95	83	72	62	53	31
Traditional							
Improved G-M-G Rotation with TRP	412	220	185	156	133	27	5
Traditional M-M-M Rotation							
Improved G-M-G Rotation w/o TRP	132	46	31	18	1	dominated	dominated
Transitional M-M-M Rotation	44	15	8	1	dominated	dominated	dominated
Improved Sesame Cultivation	217	99	78	60	46	14	dominated
2d Year of Trans. M-M-M Rotation	53	23	15	8	2	dominated	dominated
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	358	73	55	41	29	19	dominated
Transitional							
Improved G-M-G Rotation with TRP	398	217	183	156	134	116	29
Improved G-M-G Rotation w/o TRP	96	38	27	19	12	6	dominated
Transitional M-M-M Rotation							
Improved Sesame Cultivation	172	85	68	55	45	36	17
2d Year of Trans. M-M-M Rotation							

(1) M-C: Millet-Cowpea. G-M-G: Groundnuts-Millet-Groundnuts Rotation.
M-M-M: Millet-Millet-Millet. TRP: Tilemsi Rock Phosphate.
Source: Henry de Frahan 1990, p. 411

APPENDIX B

ECONOMIC EVALUATION

Table 9. Domestic Resource Cost Ratio for Current Enterprises by Region

COMPONENT	SENO CENTER MILLET/COWPEA		DELTA FLOODING RICE		MALI SUD (3) MILLET/SORGHUM		OFFICE DU NIGER RICE (3) IRRIGATED
	Manual	Transitional (1)	Natural	Controlled	Manual	Transitional	
Net Costs for Primary Factors (CFA F/ha):							
Farm Level	6030	-689	11022	39128	21430	19533	90111
Rural Market Level (Mopti)	9729	3380	17142	50878	44710	50573	153732
Rural Market Level (Sikasso)	NA	NA	30576	76672	31617	33575	162041
Rural Market Level (Segou)	NA	NA	28545	72773	NA	NA	115460
Wholesale Level (Bamako)	26679	22025	33218	81745	48887	56142	169942
Consumption Level (Gao)	20160	14854	26761	69346	46338	52744	154658
Value Added for Tradables (CFA F/ha):							
Farm Level	61154	64236	49364	105571	69960	117792	225135
Rural Market Level (Mopti)	47785	49530	40171	86717	70699	81049	183044
Rural Market Level (Sikasso)	NA	NA	27267	61340	68547	89775	167104
Rural Market Level (Segou)	NA	NA	30602	67742	NA	NA	188034
Wholesale Level (Bamako)	28626	28454	23874	54826	52472	68342	148881
Consumption Level (Gao)	42390	43596	34627	75472	60805	79452	185200
Domestic Resource Cost Ratios (2):							
Farm Level	0.10	-0.01	0.22	0.37	0.31	0.17	0.40
Rural Market Level (Mopti)	0.20	0.07	0.43	0.59	0.63	0.62	0.84
Rural Market Level (Sikasso)	NA	NA	1.12	1.25	0.46	0.37	0.97
Rural Market Level (Segou)	NA	NA	0.93	1.07	NA	NA	0.61
Wholesale Level (Bamako)	0.93	0.77	1.39	1.49	0.93	0.82	1.14
Consumption Level (Gao)	0.48	0.34	0.77	0.92	0.76	0.66	0.84

(1) Transitional practice: Mechanized practice with no external inputs.
Manual practice: Non-mechanized practice with no external inputs.

(2) A DRC ratio under 1.00 means that the country or the region has a comparative advantage in the activities associated with such a DRC ratio, while a DRC ratio over 1.00 means that the country or the region does not have a comparative advantage in the activities associated with such a DRC ratio.

(3) Adapted from Stryker et al. (1987, Annex B).

Source: Henry de Frahan 1990, p. 229.

Table 10. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti

	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
COMPONENT	Manual	Transit.	Improved	Mech. Press	Ind. Process	Fertilization	Current	Improved	Current	Improved
Net Costs for Primary Factors (CFA F/ha):										
Farm Level	6030	-689	-1975	57217	55435	40888	11022	5557	39128	39009
Rural Market Level (Mopti)	9729	3380	-1391	83323	82018	42834	17142	13513	50878	57780
Rural Market Level (Sikasso)	NA	NA	NA	NA	NA	NA	30576	30977	76672	105492
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28545	28337	72773	98588
Wholesale Level (Bamako)	26679	22025	26152	196684	175883	54699	33218	34412	81745	114476
Consumption Level (Gao)	20160	14854	13139	167428	153343	NA	26761	26017	69346	92521
Value Added for Tradables (CFA F/ha):										
Farm Level	61154	64236	78670	231116	249694	72774	49364	62765	105571	169826
Rural Market Level (Mopti)	47785	49530	52210	157557	159017	64321	40171	50813	86717	136438
Rural Market Level (Sikasso)	NA	NA	NA	NA	NA	NA	27267	34039	61340	91501
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	30602	38373	67742	102838
Wholesale Level (Bamako)	28626	28454	21075	94581	91018	61838	23874	29628	54826	79965
Consumption Level (Gao)	42390	43596	43443	154528	135930	NA	34627	43607	75472	116525
Resource Cost Ratios (2):										
Farm Level	0.10	-0.01	-0.03	0.25	0.22	0.56	0.22	0.09	0.37	0.23
Rural Market Level (Mopti)	0.20	0.07	-0.03	0.53	0.52	0.67	0.43	0.27	0.59	0.42
Rural Market Level (Sikasso)	NA	NA	NA	NA	NA	NA	1.12	0.91	1.25	1.15
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	0.93	0.74	1.07	0.96
Wholesale Level (Bamako)	0.93	0.77	1.24	2.08	1.93	0.88	1.39	1.16	1.49	1.43
Consumption Level (Gao)	0.48	0.34	0.30	1.08	1.13	NA	0.77	0.60	0.92	0.79

(1) Transitional practice: Mechanized practice with no external inputs.
Manual practice: Non-mechanized practice with no external inputs.
Mechanized press: Mechanical oil press technique.
Industrial process: Industrial technique.

