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Issues of Sustainability in Agricultural Research in Africa

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ISSUES OF SUSTAINABILITY IN AGRICULTURAL RESEARCH IN AFRICA

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1. INTRODUCTION

This paper discusses several issues facing agricultural research institutions as attempts are made to incorporate "sustainability" concerns into research strategies. The geographic focus is Sub-Saharan Africa.

"Sustainability" here means "...the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."[2] For poor farmers and growing populations, the emphasis is on enhancement, rather than just the stabilization, of the quality and quantity of the resource base.[3]

Sustainability proponents, inside and outside research institutions, are asking: 1) farmers and governments to invest resources both to augment cropping productivity and to conserve/enhance the resource base; and 2) researchers to design productivity and sustainability innovations that farmers will want to adopt and policymakers will want to support.

Two of the most important issues that researchers face in meeting that challenge are:

1) What production systems should researchers be proposing to farmers and governments: Where and when should high input versus low input systems be promoted? What are the environmental consequences of the systems? What kinds of sustainability investments should accompany these systems? How do the answers differ between high and low potential areas?

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1. We are grateful to John Mellor, Michael Lipton, Peter Oram, and Steve Vosti for detailed and insightful comments and ideas.

2. Page ix, CGIAR TAC, 1988.

3. For Lynam and Herdt (1988) sustainability means that output is stabilized around its trend, or it is increased.

2) Will farmers want to invest in the productivity and sustainability innovations proposed to them by agricultural researchers? How should these innovations be designed to maximize the probability of adoption? What are the environmental consequences of farmers' choices? These are crucial issues for social scientists, crop scientists and environmentalists to grapple with together at the "front end" of research design.

The key perspective here is that sustainability should be viewed from the investment and resource allocation perspective, as a set of innovations (products or practices such as bunding and terracing) for which the farmer and the Government[4] expend resources (labor, land, or cash). These often compete with other investments (in the agricultural as well as non-agricultural sectors) for the pool of scarce resources at both the farm and Government level.

Research institutions need to integrate this perspective into the design and evaluation of productivity and sustainability innovations. These should be affordable and attractive to farmers, within the latter's overall investment and income earning strategy. If not, they risk being rejected.

2. ISSUE 1: SUSTAINABILITY AND PRODUCTION SYSTEMS: INPUT USE INTENSITY AND LOW AND HIGH POTENTIAL ZONES

2.1 The Debate on High versus Low Input Systems

Traditional Debate

High versus low input production systems has long been a major topic of debate in research circles.[5] It has been spurred recently by sustainability concerns. It seems that many researchers suppose that incorporating "sustainability" may be at odds with their primary objective of increasing yields and factor productivity, primarily via intensification. This appears to be linked to the assumption that by a "sustainable system" the sustainability proponent means a low input system.

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4. The term "government" here indicates all levels of government or community above the farmer: village, district, nation.

5. By low input systems is meant minimal use of inputs external to the local ecology of the farmer. High input agriculture involves substantial use of modern variety seeds, fertilizer, irrigation, animal traction, etc.

The controversy is examined from two directions: 1) high versus low input systems (abstracting from the potential of the region); 2) differences in potential among regions.

High input systems are traditionally criticized in developed countries for polluting the environment (e.g. salinization of soil from irrigation, fertilizer pollution of rivers). High input systems in developing countries can also pollute. Because the level of input use is generally low, pollution comes from misuse of chemical inputs, rather than their absolute quantity. This is more of a problem in Asia than in Africa because the level of chemical input use is much higher in the former.

A distinction has to stressed between the two types of environmental problems: pollution and degradation of the resource base. A specific set of environmental issues is associated with each stage of agricultural development. In low performance, traditional agriculture, population growth pushes farming onto marginal lands and degradation and impoverishment occur. If through effective plant breeding and good policy the process of intensification is initiated, new problems arise, e.g. soil exhaustion (from deep tilling, shorter fallows, use of varieties which are very extractive of soil nutrients). If these problems are redressed (via fertilizer application, crop rotation, etc.) pest and disease problems arise because of extensive homogeneous stands of crops. With pesticide and fertilizer use increases to meet these problems, the environmental problem finally becomes pollution.

In Africa pollution is not the main environmental problem in the medium run, although it might be in the long run. Degradation is the main problem.

High input systems can degrade the environment. For example, for both semi-arid and humid areas of Africa, deep tillage (using animal traction) can break down fragile soils and lead to erosion. In the context of the West African Semi-arid Tropics (WASAT) Nicou and Charreau point out:

> Some [agronomists] believe that deep tillage and especially ploughing has beneficial effects on soil and crops and should be generalized. Others consider that these effects are not important or regular enough to assure a good return for the costs that this practice entails for farmers. They also note that soil deep ploughing may have negative effects over a long period of time, such as increased erosion and accelerated burning of the organic matter. They recommend zero or minimum tillage.[6]

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6. Nicou and Charreau, 1985, pp. 10-11.

