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THE ROLE OF MARKET CONDITIONS IN INFLUENCING THE ADOPTION OF NEW AGRICULTURAL TECHNOLOGIES IN MALI

by

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Report to USAID/Mali prepared under

Food Security in Africa Cooperative Agreement

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Department of Agricultural Economics Staff Paper 89-109

PREFACE

This report was written during one week of a three-week visit to Mali. Because of the short time available to research and write the paper, it should be in no way interpreted as an exhaustive review of the profitability of the technologies developed by the Malian agricultural research system. Rather, the report is intended simply to raise issues and stimulate discussion among scientists and policy makers about the need to integrate the social and technical sciences more effectively in the agricultural research system in Mali.

In addition to this report, I have provided the Agricultural Development Office of USAID/Mali with a set of readings (most in English) on integrating social and technical sciences in agricultural research systems. A list of these documents is included in Annex 6.

In developing the report I drew heavily on the ideas of Malian and expatriate scientists who have worked in the agricultural research in Mali and elsewhere in Africa (see Appendix 5). Tracy Atwood and David Atwood of USAID/Mali's Agricultural Development Office also provided very useful comments on an earlier version of the report. All remaining errors of fact or omission are my responsibility.

THE ROLE OF MARKET CONDITIONS IN INFLUENCING THE ADOPTION OF NEW AGRICULTURAL TECHNOLOGIES IN MALI

by

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THE PROBLEM

Technical scientists working in the agricultural research system in Mali increasingly argue that the lack of remunerative markets for basic grains and legumes, such as maize, millet, sorghum, and cowpeas, hinders adoption of varieties and technical recommendations produced by the research system.[1] The argument is often phrased in the following terms: "Farmers are not able to afford to adopt the new technologies given current market prices." Some of the proponents of this view go on to argue that without government action to relieve the market constraints, such as a return to government-mandated support prices or a price stabilization program, little technological progress can be expected in the near future in Malian agriculture.

The argument put forth by these scientists raises a number of fundamental questions about the nature of the agricultural technologies produced by the research system in Mali, the functioning of agricultural input and output markets, and, ultimately, the need to integrate the work of technical and social scientists more closely in the Malian agricultural research system. This report attempts to address those issues, based on a review of the existing literature and discussions with several agricultural researchers in Mali.

Trying to Clarify the Question

It is not immediately clear what scientists mean when they say that "farmers cannot afford the new technologies." Several possibilities exist, and in order to analyze the issue clearly, we need to distinguish among them:

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[1] In this report, the term "technical scientists" refers to agronomists, agricultural engineers, breeders, entomologists, soil scientists, physiologists, pathologists, and scientists trained in other biological disciplines. The term "social scientists" refers to economists, sociologists, and anthropologists.

The basic argument that market constraints hinder adoption of new technologies is made in several recent documents: Schilling et al. (1989, p. B-10); IER/DRSPR (1989), Coulibaly (1989), Camara (1989), FSR/E (1989). The view was also expressed to me by several technical scientists working in the research system (see Appendix 4).

Lack of Overall (Average) Profitability

One possibility is that given the current price structure, the new technologies are less profitable, on average across various years, than the technologies currently used by farmers. If so, this implies that the unit costs of production for the new technologies are greater than for traditional ones. The unit cost of production refers to how much it costs to produce 1 unit of output, such as 1 kg of sorghum.

For example, consider four technical packages for growing sorghum, with the characteristics shown in table 1. The traditional variety, grown under manual cultivation, has low yields, uses few purchased inputs and has a cost of production of 45 CFA.F/kg. The next three packages involve varieties which require increasingly large amounts of purchased inputs, but use much less labor because they involve using animal traction. Two points are worth noting from Table 1. First, the traditional variety, in spite its low yields, has the second lowest unit cost of production of the four alternatives. Yields are low, but so are costs. Second, maximizing yields does not necessarily drive down the unit cost of production. Variety 2 has twice the yield of variety 1 but a higher cost of production. The slightly higher yield and lower labor costs of Variety 3 relative to Variety 2 results in the third variety having the lowest unit cost of production of the four alternatives. Using even more purchased inputs along with Variety 4 pushes yields even higher. But the higher input costs are not completely offset by the higher output; consequently, its unit cost of production is the second highest of the four alternatives. The general point is that there is no guarantee that using more purchased inputs and fertilizer-responsive varieties will drive down costs of production. It depends on how responsive the varieties are relative to the costs of the inputs they require. (For more details on the relationship between cost of production and farmer profitability, see Appendix 1).

If the unit costs of production are higher for the new technologies being developed by the Malian agricultural research system, then these technologies use more of Mali's scarce resources to produce a unit of food than the traditional technologies. In other words, the new technologies may allow the country to produce more food, but that food, as valued by the market, is worth less to the country than the value of the inputs used in producing it. In what sense, then, can we call these technologies "improved"? This gets down to a question of the lack of economic input in helping set criteria for breeding and other technical agricultural research. It also raises the question of whether the market somehow undervalues food crops relative to other commodities.

TABLE 1--HYPOTHETICAL EXAMPLE OF COST OF PRODUCTION
THREE VARIETIES OF SORGHUM
(IN CFA.F/KG)

COST ITEM	VARIETY 1 (TRADITIONAL)	NEW VARIETIES VAR. 2	VAR. 3	VAR. 4
LABOR COST (CFA.F/HA)				
DAYS OF LABOR	60	38	33	33
COST (400 CFA.F/DAY)	24000	15200	13200	13200
NON LABOR COST (CFA.F/HA)				
FERTILIZER	0	25000	27000	38000
ANNUAL EQUIPMENT COST	3000	13000	13000	17000
PESTICIDES	0	5000	6000	7000
TOTAL COST PER HA.	27000	58200	59200	75200
YIELD (KG/HA)	600	1200	1400	1600
UNIT COST OF PRODUCTION (CFA.F/KG)	45.0	48.5	42.2	47.0

In essence, those who argue for higher prices to spur adoption of such technology are advocating a "price-led" strategy of agricultural development. Such a strategy, as opposed to one based on reducing unit costs of production (and hence the real cost of food to consumers), raises serious questions for a country like Mali, where a large number of rural residents are net purchasers of food who would be hurt in the short run by higher food prices (Dembélé and Staatz, 1989). Higher food costs would also probably result in pressures to raise wages (and hence increase labor costs), thereby reducing the competitiveness of the non-cereals sectors of the economy. It would also increase production costs to those industries, such as poultry production, that use cereals as a major input.[2]

The lack of profitability (high unit costs of production) of the new technologies could reflect the high opportunity cost of the resources they demand (e.g., family labor at critical times in the production of other crops) or a low market value for the output for those technologies relative to that from traditional technologies. For example, consumers may discount the price of new varieties because they do not taste as good as traditional varieties.[3]

Riskiness of the New Technologies

A second possibility is that the new technologies are more profitable than traditional technologies on average, but that the returns in any single year are highly unpredictable. The new technologies may thus generate more risk than small farmers, operating at the edge of subsistence, can afford to bear. In Mali, such risk could be a function of: (a) the unpredictability of rainfall, which affects the return from investment in certain purchased inputs, especially chemical fertilizers; (b) the volatility of output markets, which serve both as outlets in which farmers sell their marketable surplus in good years and sources of purchased food in case the new technology fails; or (c) unreliability of the market for key inputs that are necessary components of the new technology. If capital markets worked well in rural areas, the risk problem would be much less, as farmers could simply borrow in bad years and repay with their higher earnings in good years.

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[2]The question of whether to follow a price-led strategy of agricultural development is at the core of the debate about whether to create a regional protected market for cereals in the Sahel. For a summary of that debate see Gabas, Giri, and Martetal; Dembélé and Staatz, Jayne and Minot, Shapiro and Berg, and Gentil and Ledoux.

[3]IER's Food Technology Laboratory at Sotuba, which was established as part of the ICRISAT/Mali project, has played an important part in reducing consumer acceptability problems of new sorghum varieties by screening such varieties for to quality before they are tested at the farm level. Nonetheless, some problems remain. Seventy percent of the farmers interviewed in the Cinzana area by Coulibaly (1989) report that the poor taste of the new sorghum variety CE-90 was an important factor in their decision not to adopt it.

