Staff Paper

Challenges for Creating and Sustaining A Green Revolution in Africa

by

**Thomas Reardon, Eric Crawford,
Richard Bernsten, Carl Eicher, Thomas Jayne,
James Oehmke, Kimsey Savadogo**

Staff Paper 1993-65 **December 1993**

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

CHALLENGES FOR CREATING AND SUSTAINING A GREEN REVOLUTION IN AFRICA

By

Thomas Reardon
Eric Crawford
Richard Bernsten
Carl Eicher
Thomas Jayne
James Oehmke
Kimsey Savadogo

Paper presented at the 1993 AAEA Pre-Conference Workshop, "Post-Green Revolution Agricultural Development Strategies in the Third World: What Next?" Orlando, Florida, July 30-31.

Department of Agricultural Economics
Michigan State University
East Lansing, MI 48824

Staff Paper No. 93-65
December 1993

CHALLENGES FOR CREATING AND SUSTAINING A GREEN REVOLUTION IN AFRICA

by

Thomas Reardon (*), Eric Crawford (*), Richard Bernsten (*), Carl Eicher (*), Thomas Jayne (*), James Oehmke (*), and Kimsey Savadogo (**)

(*) Department of Agricultural Economics, Michigan State University
(**) Faculty of Economics and Business Administration, University of Ouagadougou

Paper presented at the 1993 AAEA Pre-Conference Workshop at Orlando, Florida, July 30-31, "Post-Green Revolution Agricultural Development Strategies in the Third World: What Next?"

We are grateful for financial support from: Department of Agricultural Economics, Michigan State University; A.I.D. through the Food Security II Cooperative Agreement with M.S.U.; and Faculty of Economics and Business Administration, University of Ouagadougou.

CHALLENGES FOR CREATING AND SUSTAINING A GREEN REVOLUTION IN AFRICA

A. INTRODUCTION

A.1. Purpose

Green Revolution (GR) originally meant development and widespread and rapid adoption of fertilizer-responsive improved varieties of rice/wheat. Since the 1960s its meaning has broadened to enhanced agricultural productivity through increased use of: (a) new seed varieties; (b) non-seed inputs (fertilizer, irrigation, herbicide, pesticide); (c) technologies that employ them; and (d) capacity to manage these techniques. Our shorthand for (a)-(d) is 'GR components'.

African farmers use very few GR components compared to Asian farmers, with a few notable exceptions of places and crops where GR has occurred in Africa (discussed in section B). GR has bypassed the agroclimatically-unfavored zones (arid and parts of the semi-arid zone) of Africa as it did in Asia (Barker and Chapman, 1990). But GR also has generally bypassed the agroclimatically-favored zones (the humid tropics, the tropical highlands, the guinean belt of the semi-arid zone).

But there is a pressing need to increase agricultural productivity and output in Africa, and to do that sustainably. The challenge for policymakers is to make policies and investments that encourage and enable farmers to adopt GR components and to make accompanying farm and village-level investments that sustain the productivity increases. The challenge for agricultural researchers is to pursue research strategies that lead to the creation of GR components that are attractive to and adoptable by farmers.

To make these policies and form these research strategies, we contend that policymakers and agricultural researchers need to ask the following questions, from the farm household perspective:

(i) Are the new GR components attractive to and adoptable by farmers? Are farmers willing and able to make needed complementary investments? Are the new components more attractive to farmers than their current crop technologies? Are they more attractive than investment in livestock husbandry and non-agriculture?

(ii) Do the "local conditions" facing farmers (prices, agroclimatic conditions, hard infrastructure, support institutions such as extension and seed companies) favor the adoption of the components?

The main goal of the paper is to present a framework to guide researchers and policymakers to think about (i) and (ii) in the African context.[1]

Our message is that a close examination of the constraints and local conditions farmers face, and the strategies they employ in the face of them, will improve research strategies to promote a sustainable Green Revolution in Africa. We advocate a twofold analytical perspective on adoption -- a household economy perspective that incorporates choices within the farming system, and between agricultural and non-cropping choices, and a food systems perspective that takes into account constraints in the distribution and demand for the product, and in support systems such as extension, seed companies, and so on, that facilitate production and marketing.

The household perspective incorporates this systems perspective, looking at the potential for adoption of GR components from the horizontal and vertical viewpoints. The household economy is the focal point of interacting forces -- policies, local conditions, availability of technologies generated by research institutions, and agroclimatic conditions. To see how these relate, and what their relation implies for design of technologies and incentive measures and institutions, is our goal.

A.2. Approach and Conceptual Framework

A Green Revolution may be conceptualized as a three-stage process: (i) create; (ii) adopt; (iii) sustain.