Another example is the concern over fertilizer use in soils poor in organic matter (such as those in WASAT). Again in the context of WASAT, Spencer (1985) and Pieri (1985) argue that there is not enough organic material in the soil to facilitate cation exchange. Matlon and Spencer (1984) state that the incorporation of large quantities of organic material has to accompany chemical fertilizer use to overcome this problem. Sufficient quantities of manure and green fertilizer are often not available.

Further examples in a general context are provided by Lipton (1989). He notes obstacles to sustainability of cropping systems using "new seeds" and Green Revolution technologies. For example, effective plant breeding leads to widespread adoption of new seeds; this reduces genetic diversity. Extensive stands of homogeneous crops are more vulnerable to pests and diseases attacks than are heterogeneous stands. Moreover, he argues that new seed varieties outperform traditional seed varieties in many low input environments, partly because they extract more nutrients from the soil. This can deplete the stock of essential minerals (such as zinc) in the soil.

On the other hand, low input systems are traditionally lauded for being "kinder" to the environment -- low tillage maintains soil integrity, lack of large-scale irrigation means no soil salinization, little inorganic chemical use minimizes pollution from runoff, and so on.

New Debate in Era of Growing Food Gap

The above controversy can be thought of as the traditional clash in environmental and agronomic circles between high and low input systems. It concentrates on the static, direct impacts on the environment. The debate has recently been substantially changed by a stress on the dynamic (long run) context and consequences of the systems.

Oram (1987), CGIAR TAC (1988), Mellor (1988), and Lipton (1989) stress that high input agriculture is <u>not</u> contrary to sustainability. Low input systems have relatively low efficiency of land use and low performance. In order to grow enough to feed an increasing population, farmers have to move onto marginal lands of lower quality. These can easily be degraded (Matlon and Spencer, 1984; Mellor, 1988). A case in point is the Sudanian Savannah zone of the Sahel (Dugue, 1985). Low input systems may in themselves be hard on the environment, such as the slash and burn method.

Intensification, by contrast, leads to less pressure being exerted for farmers to move onto marginal lands. This appears to be the case in the Guinean zones of WASAT which are relatively high input areas (Matlon, 1987a). Moreover, high input systems restore fertility via fertilizer. The latter's effects can be substantially augmented if soil conservation measures are also used, such as contour tilling, bunding, and tied-ridging. (Matlon, 1985; CGIAR TAC, 1988; Mellor, 1988).

The growth factor is crucial: in the poorest developing countries population is growing the fastest, and with it food needs. Food supply has not been keeping pace with food needs in Sub-saharan Africa, and the gap is growing. In this context, what is good for national food security is "politically sustainable". The political and policy time horizons are short run -- one to five years. The environmental time horizon is of course much longer.

Agricultural productivity must be radically increased to meet this growing need, especially in areas where arable land is scarce. Recent work on land carrying-capacity has identified many areas of Africa as extremely land-scarce, despite their appearance of land abundance. For example, Niger is classed with Bangladesh in terms of population density per arable hectare. (Higgins et al. 1982; Binswanger, 1986; Matlon 1987b).

Increases in agricultural productivity lead to increased incomes for the poor through a) lower prices for food, hence higher real income, b) direct increases in income for farmers; c) creation of non-agricultural employment "upstream" and "downstream" (Mellor, 1976).

Increased farm incomes means more cash available for investment in sustainability, as well as a greater food security "cushion". The latter gives the farm household the flexibility to avoid short run strategies that damage the environment. Poverty can lead to myopic behavior on the part of farmers which is bad for the environment (e.g. soil mining, pushing agriculture onto marginal soils without adequate investment in soil protection). The degradation leads to more poverty and a downward spiral of desperate measures. (Brundtland Commission, 1987; Mellor, 1988; Lipton, 1989b). Degradation even militates against intensification. For example, in porous, poorly protected topsoils, fertilizer washes away in heavy rains. Together, poverty and degradation can negate the preconditions for

intensification: cash to invest in inputs and a cropping environment that makes both productivity and sustainability investments pay in the long run.

Low Input High Productivity Systems?

Nonetheless, there is concern that the "Green Revolution" cannot make much more headway in Asia, and that it is encountering severe difficulties in being extended to Africa. The soils, rainfall patterns, and infrastructure differ from Asia's. (Matlon and Spencer, 1984; Matlon, 1987b; Oram, 1987; Mellor 1988; Islam, 1989).