A variant on the risk argument is that the innovations being proposed are profitable and are not empirically more risky than traditional technologies, but because the farmers are unaware of the potential of the new technologies, they need a higher price (or subsidized inputs) to get them to try the innovation. In other words, the farmers perceive the innovation as being more risky than it really is. Presumably, once they have tried the innovation and found it profitable, they would continue to use it even if prices returned to market equilibrium levels. This argument is the traditional one for fertilizer subsidies when fertilizer-responsive varieties are first being introduced, farmers don't know the profit-maximizing dose of fertilizer, and because they are risk-averse, they tend to under-apply fertilizer. A subsidy induces them to apply the economically efficient amount. Surprisingly, I have not heard this argument made in Mali. The researchers I have talked to say that farmers know about fertilizers already; these researchers argue that it is just the price relationships that discourage the use of this input.

Credit Constraints

Another possibility is that the new technologies appear attractive to farmers, in that they are profitable and not too risky, but that farmers are prevented from adopting them due to a credit constraint. That is, the technologies require a large investment in purchased inputs which the farmers "cannot afford" in the short-run due to cash flow constraints even though the inputs would pay for themselves if the farmers could obtain them. This constraint would not arise if capital markets were functioning well in rural areas, but in rural Mali they do not. Such constraints are likely to be most severe when the level of investment required to adopt the new technology is high (e.g., purchase of animal traction equipment) or where the payoff to the investment accrues over several years but available credit must be paid back in one year (e.g., this may be the case for annual credit extended for the purchase of natural rock phosphate (PNT)[1], whose impact may be felt over three years [Coulibaly, 1987; Mali FSR/E Project, p.18]).

Raising agricultural prices would raise the net incomes of farmers who are net sellers of these products, thereby allowing them eventually to accumulate the capital needed to adopt the new technologies. If the new technologies really were cost-reducing, then once farmers had adopted them, the market prices could be lowered to the long-run average cost of production without farmers abandoning the new technologies. However, it may be much less costly to address the credit constraint directly through programs aimed at improving the functioning of rural financial markets than through output price policy.

Poorly Functioning Input Markets

Sometimes it is alleged that farmers face a credit constraint that prevents them from adopting new technologies, when in reality the problem is not a liquidity constraint but poorly functioning input markets. That is, farmers may want to adopt a new technology, have the liquidity to do so, but markets for the key inputs simply do not exist in the rural areas or if they do, can't

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[1]Phosphate Naturel de Tilemsi.

deliver the amount of inputs farmers want to buy. This could occur if inputs are handled by an organization (e.g., an ODR) that is driven primarily by administrative rather than market imperatives. It could also occur if potential sellers of the inputs view the market as either too small (e.g., in the early stages of adoption of a new technology) or too risky to be worth entering. The risk question may be particularly important in the market for fertilizer destined for cereal crops. Malian farmers appear to be well aware that the return to fertilizer depends on getting adequate rainfall (Coulibaly, 1989). If they put off their fertilizer purchase decisions until they see whether the rains look adequate, the fertilizer merchant ends up carrying all the inventory risk in the system. Even if farmers don't behave in this way, private fertilizer merchants may face serious problems of credit recovery given the volatility of rainfall, and hence the returns to fertilizer, in most of Mali.

It is because many agricultural development projects in Mali provide credit in kind in the form of agricultural inputs that poorly functioning input markets are often incorrectly diagnosed as a credit constraint. That is, if farmers who lack access to such in-kind credit programs fail to adopt new technologies, it is often said that the lack of credit prevented adoption. In reality, if these farmers had access to credit in cash, it is possible that they still would be unable to adopt the new technologies due to the lack of markets to provide the needed inputs. One area for further research is to distinguish between situations where adoption is blocked by a lack of farmer liquidity versus situations where the lack of functioning input markets prevent adoption.

Lack of a Cash Crop to "Pull Along" the Food Crop

Recent research (e.g., Dioné, 1989a) has stressed the positive interactions between production of cash crops, particularly of cotton, and production of food crops. These involve agronomic interactions (e.g., the residual effects of cotton fertilizers on grain crops grown in rotation with cotton) and the effects that a profitable cash crop has in capitalizing the agricultural system. For example, revenues from cotton production finance the acquisition of animal traction equipment, which is then also used to expand cereal production. Cotton cultivation also provides resources on a village and regional level for the improvement of market infrastructure, the strengthening of village cooperatives, etc., which also have important effects in improving food crop production and marketing. Introduction of new food crop technologies in areas where profitable cash crops do not already exist may be hindered by the lack of such positive interactions, making the food crop technology "unaffordable" to the farmer.

But if this is the case, it suggests that the research needs to be reoriented to more of a systems approach, focusing on how to improve the functioning of the whole farming system, including the role of cash crops in that system. Because farmers seldom adopt entirely new farming systems at once, researchers may need to consider whether initial emphasis needs to be given to finding cash crops suitable for the area that will, in a systems context, subsequently help stimulate food crop production.

Sustainability of the New Technologies

A related question increasingly raised by researchers is the economic and environmental sustainability of proposed new technologies. That is, researchers are asking whether farmers and the country as a whole can afford the proposed new technologies in the long run. This argument is raised primarily with respect to use of purchased inputs, such as pesticides and imported chemical fertilizers. Such researchers argue that greater attention needs to be placed on locally based sources of plant nutrients, such as composting, and control of pests through breeding for resistance rather than through chemical controls.

The issue of the economic sustainability of proposed technologies raises the question of the economic return to imported inputs. In other words, do the imported inputs pay for themselves when both the inputs and outputs are valued at their economic opportunity costs (that is, their value to the country after correcting for overvaluation of the domestic currency and other price distortions). Given that Mali's CFA franc is reportedly overvalued between 33 and 40 percent (Stryker et al.) and other serious price distortions exist in the economy, it is certainly possible that technologies coming out of the research system are not economically sustainable. The only study to look at this issue in Mali so far is that of Henry de Frahan et al.

Methods Used to Address the Question

The approach adopted here to try to address the research question posed at the beginning of this report is a review of the available evidence concerning the cost of production of new agricultural technologies, the riskiness of such technologies, and the existence of constraints on credit and input markets. As mentioned in the preface, given the short time available to prepare this report, the review of the evidence was by means exhaustive.

The evaluation concerns the four dry-land food crops on which major research effort has focused in recent years: millet, sorghum, maize, and cowpeas. In addition to examining direct evidence on these issues, the report also looks at indirect evidence, such as studies of the rates of adoption of new technologies and the emergence of private markets for certain inputs, from which one can draw inferences about the costs of production of the new technologies.

Methodological Issues

In addressing the question of whether prices should be raised to induce adoption of new technologies, one is faced with two major methodological questions: (1) how to define cost of production and (2) how to value agricultural outputs.

Defining Cost of Production

Prior to liberalization of coarse grains markets in Mali, the government set official producer prices on the basis of estimates of the cost of production carried out by the Institut d'Economie Rurale (IER), using data from the ODRs.[5] Yet using cost of production figures to set prices runs into a number theoretical and practical problems. These problems, discussed in detail in Appendix 1, involve defining the nature of the product produced using different technologies, deciding which costs and whose costs should be counted in calculating cost of production, determining the appropriate assumptions to make concerning the conditions under which new technologies are adopted, and deciding how to value unpaid family labor.

Because of the difficulties of comparing costs of production across varying crop mixes and of determining a realistic cost for unpaid family labor, many agricultural economists shy away from calculating costs of production for semi-subsistence agriculture. They prefer instead to compare technologies in terms of their net return to family labor measured, for example, in terms of CFA.F/day devoted to growing a particular crop or crop mix. If two technologies produced exactly the same product or mix of products (e.g., millet and cowpeas in the same proportion), then the activity that had the highest return to family labor would also have the lowest unit cost of production. The advantages of the return-to-family-labor approach is that one can easily compare the relative profitability to the farmer of enterprises that produce a different mix of products without having to make any prior assumptions about how to value family labor. For these reasons, some of the findings presented below compare technologies in terms of returns to family labor rather than unit costs of production.

Valuing Output

The other major conceptual issue involved in addressing the returns to investment in new technologies is how the output from these technologies should be valued. In Mali, the question boils down to deciding what is the appropriate value to farmers and to society of basic staples. The issue is complicated by the volatility of the market, both seasonally and interannually, which makes it difficult to simply use "market prices" to value output. One has to first decide which market price is appropriate. The volatility of market prices is related both to the thinness of the market for basic staples and the wide annual variations in production of rainfed crops due to fluctuating rainfall (Staatz, Dioné, and Dembélé; D'Agostino and Staatz).

Presumably, the value to the country of additional output is some sort of long-run average price of the product over several years, although this is may be difficult to define operationally. (One option would be to use 5-year moving average prices). The issue is complicated by the alleged overvaluation of the CFA franc, which would result in the market undervaluing import-substitutes like domestically produced grains.

