Staff Paper

Sustainability Issues for Agricultural Research Strategies in the Semi-arid Tropics: Focus on the Sahel

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ABSTRACT: To stimulate debate in agricultural research circles, the paper discusses six sets of issues for the design and strategy of agricultural research on sustainability in the semi-arid tropics of Africa, to wit: (i) what production systems to propose in what zones, in particular how and where to intensify; (ii) what measures are needed to conserve the resource base in different zones; (iii) what incentive measures, and technology design, are needed to encourage and enable farmers to adopt conservation and productivity measures? (iv) what complementary investments at farm, village, and State level are necessary to help farmers make those investments? (v) what crop and activity mix should be sustained? Are the conditions upstream and downstream from production of that mix conducive to sustained profitability? (vi) how should sustainability research be organized?

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SUSTAINABILITY ISSUES FOR AGRICULTURAL RESEARCH STRATEGIES IN THE SEMI-ARID TROPICS: FOCUS ON THE SAHEL

INTRODUCTION

Soil degradation and soil conservation have been issues in Sahel agricultural research since the 1920s. (Eicher and Baker) Thus, soil conservation and fertility, "sustainability", and the environment are not new issues in the Sahel. There was a resurgence of debate on soil conservation in the Sahel in the late 1970s and 1980s. To this "natural" resurgence, donors have added urgency, insistence, and funding (not necessarily additive to current funding) to promote "sustainability" in agricultural research agendas in the Sahel in the 1990s. But the resurgence of interest in sustainability and the environment in the Sahel needs to be seen in the context of policymakers' pressing concern to increase food and export crop production to meet needs growing rapidly, at least at the population growth rate of 2-3% a year. Growth and poverty alleviation are the primary short term concerns for national policymakers.

Sustainability issues are increasingly seen as important by policymakers (witness the recent creation of an environment ministry in Senegal, for example). But they are still seen as 'second generation problems', problems whose solution will help long-term growth, but will not stave off poverty and crisis in the short run. (Idachaba)

Agricultural research institutes in the Sahel are caught in a bind. They need to keep delivering on breeding and agronomic techniques to meet growth and food security targets. But at the same time they need to stretch shrinking resources into the relatively uncharted realm of sustainability and conservation research. Such research has not been of major importance in post-independence research institutions, so there is a need for organizational modification to accommodate it, and a need for retooling or staffing to handle it.

It is also relatively uncharted because the Sahel rural economy is very different today than it was 50 years ago. Rural incomes now appear to be more diversified, soil degradation problems worse, arable land more scarce, cropping intensification more prevalent, external inputs and hybrid seed varieties more available and used. These changes heighten the need for soil conservation but also complicate it. These points will be discussed more below.

Thus, how to add sustainability to the research agenda, or to increase emphasis on it -- in effective and feasible ways, with minimal disruption of promising ongoing research aimed at increasing yields, is now a controversy in Sahel agricultural research circles, both among NARS and IARCs.

This paper briefly discusses six sets of issues for consideration in designing overall research strategies for sustainable agricultural development in the Sahel. In most cases, for a given country, a given issue cannot be resolved without substantial additional research (for example on the economics of soil conservation measures), and so these issues are both points of debate about a strategy of research, and objects of research themselves.

ISSUES

ISSUE 1: What production systems should researchers be proposing to farmers? Where and when should high-input versus low-input systems be promoted? What are the environmental consequences? How do the answers differ between high- and low-potential areas?

There is concern in the environmentalist community that the introduction of high-input systems (using fertilizer and perhaps small-scale irrigation, and plowing) may further degrade the environment in the Sahel. This school has traditionally lauded low-input systems for being "kinder" to the environment -- low tillage, green manuring, for example, maintain soil integrity and require little reliance on imported inputs or cash outlays by farmers, or input distribution infrastructure.