Beside difficulties based in the physical context, extending Green Revolution (high input) technologies comes up against economic obstacles at the farm level: liquidity and credit constraints (Matlon, 1987a, Reardon et al., 1988); attractive opportunities outside of the cropping sector for use of household resources (discussed in section 3).

The physical and economic obstacles to the use of high input systems, combined with the traditional critique of their environmental consequences, has led to a new push for "low input high productivity" systems. There has been a particular emphasis on them in this conference. The subcategories of this type of system include:

a) modified traditional: traditional low (external input) cropping systems with new production practices grafted on (green manuring, integration of cropping with forestry or livestock husbandry), as well as resource enhancement/protection investments brought to bear (water harvesting techniques such as bunding, tied-ridging, etc.).

b) non-traditional: systems that use new types of inputs (integrated pest management, biotechnology).

The "modified traditional" systems have the advantage of promising output increases with a low level of reliance on imported inputs, soft and hard infrastructure (e.g. fertilizer delivery systems or irrigation). Given severe constraints on foreign exchange and the low level of development of infrastructure in Africa, this is a strong advantage.

However, although this is still a controversial matter, these systems deliver less of a productivity increase than does a high input system. One might want to

consider these systems as "transitional" toward high input systems, during the period in which input supply sources and infrastructure are built up.

Nevertheless, just because the "modified traditional" systems use fewer external material inputs does not mean that they use low levels of scarce inputs such as labor, extension, and even cash. Research and extension expenditures can be quite high for these systems. In an era of strapped Government resources this may pose an important problem. Moreover, given that this research is more or less in its infancy, the risk inherent in these expenditures is high. Labor and cash constraints at the farm level may also pose important problems. This issue is explored in section 3 below.

The "non-traditional" systems may promise even greater productivity increases, although this is not certain given that research is in its infancy. However, the costs can be quite high to both farmer and government. For example, Oram makes the point (verbal communication) that in the developing country context, systems such as Integrated Pest Management or biotechnology could be much more expensive and difficult to administer than conventional input systems using chemical insecticide. The systems' requirements are costly: biological control, extension, and supply infrastructure. There is also the problem of whether the private sector will want to participate, and what incentives are necessary. In short, what is relatively cheap and easy in developed countries may be a very expensive measure in African countries. There are a host of other issues related to control and content of biotechnology research, property rights to gene alterations, and so on, of which space does not permit treatment.

2.2 Debate on Research Investment in High vs. Low Potential zones

A consensus appears to be forming that the intensity and type of input systems should be closely adapted to the type of agroecological zone and farmer. This will maximize the efficiency and durability of the system. These zones can be split into low versus high potential. A zone is "low potential" if the zone's resource base can not support intensification and substantial increases in productivity, given the price environment and the available technology.

Which type of production system is most appropriate and sustainable for each type of zone? Where are the biggest problems, and hence research most needed to be brought to bear?

Low Potential Zones

These zones have the most degraded resource bases. Low input systems appear to be the most sustainable and affordable in these zones.

In many parts of Africa (e.g. the WASAT) low potential zones have relatively high population density -- both compared to more humid higher potential zones, and compared to land carrying-capacity. Sociopolitical factors (such as ethnic differences) constrain permanent population movement out of these areas (although there is a lot of seasonal migration) (Matlon, 1987b). In some cases governments are trying to overcome these factors and move people from lower to higher potential zones, but this is a very slow and difficult process. A case in point is the effort of the government of Niger to move people from the densely populated relatively dry agro-pastoral zone in the middle belt of Niger to the high potential but underpopulated southwestern region.

Physical factors also constrain these movements. Large areas of high potential zones are plagued with Sleeping Sickness and River Blindness vectors. To the extent that people can eventually move away from degraded, low potential areas, the pace of degradation will slacken, and less pressure put on marginal lands. Bush may be restored, allowing a strengthening of agropastoral systems. On the other hand, increased population pressure in high potential zones would lead to degradation in these.

Recent work has stressed the need for researchers to address the problems of low potential zones and appropriate strategies for them. (Islam, 1989; Lipton, 1989b). This is based on: 1) large numbers of people living in these areas, and their poverty; 2) the need to provide options to households in these areas in order to reduce pressure on the environment; 3) the concern that they will import degradation-promoting production techniques to new zones to which they migrate if they can; 4) the special problems of these zones (soil quality etc.).

The foremost requirement is that the production systems -- both productivity and sustainability components -- be affordable and effective in the short run. The issues of affordability and income diversification are pursued in more depth in section 3.