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[5]Organisations du Développement Rural

If the opportunity cost to the country of additional output is the long-run average or trend price, then given the volatility of market prices in Mali, there may be an economic rationale for some sort of price stabilization (but not necessarily a price support program).[6] This justification would exist if farmers lack the liquidity to weather wide price fluctuations from year to year and consequently make their technology adoption decisions based on the lowest expected price in the market rather than the average price. Past attempts to stabilize prices in Mali through OPAM's domestic buffer stock have failed, although there may be some scope for price stabilization through greater use of international trade (Dembélé and Staatz).

The value of additional production to different types of farmers will also vary. Hence, one would expect that the incentives to adopt new technologies will vary widely by farmer. For net sellers of grain, the value of additional output will be the amount these farmers can receive on the market for additional sales. If the farmers are forced to sell soon after harvest to pay taxes and meet other pressing cash needs (see Dioné, 1989a), then the value may be quite low, thereby discouraging adoption of new technologies. For net buyers (some of whom may also sell some of their crop soon after harvest), the appropriate opportunity cost of the grain is the price they have to pay for their purchases, which can be very high if made in the soudure.[7]

The value the market assigns to a given product can also be modified through changing the technical characteristics of the product itself. For example, the poor storing characteristics of cowpeas limits the development of a strong market for them, thus reducing incentives to adopt new varieties (Coulibaly, 1987).

THE EVIDENCE

Costs of Production and Farmer Returns

The evidence is very fragmented and weak concerning how the new technologies proposed by the Malian research system affect costs of production and farmer returns. This in itself says a lot about how poorly economics has been integrated into the agricultural research system in Mali. During interviews with Malian and expatriate researchers, several of whom said that farmers "could not afford the new technologies," I asked them to specify which of the possible interpretations of this statement outlined in the previous section applied. The general response was "They all do." The problem is to

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[6] A price stabilization program attempts to reduce the price fluctuations around the long term average or trend price, while a price support program aims at raising the level of that average or trend price).

[7] For example, in 1987/88, a year of wide seasonal price variation, the farm-gate price of millet in the northern OHV zone ranged from 30 CFA.F in November,1987 (the immediate post-harvest period) to 130 CFA.F during the soudure in July, 1988 (D'Agostino and Staatz).

differentiate which constraints apply in a given particular situation. Simply saying that all the problems apply may represent a sufficiently incomplete and undifferentiated assessment of farmer constraints so as to prevent better targeting of research.

Cowpeas

Perhaps the clearest evidence concerning farmer returns and cost of production concerns the development and diffusion of new varieties of cowpeas at the Cinzana research station between 1983 and 1987. Coulibaly (1987, 1989) has carefully studied the factors affecting the diffusion of these new varieties. Between 1983 and 1987 the area planted to new cowpea varieties in the Cinzana area grew from 10 ha to 1100 ha. The new varieties, which have growing cycles of 60-75 days compared with 120-160 days for traditional varieties, were widely adopted by farmers having access to in-kind credit. Over 90% of the farmers in 5 villages around Cinzana studied by Coulibaly in 1989 had adopted the new varieties.

Farmers cited three key factors that encouraged adoption of these varieties: early maturity, high yields, and sweeter taste compared to traditional varieties. The early maturity meant that the crop came in during the soudure and thus broke the hungry season. In other words, the implicit value to the family of a secure food source at this time was very high. In part because of their short cycle, which allowed the varieties to escape the effects of late-season drought, the grain yields were also much higher than traditional varieties. This translated into a lower per-unit cost of production for these varieties when cost of production is measured in terms of cost per unit seed produced. In 1986, for example, the grain yield of traditional varieties was only about 80 kg/ha, compared to 1000 kg for the new varieties when insecticides were applied (Coulibaly, 1987, p.91).[8]

The spread of the new varieties of cowpeas around Cinzana also illustrates the role of market factors in affecting adoption. Initial diffusion was stimulated by a high price offered by the Fonds de Développment Villagois de Ségou (FDVS) project, which paid farmers 100 CFA.F/kg in 1985/86 in order to obtain seeds to distribute to other farmers in the area. This price substantially exceeded the unit cost of production of roughly 62 CFA.F/kg (when family labor is valued at 500 CFA.F/day) (calculated from data in Coulibaly, 1987). The high price led to rapid adoption, but in the subsequent year the project was unable to buy all the farmers' production. Because of

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[8]Nonetheless, farmers continued also to cultivate traditional varieties because their yield in forage, used to feed draft animals, was much higher than the new varieties. In addition, work of the DRSPR team in the OHV zone suggests that the intercropping of traditional varieties of cowpeas with millet or sorghum, as is also done around Cinzana, is a risk avoidance strategy. If rains are good, as was true in 1986, the grain crop succeeds and the cowpeas yield mainly hay; whereas if there is a drought, the cowpea may provide at least some staple food (Jensen debriefing). In contrast, the new varieties of cowpeas are grown only in pure stands.

the thinness of the market (due in part to local traders being unaware of the big increase in production), farm-gate prices at harvest fell to roughly 50 CFA.F/kg. At this price, the marginal return to farmers' labor of adopting the new varieties fell below the average return to labor in the traditional farming system (Coulibaly, 1987, p. 94). Many farmers subsequently cut back production of the new varieties for the market, although they continued to produce the new varieties for home consumption, presumably because of the high value they placed on having the extra food during the soudure.

The collapse of cowpea prices around Cinzana reflects problems of market development for new varieties. Given the small amounts of cowpeas traditionally produced in the area, few traders were operating in the area when the great increase in production occurred. In addition, the poor storability characteristics of cowpeas and complicated administrative procedures involved in exporting them to Cote d'Ivoire, where traders reported that demand was strong, limited demand. Traders became more aware of the availability of substantial amounts of cowpeas in the area in 1987/88. This, combined with the reduction in production, led prices to recover to 90-100 CFA.F/kg., causing some farmers to expand their area devoted to cowpeas once again (Coulibaly, 1989, p.22). The simplification of export procedures for agricultural products initiated in June 1989 may also help strengthen the market for cowpeas. An important area for further technical research should be on improved storage techniques for cowpeas, which could help strengthen the market by allowing traders to buy cowpeas for sale later in the year. An area for further policy research is to monitor what effects, if any, the simplification of export procedures will have on the cowpea market.

Input availability and credit also played key roles in fostering the adoption of the new cowpea varieties. The profitability of the new varieties depends critically on the use of insecticides, as the varieties are highly vulnerable to insects, particularly aphids and pod bugs. The lack of access to these inputs appears to have constrained some farmers from adopting the new varieties. Coulibaly's analysis shows that only 5% of farmers in villages that had access to an in-kind credit program run by the FDVS project had tried the new varieties and subsequently quit using them, compared with 93% of the farmers in these villages who continued using the new varieties. In contrast, 80% of farmers in area villages without access to the key inputs on credit had tried the new varieties but abandoned them because they were not profitable without the insecticides (1987, p. 54). Coulibaly's analysis suggests that for most of the farmers, the main constraint was one of cash flow, as the average annual incremental cost per farm of adopting the new varieties was 21,000 - 25,000 CFA.F (1987, p. 92). He reports, however, that a few farmers who did not have access to the FDVS in-kind credit program did have sufficient liquidity to buy the inputs but that no private input market existed to supply them. Ironically, the existence of the in-kind credit program may have usurped most of the potential market demand, thus reducing incentives of private merchants to provide the needed inputs.

Millet

Researchers appear to have been less successful in developing fertilizer-responsive varieties of millet than of sorghum and maize. Kagbo reports that SAFGRAD on-farm tests of new millet varieties (NKK [an improved local variety] and IRAT P173) in the OHV zone showed them to yield on average less over three years than local varieties. Henry de Frahan et al. report that the yield advantage of these varieties in the Fifth region originally reported by SAFGRAD may have been overstated because the SAFGRAD tests did not take account of the bird damage suffered by these varieties in the absence of mass adoption by villagers.

There has been some limited adoption of shorter-cycle varieties (esp. NKK), which, on average, don't appear to yield any better than local varieties, but do have add some yield stability (i.e, they yield better in drought years). Assuming equal input costs, in good years, the unit cost of production for these varieties is higher than for traditional varieties. That is, if the local varieties outyield the short-cycle varieties in good years, as the evidence seems to suggest, the cost per kg of millet produced is higher for the new varieties (the same cost is spread over fewer kg of grain). But in poor years, when yields of the traditional varieties may fall because of late season drought, unit costs of production are lower for the new varieties. The limited adoption of these varieties (see ICRISAT/Mali appendix) suggests that farmers, on the whole, don't find that these varieties stabilize yields that much (perhaps because of bird damage?), that there are other characteristics of the varieties they dislike, or that farmers don't put a large value on the yield stabilizing aspects of these varieties.