(2) A DRC ratio under 1.00 means that the country or the region has a comparative advantage in the activities associated with such a DRC ratio, while a DRC ratio over 1.00 means that the country or the region does not have a comparative advantage in the activities associated with such a DRC ratio.

Source: Henry de Frahan 1990, p. 230.

APPENDIX C

EXPECTED DIFFUSION PATHS

A formulation commonly used to represent the diffusion path of innovations is the logistic growth function (Rogers 1957; Griliches 1957; Feder, Just, and Zilberman 1982; Martinez and Saín 1983; Thirtle and Ruttan 1986). This function is characterized as follows:

$$P(t) = K/[1+e\text{-}(a+bt)]$$

where K is the long-run upper limit on diffusion; the slope 'b' is a measure of the rate of acceptance of the innovation; and the intercept 'a' reflects aggregate adoption at the start of the estimation period and thus positions the curve on the time scale. According to Griliches (1957), who used the logistic function to describe the diffusion of hybrid corn in the United States, the parameter 'b' of the logistic function depends on factors affecting the demand for innovations, the parameter 'a' depends on factors affecting the supply of innovations, and the parameter 'K' depends on factors affecting the long-run demand for innovations, assuming that in the long run the supply conditions of the innovation are the same for all zones.

The three parameters of the expected diffusion paths for the technical packages are estimated in two steps. First, historical data on animal traction adoption collected in the rainfed area of the Region of Mopti are used to estimate the parameters of diffusion paths that have occurred. The diffusion parameters of animal traction are estimated with an ordinary least-squares (OLS) regression, using a logistic function representing the cumulative growth in the percent of farmers who have adopted animal traction from 1966 to 1987. Because of the agroclimatic environment and the institutional setting change from one agroclimatic zone to the other in the Region of Mopti, three logistic functions are estimated by the OLS regression, one function representing the cumulative growth from 1966 to 1987 for each agroclimatic zone (table 11).

Table 11. Parameters of Diffusion Paths for Animal Traction in the Rainfed Area

Parameter (1)	Northern Zone	Center and Plateau Zone	Southern Zone
a	-5.41	-6.50	-10.50
b	0.23	0.33	0.80
Normalized b (%)	11.11	21.03	16.00
K (%)	48.00	64.00	20.00
Adjusted R squared	0.86	0.94	0.89

(1) OLS regression using a logistic functional form expressed as K/[1+exp-(a+bt)]. All the parameters are statistically significant at the 1% level. The parameters b are normalized by multiplying them by K to make them comparable between agroclimatic zones. The value of K, the ceiling, is the one that optimizes the fit of the regression, a technique similar to the one used by Griliches (1957).

Source: Henry de Frahan 1990, p. 234.

Second, a relationship between the values of the parameters estimated for the diffusion of animal traction and the factors of adoption is sought to extrapolate the results to the diffusion of the proposed technical packages. Although the rate of acceptance 'b' of the innovations depends on several demand factors such as profitability, the reduction in income or yield variability (a proxy for risk), and the availability of arable land for land-increasing technologies (i.e. animal traction), only one indicator of profitability is used here as an independent variable to explain the variation in the rate of acceptance. Since only three observations are available (one per agroclimatic zone), the limited degrees of freedom prevent the use of additional explanatory variables for the OLS regression. The marginal rate of return (MRR) of adopting animal traction is chosen as the single independent variable because (1) the MRR indicates the profitability of substituting the new technology for the old and, therefore, reflects the decision making process and (2) the range of estimated MRRs for animal traction adoption are similar to the range of the estimated MRRs for the technical packages that FSR could develop and, consequently, extrapolation of the estimated 'b' values from animal traction to the potential innovations is realistic. Table 12 presents the relationship between the parameter 'b' and the MRR.

Table 12. Relationship between MRR and Rate of Acceptance (b) for Animal Traction

	DATA (1)	
ZONE	Normalized b (%)	MRR (%)
Northern Zone	11.11	56.40
Southern Zone	16.00	64.90
Center & Plateau Zone	21.03	71.80
ESTIMATED PARAMETER (2)		
Ceiling (K)	100.00	
Origin (a)	-4.85	
Slope (b)	0.05	
Adjusted R squared	0.99	

(1) Data for the normalized rate of acceptance(b) and MRR are taken for mixed farmers, respectively from tables 11 and 3 to 5.

(2) Using an OLS logistic regression on the above data with a functional form expressed as K/[1+exp-(a+bt)].

Source: Henry de Frahan 1990, p. 236.

The values of the intercept 'a' estimated for the diffusion of animal traction in the three agroclimatic zones are used for the expected diffusion of the proposed technical packages. The intercept 'a' depends on factors affecting the supply conditions of the innovation. However, because one important component of the technical packages is animal traction, the 'a' values are lower for those who have already adopted animal traction. Reducing 'a' by one-half for these farmers is considered realistic.

The upper limits on diffusion 'K' for each proposed technical package are modified according to the profitability of the technical package, the type of farming system (mixed farming versus herding), land availability, and market conditions in each agroclimatic zone. Table 13 presents the values of the parameter K according to the farming system and the technical package.