Cheap methods of enhancing low input systems should be sought for these zones. Examples include using veteba grass rather than stone bunds, using green

manure rather than chemical fertilizer, using tied ridging, etc. (Matlon and Spencer, 1984; Spencer, 1985; Oram, 1987).

The second requirement is that these systems take into account that cropping needs to be closely integrated with alternative but complementary income activities in the low potential areas. In particular, agro-pastoral and agro-forestry systems have to pursued. This is because of the need for complementary inputs from trees and animals to redress soil fertility and reduce erosion; they also reduce ill effects of chemical fertilizer use by providing organic matter. They also provide supplementary income where cropping is not capable of feeding the household in poor years.

This does not mean that components of the "Green Revolution" cannot also be considered for low potential zones. There is still a good deal of controversy about which can. As noted before, fertilizer use in degraded areas poses problems of soil damage and lack of response (Matlon and Spencer, 1984). Water resources for irrigation are lacking and rainfall is erratic. Soils are poor. However, even in high stress situations, Lipton (1989) emphasizes that modern variety seeds often outperform traditional varieties due to their ability to deal with stress and to more efficiently extract nutrients from the soil. Lipton (1989) and Matlon (1987b) point out that there are limits at present tho this superiority. In the degraded zones of the WASAT, traditional varieties still outperform most modern varieties in low input, on-farm situations. The potential is still there, however. For example, breeding plants to use more efficiently given levels of soil nutrients would overcome the problem of modern varieties relying on more inputs to perform well, and it would obviate the nutrient exhaustion of the soil (Lipton, 1989a).

Finally, rainfall instability (over years) in degraded zones complicates the choice of production systems as well as sustainability measures. Matlon (1985) argues that breeders should take yield stability as a goal in this setting. Walker (xx) argues that breeders should aim for maximum yields in good years. The issue is complex, because of difficulties of storage, price fluctuations, and underdeveloped consumer credit markets.

High Potential Zones

The issue of high potential zones is a complex one. A zone can be high potential but currently "low performance" -- that is, the process of intensification has not

begun (or has not yet succeeded) and yields are still low. An apparent example is the Sudano-Guinean region of the WASAT; Matlon (1987b) and Matlon and Spencer (1984) argue that there is even higher potential in the semi-arid areas than in the humid regions.[7]

Intensification would bring dramatic yield increases, and positive effects on income and intersectoral growth linkages. Also, Mellor (1988) stresses that proper development of high potential zones would reduce pressure on low potential zones.

It is crucial that agricultural research institutions identify these high potential-- but currently low performance -- zones and encourage sustainable intensification there. The highest payoffs to research may well be in these zones. Marginal returns to research in high "potential", already-high performance zones might be much smaller.

Moreover,, a strategy has to be developed which links intensification and sustainability measures (such as soil protection). It is here that the crucial issue of the capacity and desire of the farmer to invest in these measures will come to the fore. This is the focus of section 3 below.

Agroecological Zoning

The distinction between low potential and high potential zones, and the different productivity/sustainability strategies implied for agricultural research, requires careful agroecological zoning (Oram, 1986). A socioeconomic component needs to be added to the traditional agroecological approach (Oram, 1987). This needs to take into account more than markets and prices. It should reflect the capacity of farmers to invest in productivity and sustainability measures -- i.e. explicit account should be taken of opportunity costs of resource use in non-cropping activities, and of credit markets.

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7. Lipton (1989a) also cites Bhalla and Fyagi's findings for a number of districts in India: several decades ago the majority of the currently high performance zones were low performance zones, with "disguised" high potential.

3. ISSUE 2: SUSTAINABILITY INVESTMENTS WITHIN THE CONTEXT OF INVESTMENT AND RESOURCE USE STRATEGIES OF FARMERS AND GOVERNMENT

3.1 Household Choices

Proponents of productivity increases need to see that in certain circumstances they can be in competition with sustainability proponents, vying for the use of the same resources at the farm and the government levels. Both groups, in turn, might be missing what the rural household really wants. In a degrading and unstable environment, the priority of the household may well be to diversify away from farming. It may want to maximize present earnings in cropping, and invest the surplus in livestock and off-farm enterprises. Off-farm earnings might not be reinvested in cropping, but instead used to diversify further.

The above possibility is often neglected by both agricultural researchers and environmentalists who assume that the rural household in regions at environmental risk is first and foremost a farming household.