The problem, however, with extensive systems that rely primarily on recycling organic nutrients is that they have historically been found to yield sustained agricultural growth rates of around 1% (Ruttan), well below the growth rate of food demand in the Sahel based on population growth. Even an intensified 'organic recycling system' (that uses animal and green manure and sustainable agronomic techniques, but no 'external ingredients' such as chemical fertilizer, animal traction, small-scale irrigation, and so on) will underperform intensive systems that use 'external ingredients', and produce agricultural output growth rates still below growth in demand. (Matlon and Adesina; Sanders). Organic farming will not solve short-run food problems in the Sahel.

Moreover, low input systems are not necessarily kind to the environment over time. Poor farmers stay poor when they use few external inputs; but population still grows, so food demand rises, pushing farmers to crop marginal lands of lower quality, which are easily degraded. This is the classic process generating a "Ricardian Food Bottleneck".

Some relatively-new "non-traditional" low-input systems such as integrated pest management promise yield increases. Although these systems may not rely on fertilizer, pesticides, and herbicides, and have been shown to have good results in some places in the developing world (de Haen), they nevertheless generally do cost farmers labor and equipment, and cost the State for extension and support systems (both expenditures or systems that are specific to the technology, e.g. delivery, storage, research, extension of the techniques, and general, e.g. roads, schooling). These systems may be too expensive for Sahel farmers and governments in the medium term.

Given that for the medium term, available low-input extensive systems will not meet growth needs, and under usual circumstances can lead to degradation of marginal lands, the solution lies in intensification through use of fertilizer, small-scale irrigation, animal traction, and hybrid seeds. Two subissues arise regarding intensification: where and how -- each addressed below.

Where to intensify: It would be difficult to sustainably intensify crop production in the "low-potential zones", the Sahelian and Sahelo-Sudanian zones, below 600-700 mm. rainfall, that are typified by high degradation, fragile soils (erosion, porosity, and low organic content), insufficient water, and, often, high population density. Sociopolitical factors and diseases and pests in higher-potential zones constrain permanent migration out of the low-potential zones. (Matlon) It is difficult to imagine going beyond current low-input extensive systems in the northern and middle belts in the near future. Rather than intensification, the challenge will be to stabilize low yields and conserve soils. (Matlon and Adesina). Savadogo et al. find that average labor and land productivity in good rainfall years in the Sahelian and Sudanian zones is about as high as productivity in the Guinean zone in normal years. This supports investments in farm and village level conservation investments to protect these peaks of productivity in the fragile environment of the northern and middle belts, and to stabilize output in the troughs of the poor rainfall years.

Sustainable intensification can occur in the higher potential zones, the Sudano-Guinean and Guinean, above 700 mm rainfall. Most of the Sahelian countries have considerable area in such zones. Population densities are for the moment lower than those in the low-potential zones, with a greater agricultural frontier, to be opened as disease and pests are vanquished (e.g. river blindness). Relatively high 'external input' systems perform much better in these zones, allowing yield increases that come much closer to growth targets. (Lele and Stone; Matlon 1990)

Intensification of production in high potential zones would help agricultural sustainability in both high and low potential zones. In high potential zones, it would reduce pressure to crop marginal lands. Higher incomes would produce growth linkages and provide more cash for investments in soil conservation. Cheaper grain from high potential zones would mean higher real incomes and less poverty

in low potential zones (where there are lots of net buyers of cereal, see Weber et al.), and thus less pressure on marginal lands to survive.

How to intensify: The traditional view (held a few decades ago) was that the Sahel is land-rich and labor seasonally-scarce. The latter may still be true, but evidence is mounting that land is scarce at least in certain zones, especially the sahelian and sahelo-sudanian (Matlon 1990; Savadogo et al.). This may not be immediately apparent when looking at simple population density per square kilometer; rather, when one looks at population density per unit of carrying capacity (standardized land), rural Niger compares with rural Bangladesh, for example. (Binswanger). With population steadily migrating into the Sudano-Guinean and Guinean zones of most Sahel countries (Lallement), the arable land frontier will eventually shrink even in these high potential zones.

Hence, rather than increasing output per person to meet growth in demand by getting more output per unit of labor via land-using technologies, and rather than being able to depend on a considerable arable land frontier, output will increasingly need to be expanded through the use of land-saving techniques such as fertilizer and small-scale irrigation. It is difficult to imagine intensification sufficient to meet growth in food demand without major increases in fertilizer, small-scale irrigation, and animal traction.