Tests have also been run on the responsiveness of millet varieties to fertilizer, particularly PNT. Informal discussions with agronomists indicate that while there is some biological response, most believe that it is not sufficient to make use of the fertilizer profitable given current price relationships.

Sorghum

Sorghum varieties have been developed by the research system that are more fertilizer-responsive than the new millet varieties, yet the economics continues to look questionable. SAFGRAD tests in OHV from 1983 through 1985 showed that improved varieties outyielded local varieties in two out of three years, but that the local variety (Tiémantié) did better in the lowest rainfall year (1983). This reflects a problem that several researchers allege is common for varieties coming out of the research system: they perform no better (sometimes worse) under the low fertility and management conditions that characterize many Malian farms. Camara's analysis (1989) suggests that the unit cost of production of sorghum in the OHV zone using new varieties and more intensive input use is about 10% higher than under traditional technology. Coulibaly's analysis (1989) shows that farmers would lose on average 8,650 CFA.F/ha if they applied the fertilizer level recommended by the extension service (135 kg/ha), while they made 1,500 CFA/ha using 34 kg/ha. (These figures assume a labor cost of 500 CFA.F/day).

Some potentially promising work coming out of DRSPR on sorghum-cowpea intercropping using PNT and higher densities of cowpeas. This allows higher yields of cowpeas with no or little loss in sorghum yields. Also increases organic material in the soil (root formation of cowpeas), reduces weeds, and increases friability of the soil (Caldwell, personal communication; McKenna). To date, the economics hasn't been analyzed.

Maize

There has been widespread adoption of improved varieties, particularly Tiémantié (an improved local variety) and Safita 02, in the OHV zone and especially in the CMDT region, which seems to reflect yield superiority and fertilizer responsiveness (see Kagbo). A number of factors seemed to have fostered adoption of these varieties in addition to their higher grain yields:

1. For a given quantity of milled maize, Tiémantié reportedly yields more flour ("semoule") (Kagbo).

2. The widespread availability of urea and other fertilizers through CMDT distribution channels.. Not only was cotton fertilizer available on credit, some of which was used on maize, but CMDT also extended credit explicitly for fertilizer to be used on maize.

2. The generally good market infrastructure in the CMDT zone, which aided in the marketing of the crop.

3. The early maturity of the maize relative to millet and sorghum. Maize has become the most important crop in "breaking the soudure" in much of southern Mali. As a consequence, only a small proportion of the crop, about 2.5%, appears to be marketed (Dioné, 1989a).

4. CMDT's willingness to offer a guaranteed market for maize, particularly in 1985/86 when CMDT acted as a buying agent for OPAM. CMDT has ceased playing this role after 1985/86 because OPAM never reimbursed CMDT for the maize it purchased in that year.

5. The official pricing structure that was in place until 1988, which priced maize at the same level as millet and sorghum. In the market, by contrast, maize generally sells at a lower price than the other two cereals. When the state attempted to defend the official producer price of 55 CFA.F/kg in 1985/86, maize prices rose substantially relative to millet and sorghum, encouraging adoption of new maize varieties.

In the last year, however, the economic advantage of the new maize varieties may have been compromised by poor quality seed distributed by CMDT. John Caldwell (personal communication) and James McKenna report germination rates as low as 50% for some of the maize seed distributed to farmers in southern OHV.

Millet-Maize Intercropping

Here the evidence seems to suggest that the technology is profitable. As mentioned in Appendix 1, there are problems in evaluating costs of production in intercropping when the relative amounts of the different crops change across technologies, but Cissé's analysis shows that farmers returns were higher with this technology than with traditional cropping patterns. In his linear programing analysis of farms using manual cultivation in the Mali-Sud region, by far the highest returns per ha. of all cropping activities accrued to the millet/maize combination. (The other alternatives were (a)sole cropping of sorghum and millet, (b) a cotton and sorghum rotation,(c) a combination of sorghum and millet along with cotton, and (d) sorghum and millet, combined with sole cropping of maize.) Camara (1988) showed that 80% of the millet in the area of Deguela (OHV zone) was intercropped with maize, compared with only 26% of the sorghum. His analysis, like that of Cissé, showed farmers returns were highest, using both manual cultivation and animal traction, for the millet/maize intercrop.

Certainly the widespread adoption of this intercropping system would tend to confirm its economic advantages.

Fertilizer Recommendations

Fertilizer recommendations of course vary by crop. Fertilizer response also varies widely by area, based on rainfall (response is much higher on average in the south than in the north) and the underlying soil fertility. Given the wide variations in soil fertility, even within a village (McKenna), making uniform fertilizer recommendations is very risky.

The economics of fertilizer use for each of the different commodities is addressed above. Another important issue is the form in which the nutrients are delivered. This is most apparent for phosphates, where the options include imported forms (ammonium phosphate and simple superphosphate) and locally produced natural rock phosphate from Tilemsi (PNT). Although agronomic response is higher with the imported versions due to their higher concentrations of P_2O_5, price relationships seem to favor PNT. Coulibaly (1989) reports that PNT is highly subsidized, selling for 30 CFA.F/kg compared with 150 CFA.F/kg for simple superphosphate. Assuming that PNT contains 6% P_2O_5 compared with 18% for simple-super, PNT cost 40% less per unit of nutrient than the imported alternative. Perhaps coincidently, the 40% lower cost, if totally attributable to the subsidy, would just offset the price advantage of the imported fertilizer that could be attributed to the overvalued exchange rate.

Some farmers have been reluctant to adopt PNT, however, because its powdery form (necessary to ensure solubility) makes it appear like dust. They fear that given its appearance, sellers could easily fill it with inert material, thereby reducing its nutrient content (McKenna). Hence insecurity about the input supply system (which is related to the more general problem of insecurity of contract in Mali) may be hindering the adoption of a profitable technical innovation.

Other Indirect Evidence

Private markets have emerged for some general purpose "improved" inputs, primarily in the southern, higher rainfall areas of Mali. The emergence of such markets suggest that such technologies reduce unit costs of production (raise farmer returns). It also suggests that private markets can emerge for inputs that have broad use. In contrast, highly specialized inputs may represent too thin a market to induce private merchants to enter, particularly in the early stages of diffusion of technologies based on such inputs.

Animal Traction Equipment

In the CMDT zone, private markets exist for animal traction equipment, including both large equipment, like locally manufactured carts and multi-purpose plows, as well as spare parts. The emergence of this market was in response to farmers' effective demand for this apparently profitable technology, particularly as it relates to cotton production. (For a review of the evidence on the profitability of animal traction, see Dioné, 1989a, pp. 235-48). It was helped on the supply side as well by large efforts by the World-Bank funded projects and others to train local blacksmiths and improve their supply system for inputs, particularly for tempered steel. In contrast, Henry de Frahan et al. report that blacksmiths' problems in getting access to tempered steel in the Fifth Region restricts the emergence of a market in high-quality locally produced animal traction equipment. Because of supply problems of SMECMA, the main animal traction manufacturer in Bamako, farmers in the Fifth Region are also frustrated from getting the equipment they need, even though many have had down payments on such equipment for over a year. Camara (1988) reported similar problems in the Deguela region of OHV.

The evidence, reviewed by Dioné (1989a), suggests that farmers do find such equipment profitable, and that some, at least, can obtain the capital to purchase their equipment even in the absence of formal credit programs.[9] One area for further economics research is on the functioning of the markets for these inputs in areas like the Fifth Region to understand better why the market hasn't responded well to what appears to be an effective demand.

Chemical Inputs

Perhaps the most widely used chemical input for which a private market has developed in Mali is fungicide used for treating cereals and cowpea seeds. This fungicide (thioral) is widely available in small packets that typically cost 50 CFA.F in southern Mali and treat 10 kg of seeds. Henry de Frahan et al. report that the fungicide is widely available even in small rural markets of the Fifth Region, and area generally poorly served by input markets. The proven efficacity of the product, its low bulk, and low price have all contributed to the development of an effective private distribution system.

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[9]Dioné (1989a, pp. 248-56) discusses in detail how farmers in the CMDT and OHV zones have financed their acquisition of animal traction equipment.