The implication of their assumption is that innovations that can improve the farm resource base are automatically attractive to households. It is precisely in the areas at greatest risk where this assumption is least tenable. A case in point is the WASAT, where recent work by Reardon et al. (1988, 1989) and Reardon and Matlon (1989) shows that cropping constitutes from a quarter to a half of income in rural Burkina households in the Sudano-Guinean (high potential) to the Sahelian (low potential) zones. Overall income (from cropping and non-cropping income) is a much more important determinant of household food security than is cropping income. A substantial portion of their food intake comes from purchases; this runs counter to the conventional image of Sahelian households as autarkic, subsistence farmers. The implications of this are explored below.

The issue of whether farmers will want to adopt productivity or sustainability innovations needs to be viewed within the framework of the rural household's set of resource allocation decisions: over sectors, over crops, and over types of investment.

3.1.1) Choice of Activity Mix -- Over Sectors (cropping, and non-cropping activities -- livestock husbandry, local off-farm activity, and migration)

At a given time, the rural household has a set of resources or "factors" (land, labor, cash/liquefiable capital) available for cropping and/or non-cropping activities. The use of a resource in a given activity is evaluated in terms of its net return. This return is compared with potential returns from its use in other activities. Hence, factor (capital, land and labor) opportunity costs determine where the household will put scarce resources, for the highest return. (The "opportunity cost" is the benefit from B foregone by doing A.) The returns to a factor's use in two different activities might be the same, but the variance or risk associated with the return might be different. Returns to factor use in alternative activities are dependent on the riskiness of production and the product's price level and variation.

Factors other than returns and risk also condition the choice of activities: opportunities in cities, mines, and factories; cultural traditions; and capital market constraints (to get the amount of cash needed, at the proper time). The demand-side sustainability of an activity depends on its income/demand base. Mellor (verbal communication) warns of the precariousness of activities and development strategies based in demand that is driven by foreign aid. The most sustainable situation is where growth in agricultural leads to intersectoral linkages and balanced growth. (Mellor, 1976). The physical base of the activity has to be taken into account. For example, livestock husbandry depends on adequate forage, hunting/fishing on wildlife -- "the commons".

Special emphasis needs to be given to capital market constraints.The latter is crucial. In Africa, distortions in the capital market are usual. Constraints on access to capital/credit make it difficult to make minimum "entry" investments. This may either be true year-round or merely seasonally.

To increase overall income, to diversify income sources because of risks inherent in the activities, and to smooth consumption in the face of fluctuations in cropping outcomes, rural households undertake non-cropping activities. The extent to which they diversify is a function of relative returns and riskiness of activity. The direct "meeting of needs" (e.g. having to grow food in order to eat) is often overstressed. Widespread monetization means that income from any source can be used to meet needs (i.e. income is fungible). In fact, a substantial

portion of food is purchased even in areas where conventional wisdom has it that households are autarkic, subsistence farms, such as in the West African Semi-Arid Tropics (WASAT). In these same areas the majority of income comes from non-cropping sources. (Reardon et al. 1988, 1989; Reardon and Matlon, 1989.) Hence rural households do not necessarily perceive the need for cropping per se in order to meet food security objectives. This of course varies by region.

An example from the Sahel is pertinent. Rainfall fluctuates in an extreme and unpredictable manner, which leads to extreme fluctuations in crop output. Thin markets and poor infrastructure translate these into large variations in price. As demand is inelastic, a supply increase brings more than a proportionate fall in price, and hence a drop in the total return to factor use. Hence, yearly returns to a given investment vary greatly over time.

This can be contrasted with relatively stable returns to cropping on the humid coast of West Africa. Migration remittances from labor in coastal agriculture compensate cropping outcome variations in the Sahel, and smooth income and consumption over years.

Thus, Sahelian households find it worthwhile to invest in migration channels. They also invest in local non-cropping activities, such as commerce, food processing and livestock husbandry. Most rural households in semi-arid areas of Africa practice sedentary agriculture but also invest as much as they can in livestock. Livestock husbandry is a speculative activity, a source of milk/protein, and most importantly, a savings/insurance mechanism in the face of under-developed credit/capital markets and fluctuations in cropping output. The more pronounced the latter, and the lower the downside fluctuation, the greater the incentive to build livestock herds. The overall result of this income diversification is that more than half of the income in both the low potential Sahelian zone villages and the high potential Guinean zone villages comes from non-cropping activities. (Reardon et al. 1988; Reardon et al. 1989).

How do these income diversification strategies affect investment in cropping--productivity and sustainability? Although there is not much evidence on this score, the observations that exist are striking. Kelly (1988) asked farmers in Senegal if they would be willing to invest non-agricultural income in fertilizer. The reply was that given relatively low payoffs and high risk from fertilizer use,

they preferred putting the cash into livestock and off-farm activities. Livestock had the added benefit of being more easily liquefiable.