Table 13. Value of the Parameter K (%), the Ceiling of the Diffusion Curves

FARMING SYSTEM		TRANSITIONAL TECHNOLOGY	MILLET-COWPEA INTERCROPPING	ROTATION G-M-G (1)	SESAME
AGROPASTORAL SYSTEM:					
NORTH	Non-equipped	48	21	NA	NA
	Equipped	NA	17	NA	NA
CENTER/	Non-equipped	64	20	14	NA
PLATEAU	Equipped	NA	NA	33	18
SOUTH	Non-equipped	20	NA	NA	43
	Equipped	NA	NA	NA	90
PASTORAL SYSTEM:					
NORTH	Non-equipped	32	11	NA	NA
	Equipped	NA	9	NA	NA
SOUTH	Non-equipped & Equipped	10	0	NA	21

(1) Groundnut-Millet-Groundnut.
Source: Henry de Frahan 1990, p. 239.

The cumulative growth in the percentage of farms that adopt the proposed packages is converted into area, using the national estimates of cultivated area and field survey results. First, *Opération Mil Mopti* estimates of cultivated area in millet are used to estimate by agroclimatic zone the potential area of adoption of the "millet-cowpea intercropping" package. Estimates of the cultivated areas that could benefit from the "groundnut-millet-groundnut rotation" and "sesame cultivation" packages are based on the areas currently cultivated in groundnuts (estimated at 5% of millet area) and in sesame (estimated at 10% of millet area) respectively. These areas may be expanded if the profitability of these two technical packages are large enough to induce a wide diffusion.

As the diffusion paths of the proposed technical packages will vary with respect to the principal occupation of the potential adopter (farming or herding) and his or her current technological level (equipped or non-equipped) in addition to the agroclimatic zone to which (s)he belongs, field survey results on proportions of farmers to herders and proportions of equipped to non-equipped producers are used to estimate the acreage corresponding to each category of potential adopter. Table 14 presents these estimates by category of potential adopter for millet cultivated area.

Table 14. Millet Cultivated Area by Target Groups in the Rainfed Area

Agroclimatic Zone	Millet Cultivated Area (HA)	(%)	Farming System Agropastoral (%)	Farming System Pastoral (%)	Equipment Agropastoral (%)	Equipment Pastoral (%)	Farmers Equipped (HA)	Farmers Non-Equipped (HA)	Herders Equipped (HA)	Herders Non-Equipped (HA)
NORTH	31250	24	79	21	20	8	4938	19750	525	6038
CENTER	37250	29	95	5	46	-	16278	19109	-	-
PLATEAU	10100	8	90	10	32	-	2909	6181	-	-
SOUTH	50550	39	72	28	20	4	7279	29117	-	14154
SUB-REGION (1)	129150	100								

(1) Circles of Bandiagara, Bankass, Koro, and Douentza and the districts of Boni, Mondoro, Hombori, and Central Douentza of the Circle of Douentza.
Source: Henry de Frahan 1990, p. 376-77.

APPENDIX D

FSR PROJECT EVALUATION PROCEDURE

To estimate the economic return to the FSR project, the "with project" situation is compared to the "without project" situation. The economic return to the project corresponds to the incremental net benefit stream over time as a result of the project, which can be calculated by subtracting the "without project" net benefit stream from the "with project" net benefit stream. Instead of estimating separately the "with" and "without project" net benefit streams over time and subtracting them, the incremental net benefit of adopting the proposed technical packages is estimated on a per hectare basis and then multiplied by the expected area that will benefit from the technical change every year.

However, the estimation method needs to be corrected for the continued adoption of animal traction, which is expected to occur anyway. Without the project, farmers will continue to adopt animal traction according to the diffusion paths identified for the past two decades if similar conditions of supply for and demand of animal traction persist. With the project, non-equipped farmers of some target groups may choose to adopt animal traction alone and not the proposed technical packages. Therefore, the incremental net benefits generated from adopting animal traction under the "without project" situation will be subtracted from the "with project" net benefit stream, while the incremental net benefits generated from adopting animal under the "with project" situation will be included in the "with project" net benefit stream.

The economic analysis is carried out in five steps. The first step consists of transforming financial budgets, which have been estimated per unit area for each package and for each zone, into economic budgets. These economic budgets are expressed in CFA francs per hectare per year (CFA F/ha/year) for each technical package and for each target group. Only the increases in gross benefits and in costs of production are retained for the second step.

The second step consists of multiplying these incremental economic results, expressed in CFA F/ha/year, by the annual expected cumulative area benefitting each year from a proposed technical package. This area has been determined for each proposed technical package and target group by applying an annual adoption rate to the available area. Estimates of the available area and anticipated annual rates of adoption for each technical package and target group are those calculated in appendix C. The economic results of this second step are expressed in CFA francs per year (CFA F/year) for each technical package and target group. Consequently, this second step yields an annual flow of incremental gross benefits and incremental costs of production. By subtracting the latter from the former, an annual flow of incremental net benefits aggregated for each technical package and target group is obtained. These results are given in tables 15 to 17 for the millet-cowpea intercropping, the groundnut-millet rotation, and the sesame cultivation technical packages respectively.

The incremental net benefit flows generated from adopting animal traction under the "without project" situation are estimated for each target group, using the estimated incremental net benefits of adopting animal traction and the projections of the historical diffusion path of animal traction for the next 20 years (table 12). In table 18, the incremental net benefits flow generated from adopting animal traction under the "with project" situation is estimated on the basis of the diffusion parameters of animal traction for each target group.[20] The incremental net benefit flows generated under the "without project" situation are subtracted from the incremental net benefit flows generated from adopting animal traction alone under the "with project" situation. The difference of these two sets of incremental net benefits flows is included in the economic value of the project.