According to researchers consulted during the course of carrying out this assignment, private markets exist for chemical fertilizers close to the Guinean and Ivoirian borders. These markets have developed in part because fertilizer subsidies in Guinea and Cote d'Ivoire make smuggled fertilizer cheaper than legally imported substitutes available largely through the ODRs. Nonetheless, the emergence of such markets also indicates that farmers, even in the absence of credit programs, will buy such products if price/productivity relationships are favorable. Most researchers believe that most of these fertilizers are going onto cotton and maize, two of the most fertilizer-responsive crops in southern Mali. A relatively flourishing private market for fertilizers and other chemical inputs also seems to have developed in Bamako to serve fruit and vegetable producers in the capital area. The emergence of these markets seems to indicate that at least for these general purpose inputs, the private market is responsive if there is effective demand for the inputs. The effective demand is in turn a function of the marginal value product of the inputs, that is, the physical productivity of the input (a function of the type of plant and its growing environment, especially the level of soil moisture throughout the growing season) and the price of the final output. It is much less likely that such markets will emerge for crops of low responsiveness, such as millet, grown in the more arid north.

Organic Manures

Malian agricultural researchers also report that markets have grown, especially in the southern part of the country, for animal manures, as farmers increasingly recognize their value in improving soil structure and providing nutrients. Again, the emergence of such markets suggests that there are no inherent reasons why markets for general purpose agricultural inputs can't emerge in Mali. The key factor is that the input be productive enough when evaluated in terms of the market value of the increased production that it engenders.

The fact that markets have developed for some general purpose inputs suggests that if markets are missing for other types of inputs, the first hypothesis that should be tested is that, given current relative prices, the input won't pay for itself at the farm level. The policy implication of this hypothesis, if verified, is that efforts should be put first into increasing the productivity of the input rather than trying "artificially" to create a delivery system for which insufficient effective demand exists, unless such a delivery system can substantially reduce the real delivered cost of the inputs to the farmers.

IMPLICATIONS FOR AGRICULTURAL RESEARCH IN MALI

It is a healthy sign that technical agricultural researchers in Mali are raising the issue of how market conditions affect the adoption of technologies developed by the research system. This concern reflects an increasing recognition of the need to incorporate economics and other social-science input earlier into the research process. Traditionally, many technical scientists in the Malian agricultural research system saw the role of

economics as simply partial budgeting (Jensen). Technologies were developed by breeders, agronomists, etc., and the role of the economist was to see if it was in the financial interest of the farmer to adopt them. More recently technical scientists have become concerned about marketing constraints, particularly for grains and cowpeas, but also for livestock. As discussed above, the interest seems to be to have economists study the markets so as to come up with ways of making markets more stable and remunerative to farmers so that they will adopt the technologies that have been developed. A few technical scientists also see the need for economic input earlier in the design of the technologies themselves.

Despite the call of some technical scientists to involve social scientists earlier in the process of technology design (in helping to identify farmer constraints and set research priorities), in the current research structure in Mali, economists and other social scientists still are "at the end of the line." In other words, the social scientists are asked to deal with socio-economic issues as they relate to technologies after they have been developed.

The lack of integration of economics and technical research goes both ways. For example, many economists in Mali are currently studying agricultural marketing reforms, however to date there has been little input from technical scientists on these issues. Yet the success of such reforms often depend on technical issues. For example, whether liberalizing fertilizer markets will result in supplies of fertilizer being available in rural areas depends on the fertilizer responsiveness of current varieties, which in turn is a key determinant of the effective demand for the input.

If social science and technical agricultural research are to be integrated more productively, the demand for such integration must come from the researchers themselves and be supported by those high in the research system. Such integration can't be imposed from above or from an outside funding agency if the researchers themselves aren't convinced of its value. Yet, given the desire of technical and social scientists in the system to work more closely together, support from above and from outside can be very useful in helping bring about the integration. Given that at least some in the Malian research system see the need for greater collaboration of technical and social scientists, it is appropriate that the leadership of IER and USAID consider what actions they can take to help foster such integration.

First Steps

Integrating social and technical sciences more productively in the agricultural research system will take time. The current structure of IER, which places all the social scientists in three divisions (DPE, DET, and DRSPR), while most of the technical scientists are in another division (DRA), is certainly not conducive to interactions among the disciplines.[10] The

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[10] DPE = Division de Plannification et d'Evaluation;
DET = Division d'Etudes Techniques
DRSPR = Division de Recherches sur les Systèmes de Production Rurale

recently initiated IER journal could be an important first step in fostering communication across divisions, but by itself it is insufficient. Although a structure exists within DPE (the Section d'Organisation et des Méthodes) which is authorized to organize training sessions and seminars across divisions in IER, no such sessions have been held since 1986. An early step to help foster greater interaction across disciplines in IER would be to organize a series of workshops that would bring together researchers from the different divisions. Useful topics could include:

1. Ways in which Social Scientists Can Contribute to Technical Agricultural Research (See Appendix 3)

2. Ways in Which Technical Agricultural Research Can Contribute to Research on Agricultural Policy Reform (See Appendix 4)

3. Elements of Partial Budgeting and Marginal Analysis for Non-Economists. Currently, fertilizer recommendations are made with little ex-ante budgeting and no marginal analysis to determine economically efficient levels of input use. This is partly because of the design of the fertilizer trials themselves, which typically test only a couple of levels of application and thus provide mainly information on average responses, not marginal responses. The aim of such a workshop would be to provide technical scientists with at least some understanding of how marginal analysis can help guide the development of farmer recommendations. Matlon has also shown how just one or two years of data from such trials, if designed well and spread out geographically, can provide very useful information on the stability of yield responses as well.

   The aim of the seminar would not be to make the technical scientists do the work of the economists (although, as outlined in Appendix 2, there is plenty for the economists to do beyond just evaluating input-use recommendations), but to get the economist and technical scientist speaking enough of a common language so that they can understand each other.

4. Subject matter seminars built around specific commodities (e.g., a series on "What's New in Sorghum?") that would bring together technical and social scientists working on different topics related to the same commodity or commodities. Such seminars would help scientists see how their work related to that of others and perhaps force or permit scientists working in different areas to learn some basic elements of each other's discipline. Knowing at least some of the basic concepts and terms of one's colleagues' discipline is a prerequisite for effective communication across disciplines. In the Malian context, the problem may be more severe for technical scientists talking with agricultural economists rather than vice versa because most agricultural economists in Mali have at least some undergraduate training in agronomy.

DRA = Division de Recherches Agricoles

In addition, it should become standard practice that at least some technical scientists be routinely invited to major national seminars on agricultural policy and that economists working on policy reforms be invited to conferences on new developments in breeding and cropping research. The lack of integration between technical and social sciences in IER was graphically illustrated in 1988, when in the space of one week IER helped organize two major national seminars, one on cereals market reform and the other on developments in sorghum production. There were no common invitees to the two conferences.

Longer-Term Restructuring Options for IER[11]

In the longer run, IER needs to consider changes in its structure to help foster greater interaction among disciplines. One option being proposed by some researchers would involve merging DPE and DET in order to get a critical mass of social scientists within one division. Several of the economists in the new division would then specialize along commodity lines and be based at the research station dealing with their commodity(ies). For example, the millet economist would be based at Cinzana. Each commodity economist would be responsible for investigating all issues in the commodity subsector, from production through marketing. Among their first activities would be to try to examine the set of questions posed at the beginning of this report regarding farmers "not being to be able to afford the new technologies" in order to be more precise about the factors hindering adoption.

A certain number of economists and other social scientists in the new division, probably based in Bamako, would specialize on issues that cut across subsectors--e.g., problems of agricultural credit or processing. They would also travel periodically to the stations to work with the commodity teams on how these "cross-cutting" issues would relate to particular commodities.

Such a reorganization would pose some challenges in coordinating the research effort, such as:

1. How to link the various parts of the research program so that, for example, the credit issues get linked to the commodity issues. This involves tough choices of how to cut up the research issues both conceptually and among researchers and then how to coordinate the various pieces.

2. While posting social scientists on the stations has some advantages, there is also a risk of dispersing them so much that IER would lose the critical mass that it gained by merging DPE and DET. Again, the question of how the station economists would relate to the Bamako staff, as well as each other, becomes critical.

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[11]This section draws heavily on discussions with several Malian researchers, particularly Oumar Niangado, Ousmane N. Coulibaly, and Binou Témé; and with my colleague from Michigan State, Eric Crawford, who has spent several years working with the Senegalese agricultural research system.

3. Would the station-based social scientists have enough travel funds and contact with Bamako to allow them to pursue marketing issues throughout the subsector and keep up to date on policy issues affecting the costs of producing and marketing "their" commodities?

4. How would these social scientists and the station scientists relate to the members of the DRSPR teams? Any plan to integrate social and technical sciences in the overall research system needs also to include DRSPR in the plan.