3.1.2) Choice of Crop Mix

The crop mix chosen by the farm household depends on:

a) net returns to different crops. (this again implies a comparison of relative factor opportunity costs). Returns depend on market conditions, available technologies, and government intervention.

b) climatic factors (water availability and rainfall intensity).

c) market outlets (for sale and purchase) and traditions/tastes in consumption.

d) credit facilities related to specific crops.

e) soil conditions: these depend in turn on fertility enhancement measures (availability and cost of fertilizer) as well as on soil conservation measures (bunding etc.). The "land" is the key link to the general environment. It conditions the flexibility of the farm to adjust to risk and new incentives and market opportunities. Moreover, certain crops are able to deal better with environmental stress. Modern varieties are increasingly designed to handle water stress. Cassava handles lack of phosphate. Millet handles drought better than other cereals. (Lipton, 1989b)

3.1.3) Investments in Productivity and Sustainability

To use productivity innovations, farmers must expend labor and cash, e.g. purchase new seeds and fertilizer, build irrigation canals. The government invests in extension, seed reproduction, and infrastructure. Sustainability investments also require cash and labor expenditures, e.g. for bunding, tree planting, alley cropping, terracing.

Just as investments in cropping compete with investments in non-cropping activities, outlays for cropping sustainability investments vie for scarce resources with other cropping investments (in fertilizer, animal traction, etc.), as well as

investments in non-cropping activities. The competition is over cash resources as well as labor time. For example, there are severe labor bottlenecks during the rainy season in the WASAT (Delgado and Ranade, 1987). However, the opportunity cost of labor also appears to be high in the (misnamed) "slack season". In Burkina Faso for example, households in Sahelian and Sudano-Guinean zones earned more income in the slack season than in the cropping season. (Reardon et al. 1989)

Building soil conservation infrastructure at the household or village level during the dry season confronts three obstacles. The first was just mentioned: the opportunity cost of labor in well-paying alternative activities such as migration, transhumance, etc. The returns to these might be perceived as more immediate and tangible than those to soil protection in a risky environment. These alternative activities are also seen as investments in the future -- migration channels and contacts are established, cattle herds are built up, etc.

The second obstacle to both households and villages is the underdeveloped and limited character of the rural capital market. It is rare that the amounts represented by foregone current income and investment costs can be generated locally or even if present, borrowable locally. It is also hard to borrow for long-term investments.

The third obstacle is that it is sometimes difficult to get households to pay for infrastructure that benefits the community. (There are positive externalities to the household investment.) Households may wish the government to pay in this case (Swindale, 1988). This also leads to free-rider problems. For example, Barett et al. (1988) cite the difficulties of persuading pastoralists in Niger to invest in common borehole maintenance. Mellor (1988) suggests food-for-work schemes to build this type of infrastructure during the dry season. In view of the above discussion, remuneration levels should take into account intersectoral factor opportunity costs. Provision should also be made for maintenance (another separate investment from the household's or village's viewpoint), the costs of which can be significant.

The point that productivity and sustainability investments can be in competition requires three qualifications. First, in some fortunate cases neither sustainability nor productivity innovations cost the farmer a penny and hence do not compete

for resources. They may just be useful notions of how to do a task differently. Examples are proper plant spacing and contour plowing.[8]

Second, productivity enhancement reduces poverty. This increases sustainability because practices which degrade the environment in Africa are to a large extent born from poverty. (Brundtland Commission, 1987; Mellor, 1988). Household income increases can be seen as indirect investments in the sustainability of cropping in that they may lead to less pressure to extend cropping into marginal lands and "mine" the best soils. It does not necessarily follow that extra income will be invested directly in protecting the resource base (bunding, terracing for example).

Third, certain resource conservation measures have immediate productivity payoffs. For example, bunding installed at the beginning of a rainy season in the Sahel, where rain falls with violence, can directly increase the output that season, as well as succeeding ones. (Matlon, 1985).

3.2 Investment and the Time Horizon

Instability in returns over years to an investment today makes it difficult for the farmers to judge what the payoff will be. This makes large investments appear risky, and shortens the planning horizon. The farmer's discount rate is often quite high in areas at high risk of degradation. This is because of instability, as well as the pressing need for relatively high payoffs to cash and labor use in the short run (e.g. to meet today's food needs). High interest rates (Lipton, 1989c) and speculative land markets (Vosti, verbal communication) compound the problem. In this context soil mining may appear to farmers to be a rational act; investments in soil conservation in the face of violent rains and periodic drought simply might not appear worth it.