The third step consists of summing annually and individually the incremental gross benefit and incremental costs of production which have been estimated annually for each target group and technical package. This step gives a flow of annual incremental gross benefits, a flow of annual incremental costs of production, and, by subtracting the latter from the former, a flow of annual incremental net benefits aggregated for all target groups and proposed technical packages.

The fourth step consists of bringing together the results of the third step with the costs of the FSR project. This step is accomplished in table 19. In this table, the incremental annual gross benefits accruing to farms adopting the technical packages constitute the inflows, while incremental annual costs of production accruing to farms adopting the technical packages and the annual costs of implementing the FSR project constitute the outflows of the project. The flow of annual incremental net benefits of the project (net cash flow) is calculated by subtracting the outflows from the inflows.

The fifth step consists of calculating the three evaluation criteria of the FSR project. The first criterion is the net present value at a 12% opportunity cost of capital. The second criterion is the internal rate of return. The third criterion is the net benefit-investment ratio at a 12% opportunity cost of capital. The value of these three criteria is given at the bottom of table 19 and reported in table 20.

[20] It is considered that, under the "with project" situation, the diffusion paths of animal traction alone will continue at half the rate of the diffusion paths of animal traction that would have prevailed under the "without project" situation. This assumes that half of the potential adopters of animal traction which would have chosen to adopt animal traction under the "without project" situation are actually adopting the "millet-cowpea intercropping" technical package provided under the "with project" situation

Table 15. Economic Analysis of the Improved Millet-Cowpea Intercropping by Stratum and Year

Item by Stratum (1)	Value per ha	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.09	0.18	0.32	0.60	1.08	1.93	3.33	5.46	8.32	11.58	14.67	17.13	18.82	19.87	20.49	20.83	21.03
Area (ha): 19750		0	0	0	19	35	64	118	214	381	658	1079	1644	2288	2898	3382	3716	3924	4046	4115	4152
Incremental gross benefit (CFAF 1000):	30	0	0	0	577	1063	1943	3582	6497	11566	19975	32756	49908	69458	87976	102669	112809	119123	122827	124922	126045
Incremental costs (CFAF 1000):	23	0	0	0	429	791	1446	2667	4836	8610	14870	24385	37154	51708	65493	76432	83980	88681	91438	92997	93833
Incremental net benefit (CFAF 1000):	8	0	0	0	147	272	497	915	1660	2956	5105	8371	12754	17750	22483	26238	28829	30443	31389	31924	32212
STRATUM 2																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	1.07	1.81	2.97	4.64	6.80	9.22	11.54	13.45	14.84	15.76	16.33	16.67	16.87	16.98	17.05	17.09	17.11
Area (ha): 4938		0	0	0	53	90	147	229	336	455	570	664	733	778	806	823	833	839	842	844	845
Incremental gross benefit (CFAF 1000):	20	0	0	0	1045	1775	2899	4516	6627	8974	11242	13096	14457	15344	15896	16232	16429	16547	16606	16646	16666
Incremental costs (CFAF 1000):	15	0	0	0	819	1391	2272	3539	5193	7032	8810	10262	11329	12024	12457	12720	12874	12967	13014	13044	13060
Incremental net benefit (CFAF 1000):	4	0	0	0	226	384	627	977	1434	1942	2432	2833	3128	3320	3439	3512	3554	3580	3593	3601	3606
STRATUM 3																					
Cumulative adoption rate (%ha):		0.00	0.00	0.03	0.05	0.10	0.18	0.32	0.58	1.03	1.80	3.04	4.92	7.44	10.34	13.17	15.49	17.15	18.22	18.87	19.24
Area (ha): 25290		0	0	7	14	25	45	81	146	260	454	769	1244	1881	2616	3330	3917	4337	4607	4771	4866
Incremental gross benefit (CFAF 1000):	40	0	0	280	560	1001	1801	3242	5844	10406	18171	30779	49791	75287	104705	133283	156777	173588	184395	190959	194761
Incremental costs (CFAF 1000):	30	0	0	211	422	754	1357	2442	4401	7838	13686	23182	37501	56703	78860	100384	118079	130740	138879	143823	146687
Incremental net benefit (CFAF 1000):	10	0	0	69	138	247	445	800	1442	2569	4485	7597	12290	18584	25845	32899	38699	42848	45516	47136	48074
STRATUM 4																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 19187		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 5																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 29117		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 15. (cont'd.)

Item by Stratum (1)	Value per ha	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 6																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 7279		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 7																					
Cumulative adoption rate (%ha):		0.00	0.00	0.05	0.10	0.21	0.43	0.86	1.67	2.99	4.80	6.75	8.35	9.41	10.01	10.32	10.48	10.56	10.59	10.61	10.62
Area (ha): 6038		0	0	3	6	12	26	52	101	181	290	407	504	568	604	623	633	637	640	641	641
Incremental gross benefit (CFAF 1000):	30	0	0	91	182	364	789	1579	3066	5495	8804	12356	15300	17243	18336	18913	19216	19338	19429	19459	19459
Incremental costs (CFAF 1000):	23	0	0	68	136	271	588	1175	2283	4091	6554	9198	11390	12837	13650	14080	14305	14396	14464	14486	14486
Incremental net benefit (CFAF 1000):	8	0	0	23	47	93	202	403	784	1404	2250	3158	3910	4407	4686	4833	4911	4942	4965	4973	4973
STRATUM 8																					
Cumulative adoption rate (%ha):		0.00	0.00	0.54	1.00	1.79	2.94	4.37	5.77	6.89	7.63	8.07	8.31	8.43	8.50	8.53	8.55	8.56	8.56	8.56	8.57
Area (ha): 525		0	0	3	5	9	15	23	30	36	40	42	44	44	45	45	45	45	45	45	45
Incremental gross benefit (CFAF 1000):	20	0	0	59	99	178	296	454	592	710	789	828	868	868	888	888	888	888	888	888	888
Incremental costs (CFAF 1000):	15	0	0	46	77	139	232	355	464	556	618	649	680	680	695	695	695	695	695	695	695
Incremental net benefit (CFAF 1000):	4	0	0	13	21	38	64	98	128	154	171	179	188	188	192	192	192	192	192	192	192
STRATUM 9																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 14154		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 15. (cont'd.)