With increasing land scarcity, the economic incentive to adopt land-saving technologies should increase. Labor relative to land will become more abundant, lower the implicit price of labor relative to land, which means that land-saving techniques, such as substitution of fertilizer, tools, and labor for land will be increasingly attractive. (Matlon 1990; Ramaswamy and Sanders 1992)

There is, however, question as to whether farmers can or want to pay for the inputs (for intensification, or for conservation measures) even if their use would be absolutely profitable. This introduces the issues of liquidity constraints and opportunity cost of resources, discussed under Issue 3,

as these questions are pertinent both to adoption of technologies for intensification, and adoption of soil conservation measures, the subject of Issue 2.

ISSUE 2: What soil conservation measures are needed to make intensification environmentally sustainable?

Eventual intensification in the Guinean savannah belt will put a strain on the soil, which can increase erosion and undermine yield increases. Thus "sustainability" measures (mainly soil conservation investments such as incorporation of organic matter in soil and bunding and terracing to prevent erosion) need to be given high priority. Soil conservation measures augment productivity both directly, by holding topsoil, and indirectly, by keeping fertilizer and manure from being washed away by heavy rains. Much less of an issue for the next two-three decades is pollution of groundwater due to excessive use of fertilizer, herbicides, and pesticides (an issue faced in East Asian developing agriculture after the Green Revolution; see Pingali and Rosegrant 1993). So little of these three are used currently in the Sahel that even if their use was increased greatly during intensification, there would still be little pollution problem.

Technology packages that combine productivity increases with conservation investments can be called "overlap technologies". Matlon (1990) suggests a number of these: e.g. combining fertilizer with bunds with "water-harvesting" structures such as bunds of laterite, dirt, or veteba grass, bushrows, terraces, tied ridges. Creating these technologies and making them economic/attractive to farmers is the central sustainability challenge to agricultural researchers in the Sahel (Reardon and Islam 1989). To make them adoptable and economic, issue 3 needs to be addressed.

ISSUE 3: Will farmers want to and be able 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 incentive policies and support institutions (extension, credit, agricultural research) need to be in place to make the farm-level and village-level investments attractive?

Conservation measures require farmer and village expenditures of cash for equipment, raw materials, and hired labor, as well as expenditures of family labor.

There are two paradoxes here. First, these conservation expenditures can compete with outlays for fertilizer, animal traction, and small-scale irrigation. Researchers and governments want farmers to invest in both kinds of inputs without necessarily taking into account that the household usually does not have enough resources to pay for both, nor a reliable credit market to help. But at the same time, conservation investments can increase the profitability of investments in e.g. fertilizer (the point made above about bunds keeping soil and fertilizer from washing away in heavy rains).

Second, investment expenditures by farmers for both conservation and productivity investments together can compete for family resources with expenditures to start off-farm businesses -- to diversify family incomes. In a degrading and unstable environment such as the Sahel's, perhaps the household's first priority should be to diversify away from farming. This runs counter to the traditional image of Sahelian households as autarkic, subsistence farmers. Households diversify income because of extreme fluctuations in returns to cropping (due to output and price fluctuations from erratic rainfall and thin markets). Households are sensitive to the net payoff and when they receive it of investments in the various sectors, including cropping, livestock, and off-farm activities. Reardon et al. (1992) show that cropping constitutes from a quarter to a half of income in rural Burkinabe, Nigerien, and Senegalese households. Overall income -- from cropping and non-cropping sectors combined -- is a much more important determinant of household food security than is cropping income alone. A substantial portion of these household's food comes from purchases.

The above discussion of income diversification suggests that it is precisely in areas at the greatest risk that this assumption is least tenable. Households may want to maximize present earnings in cropping and invest the surplus in livestock and off-farm enterprises. Instead of reinvesting off-farm earnings in cropping or water-harvesting structures, households may use them to diversify overall income further.

In this context, investments in water harvesting and soil conservation structures compete with investments in activities that may have higher short-run payoffs, more stable long-term payoffs, and the potential to serve as repositories of savings and hence insurance (such as livestock).