(i) The creation of GR components involves agriculture research. A crucial first issue is how to

---

[1]. We put less emphasis on alternatives open to policymakers to alter local conditions; this, and an assessment of policies to promote better functioning of the food system forming the context for the household's choices, is the focus of the paper by Staatz et al. for this conference.

organize and sustain research institutions, but that is not treated in this paper due to space constraints.[2]

A second issue is what research strategies to use -- what crop mix, what characteristics of variable and capital inputs, what zones and types of farmer to focus on, what mix of yield level and stability to breed for, and so on. The paper offers principals or perspectives to guide the choices.

(ii) The issue of adoption of GR components can be seen in a household investment function framework. The conditions that encourage and enable adoption are the two sets of arguments in the function: (a) incentive to invest (the mean and variance of return on the investment), and (b) capacity (or constraints thereon) to invest (availability of own liquidity, credit, knowledge, and complementary infrastructure, including extension support, input availability, and access to product markets).

In turn, agricultural researchers, policymakers, and private companies in the food system (e.g. seed companies) affect the incentives and capacity of farmers to invest by their influence on the design of the components farmers use, and on the local conditions (e.g. prices, infrastructure, support systems) that affect the farmers' incentive and capacity to make these investments. These technology design and policy influences, in interaction with structural factors such as variable rainfall, can and often do create conditions that spur households to choose general strategies that limit adoption of components of GR. We think agricultural research institutions often ignore these conditions, apparently assuming that the appropriate conditions are present, when instead they often are at the center of non-adoption or disadoption.

(iii) Issues related to sustaining a GR cover several domains:

A first issue is how to conserve/protect the resource base so that productivity increases are not undermined by nutrient loss and degradation over time, a key focus of part D of this paper. The issue

---

[2] There is much controversy about how to organize, to finance, and to sustain research, extension, and production/distribution of inputs in a way that will put appropriate GR components at the disposal of farmers. We will not tackle these issues in this paper (see e.g. Matlon 1989; Eicher 1992; Lipton 1989).

we address is whether adoption/investment issues in the sustainability domain differ substantially from those related to 'traditional' GR components.

A second issue is how to sustain the institutional/support and infrastructural base to support long-term productivity increases[3].

A.3. Organization of the paper

The paper is organized in four sections as follows:

(1) Before we can discuss constraints to adoption/investment and sustaining a GR, we need to inventory the extent of GR in Africa -- where has adoption occurred, in what crops, under what conditions; what is on the shelf that could be adopted; what has been offered to farmers but not adopted; what has been adopted but later disadopted.

(2) We then discuss constraints to adoption from the household's perspective, both from the perspective of the household economy/farming system, and the food system.

(3) We then discuss how a GR once adopted can be sustained -- how the resource base can be sustained through conservation investments.

(4) We conclude by recommending ways that the research community can incorporate the horizontal and vertical elements of the household perspective in the design of appropriate strategies for promotion of a sustainable Green Revolution in Africa.

B. INVENTORY OF GREEN REVOLUTION IN AFRICA

B.1. General Record and Evolution

Farm-level adoption of GR components has in general a poor record in Sub-Saharan Africa. Fertilizer use is only 9 kg/ha compared to 58.3 kgs/ha in all developing countries in 1985 (Bumb 1988). Pesticide and herbicide use is even lower. Only a very small portion of cultivable land is irrigated.

[3]. A crucial issue but one not examined in this paper due to space constraints; see Eicher 1989.

The proportion of farmers planting improved seeds is on average low but varies greatly by crop, with notable successes (described more below) in hybrid maize in eastern and southern Africa, cotton in West Africa, potatoes in east Africa, and traditional export crops such as coffee and cocoa in west and east Africa, but limited success in diffusing improved varieties of other major food crops, especially roots and tubers, millet, and sorghum.

Before the 1970's, African agricultural research focused narrowly on cash/export crops to the neglect of food crops. In response to the world food crises of the early 1970s, there was a switch of emphasis in the 1970s and 1980s from export to food crops, with a focus on a couple crops. (Spencer 1985)

B.2. Commodity successes and failures

For maize, improved techniques for increasing farm-level productivity are available and perhaps most widely adopted by farmers. Improved varieties have been released for almost every agroclimatic zone in which maize can be grown: characteristics differ somewhat according to the biotic and abiotic stresses of the ambient environment and farmer needs. With over 300 varieties released since 1966 in Africa, the number of varietal choices available to African farmers is equivalent to that for farmers in other developing regions. Less work has been done on agronomic recommendations, with many recommendations insufficiently tailored to individual farm conditions. (Byerlee, 1992)

Hybrid maize had great success in Zimbabwe and Kenya in the 1960's, and in Malawi, Zambia, Nigeria, and Ghana in the 1980s-1990s. In Kenya, 65 percent of farmers now use hybrid varieties (Byerlee and Heisey): currently recommended varieties yield 2-3 times more than traditional varieties on farm fields.