In order for such coordination to work, IER would need either a strong national research coordinator or technical assistant with sufficient travel funds to visit the various station-based researchers frequently as well as funds for the station researchers to come to Bamako periodically to consult with their colleagues based there.

A slightly modified alternative that has been used in Senegal is to base farming systems teams directly at regional research stations in order to increase their contact with on-station scientists. A second economist, from the "Macro-economics Unit" (BAME), the division of ISRA[12] that deals with agricultural marketing, is also based on the station to deal with issues related to input and output marketing. A small unit at ISRA headquarters in Dakar helps coordinate the work of the farming systems teams, the station-based BAME researchers, and BAME researchers working in Dakar on agricultural policy issues. According to Eric Crawford (personal communication), this system has worked fairly well. One of its advantages is that by having both farming systems researchers and the marketing economist at the station, there are at least two social scientists at each location, who can consult with each other.

A less costly alternative, particularly if there are not enough social scientists to staff all the stations and still handle the cross-cutting work, would be to appoint some social scientists as "circuit riders" to travel regularly to certain stations to work with the technical scientists there. (This could be done whether or not the DRSPR teams were also assigned to work out of the research stations.) Each circuit rider would have certain assigned commodities and would try to develop a joint program with the technical scientists. Here, coordination with the Bamako staff would be better, but maybe poorer links would exist with the station scientists. Again, such an alternative would obviously require adequate travel funds.

If it proves impractical to reorganize the divisions in IER, a relatively simple step would be to consider giving both technical and social scientists split appointments across divisions. That is, an economist or agronomist might be assigned 50% of the time to DRA and 50% of the time to DPE, working, for example, on issues related to rice production and marketing. This arrangement might pose some questions about who would supervise the scientist's work, but it might be considered as an expedient in the interim

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[12]Institut Sénégalais de Recherches Agricoles

before a more fundamental restructuring of IER takes place.

Difficulties in Integrating Social and Technical Sciences in Agricultural Research

There are some inherent difficulties in trying to get social and technical scientists to work together more closely in any agricultural research system. IER and USAID should be aware of these as they consider changes in IER. In other words, we should be modest in our expectations, at least in the short term.

The first common problem is simply that of disciplinary egoism, the belief that one's own discipline addresses the truly important questions and the other disciplines are somewhat secondary. Some professional egoism is unavoidable. Yet the call by technical scientists for greater social science input into research in Mali indicates that it is weakening, at least among the technical scientists. Perhaps more damaging is the perception or belief by members of one discipline that other disciplines devalue their work. For example, a common complaint of agronomists in Mali is that economists "come in sounding like they know everything and want to tell the technical scientists what they should work on."

A related problem hindering greater interdisciplinary work is the lack of knowledge by scientists in one discipline of the basic concepts and concerns of the other discipline. Often, however, people in one field may erroneously believe they know what the other field is about (e.g., some technical scientists in Mali appear to believe that economics is mainly partial budgeting). The lack of knowledge of the basic concepts and concerns of each other's disciplines means that scientists working in different fields often don't have a common language in which to communicate. The series of seminars suggested above is aimed primarily at getting scientists in different disciplines within IER familiar, at least a rudimentary level, about what is going on in the other disciplines.

Collaboration is also sometimes hindered because a scientist in one discipline sometimes doubts that his colleagues in other disciplines have much to offer that is directly relevant to his own professional concerns. Because they have not collaborated much in the past, the different disciplines often lack a track record of making useful contributions to each other's fields. This is in part due to the past structure of the research system. For example, if economists are limited to evaluation of technologies that have already been developed, the economist is often put in the position of telling the technical scientists that they have been wasting their time developing technologies that make no sense economically. Such a message is not likely to be interpreted as a useful contribution to plant breeding or agronomy. It is therefore incumbent on technical and social scientists, when they work together, to try to appreciate their colleagues professional concerns and direct at least some of their research effort to addressing those.

Finally, there are problems of professional insecurity that may block wholehearted collaboration. This is more likely where, as in Mali, researchers are predominantly young, with a relatively low level of

professional training. Some such researchers, feeling professionally insecure and threatened by new approaches about which they know little, may tend to attack each other to try to demonstrate their own professional competence rather than openly discuss how they can help each other. A related problem may occur where, as in Mali, the social scientists in the system are relatively young and many of the technical researchers are older and more established. It may be socially unacceptable for the younger social scientist to question the work of his or her older colleague or be treated as an equal in a collaborative research effort.

These problems, while real, are not insurmountable. But they must be taken into account when planning reforms of the research system.

APPENDIX 1

THEORETICAL AND PRACTICAL PROBLEMS IN CALCULATING COSTS OF PRODUCTION

Theoretically, the concept of cost of production is very slippery.[1] Economic theory states that given perfect knowledge, a farmer will produce a good as long as the marginal benefit derived from the good exceeds marginal cost. Since in the long run, when all factors of production can be varied, marginal cost equals average cost, the fact that a farmer produces a good could be taken as a priori evidence that the marginal benefit exceeds the cost of production. Similarly, if a good is not produced, it could be concluded that the marginal benefit of the good is less than the cost of production.

Applying the simple theory to Mali requires some caveats. First, most Malian farmers produce basic staples primarily for subsistence. In this context, one would expect them always to produce some staples. Given their limited alternative employment possibilities, the marginal benefit to these farmers of assuring a minimum supply of basic staples for their family is very high, since the alternative is starvation. In other words, one can argue that up to a certain point, producers place an implicit value on staples produced for family consumption that exceeds the market value (See Dioné, 1989b). Hence, Malian producers continue to produce basic staples even though the market price falls below IER's estimated cost of production.[2] Nonetheless, the aim of much of the agricultural technology development in Mali is to transform basic staple production into more of a commercial enterprise. If producers do not produce large surpluses of basic staples for the market, this can be taken as a priori evidence that the marginal cost of production exceeds the marginal revenue the farmer can obtain from such production.

The second caveat is that Malian farmers obviously do not operate in a context of perfect knowledge. Given the vagaries of weather and the market in Mali, farmers make mistakes in deciding how much to produce. In order to have a margin of safety in case of bad weather, insect damage, etc., most farmers try to plant in excess of family needs. They may, therefore, find themselves ("by mistake") having a marketable surplus of basic staples at the end of the season even though it was not their main intention to produce these crops for

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[1] Perhaps the best theoretical discussion of the problems of defining cost of production is found in Clark.

[2] For example, the rural assembly market level price of millet in southern CMDT in November, 1988 (immediately after harvest) was approximately 30 CFA>F/kg. compared with IER's estimated cost of production of 50 CFA.F/kg. A major problem with the IER cost of production estimates, however, is how unpaid family labor is valued (see below).

the market.[3] In such a situation, it is possible that the marginal cost of producing the marketable surplus exceeds the marginal revenue the farmer can obtain for it from the market.

There are several other conceptual problems in comparing costs of production between traditional and new technologies. The first arises because new technologies may involve producing a mix of products that is different from that produced with the traditional technology. This is most apparent in research on intercropping, where the recommended practices may involve producing different proportions, say, of grains and legumes, than in traditional intercropping. Because the product mix is not the same, there is no common denominator on which to compare unit costs of production. New intercropping methods may, for example, produce millet more cheaply per kg than traditional practice but be more costly per kg of cowpeas produced. The problem is not limited to intercropping. Cowpeas, for example, are grown for both seed and forage, the latter being extremely valuable in maintaining work animals during the dry season. While new varieties of cowpeas developed at the Cinzana research station far outyield traditional varieties in terms of seeds, they are poorer producers of forage (Coulibaly, 1987). The new varieties thus appear to have lower unit costs of production when evaluated in terms of grain yield, but higher costs of production when evaluated in terms of forage yield.[4]

Another problem in using cost of production to guide price policy is deciding whose cost of production is relevant. Costs of production vary geographically and across technological levels, so that setting prices to cover costs of production will involve deciding whose costs should be covered (Table 1).

Related to this are the issues of which costs of production to include in the calculation and what assumptions to make about the conditions under which the technologies are adopted. Should, for example, cost of production estimates include the cost of extending the new technologies to farmers? Typically such costs are not included, yet if the technology is to be sustainable in the long-run, someone will have to bear these costs. Similar concerns can be raised over whether the costs of environmental damage due to heavy use of pesticides, etc., should be included in costs of production estimates.[5]

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[3]This is not meant deny that some Malian farmers view basic staples as a cash crop and try to produce a surplus for the market. An important topic for future research is to determine what distinguishes these farmers from the bulk of the rural population, who seem to sell coarse grains, if at all, more as a result of overproducing for home consumption rather than as an intentional commercial enterprise.