These possibilities are often neglected by crop researchers, governments, and environmentalists, who assume that the rural household in a region at environmental risk is first and foremost a farming household. This implies that innovations that can improve the farm resource base are automatically attractive to households.

But the other side of the second paradox is that off-farm income is by far the most important cash source both for farm inputs and for food purchases in the Sahel; small animal and cash crop sales are also important but rank far below off-farm income; borrowing ranks much lower yet. (for Burkina see Reardon and Mercado-Peters).

In sum, the above two paradoxes tell us that conservation investments both compete with and are complementary to productivity investments, and that both these investments both compete with and are complementary to income diversification investments.

What are the implications of this issue for agricultural researchers who want to introduce sustainability issues into Sahel research?

First, when they design conservation investments as well as productivity investments, researchers need to take into account the opportunity costs between farm and nonfarm sectors, and the capital/liquidity constraints facing rural households. They have to be relatively cheap and emphasize

short-run payoffs. Adoption of these measures faces competition with investments by the household in non-cropping sectors, which means that the opportunity cost of labor/cash at household level in the various alternatives has to be examined. Innovations need to have higher and more stable returns than alternatives. Given credit and liquidity constraints (that are part responsible for the interest of households in income diversification), the researcher needs to be careful about the affordability of the innovation. The investments need to be attractive, not just that 'net profitability is greater than zero', but also more profitable than competing opportunities off farm.

Second, researchers need to understand the ways in which Sahel governments can influence household investment patterns and incentives through policies that affect (1) net returns and transaction costs (directly via price policy and indirectly via food aid and infrastructure); (2) the stability of the investment climate (even at the rural level) and hence the farmer's planning horizon; and (3) financing of research and hence the stock of appropriate and available innovations from which farmers can choose.

But it is important to guard against simply assuming that higher average crop prices are feasible, or will lead automatically to either farmers' investment in sustainability or higher rural welfare in degraded zones. The disincentive to investment is not just in the average level of prices but in their extreme fluctuation. Moreover, higher prices have occurred without an investment boom taking place, but this has usually been in drought years. During the last two decades in the Sahel, domestic grain prices have tended upward. In individual years crop prices have been extremely high. It is hard to imagine that in the medium term Sahel governments will have the fiscal resources to keep prices high (through buffer stocks for example) in normal years. This is extremely costly in African countries with high transaction costs (Pinckney). It is difficult to increase normal year prices through closing borders to trade because Sahel borders are quite porous to informal trade (Egg and Igue). Even when local producer prices are high for millet and sorghum from degraded zones, merchants and even governments make available cheap

maize and sorghum from zones relatively unaffected by drought. The degraded zones are not closed economies in which farm investment incentives can be controlled and enforced. Even if governments succeeded in raising normal year prices, this would hurt the majority of net cereal buyers in the Sahelo-Sudanian and Sahelian zones (Weber et al 1988, Dione 1989, and Reardon and Mercado 1991).

The ways are complex that policies (especially exchange rates, marketing regulations, and interest rates) influence markets, intersectoral opportunity costs, and hence the environmental choices of rural Sahelian households. Overvaluation of the CFA franc reduces the attractiveness of Sahelian cattle exports to the coastal countries, relative to cheap imports of meat from the European Community or Argentina. (Delgado) Given that livestock husbandry is probably one area where the low-potential zones of the Sahel have comparative advantage, these policies may promote distortions in the local economy and act as disincentives to developing appropriate crop-livestock linkages, may create distortionately excessive incentive for grain production relative to livestock production, or create an incentive to sedentarize cattle in the Guinean zone (Josserand). On the other hand, cheaper grain could make it practicable to increase herds sustainably in the northern zones, putting less pressure on the southern zones (Delgado).

Bottlenecks and controls resulting from marketing regulations may create thinner markets and greater price fluctuations, which render investment in agriculture less appealing. High real interest rates due to underdeveloped capital markets may encourage households to shorten their investment planning horizons and will probably discourage sustainability investments.