In Malawi, the maize sector was doing poorly until recently. In the 1980's, the dominant, improved varieties were dents with less desirable storage, processing and/or taste characteristics than the local, flinty varieties. In 1986 the Malawi maize research team embarked on an effort to develop a high-yielding, flinty variety, and succeeded with the release of MH17 and MH18 in 1991. The yield advantages of hybrids over local varieties in on-farm demonstrations was 48 percent in the "normal" years of 1990 and 1991, and 77 percent in the drought year of 1992 (Byerlee and Heisey). In part because of the superior yield performance of the new hybrids in adverse conditions, adoption of hybrids has increased rapidly in the past two years.

Maize has also done well in the Guinean semi-arid zone of Northern Nigeria, where the introduction of the TZB variety provided a yield advantage of 21 - 115 percent in farmer fields, with maturation about 1/2 months earlier than sorghum. Due to the increased yield and profitability of TZB, the number of villages growing maize as a major food crop tripled from the 1970s to 1989, and the number growing it as a major cash crop went from few to 70 percent over the same period. (Smith et al., forthcoming) Maize also has bright prospects in the Guinean zone of the Sahel (Matlon 1990).

In Zimbabwe, hybrid maize accounts for 100 % of the maize area of commercial farmers and around 90 % of the maize area of smallholders. In Zambia, hybrid varieties generate average yield increases of 20 % above traditional varieties, and are planted on 61 % of maize area (Howard et al.) Large-scale farmers are financing privately-funded research in Zimbabwe.

Smallholder cotton production in Francophone West Africa is one of the great success stories on the continent. Much of this success is due of the carefully coordinated research, extension and marketing partnerships between French agencies and African governments. (Lele et al. 1989) But there have been failures to improve varieties quickLY enough to compete with Asian exports (e.g. oil palm and cocoa, see Eicher 1992)..

Africa is importing about $600 million of rice each year, mostly from Asia. Rice is a unique commodity, since it is one of the two commodities first generating green revolution in Asia, and is widely grown in parts of West Africa. But modern varieties have been adopted on a small percentage of the total rice area of Africa. Most rice is grown under rainfed conditions. There are a few examples of adoption of new varieties and increased farm income due to this adoption (Adesina), although broad-based survey data are not yet available. Agronomic and water-control recommendations for the rice varieties are available. Current techniques provide increased yields, fertilizer responsiveness, and ability for weed control. The potential increase in West African rice output due to these techniques is 280,000 tons. (Matlon)

Adoption of hybrid sorghum has been impressive in the Gezira irrigation scheme in Sudan (Ahmed and Sanders), but other examples of sorghum success are hard to find.

New blight and wilt-resistant potato varieties have an adoption rate of nearly 100 percent in eastern Africa, due in large part to the devastation of traditional varieties by these stresses (Euell).

B.3. Prospects

Available evidence is unclear whether on-shelf technology is sufficient to stimulate green revolutions, even if accompanying components are in place. There are disturbing instances of disadoption or other causes of diminished impact on farm fields. For example, the low use of fertilizer throughout Africa creates widespread problems of "declining soil fertility and increasing soil degradation through nutrient mining" (Byerlee, 1992).

The elimination of input subsidies due to structural adjustment in a number of countries has jeopardized the use of modern techniques and inputs (e.g. see Kelly and Delgado 1991 for Senegal). On the other hand, the fiscal burden of the subsidies is substantial and probably unsustainable; 17 % of the government budget in Zambia was going to maize subsidies until they were discontinued in 1992.

Moreover, there have been structural and strategic deficiencies in agriculture research that jeopardize future creation and adoption of GR components. Agricultural research has focused too intently on farm production, to the neglect of the consumer, even when that consumer is the farm household. In the worst case, this leads to development of improved techniques which may increase farm output when there is little or no demand for that increased output, or when the consumer cannot use the output profitability, so that the techniques have little impact on agriculture or on the welfare of the poor farm family. For example, "...maize breeding progress have given insufficient attention to post-harvest evaluation of grain quality, storability, and small-scale processing. ...when grain yields are corrected for post-harvest losses incurred in small-farm storage and processing, many available hybrids are found to be inferior at low input levels (Byerlee)."

There has been insufficient emphasis on subregional crop research capacity and the human capital buildup that should be its concomitant. These two elements that were important in Asia, with decades of investment, and are sorely needed in Africa in the 1990's. (Eicher 1992)

African farming systems are more varied, and number of crops grown greater, than in GR Asia (Timmer 1992). A narrow focus on a few food crops, in research, as is often the agenda now, bypasses both the variety of the system, and important crops that were not selected as the focus. The diversity in the farming system needs to be addressed.