[4]As a consequence, farmers who have adopted the new varieties also continue to produce the old varieties, primarily for forage (Coulibaly, 1987).

[5]The general theoretical point is that all costs are socially determined. That is, they are a function of decisions by society or the political system regarding which costs different people have to take into account when making their production decisions.

Assumptions regarding the conditions under which the technologies are adopted can also dramatically affect cost of production estimates. For example, a serious problem faced by Malian farmers who try to adopt new short-cycle millet and sorghum varieties is bird damage (Coulibaly, 1989; Henry de Frahan et al.). If only a few farmers in a village adopt the new varieties, the new varieties mature before the rest of the crops in the village and are heavily damaged by hungry birds. The bird damage greatly reduces yields, thereby driving up the unit cost of production. If, on the other hand, everyone in the village were to adopt the new varieties at once, the damage would be spread out over a larger crop and farmers could organize mass bird-scaring operations. Obviously, the assumptions made about how many farmers in the village adopt the new technology at once will affect estimated unit costs of production.

There is also a major practical problem in calculating costs of production for alternative technologies: the valuation of unpaid family labor, particularly when such labor is the major input in the production process, as is the case with most traditional technologies in Mali. In theory, the appropriate value for such labor is its opportunity cost in other enterprises, that is, the value of what the labor could produce for the family if it were not engaged in production of basic staples. Some argue that such opportunity costs are extremely low in traditional agriculture, approaching zero. (For a discussion of the debate, see Gittinger.) In the absence of firm data on the opportunity cost of family labor, the standard practice in calculating costs of production in Mali has been to assign an arbitrary value to such labor, usually close to the official rural minimum wage. For example, IER cost of production estimates assume a value of family labor of 600 CFA.F/day for production of all commodities throughout the country. The justification given for this estimate is the following (République du Mali, p. II):

> La rémunération de la Journée de Travail tient compte du niveau géneral des salaires tout en étant suffisament élevée pour consitituer une incitation à la culture. En la practique, elle est assimilée au salaire journalier du manoeuvre occasionnel. Ce salaire, quoique supérieur au tarif officiel, consitutue le minimum en deÇa duquel il n'est plus possible de recruter de la main-d'oeuvre.

Varying the implicit value of family labor can have dramatic effects on the estimated cost of production (Table A.1), particularly for those crops for which labor is the major input. For example, varying the implicit value of labor used in manual cultivation of millet and sorghum in the Opération Mils Mopti zone between 0 CFA.F/day and 600 CFA.F/day results in estimated costs of production varying from 2 CFA.F/kg to 63 CFA.F/kg. The problem is less severe for crops like cotton, where a larger proportion of total inputs are purchased, but even here, the same variation in labor costs results in the estimated cost of production varying between 54 CFA.F/kg and 115 CFA.F/kg.

TABLE A.1--ESTIMATED COST OF PRODUCTION AS A FUNCTION OF THE VALUATION OF LABOR (IN CFA.F/KG)

COST ITEM	CROP/LOCATION MAIZE IN MALI SUD (ROT. WITH COTTON)	MILLET/SORGHUM MALI SUD (ROT. WITH COTTON)	MILLET/SORGHUM OMM (MANUAL CULTIVATION)	COTTON CMDT
NON-LABOR COST (CFA.F/HA)	42900	9804	1105	64608
LABOR INPUT (DAYS/HA)	99	50	61	122
YIELD/HA (KG)	1600	800	600	1200
TOTAL COST/KG WHEN LABOR COST/DAY (IN CFA.F) IS VALUED AT:				
0	26.8	12.3	1.8	53.8
100	33.0	18.5	12.0	64.4
200	39.2	24.8	22.2	74.2
300	45.4	31.0	32.3	84.3
400	51.6	37.3	42.5	94.5
500	57.8	43.5	52.7	104.7
600	63.9	49.8	62.8	114.8

SOURCE: CALCULATED FROM DATA IN MINISTERE DE L'AGRICULTURE. INSTITUT D'ECONOMIE RURALE. "DETERMINATION DES COUTS MOYENS DE PRODUCTION DES PRINCIPAUX PRODUITS AGRICOLES. CAMPAGNE 1989/1990." BAMAKO: FEVRIER 1989.

APPENDIX 2

BASIC DEFINITIONS RELATED TO ECONOMICS TERMS AND RELATIONSHIPS RELATED TO COST OF PRODUCTION AND FARMER RETURNS

(1) YIELD = PRODUCTION/HECTARES

(2) UNIT COST OF PRODUCTION = (TOTAL COSTS)/(TOTAL PRODUCTION)

= (TOTAL COST/HA)/YIELD

From (2) it can be seen that the unit cost of production will fall as yield increases only if the total costs of production per hectare rise proportionally less than the yield.

(3) TOTAL REVENUE PER HA = YIELD X OUTPUT PRICE

(4) NET REVENUE PER HA (TOTAL FARMER RETURNS/HA) = TOTAL REVENUE - TOTAL COSTS =

YIELD X OUTPUT PRICE - TOTAL COSTS PER HA

From (4) it is apparent that farmer net revenues will increase (for a given output price) only if yields increase proportionately faster than costs per ha.

(5) FARM FAMILY NET RETURN/DAY = (TOTAL REVENUE/HA)/(LABOR INPUT/HA)

From (5) it is apparent that farm family net returns per day will increase only if total revenues/ha increase proportionately faster than labor input per ha.

(5) MARGINAL PHYSICAL PRODUCT (MPP) OF AN INPUT = INCREASE IN OUTPUT RESULTING FROM USING ONE MORE UNIT OF THE INPUT (FOR EXAMPLE, THE NUMBER OF KGS OF MAIZE OBTAINED FROM INCREASING UREA INPUT FROM 50 KG/HA TO 51 KG/HA)

(6) MARGINAL VALUE PRODUCT (MVP) OF AN INPUT = MPP X PRICE OF THE OUTPUT. FOR EXAMPLE, IF THE MPP OF UREA USED ON MAIZE IN THE ABOVE EXAMPLE IS 3 KG AND THE PRICE OF MAIZE IS 30 CFA.F/KG, THEN THE MVP OF UREA IS 3 KG X 30 CFA.F/KG = 90 CFA.F.

(7) MARGINAL COST (MC) OF AN INPUT = COST OF OBTAINING 1 MORE UNIT OF THE INPUT (E.G., THE PRICE PER KG OF UREA).

(8) IT IS PROFITABLE TO CONTINUE TO ADD MORE INPUT ONLY SO LONG AS ITS MARGINAL COST IS LESS THAN ITS MARGINAL REVENUE. IN OTHER WORDS, THE ECONOMIST ASKS, "WILL THE NEXT UNIT OF INPUT PRODUCE ENOUGH REVENUE TO PAY FOR ITSELF?" IN THE ABOVE EXAMPLE, IF THE PRICE OF UREA WAS LESS THAN 90 CFA.F/KG, THEN IT WOULD PAY TO CONTINUE ADDING IT BEYOND 50 KG/HA. IF THE UREA COST 100 CFA.F/KG, IT WOULD NOT PAY TO ADD MORE UREA BEYOND 50 KG/HA EVEN IF DOING SO WOULD CONTINUE TO RAISE YIELDS. THE REASON IS BECAUSE THE EXTRA MAIZE PRODUCTION THAT WOULD BE OBTAINED IS WORTH LESS IN THE MARKET THAN THE COST OF THE ADDITIONAL FERTILIZER.

APPENDIX 3

WAYS IN WHICH SOCIAL SCIENTISTS (ESPECIALLY ECONOMISTS) CAN CONTRIBUTE TO TECHNICAL AGRICULTURAL RESEARCH

I. Partial Budgeting, in Financial Terms, of Innovations Developed by the Research System

A. Partial budgeting, in financial terms, involves evaluating the marginal costs and benefits of an innovation, evaluated in market prices. The aim is to see whether it is in the farmer's current interest to adopt the innovation. Because of the problems discussed in Appendix 1 of valuing unpaid family labor, often the partial budgets estimate the incremental returns to family labor and capital taken together rather than just the return to capital.

B. Many technical scientists have traditionally viewed the role of the economist in agricultural research as limited to carrying out such partial budgeting. (In the Malian context, even this is a rather recent development. It is also how economics first became incorporated into the work of the International Agricultural Research Centers (IARCs).

C. While obviously giving some useful information, there are some serious drawbacks to limiting the role of social scientists to ex-post financial evaluations of the innovations produced by the research system.