On the other hand, over time, is degradation "self-correcting"? That is, do sustainability investments become profitable because of the effects of degradation on aggregate output, hence prices and returns to conservation? Whether this occurs depends mainly on the degree of "closedness" of the local economy -- the extent to which local prices are determined by local demand and supply. If the

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8. However, diffusion of new notions costs the government (extension services).

local economy is "open", supply (or demand) from outside the zone will influence prices.

In general, the regions at environmental risk are open economies. This is mainly because households in these regions diversify their incomes and purchase substantial portions of their food; moreover, local agriculture cannot consistently produce sufficient food for the region. The result is illustrated by the case of the Sahel in Burkina. It is not a closed economy. For example, cheap maize flowed into it from well-watered zones (Ghana, Southwest Burkina) during the drought of 1984-5. (CRED, 1987). Grain prices for the main local grain (millet) were quite high during the period, while maize and red sorghum, "imported" to the region from outside, had much lower prices. The majority of cereal consumption was in the latter "exotic" grains (Reardon and Matlon, 1989).

3.3 Environmental Consequences of Household Choices

Household activity (sectoral) choices affect the environment. There are direct and indirect effects. An example of a direct effect is as follows. Building up livestock herds can result in over-grazing and over-browsing of bush and grass cover. This strips the land of protection and leads to topsoil reduction. This lowers the downside level of crop output fluctuations, thus increasing the need for insurance in one of the few available forms, livestock holding. This is a vicious circle.

Indirect effects of activity choices, on the other hand, can be as important as direct effects, but are less discussed. For example, cash and labor going into migration or local off-farm activities in the dry season means there are fewer resources available at that time to build bunds and terraces.

The environment can itself influence activity choices and overall household productivity and welfare. An example is degradation increasing transaction costs. Kumar and Hotchkiss (1989) shows that deforestation in Nepal obliges women to go greater distances to collect fuelwood. This reduces labor available for cropping. In the Sahel deforestation and desertification increase household transaction (gathering) costs for wood and water, as well as transhumance distances and times. (Webley, 1986).

Cropping choices also influences the environment. This mainly occurs through the genetic characteristics of the plant (e.g. the degree to which it extracts nutrients), and agronomic practices required to grow it (e.g. tilling, fertilizer application, etc.). Examples of the former are the following: a) Cassava is cited by the CGIAR TAC as a "low input" crop in that it produces a high edible output with a low phosphate input. However, Lipton (1989b) notes that certain highly productive cassava varieties are also highly extractive of soil nitrogen. b) High-yielding, modern varieties of cereals have been found by researchers at Haryana University in India to extract essential minerals from the soil, zinc in particular. This exhausts the soil over time. (Lipton, verbal communication).

An example of a cropping choice that has environmental effects primarily because of agronomic practices associated with it is that of perennials versus annuals (Mellor, 1988; Vosti, 1989). The tilling and clearing required for annuals can have destructive effects on fragile soils, especially on slopes. Perennials protect the latter. Moreover, as incomes rise, demand diversification provides a strong market for products of perennials. Ensuing rural income growth reenforces cropping sustainability in the ways discussed above. (Mellor, verbal communication).

3.4 Role of the Government

Sustainability proponents often put special emphasis on direct investments in resource conservation by the government, due to the problems of externalities, capital constraints and short planning horizons at the household and village level. A set of issues similar to those discussed above in the context of the household arise from the government. The investment of scarce fiscal and foreign exchange resources (in infrastructure, extension, etc.) involves difficult choices. In the era of Structural Adjustment fiscal resources and personnel are acutely scarce.

The government can influence household investment patterns and incentives. Their policies affect: a) net returns and transaction costs (directly via price policy and indirectly via food aid and infrastructure); b) the stability of the investment climate (even at the rural level) and hence the farmer's planning horizon; c) government finances agricultural research and hence the stock of innovations from which to choose.

NARCs and IARCs need to investigate how a government can most effectively-- and cheaply -- encourage sustainability investments at household and village level, and where direct supporting investments by the State are necessary, and what they should be.

4. CONCLUSIONS

Five points need to be stressed in conclusion.

1) High Potential Low Performance Zones: The greatest payoff in terms of crop output to sustainability research in Africa appears to be in the high potential but currently low performance zones. The biggest challenge will be breaking the poverty cycle and initiating an intensification process, while maintaining or enhancing soil quality. The latter will require significant sustainability investments such as bunding, and household and village levels.