Agricultural research in Africa has also put the emphasis on breeding for high yields and less on agronomic and economic constraints to adoption, and the necessary alteration of technology characteristics that would be needed to accommodate the constraints. It is to these household level constraints that we now turn.

C. ADOPTION CONSTRAINTS FROM THE FARMER'S PERSPECTIVE

The conceptual sequence of the determination of adoption and investment is as follows: (a) Farm-level adoption of new seeds and investment in accompanying variable and capital inputs depends on (b) general farm household strategies/behavior regarding income-earning, cropping, investment, and consumption, which are shaped by household reactions to (c) 'local conditions' (economic structure such as price risk, agroclimate such as rainfall levels and instability), which in turn are partly influenced by (d) policies. The analytical chain can be seen as follows:

Diagram 1:

(a)		(b)		(c)		(d)
GR components: Adopted and sustained	<---->	Household behavior/strategies (horizontal, across sectors; vertically, in the market system)	<-->	Local conds.	<-->	Policies and other

Note that the column (b) in the diagram incorporates two categories of household behavioral choices, which in turn implies that there are two ways or directions by which local conditions can affect household behavior: (i) the horizontal dimension of the household economy, as it operates in multiple sectors -- cropping, livestock, forestry/gathering, off-farm enterprises, and within cropping, across the crop mix; (ii) the vertical dimension, of which the household economy is a part, is the food system, a chain from input distribution, to crop production, through crop distribution, to final consumption or intermediate use.

Examples of research on the 'horizontal perspective' are found in research on farming systems, and on farm household income diversification and investment strategies. Examples of the 'vertical perspective' are found in research on commodity subsectors and general equilibrium models.

Both perspectives are needed to successfully assess constraints to sustainable Green Revolution in Africa, and both should be used to address the following two sets of questions that are based on the logical sequence shown in diagram 1:

1. What are local conditions that might lead to household strategies antithetical to GR adoption? How do policies, or gaps in policies, influence these local conditions?

2. How do households respond (in strategy/behavior, e.g. income and crop diversification) to these local conditions? How can this behavior threaten adoption of GR?

The following two subsections address those questions.

C.1. Local conditions that constrain household adoption of and investment in GR components

Four interrelated sets of local conditions push households to adopt strategies that have impeded or would impeded the spread of GR components, even when and if they are available:

(a) High risk/instability and high transaction costs

African agriculture is very risky mainly because of unstable rainfall and prices. Rainfall is especially variable in semi-arid areas. This basic risk is exacerbated by the following factors:

(i) There is very little irrigation at present, major constraints to large-scale irrigation increases, but potential for increases in small-scale irrigation (Matlon and Adesina 1991). Only about 5 % of the arable land in Africa is irrigated. This compares with 40 % in India and 60 % in Indonesia. (Eicher 1986)

(ii) High transaction costs "bottle up" output supply, causing prices to be determined in thin markets within zones with unstable rainfall. The high transaction costs are due to high transport costs, inappropriate market regulations, including poor legal foundations and enforcement, and protectionist, trade-reducing macro and trade policies 'bottle up' the variable output. This effect is much greater in Africa than in Asia because there is less road per person in Africa, due to low population density and to inadequate public and private investment.[4]

Price and market stabilization schemes can counteract this risk, and do so in Asia mainly in humid tropics (e.g. Indonesia, in Bernsten 1993). This task may be more difficult in drier zones and non-irrigated areas with highly unstable rainfall, which characterizes half of Sub-Saharan Africa. Price stabilization schemes for grains have not worked well in Africa. Pinckney (1988) finds that Kenya maize price stabilization is extremely expensive, beyond the fiscal means of the government. Output instability combined with weak fiscal and infrastructural base are major problems. Zimbabwe's procurement programs safeguarded against large price changes for maize but at high fiscal cost (Rohrbach; Jayne and

[4] McIntire 1981; Ahmed and Rustagi 1987; Gabre-Madhin et al. 1992; Schmid 1992; Badiane 1992; Staatz et al. 1993.

rukuni 1993). Increases in intra-regional trade are key to mitigating this problem at low fiscal cost (McIntire 1981; Badiane 1989; Koester 1989)

(iii) Price instability is exacerbated by product demand constraints, which also can limit the market for a product with good production potential. When output supply increases greatly (such as in the Sahel bumper crop of 1985), producer prices plummet because of limited market outlets for bumper harvests that 'simulate' GR-type technology breakthrough. Sahel coarse grains in general have difficulty competing with rice in West Africa (Reardon 1992). These demand constraints reduce the size of the local market; thinner markets have more unstable prices.