Item by Stratum (1)	Value per ha	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Strata 1 to 9:																					
Area (ha) : 126278		0	0	1	2	4	7	11	16	22	29	37	45	53	60	66	70	73	75	76	77
Cumulative adoption rate (% ha):		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Incremental gross benefit (CFAF 1000):		0	0	430	2463	4380	7728	13373	22625	37151	58981	89815	130323	178200	227801	271984	306119	329484	344144	352873	357818
Incremental costs (CFAF 1000):		0	0	325	1883	3346	5894	10178	17177	28127	44538	67676	98053	133952	171156	204310	229934	247479	258489	265046	268762
Incremental net benefit (CFAF 1000) :		0	0	105	580	1034	1834	3194	5448	9024	14443	22139	32270	44248	56645	67674	76185	82005	85655	87827	89057
Inc. gross benefit (1000 $US): 300 = 1$ US		0	0	1	8	15	26	45	75	124	197	299	434	594	759	907	1020	1098	1147	1176	1193
Incremental costs (1000 $US): 300 = 1 $ US		0	0	1	6	11	20	34	57	94	148	226	327	447	571	681	766	825	862	883	896
Inc. net benefit (1000 $US): 300 = 1 $ US		0	0	0	2	3	6	11	18	30	48	74	108	147	189	226	254	273	286	293	297

(1) Stratun 1: Séno North, farmers, non-equipped.
Stratum 2: Séno North, farmers, equipped.
Stratum 3: Séno Center & Plateau, farmers, non-equipped.
Stratum 4: Séno Center & Plateau, farmers, equipped.
Stratum 5: Séno South, farmers, non-equipped.
Stratum 6: Séno South, farmers, equipped.
Stratun 7: Séno North, herders, non-equipped.
Stratum 8: Séno North, herders, equipped.
Stratum 9: Séno South, herders, equipped & non-equipped.
Source: Henry de Frahan 1990, p. 442-3.

Table 16. Economic Analysis of the Groundnuts Rotation by Stratum and Year

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 988		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 2																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 247		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3																					
Cumulative adoption rate (%ha):		0.00	0.00	0.32	0.55	0.93	1.54	2.47	3.80	5.48	7.37	9.19	10.70	11.83	12.59	13.07	13.37	13.54	13.65	13.71	13.74
Area (ha): 1897		0	0	6	10	18	29	47	72	104	140	174	203	224	239	248	254	257	259	260	261
Incremental gross benefit (CFAF 1000):	27	0	0	162	270	487	784	1270	1946	2811	3784	4704	5487	6055	6461	6704	6866	6947	7001	7028	7055
Incremental costs (CFAF 1000):	20	0	0	118	196	353	569	922	1413	2041	2747	3415	3984	4396	4690	4867	4985	5044	5083	5102	5122
Incremental net benefit (CFAF 1000):	7	0	0	44	74	133	215	348	533	770	1037	1289	1504	1659	1770	1837	1881	1904	1918	1926	1933
STRATUM 4																					
Cumulative adoption rate (%ha):		0.00	0.00	1.22	2.74	5.78	10.98	17.76	24.10	2840	30.73	31.84	32.34	32.56	32.65	32.69	32.71	32.71	32.72	32.72	32.72
Area (ha): 1439		0	0	18	39	83	158	256	347	409	442	458	465	469	470	470	471	471	471	471	471
Incremental gross benefit (CFAF 1000):	20	0	0	355	769	1636	3115	5047	6840	8063	8713	9029	9167	9245	9265	9265	9285	9285	9285	9285	9285
Incremental costs (CFAF 1000):	12	0	0	222	481	1023	1948	3156	4278	5043	5450	5647	5733	5783	5795	5795	5807	5807	5807	5807	5807
Incremental net benefit (CFAF 1000):	7	0	0	133	288	613	1167	1890	2562	3020	3263	3382	3433	3463	3470	3470	3478	3478	3478	3478	5478
STRATUM 5																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 1456		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 16. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 6																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 364		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 7																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 302		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 8																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 26		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 6314		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 16. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1 to 9																					
Cumulative adoption rate (%ha):		0.00	0.00	24	49	101	187	303	419	513	582	632	668	693	709	718	725	728	730	731	732
Area (ha): 6314		0	0	0.4	0.8	1.6	3.0	4.8	6.6	8.1	9.2	10.0	10.6	11.0	11.2	11.4	11.5	11.5	11.6	11.6	11.6
Incremental gross benefit (CFAF 1000):		0	0	517	1039	2123	3899	6317	8787	10874	12498	13732	14654	15301	15726	15969	16151	16232	16286	16316	16340
Incremental costs (CFAF 1000):		0	0	340	677	1377	2517	4079	5691	7084	8197	9062	9717	10179	10485	10662	10792	10851	10898	10910	10929
Incremental net benefit (CFAF 1000):		0	0	177	362	746	1381	2238	3095	3790	4300	4670	4937	5122	5240	5307	5359	5381	5396	5403	5411
Inc. gross benefit ($ US 1000): 300=1 $ US		0	0	2	3	7	13	21	29	36	42	46	49	51	52	53	54	54	54	54	54
Incremental costs (($ US 1000): 300=1 $ US		0	0	1	2	5	8	14	19	24	27	30	32	34	35	36	36	36	36	36	36
Inc. net benefit (($ US 1000): 300=1 $ US		0	0	1	1	2	5	7	10	13	14	16	16	17	17	18	18	18	18	18	18

(1) As defined in table 15
Source: Henry de Frahan 1990, p. 444-45.