2) Low Potential Zones: Researchers need to base their approach on the maintained hypothesis that goal of households in these zones is to diversify their incomes -- both over crops and over sectors -- and to aid the households to stabilize and maximize the results of the strategy. In these zones an emphasis should be put on effective mixed systems: agropastoral, agroforestry. Low input cropping systems with cheap soil conservation and water harvesting measures are most appropriate for the cropping component. Livestock husbandry should be particularly stressed as a complement (both in income and production) to cropping. The comparative advantage of these zones is usually livestock, and it also forms a crucial savings or insurance mechanism. Attention then needs to be given to feeding systems that do not remove bush cover.

3) Household level sustainability investments: There are a variety of options that compete with and forces that militate against sustainability investments at the rural household's level. If the gains are higher or less risky for the investment of resources in non-cropping activities, the rural household may ignore the sustainability and productivity investments that agricultural researchers or the government want it to make. It will put its money and time where the payoff to its food and income security is the highest. At the margin this may be neither sustainability nor farming itself.

For both sustainability and productivity innovations, it is necessary to make sure that the farmer perceives that the investment has a high enough net payoff to compete with alternatives, not just in cropping, but in all sectors. It should not be assumed that the innovations are attractive to the household just because they protect the resource base. Researchers should study the returns from alternative activities for earning income open to rural households (both potentially and actually). The households priorities and perspective needs to be given "front seat".

The total household expenditure (in terms of labor and cash) for a given innovation has to be compared with cash and labor constraints. Because of severely underdeveloped credit markets, households face important constraints on cash flow.

4) Time Horizon: It is difficult for the researcher or even the government to alter the planning time horizon of rural households. The horizon is usually short-term due to risk and uncertainty, capital market constraints and high interest rates, and pressing food security needs. It appears best for researchers to take the short run perspective of the household as given, and design innovations to meet the perspective. The financial risk for a pilot innovation needs to be assumed first by the government or the research institution and let the households see that it works. This may even spur development of credit sources.

Moreover, it is also difficult for researchers to persuade governments to assume the long-run planning horizon that is necessary for reversal of environmental degradation. This is because the policy and political time horizon is usually short-run, and resource constraints limit long-run initiatives.

5) Policy and the Role of Government: Government can support sustainability via two sets of mechanisms: a) providing incentives to households and villages to make the necessary investments; b) providing supporting infrastructure and extension. Raising incentives to cropping itself may be difficult due to more attractive alternatives in other sectors. High transaction costs and uncertain payoffs to local investments imply that the government would have to create adequate hard and soft infrastructure to lower the costs and marketing mechanisms to stabilize returns.

In both the African semi-arid as well as humid tropics these measures will be extremely expensive to implement. Two options are apparent. The first is for government resources to be augmented. This is highly unlikely in the era of Structural Adjustment. Even if they were augmented it would have to be clear to governments how sustainability investments dovetail with short-term priorities. Basically this means that researchers have to demonstrate that resource enhancement and conservation measures have immediate cropping productivity payoffs. Policy research is crucial to determine policy mixes that create these links.

The second option is to make infrastructural investments more productive, and hence a given level of funding will have more impact. This means that agricultural research institutions need to take a much higher profile in the domain of infrastructure: how can it be made cheaper, last longer, fit in more closely with local agricultural needs, etc.

Finally, is the current structure of research at NARCs and IARCs conducive to the incorporation of sustainability concerns in light of the above discussion? Three points are pertinent.

First, crop-specific or even input-specific research mandates may be at odds with sustainability objectives, in view of the discussion on farmers' choice of activity and crop mix. A certain crop or even cropping alone may not be sustainable economically or environmentally in a certain region, but it nevertheless might be an institution's mandate and thus it is incumbent on the institution to find ways to make it sustainable". This leads to inefficient use of scarce research resources.

As a solution, the CGIAR TAC recommends cooperation across IARCs with different mandates. An obstacle that might arise is that the product research of a given institution may need to be an input for a separate system, such as agropastoral, and the latter may be in the purview of a separate institution.

Second, the conventional agricultural research approach of top-down has been criticized in recent years (e.g. Richards, 1985; Rhoades, 1989). The 'farmer first' school believes that the farmer should be brought directly into the research loop in order to take into account what farmers want and their constraints, and to design acceptable and sustainable technology options. There is a general

consensus on the merit of this approach, but not on the practical means of implementing it.

Third, if research institutions are to embrace the perspective of the rural household as much more than merely a cropping unit, but rather a unit with multisectoral income strategies, socioeconomic analysis has to be brought much more to bear than at present. Economists, sociologists, and anthropologists need to work closely with breeders and agronomists in the early stages of innovation design, not just the usual post facto stage. (Lipton, 1989a; Reardon, 1989). Moreover, it is essential that policy research (on incentive measures and infrastructure) be stressed so that farmers will be encouraged and supported in undertaking sustainability investments.

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