Product demand constraints have diverse causes: consumer preferences (say for convenience grains such as rice and wheat), trade restrictions, transaction costs of obtaining the product, inadequate grading (which stymie the spread of improved sunflower varieties in Zimbabwe). Processing can be the bottleneck. The consumption role and hence the market for maize in Mali is limited because maize meal processing is costly. (Kelly et al 1992)

Downstream distribution constraints can reverse a promising Green Revolution. GR-type production system changes were made in cowpeas in Northern Senegal in the mid 1980's, but because of inadequacies in the distribution system for the product, farmers' inventories went unsold and farmers turned away from cowpeas in the late 1980's (Kelly et al 1989). A similar case occurred in Mali (Coulibaly, 19xx).

Distribution constraints are important not only for final demand for the product, but intermediate demand in downstream linkage enterprises, such as beer brewing, grain milling, etc. Infrastructure constraints limit local forward and backward linkage activities. These linkages are crucial to maximizing the local growth impact of a GR, which in turn generates surplus to reinvest in cropping, thus creating a growth spiral (Mellor 1976; Hazell and Ramasamy 1991).

(iv) Input supply/distribution is often unreliable in Africa, which increases the risk of relying on them. Abrupt changes of marketing rules increase uncertainty (for Senegal, see Newman and Ndoye, 19xx). Because fertilizer, herbicides, and pesticides are mostly imported, problems with timing of imports and delivery of imported stocks cause lots of uncertainty for farmers (e.g. in the Gambia, see von Braun, 19xx).

Policy-induced fluctuations in cost of inputs cause uncertainty. Bumb (1988) for SSA in general, and for Senegal, Gaye (1987), Commander et al (1989), and Kelly and Delgado (1990), point out that Structural Adjustment increased fertilizer prices (in Senegal, by removing price subsidies, input credit, and public marketing institutions, and in general, by doing same plus country devaluations) or made them more uncertain.

(b) Infrastructure constraints

The dearth of infrastructure impedes technology adoption and input investment at the household level, even if appropriate GR components are available, by limiting needed service provision (such as seed company operations, fertilizer commerce, and implement distribution).[5]

Complementary public/village production infrastructure is often lacking at the local level. To overcome local resource constraints (water, soil degradation) and to provide the needed base for productivity investments (fertilizer), farmers need to invest in small-scale irrigation, windbreaks, bunds, and so on. These require accompanying public investments (such as wells or culverts or dams, and irrigation canals for small-scale irrigation to branch off of). Public investments in these kinds of complementary infrastructure were crucial to Asia's GR (Bernsten 1993). Village and household level investments of this type are also important; secure land tenure encourages these, although whether tenure is necessary is still controversial. Some of these investments are important for initial adoption to occur, and some are needed at later stages (second generation) of growth of the GR. In African village studies, these constraints are often cited as important (for Senegal, see Diagana et al. 1990).

---

[5] For Zimbabwe case, see Wanmali and Zamchiya (1992); for Zambia case, see Celis et al. (1991).

Low farmer education and lack of extension services can be a crucial constraint to adoption. These plague most of African rural areas, except for pockets of cash crop schemes. This lack also reduces feedback to agriculture research centers concerning component characteristics, further impeding adoption. (Eicher 1992)

(c) Low absolute and relative profitability of agriculture

(i) A lot has been written on the unprofitability of agriculture in Africa, especially in the 1980's literature promoting Structural Adjustment. The culprit identified is macroeconomic policy and trade regimes that tax agriculture, such as protectionism accompanying import substitution industrialization (see Badiane 1992), and overvaluation of currency (see Berg).

Without question, macro-level policies and institutions, including property rights and other "rules of the game," are important to encourage adoption of GR components. For example, maize in Mali was rapidly expanded thanks to guaranteed prices and integrated technology delivery and marketing system established by the cotton parastatal. But good macro policy is necessary but not sufficient to encourage and enable farmers to invest in GR components -- public and private investments are critical, as are sector-specific interventions.

Moreover, while macro policies can reverse perceived distortions in price levels, they may or may not reduce price instability. Devaluation could even increase price instability by increasing transport costs (raising price of imported spare parts and fuel), further 'bottling up' local supply and demand.

(ii) Structural factors such as "urban bias" in public and private investments/infrastructure and "Dutch Disease" (drawing resources from other sectors to mines or foreign aid or oil) draw resources from agriculture. They make investments in migration and local non-agricultural activity look more profitable and less risky than on-farm investments. These factors increase the opportunity cost of adoption investments.

(iii) High transport costs also increase input costs, and lower profitability. High food costs translate to high wage costs a la Ricardo, which make export agriculture less competitive, and reduce overall resources available for investment at the farm level.