To make conservation measures adoptable, complementary investments at the farm, village, and State levels are needed; this is discussed under Issue 4.

ISSUE 4: What complementary investments by villages and national governments in rural infrastructure are needed to make farm-level investments attractive and feasible?

Public investments either directly in resource conservation or indirectly in support of farm level investments, should be made by Sahel governments, due to the problems of externalities, capital constraints, and short planning horizons at the household and village level. The investment of scarce fiscal and foreign exchange resources involves difficult choices. These could include for example wells to water live windbreaks during the dry season, or culverts to divert water flow to protect farm fields. Government trucks are now being used in Burkina to haul laterite pieces to use in bund construction; this is an example where a government has followed the successful examples of earlier projects such as that of ICRISAT or Oxfam in the first half of the 1980s that promoted village and farm level bund construction, helping with complementary investments such as trucks or carts to haul the primary material (Matlon 1985). These complementary investments appear to be key to a current 'water revolution' in Burkina where farmers are investing in bunds (Sanders et al). The farm level investments could be due to a propitious combination of farmers' realization of the long-term and short-term benefits of the practice, or of fewer opportunities off-farm, especially in migration to the declining economies of the humid coast, and in particular due to government providing the critical capital input of trucks to haul the rocks, leaving only the (substantial) labor expenditure for the villagers.

ISSUE 5: What crop and activity mix should be sustained? Are the conditions upstream and downstream from production of that mix conducive to sustained profitability (are there market outlets, do consumers want to consume more of the crops or output of other activities)? What impact does crop mix have on soil fertility and integrity?

The first concern is what crop mix and non-cropping activity mix to sustain. The danger here is that a researcher might look at the crop mix currently being produced by farmers in a given area and conclude that is the mix to sustain. But it is quite possible that the farmers want to (or would want to with

sufficient information, institutional support, risk reduction) sustain a different mix of crops and activities -- to shift from sorghum to cotton, or grow more maize, or shift to more livestock or off-farm activities. The farmer households aim at sustaining their livelihoods, their overall welfare and food security, and not necessarily a given crop. If shifting away from millet, for example, to other crops or activities looks like it will raise and stabilize incomes, then the farmers will want to develop and sustain these new activities. But the shift might in the medium term benefit production of the original crops. Dione (1989) shows that cotton production helps grain yields in southern Mali through spillover of equipment availability and variable inputs to grain production. The goal of research, to coincide most closely with farmers' goals, would be to promote the mix of crops and activities that would assure the greatest overall growth and stability of the local economy. This may well mean adding more livestock research to current research agendas, and adding research on intersectoral linkages between crops and off-farm activities.

The second concern is the economic sustainability of a given crop mix in terms of the vitality and opportunities of the market for the product. A vertical systems perspective, focusing on the food system, leads research to go beyond the farmgate and take into account constraints to adoption coming from constraints to input distribution, to output distribution and marketing, and to intermediate and final demand. Constraints downstream and upstream from crop production can disable nascent development and eventual sustainability of production of a particular commodity. (see Bernsten and Staatz)

The third concern is the effect of a given product mix on the fertility and integrity of the soil: how does cotton affect the soil differently from sorghum? Intercropping relative to pure stands? There has been a relatively large amount of work done on this in field research stations, so that "C values" are assigned to different mixes and crops. There has been less work relating this to the evolution of erosion in fragile zones.

ISSUE 6: How should "sustainability research" be organized? How transferable is this sort of research from one Sahelian country to another? Does it make sense to headquarter certain types of conservation research in a regional center? or in certain national centers?

The nature of the subject implies long-term effort (how can one tell if a measure is effective over time if research does not monitor effects over a half-decade or even a decade or more)? That implies a commitment to long-term research. But that can only take place in the context of a long-term commitment to building agricultural research institutions in the Sahel -- to the long-term sustainability of the institutions themselves (Eicher).

But it is essential that these new lines of research not undermine ongoing research aimed at raising yields and increasing their stability. That is key to immediate growth in agricultural productivity, which is the priority. The key is to minimize the potential disruptiveness of introducing a major new theme by integrating it as much as possible with ongoing research. That is the purpose of conceiving of the challenge of sustainability in ag research as creating "overlap" technology packages, that add conservation measures to yield-enhancing intensification techniques.