Table 17. Economic Analysis of the Sesame Cultivation by Stratum and Year

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 1975		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 2																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 494		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 2529		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 4																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.68	1.19	2.03	3.34	5.22	7.63	10.28	12.75	14.72	16.11	17.01	17.56	17.88	18.06	18.17	18.22	18.26
Area (ha): 1919		0	0	0	13	23	39	64	100	146	197	245	282	309	326	337	343	347	349	350	350
Incremental gross benefit (CFAF 1000):	23	0	0	0	304	537	911	1495	2337	3412	4603	5725	6589	7220	7618	7875	8015	8108	8155	8178	8178
Incremental costs (CFAF 1000):	7	0	0	0	95	168	285	467	729	1065	1437	1787	2057	2254	2378	2458	2502	2531	2546	2553	2553
Incremental net benefit (CFAF 1000):	16	0	0	0	209	370	627	1029	1607	2347	3166	3938	4532	4966	5239	5416	5513	5577	5609	5625	5625
STRATUM 5																					
Cumulative adoption rate (%ha):		0.00	0.00	0.09	0.28	0.82	2.37	6.39	14.72	26.09	35.19	39.84	41.68	42.33	42.55	42.63	42.65	42.66	42.67	42.67	42.67
Area (ha): 2912		0	0	3	8	24	69	186	429	760	1025	1160	1214	1233	1239	1241	1242	1242	1242	1242	1242
Incremental gross benefit (CFAF 1000):	41	0	0	124	330	991	2850	7683	17721	31393	42340	47916	50147	50932	51180	51262	51304	51304	51304	51304	51304
Incremental costs (CFAF 1000):	14	0	0	43	116	348	1000	2697	6219	11018	14860	16817	17600	17875	17962	17991	18006	18006	18006	18006	18006
Incremental net benefit (CFAF 1000):	27	0	0	80	214	643	1850	4987	11501	20375	27480	31099	32547	33056	33217	33271	33298	33298	33298	33298	33298

Table 17. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 6																					
Cumulative adoption rate (%ha):		0.00	0.00	1.38	3.97	10.83	25.99	49.14	70.19	82.03	86.97	88.77	89.39	89.60	89.67	89.70	89.71	89.71	89.71	89.71	89.71
Area (ha): 728		0	0	10	29	79	189	358	511	597	633	646	651	652	653	653	653	653	653	653	653
Incremental gross benefit (CFAF 1000):	34	0	0	340	986	2685	6424	12168	17368	20291	21514	21956	22126	22160	22194	22194	22194	22194	22194	22194	22194
Incremental costs (CFAF 1000):	7	0	0	74	213	581	1390	2633	3758	4390	4655	4750	4787	4794	4802	4802	4802	4802	4802	4802	4802
Incremental net benefit (CFAF 1000):	27	0	0	266	772	2104	5034	9535	13610	15901	16859	17206	17339	17365	17392	17392	17392	17392	17392	17392	17392
STRATUM 7																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 604		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 8																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 53		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9																					
Cumulative adoption rate (%ha):		0.00	0.00	0.11	0.22	0.41	0.78	1.46	2.64	4.57	7.36	10.75	14.13	16.87	18.76	19.92	20.58	20.93	21.12	21.22	21.28
Area (ha): 1415		0	0	2	3	6	11	21	37	65	104	152	200	239	266	282	291	296	299	300	301
Incremental gross benefit (CFAF 1000):	41	0	0	83	124	248	454	867	1528	2685	4296	6279	8261	9872	10988	11649	12020	12227	12351	12392	12433
Incremental costs (CFAF 1000):	14	0	0	29	43	87	159	304	536	942	1508	2204	2900	3465	3856	4088	4219	4291	4335	4349	4364
Incremental net benefit (CFAF 1000)	27	0	0	54	80	161	295	563	992	1743	2788	4075	5362	6408	7131	7560	7802	7936	8016	8043	8070

Table 17. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1 to 9																					
Cumulative adoption rate (%ha):		0.00	0.00	15	53	132	308	629	1077	1568	1959	2203	2347	2433	2484	2513	2529	2538	2543	2545	2546
Area (ha): 12628		0	0	0.1	0.4	1.0	2.4	5.0	8.5	12.4	15.5	17.4	18.6	19.3	19.7	19.9	20.0	20.1	20.1	20.2	20.2
Incremental gross benefit (CFAF 1000):		0	0	546	1744	4462	10640	22214	38953	57781	72753	81876	87124	90184	91979	92979	93533	93833	94003	94068	94109
Incremental costs (CFAF 1000):		0	0	146	468	1184	2834	6100	11243	17416	22460	25558	27344	28389	28999	29340	29529	29630	29688	29710	29725
Incremental net benefit (CFAF 1000):		0	0	100	1276	3278	7805	16113	27710	40365	50294	56317	59780	61795	62980	63639	64004	64202	64315	64358	64385
Inc. gross benefit ($ US 1000): 300=1 $ US		0	0	2	6	15	35	74	130	193	243	273	290	301	307	310	312	313	313	314	314
Incremental costs ($ US 1000): 300=1 $ US		0	0	0	2	4	9	20	37	58	75	85	91	95	97	98	98	99	99	99	99
Inc. net benefit ($ US 1000): 300=1 $ US		0	0	1	4	11	26	54	92	135	168	188	199	206	210	212	213	214	214	215	215

(1) As defined in table 15.
Source: Henry de Frahan 1990, p. 446-47.