(iv) Degradation (from poor land use practices and lack of conservation investments) raises farming costs and reduces incentives for investments in traditional GR components, and in conservation investments to make them sustainable -- a vicious circle.

(d) Credit constraints

(i) Rural credit and insurance markets are underdeveloped in SSA. Input credit apart from that supplied by parastatal schemes is rare.[6]

(ii) The underdeveloped credit market, and sometimes missing credit market, is due to a low savings rate, caused by poverty, underdeveloped savings institutions and counterproductive regulations[7], and risk. Another vicious circle is present: more profitable agriculture would generate more savings, which would fuel the informal credit market, which would help investments in components of the GR, which would make agriculture more profitable.

(iii) Structural Adjustment closed public credit institutions that were highly deficitary, further reducing credit access.

C.2. Household strategic responses to local conditions, and how these stymie GR adoption

Although we discuss African rural households' strategic responses in both the cropping and non-cropping sectors to the above conditions, we put particular emphasis in this section on the response of income diversification -- where farmers supplement cropping income with livestock husbandry and off-farm income. This emphasis is partly because we think that such diversification is an archetype of the kind of complication to the adoption issue that is not adequately taken into account in agricultural research

[6] Tapsoba, 198x; Binswanger 1986; Christensen 1989

[7] ...lack of public investment in rural banks of the type found in Bangladesh (Grameen Bank), and collateral rules for existing banks that limit access (e.g. need to have secure land title).

institution's deliberations on what GR components to create and what might be the acceptability of them to farmers.

There is evidence that some agricultural researchers working with African farm households tend to see them as only farmers, instead of such households as multisectoral firms, often with many options in the non-cropping sectors. The import of this is that it contradicts the idea that farmers are 'stuck with' whatever cropping innovations research institutes present to them, with the latter implying that farmers will want to adopt whatever innovations they can afford and that offer a better profit than their current cropping practices. Rather, as discussed below, African farm households are accomplished diversifiers, and when deciding on where to put cash and labor time, look at the returns from cropping innovations in comparison to non-cropping options, in livestock husbandry and off-farm. That means adoption of GR components is far from automatic, even if those components won laudits within the agricultural research community. We think the evidence shows that this has happened in a number of cases in Africa.

a. income diversification

(i) African farm households diversify their incomes. Haggblade, Hazell, and Brown (HHB) (1989) reviewed evidence of rural off-farm employment in sub-Saharan Africa. They found that the share of off-farm income ranged from 25 to 30 % of total household income. Reardon et al. (1992b) reviewed recent survey evidence from West African semi-arid tropics showing a range of 20 to 61%, with an average share of 38% for off-farm income for non-cropping income (off-farm plus livestock income). These figures contradict the conventional image of rural African households being only farmers.

(ii) Diversification strategies differ by agroecological zone. Diversification of household incomes in drier, lower-potential, zones tends to be oriented outside the zone (migration, rural-urban linkages) to compensate for low and unstable yields. Diversification in fertile, higher-potential zones tends to be based on backward and forward growth linkages with theIR more dynamic agriculture. The degree of diversification tends, however, to be similar between the two types of zone.

(iii) Diversification is driven by push and pull factors linked to the 'local conditions' described above:

Agricultural risk: Reardon et al (1992b) present WASAT evidence showing that income diversification is the main means by which households mitigate production risk and assure food security in the face of harvest shortfalls (with distant second inter-household transfers, net borrowing, and selling assets).

Credit constraints: reinforce the drive to diversify because households need non-farm income as a liquidity substitute for missing consumption and input credit.

Land and water constraints: While land constraints are obvious in places like Rwanda, in parts of Africa that have traditionally been considered land-abundant, there is evidence that there are growing land constraints. (Matlon 1987; Tschirley 1993). Land scarcity pushes farmers to substitute to supply more labor per unit of land, which reduces the agriculture wage (in the absence of new technology), and makes farm labor less attractive relative to labor in other sectors. On the other hand, land scarcity can force technological innovation, a la Boserup (1981), especially adoption of land-saving technologies (e.g. improved seeds and fertilizer). Matlon (1991) contends this is happening in the Sahel, long considered a land-extensive situation.

Water constraints, especially the lack of irrigation in most of Africa, and hence limited growing season, militate against households' specializing in agriculture as they can in irrigated portions of Asia.

Farms reallocate cash and labor to non-cropping activities when returns to the latter become higher and/or more stable than returns to cropping. An increase in labor demand in cities (from 'urban bias' or Dutch Disease from natural resource boom, or from foreign assistance, can thus affect relative prices; local off-farm opportunities, perhaps linked to agriculture, can also do this.