1. Because the technology has already been developed, there is very little chance at this stage for input from the economist or other social scientist to modify its design to make it more profitable or otherwise attractive to farmers, traders, or consumers. The economist is thus often put in the position of being a nay-sayer, telling the technical scientists that they have spent all their time developing technologies that are not attractive to the end-users. This obviously does not foster very productive relationships between social and technical scientists.

2. Because the analysis is conducted in financial terms, technologies are evaluated solely in terms of prevailing market prices, which may be highly distorted. Hence, the analysis may end up "endorsing" technologies that are adapted to a domestic price structure that is not macro-economically sustainable. Macroeconomic reforms that change the price structure would then draw into question much of the research effort. For example, Eicher (personal communication) reports that IITA during the 1980s spent considerable effort developing improved cowpea varieties for Nigeria, which were widely diffused. But the technology depended upon key imported inputs, such as ULV

sprayers, that were very cheap when the exchange rate between the niara and the US dollar was 1:1, but prohibitively expensive when devaluation changed the rate to 4:1. With devaluation, many farmers sharply reduced their cultivation of the improved varieties.

II. Partial Budgeting, in Economic Terms, of Innovations

A. Partial budgeting in economic terms involves evaluating the marginal costs and benefits of an innovation evaluated in terms of economic prices, i.e., prices that reflect the true scarcity value to a country of the resources involved in the production of the good and the value of the output.

B. Economic analysis is thus an attempt to evaluate the worth to the country as a whole of an innovation--i.e., whether the extra output gained from the innovation is worth the opportunity cost of the resources that go into producing the extra output. Economic analysis thus corrects for the problem of price distortions that limits financial analysis. (Economic analysis is not a substitute for financial analysis, however, as financial analysis is necessary to evaluate whether farmers, facing current prices, have any incentive to adopt the innovation, even if it is worthwhile for the country as a whole to have it adopted).

C. Limiting social science input to ex-post economic analysis still confronts the problems outlined above for financial analysis of incorporating economic considerations very late in the process of technology development and putting economists in the position of nay-sayers.

D. References:

According to Ousmane N. Coulibaly and Binou Temé, the only evaluation of technology by IER that has carried out any budgeting in economic terms is the report of Bruno Henry de Frahan et al. on the extension of the DRSPR work into the Fifth Region.

III. Evaluating Farmer Socio-economic Constraints and Helping Set Research Priorities for Technical Scientists

A. Role of FSR and farm-level research

B. Techniques--Rapid Reconnaissance vs. Baseline surveys. Trying to decide how to strike a balance between these can lead to conflicts with technical scientists.

C. Examples of issues identified and their implications for agricultural research:

1. Identification of key constraints, such as overall or seasonal labor bottlenecks (e.g., DRSPR work in OHV)--Implications for selective mechanization (Jensen).

2. Evaluation of risk via multi-shot surveys over 1 to 2 years to illuminate agronomic response to rainfall variation (see Matlon)

3. Evaluation of other complementary services needed in order to adopt an innovation (credit, etc.)

4. Farm-system interactions with other farm enterprises. E.g.,

   a. need to develop crops that spread out rather than accentuate labor demand emanating from other enterprises

   b. Recognition of how developments in market for another crop may affect the practices for a "target" crop--e.g., of how the development of a market for tomatoes in Kati induced a farmer to use herbicides on his sorghum to free labor for tomato cultivation (McKenna).

5. Importance of socio-economic factors in defining recommendation domains--e.g., the impact of differing land tenure arrangements on the payoff to improved maize package in Haiti (Yates, 1987).

6. Understanding the social behavior and management processes of farmers and how they affect the design of IPM and more management-intensive technologies. As you move a way from relatively simple "first-wave" biochemical technologies such as just NPK fertilizers and insect control through insecticides, to more sophisticated systems, such as IPM, micro-nutrient monitoring, etc., management becomes more important. In designing IPM, particularly, it is important to understand how people's behavior affects pest populations (creation of habitat, etc.) MSU IPM researchers report that social scientist input into understanding why people behave as they do (e.g., storage practices, household practices, etc.) is critical in the design of effective IPM. This is important as we try to move to more environmentally sustainable technologies.

D. References:

There is a huge literature in this area, not all of it that good in that FSR often treated like a religion. Better references include CIMMYT manuals, Crawford and Kamuanga, Matlon, and Boughton, Crawford, and Krause.

IV. Evaluation of non-farm considerations in the design of technology.

A. Debate about designing technologies for low- vs. high-levels of outside inputs (nutrients, credit, extension). Without information from social scientists, in short run technical scientists may end up designing technologies that are intensive in inputs that are not available to farmers. (This is a big complaint of some IER economists)

B. This partly a boils down to a question of what one should take as given or fixed in the system. In the longer run, these constraints on input supply, credit, etc. may be lifted, and in fact on-farm research may be key in creating pressure to bring about such changes (see below). But given ceteris paribus, the point is that one is probably better off opting for the less input-intensive technology. The problem is, one never faces a true ceteris paribus.

V. Evaluating the Dynamics of Marketing Systems and their Implications for Technology Development. Examples:

A. Seasonal price analysis as identifying needs and opportunities for technological developments. For example, sharp seasonal peaks for agricultural commodities may indicate a high payoff to developing varieties with different maturity dates (to hit the high-priced market) or better storage characteristics.

B. Understanding what is driving demand in the market as a guide to technological development. For example, what are the relative importance of changes in relative market prices vs. ease of preparation in driving the shift in consumption from coarse grains to rice in the Sahel? Some (e.g., Delgado) argue that when the costs of preparation are taken into account (pounding, fuel costs, opportunity cost of the wife's time), coarse grains are not nearly as competitive with rice as would be suggested by the relative prices of these cereals in the market. Therefore, understanding the importance of these "ease-of-preparation" factors in affecting demand suggests that reducing farm-level costs of production is not the only way of increasing the competitiveness of coarse grains relative to rice. Research on improved methods of processing may also be key in helping reduce the "on-the-table" cost of coarse grains.

C. Understanding traders' constraints and their implications for technical research. For example:

1. How problems of storability hinder the development of a stronger market for cowpeas.

2. Problems of easy bruising in the transport of perishables.

D. References: Coulibaly, Delgado

VI. National Research Planning and Setting of National Research Priorities

A. Research is an economic activity, using scarce resources in an attempt to produce valuable outputs. Because resources are scarce, particularly in a country like Mali, the allocation of those resources need to be guided by economic principles. Choices need to be made about where to concentrate scarce resources; otherwise, they will be spread too thinly over too many areas. Economists can help make valuable contributions in:

1. Inventorying available research resources

   a. Human resources

   b. Physical Resources

   c. Backlog of research results to date--helping evaluate, with technical scientists, where breakthroughs are most likely and what resources are needed to get them

   d. Financial resources, both national and from foreign assistance

2. Helping set priorities based on various indicators of the value of the commodity to the nation, the importance of the breakthrough to key social goals (improved nutrition, etc.)

B. Other social scientists (sociologists, organization theorists) can make contributions on more productive ways organizing the research system so as to foster greater interaction among scientists.

C. References: Idachaba, Norton et al.

APPENDIX 4

WAYS IN WHICH TECHNICAL AGRICULTURAL RESEARCH CAN CONTRIBUTE TO AGRICULTURAL POLICY RESEARCH

I. The focus of much of the work carried out under the Food Security in Africa Cooperative Agreement stresses that many economic policy issues have a technological dimension. Addressing the policy problem often requires input from technical scientists and many times a technical solution. Examples:

   A. Whole supply response question--Magnitude of response is a function of available technology

   B. Differential capacity of farm households in southern Mali to respond to opportunities opened up by cereal market liberalization depends on their technological standing (equipment, cotton, etc.) [Dioné 1989a, 1989b]

   C. Seasonal price peaks reflecting poor storability or timing of maturity of crop (i.e., marketing problems often require technical solutions).

   D. References: Jayne and Weber, Dioné (1989a, 1989b)

II. Analysis of and Formulation of Policy Options often Depends on Technical Relationships--Examples:

   A. Success of the liberalization of fertilizer markets depends on whether, in the absence of state delivery systems and subsidies, there would be any effective demand for the product. This, in turn, is a function in part of the biological response of the various crops to fertilizer (i.e., the marginal physical product of fertilizer) and the riskiness of its application (i.e., the variance of the physical response given fluctuating rainfall, etc.)

   B. At the same time, information on the physical response may be very useful in analyzing the costs of existing policies that restrict availability of inputs and in pushing for reforms of those policies (Yates et al.)

   C. References: Yates et al.

APPENDIX 5

PERSONS CONTACTED

INTEGRATION OF SOCIAL AND TECHNICAL SCIENCES IN AGRICULTURAL RESEARCH

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APPENDIX 6

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