Table 18. Economic Analysis of the Transitional Millet-Cowpea Intercropping by Stratum and Year

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1																					
Cumulative adoption rate (%ha):		2.70	5.46	8.22	10.85	13.34	15.61	17.60	19.23	20.43	21.13	21.24	20.80	19.98	19.10	18.42	18.02	17.85	17.82	17.88	17.97
Area (ha): 19750		533	1078	1623	2143	2635	3084	3475	3797	4036	4173	4195	4107	3946	3773	3638	3558	3524	3520	3531	3549
Incremental gross benefit (CFAF 1000):	10	5229	10576	15923	21024	25851	30256	34092	37251	39596	40940	41156	40293	38713	37016	35692	34907	34573	34534	34642	34818
Incremental costs (CFAF 1000):	7	3811	7708	11605	15323	18841	22052	24848	27150	28859	29839	29996	29367	28215	26978	26013	25441	25198	25169	25248	25377
Incremental net benefit (CFAF 1000):	3	1418	2868	4318	5701	7010	8205	9245	10101	10737	11102	11160	10926	10498	10038	9678	9466	9375	9365	9394	9442
STRATUM 2																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 4938		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3																					
Cumulative adoption rate (%ha):		4.39	8.17	11.27	13.75	15.67	17.11	18.16	18.86	19.25	19.31	19.02	18.32	17.23	15.90	14.58	13.49	12.70	12.20	11.90	11.73
Area (ha): 25290		1111	2065	2850	3477	3963	4328	4592	4770	4868	4885	4810	4633	4358	4022	3688	3411	3213	3086	3010	2967
Incremental gross benefit (CFAF 1000):	12	13719	25499	35193	42935	48937	53444	56704	58902	60112	60322	59396	57210	53814	49665	45541	42120	39675	38107	37169	36638
Incremental costs (CFAF 1000):	8	8940	16617	22935	27980	31891	34828	36953	38385	39174	39311	38707	37283	35070	32366	29678	27449	25856	24834	24222	23876
Incremental net benefit (CFAF 1000):	4	4779	8882	12258	14955	17046	18616	19751	20517	20938	21011	20689	19928	18745	17299	15863	14671	13820	13274	12947	12762
STRATUM 4																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 19187		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 5																					
Cumulative adoption rate (%ha):		0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Area (ha): 29117		4	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Incremental gross benefit (CFAF 1000):	10	41	62	62	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Incremental costs (CFAF 1000):	7	29	43	43	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Incremental net benefit (CFAF 1000):	3	13	19	19	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23

Table 18. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 6																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 7279		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 7																					
Cumulative adoption rate (%ha):		1.40	2.91	4.48	6.10	7.71	9.24	10.62	11.73	12.47	12.85	13.03	13.25	13.61	14.08	14.58	15.06	15.50	15.87	16.19	16.45
Area (ha): 6038		85	176	271	368	465	558	641	708	753	776	787	800	822	850	881	910	936	958	977	993
Incremental gross benefit (CFAF 1000):	10	834	1727	2659	3610	4562	5474	6289	6946	7388	7613	7721	7849	8064	8339	8643	8928	9183	9399	9585	9742
Incremental costs (CFAF 1000):	7	608	1258	1938	2631	3325	3990	4583	5062	5384	5549	5621	5720	5878	6078	6299	6507	6693	6850	6986	7100
Incremental net benefit (CFAF 1000):	3	226	468	721	979	1237	1484	1705	1884	2003	2064	2094	2128	2187	2261	2344	2421	2490	2549	2599	2642
STRATUM 8																					
Cumulative adoption rate (%ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (ha): 525		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (CFAF 1000):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9																					
Cumulative rate of adoption (%ha):		1.19	2.27	3.17	3.85	4.33	4.66	4.87	5.01	5.10	5.16	5.19	5.21	5.23	5.23	5.24	5.24	5.24	5.24	5.25	5.25
Area (ha):		168	321	448	545	613	659	690	709	722	730	735	738	740	741	741	742	742	742	742	743
Incremental gross benefit (CFAF 1000):	10	1742	3328	4644	5650	6355	6832	7153	7350	7485	7568	7620	7651	7672	7682	7682	7692	7692	7692	7692	7703
Incremental costs (CFAF 1000):	7	1200	2293	3201	3894	4379	4708	4930	5065	5158	5215	5251	5273	5287	5294	5294	5301	5301	5301	5301	5308
Incremental net benefit (CFAF 1000):	3	541	1034	1444	1756	1975	2124	2224	2285	2327	2353	2369	2378	2385	2388	2388	2391	2391	2391	2391	2394

Table 18. (cont'd.)

Item by Stratum (1)	Value per Hectare	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
STRATUM 1 to 9																					
Cumulative adoption rate (%ha):		1901	3646	5198	6540	7683	8636	9405	9991	10386	10571	10534	10285	9873	9393	8955	8628	8422	8313	8267	8259
Area (ha): 126278		1.5	2.9	4.1	5.2	6.1	6.8	7.4	7.9	8.2	8.4	8.3	8.1	7.8	7.4	7.1	6.8	6.7	6.6	6.5	6.5
Incremental gross benefit (CFAF 1000):		21565	41192	58481	73293	85778	96079	104311	110522	114653	116516	115965	113075	108336	102775	97630	93720	91196	89805	89161	88974
Incremental costs (CFAF 1000):		14588	27920	39721	49878	58487	65628	71363	75713	78625	79963	79631	77692	74500	70766	67335	64748	63097	62204	61807	61711
Incremental net benefit (CFAF 1000):		6977	13272	18760	23414	27291	30451	32947	34809	36028	36553	36334	35383	33837	32009	30296	28972	28099	27601	27353	27262
Inc. gross benefit ($ US 1000): 300=1 $ US		72	137	195	244	286	320	348	368	382	388	387	377	361	343	325	312	304	299	297	297
Incremental costs (($ US 1000): 300=1 $ US		49	93	132	166	195	219	238	252	262	267	265	259	248	236	224	216	210	207	206	206
Inc. net benefit (($ US 1000): 300=1 $ US		23	44	63	78	91	102	110	116	120	122	121	118	113	107	101	97	94	92	91	91

(1) As defined in table 15.
Source: Henry de Frahan 1990, p. 440-41.