African household-level studies tend to confirm that farmers are sensitive to relative sectoral profitability (intersectoral terms-of-trade) in their factor allocation and investment decisions, including in GR components. Norman (1973) found that intersectoral returns influence Northern Nigerian households' labor allocation between dry season gardening and off-farm work. Delgado (1989) found that farmers were sensitive to the off-farm wage when deciding whether to invest in animal traction. Reardon et al. (1992a) found that terms-of-trade affected the degree of income diversification in Burkina rural areas.

(iv) Diversification can hurt or help adoption of GR components, depending on local conditions.

On the one hand, diversification activities can compete for resources with investments in GR components at the household level. The competition can be for labor in the cropping season, or for resources to construct soil conservation infrastructure in the dry season. Reardon and Islam (1989) point out:

> 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 be 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.

Examples of this in the literature: For Botswana, Low (1986) shows that adoption of hybrid maize was constrained by farmers desire to diversify.[8] For Niger, Lowenberg de Boer (1993) compares crop investments of the Green revolution variety with investments off-farm, and shows that the latter are often preferred and more profitable. For Senegal, Kelly (1988) shows that off-farm investments are preferred to fertilizer in some zones. Christensen (1989) shows for Burkina that off-farm investments compete with agrarian capital formation in the Sahelian and Sudanian zones.

Household income diversification also means that households forego economies of specialization

[8] Many observers press for labor-intensive technologies, instead the African farm household wants to save labor on farm to use this labor off-farm. We would add that even if labor-saving technologies are not available or affordable, household might choose to labor off-farm and provide the minimum labor to their farms.

(where one household might specialize in cropping, or commerce, and so on). But given that there is very little irrigation inter alia, specialization in cropping (meaning only doing cropping, not working off-farm) is not much of an option in the near future.

The issue of competition between income diversification and adoption of GR components is complicated by ambiguity in the causal direction, however. Are households diversifying because good opportunities in cropping are not available (profitable GR components not present), or is the diversification blocking adoption of available components. The answer depends in part on the situation. The example from Low above is a case where hybrid maize was available but off-farm opportunities looked better to farmers. This first case is the most interesting and worrying for our subject, because it either means that the product was not designed appropriately (Low's hypothesis is that the technology should save labor rather than use it), or other accompanying conditions are not present (such as developed credit market). In other cases, for example the northern belt of the Sahel, there is a dearth of cropping options that can effectively compete with livestock and off-farm opportunities, and diversification is both by default and by design (to manage risk). But there can also be a combination of the two extremes, a vicious circle where an initial lack of profitable cropping opportunities or high risk or both, incite households to diversify. They hold on to the latter because of its long-term income stabilization attributes, and then when GR components become available, they may not adopt because of the opportunity costs involved.

On the other hand, however, diversification can help adoption, however, by providing own-liquidity for investments, in the presence of capital market constraints or failure. Collier and Lal (1980) show that migration remittances are important for investment in hybrid maize and accompanying capital investments in Kenya. Reardon et al. (1990) show that non-agricultural income is important to ability to purchase fertilizer in areas where fertilizer use is profitable and public institutional credit for inputs is not available (non-cotton zones). Kelly (1989) shows a similar connection in Senegal. Dione (1989) shows that non-agricultural income helps adoption of animal traction in Mali.

Moreover, at the local economy level, diversification activities such as cottage manufacturing and repair of animal traction equipment, provision of fertilizer, and so on, can reduce the prices and increase the availability of inputs needed to raise productivity.

But liquidity for investments depends substantially on farmer's access to non-agricultural income (beside cash crop income), yet local growth linkages that would create off-farm income depend on market facilities and roads (Anderson and Leiserson 1980). The lack of infrastructure that directly impedes GR also indirectly impedes by limiting growth linkage activities.

Finally, unlike in Asia, research in a variety of agroclimates (e.g. semi-arid, Reardon et al 1992, or tropical highlands, Loveridge 1992) shows that poor households in Africa have relatively less access to these off-farm jobs, thus less access to liquidity for GR investments. This means inequitable social differentiation in future GR in Africa.

(b) Cropping diversification

African farming systems are extremely diversified, mainly as a means of managing cropping risk (Matlon 1989).

On the one hand, this diversity makes a GR harder in Africa than in Asia all else equal, because in Africa one must spread scarce research funds thinly over many crops while a narrow and efficient use of resources (on rice, wheat) was possible in Asia (Eicher 1992; Bernsten 1992).