But some tradeoffs are inevitable. Ways to internally generate resources that could be used for sustainability research include the following: (i) save resources by focusing on a priority set of commodities; (ii) gain scale economies by consolidating programs; (iii) regionalize some programs.

SUMMARY and RECOMMENDATIONS

Issues that relate to the sustainability challenge in agriculture research in the Sahel include:

(i) what production systems to propose in what zones, in particular how and where to intensify;

(ii) what measures are needed to conserve the resource base in different zones;

(iii) what incentive measures, and technology design, are needed to encourage and enable farmers to adopt conservation and productivity measures?

(iv) what complementary investments at farm, village, and State level are necessary to help farmers make those investments?

(v) what crop and activity mix should be sustained? Are the conditions upstream and downstream from production of that mix conducive to sustained profitability?

(vi) how should sustainability research be organized?

I have discussed each of the issues to stimulate further debate in national and international agricultural research circles concerned with agricultural sustainability in the semi-arid tropics, not to resolve fully these issues. My main recommendation is to focus on finding 'overlap technologies' that combine productivity increases with soil conservation; these can be for example combinations like fertilizer plus bunds plus new varieties. The challenge is the sustainability and adoptability of an intensification of production -- a Green Revolution -- with a focus on overcoming constraints in a way that is sustainable in technical and economic terms.

But adding a sustainability component to Sahel research is potentially competitive, as it may displace budget and personnel in ongoing breeding and agronomic programs aimed at raising yields. The latter are crucial for growth, and should not be neglected. If budgets stay the same, and there is mere displacement, the sustainability effort will over time be undermined. For it not to be, total resources have to go up and those present used more efficiently, a longer commitment envisioned, and sustainability and productivity research integrated.

To tackle the six sustainability issues at the research institute level, it will be necessary to approach the problems from the following four angles.

First, research needs to examine cropping systems (over crops) and the relation of livestock and cropping, and the livestock sector itself. Sahel research institutes can capitalize on substantial past investments in farming systems research.

Second, a multisectoral perspective is needed. I underscored above the great importance of income diversification in Sahel farm households, and its double nature of competitiveness and complementarity with sustainability measures at the farm level. How do off-farm income strategies of rural households condition their willingness and ability to under conservation investments?

Third, sustainability research needs to differentiate agroecological zones, between Sahelian and Sahelo-Sudanian on one side, and Sudano-Guinean and Guinean on the other. The first group of zones (what I have called the low potential zones after Matlon (1990)) is not a candidate for large productivity increases and intensification, but rather modest yield increases combined with the need for soil conservation and diversification of activities into livestock and off-farm. The issue of the carrying capacity of the commons to support further livestock development will be increasingly important. The second group of zones (the high potential zones) is a candidate for intensification combined with sustainability measures, and the target for 'overlap technology' research. But just because degradation has proceeded further in the low potential zones does not mean that sustainability research should have its center of gravity there. Rather, as noted above, increasing production in the high potential zone will decrease grain prices thus increasing real incomes of net buyer farmers (the majority) in the low potential zone, reducing pressure on the land there, and perhaps spurring an intensive-feeding livestock industry in the longer run.

Fourth, there needs to be more research on the economics of soil conservation. This economic research needs to be in four areas: (i) micro, technical analyses of returns to specific investments/techniques; (ii) positive policy research on how current policies affect incentives to adopt

these measures at the farm level; emphasis also needs to be placed on tracing the effects of sectoral and macro policies, such as exchange rates, food prices, and price and availability of credit, on investment incentives both in cropping in general and in water-harvesting structures in particular; (iii) normative policy research asking how governments can most effectively -- and cheaply -- encourage sustainability investments at household and village levels. Research should help determine where governments should provide indirect supporting investments (for infrastructure) and what they should be; (iv) institutional analyses of the functions and roles and constraints to support institutions (such as the CFDT in Burkina Faso) in promoting sustainable development.

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