Table 19. Economic Value of the Project (US $ '000)

Item by Stratum (1)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
INFLOW (INCREMENTAL CROP BENEFIT)																				
Transitional millet-cowpea technology	72	137	195	244	286	320	348	368	382	388	387	377	361	343	325	312	304	299	297	297
Improved millet-cowpea technology	0	0	1	8	15	26	45	75	124	197	299	434	594	759	907	1020	1098	1147	1176	1193
Groundnuts-Millet-Groundnuts rotation	0	0	2	3	7	13	21	29	36	42	46	49	51	52	53	54	54	54	54	54
Sesame cultivation	0	0	2	6	15	35	74	130	193	243	273	290	301	307	310	312	313	313	314	314
Transitional millet-cowpea technology (w/o project	71	136	193	243	285	320	349	374	394	410	424	435	444	452	458	463	467	470	472	474
TOTAL INFLOW	1	1	7	19	38	75	138	229	341	459	580	715	862	1009	1137	1236	1303	1344	1369	1383
OUTFLOW																				
ON-FARM PRODUCTION COST:	49	93	132	166	195	219	238	252	262	267	265	259	248	236	224	216	210	207	206	206
Transitional millet-cowpea technology	0	0	1	6	11	20	34	57	94	148	226	327	447	571	681	766	825	862	883	896
Improved millet-cowpea technology	0	0	1	2	5	8	14	19	24	27	30	32	34	35	36	36	36	36	36	36
Groundnuts-Millet-Groundnuts rotation	0	0	0	2	4	9	20	37	58	75	85	91	95	97	98	98	99	99	99	99
Sesame cultivation	48	92	131	165	194	218	239	256	270	282	292	300	306	311	316	319	322	324	326	328
Transitional millet-cowpea technology(w/o project)																				
TOTAL ON-FARM PRODUCTION	1	1	4	11	21	38	67	110	167	235	315	410	517	627	723	798	848	880	899	910
PROJECT COSTS																				
Capital Costs financed by USAID:																				
Technical assistance	0	340	325	310	305	5	5													
Short-term training	0	35	28	28	28	0	0													
Vehicles	0	60	0	0	60	0	0													
Research equipment	0	24	2	14	27	12	14													
Office equipement	0	20	0	0	20	0	0													
Furnishing	0	175	25	0	0	0	0													
Construction	306	348	76	0	0	0	0	-438												
Contingency (10%)	31	100	46	35	44	2	2													
Sub-total	336	1102	501	387	483	18	21	-438												

Table 19. (cont'd.)

Item by Stratum (1)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Recurrent Costs Financed by USAID:																				
Salaries																				
Professional staff	0	15	15	15	15	15	15													
Support staff	0	20	20	20	9	20	20													
Vehicle maintenance	0	14	15	15	11	11	11													
Offices supplies	0	10	10	10	7	7	7													
Rents, utilities, building, maintenance	0	17	17	17	12	12	12													
Expendables research supplies	0	12	12	12	8	8	8													
Cooperative research, studies	0	31	31	31	31	31	31													
Evaluations	200	0	0	40	0	0	80													
Contingency (10%)	20	12	12	16	9	10	18													
Sub-total	220	129	130	174	101	113	201													
Recurrents costs financed by the Government of Mali:																				
Salaries																				
Professional staff																				
Support staff	0	37	37	37	37	37	37													
Vehicle maintenance	0	4	4	4	15	4	4													
Office supplies	0	0	0	0	4	4	4													
Rents, utilities, building, maintenance	0	0	0	0	3	3	3													
Expendable research supplies	0	0	0	0	5	5	5													
Cooperative research, studies	0	0	0	0	4	4	4													
Contingency (10%)	0	0	0	0	0	0	0													
	0	4	4	4	7	6	6													
Sub-total	0	45	45	45	75	62	62													

Table 19. (cont'd.)

Item by Stratum (1)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
TOTAL PROJECT COSTS	556	1277	676	606	659	194	285	-438												
TOTAL OUTFLOW	557	1278	680	617	679	232	351	-328	167	235	315	410	517	627	723	798	848	880	899	910
TOTAL ON-FARM INCREMENTAL NET BENEFITS	0	0	3	8	17	37	71	119	174	223	266	305	345	382	414	438	454	464	470	474
INCREMENTAL NET BENEFITS (net cash flow)	-556	-1276	-673	-598	-641	-157	-213	557	174	223	266	305	345	382	414	438	454	464	470	474

NET PRESENT WORTH AT 12% OPPORTUNITY COST OF CAPITAL ($US '000) = -1864
INTERNAL RATE OF RETURN (%) = 1.68
NET BENEFIT-INVESTMENT RATIO AT 12% OPPORTUNITY COST = 0.36

(1) Direct effects only.
Source: Henry de Frahan 1990, p. 448-9.

Table 20. Economic Value of the Project (Summary)

CRITERIA	VALUE
NET PRESENT VALUE ($US '000):	
at 10%	-1745
at 12%	-1864
at 15%	-1949
at 20%	-1950
INTERNAL RATE OF RETURN (%)	2
NET BENEFIT-INVESTMENT RATIO	0.4

Source: Henry de Frahan 1990, p. 252.

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