On the other hand, the cropping diversification often involves adding cash crops, such as cotton, to grain or tuber systems. While this sort of cropping diversification has traditionally been seen as a drain on the vitality of the staple foodcrop sector, recent evidence (e.g. Dione 1989 for Mali) shows that cash crops work in synergy with the staple food crop sector. Cash crops provide liquidity for agrarian capital formation and purchase of GR components such as oxen and fertilizer, both of which benefit staple food crops as well, and overcomes credit market constraints. But the cost of producing cash crops, and hence their competitivity, depends in part on the price of staple food crops (e.g. see Delgado 1992, Jayne 1993).

But high transaction costs and high risk reduce the commercialization rate, which reduces the incentive to invest in new technology. The larger price band also discourages supply responsiveness of farmers (de Janvry et al. 1991).

(c) Demand-side constraints to input use

In discussions of constraints to extension of GR to some parts of Asia, the debate focuses on supply-side constraints to input use (e.g. Ahmed 1988). While there are important distribution constraints on inputs in Africa (see discussion above), equally important are effective input demand constraints. It may be limited due to cash constraints (credit constraint or lack of access of income diversification), or high perceived risk. Example: fertilizer in Senegal (Kelly 1988).

(d) Strategic planning horizon of farmers is short, leads to resource mining/degradation

Theory and practice show that poor farmers invest less and have shorter planning horizons. This drives them to 'mine resources' and neglect conservation investments. Land degradation results, which then makes investment in GR components unattractive at the farm level. This is a vicious circle because the poverty and price risk and lack of education/extension that impedes GR investment also can impede investments in soil conservation that precondition and sustain GR investments, which is the topic of the next section.

D. SUSTAINING A GREEN REVOLUTION IN AFRICA

D.1 Second Generation Issues

Adoption is not the end of the story. In Asia and Latin America, in their GR's since the 1960's, and in Africa in the 1970's and 1980's, in various cases initial adoption is followed by disadoption. Pachico (1989) gives the example of new CIAT bean varieties in Central America. Rohrbach (1988) discusses disadoption of maize varieties in Zimbabwe.

Hence, there are important second generation issues to consider, after GR components have been adopted. Because there has not yet been much GR in Africa, these second generation concerns are relatively less important at present, but will become more important later. Moreover, it is important to consider them at the design stage, so that issues of initial adoption and sustaining the adoption should be simultaneous in the deliberations of the agricultural research institution.

Many of the same issues that were discussed above that influence initial adoption continue to be important in maintaining adoption -- profitability of investment, capacity of farmers to invest, efficiency of resource use. There are some issues to emphasize in the aftermath of adoption, however. These revolve around the importance of sequencing the introduction of complementary investments, market reforms, and policy and institutional changes that maintain the profitability of the initial investment. (Eicher 1992, Byerlee 1992) Maintaining quality and profitability in seed multiplication and distribution were critical to sustaining adoption in most of the countries studied by MSU in the technology impact studies (esp. Niger and Uganda) (see Oehmke and Crawford 1992).

At the macro level, economic profitability is important in the long run. Government price supports and marketing and input subsidies impose a budgetary cost that is hard to sustain. (as illustrated by the Zambia example where subsidies had to be eliminated in 1992, which provoked significant disadoption of HYV maize). Alternate solutions for reducing budget costs include aligning technology innovations more closely to comparative advantage, and institutional and policy reform to improve market performance and reduce transactions costs so that fewer budgetary subsidies are needed to create incentives. Innovations in product processing and marketing can also increase market outlets for the product, and relieve the need to artificially support its profitability through production subsidies. (Byerlee 1992; Staatz and Bernsten 1992).

What the critical constraints are, and how best to overcome them, depends on where one is in the sequence of adoption and use of GR components. Tailoring and sequencing solutions to suit specific environments is critical. Initially, technology can be imported via regional research network working in collaboration with the local research system to screen promising varieties. Maintaining GR gains, however, may require establishing strong breeding programs to address location-specific constraints, including consumer preferences (color, taste), and disease and pest resistance. The necessary physical infrastructure and support services must be put in place, largely through public investment. This requires a long-term commitment by governments and donors to help build NARS research capacity and effective extension services. The post-adoption phase also requires farmer education, training, and improved information dissemination systems. This capacity building has almost always been the precondition for successful Green Revolution in Asia and in Africa (e.g. Kenya HYV maize in the 1950s-1960s). (Byerlee 1992; Eicher 1992).

But achieving sustainable productivity gains also requires monitoring of resource quality, and adaptive research to identify sustainable practices appropriate to local circumstances. This topic is addressed in the next section.

D.2. Farm-level conservation investments to sustain productivity increases from a GR

(a) The challenge for the second Green Revolution: Combine Growth and Sustainability

In the long run, degradation of soil and water resources will likely undermine initial gains in productivity from adoption of GR components. While agricultural researchers and policymakers in Asia and Africa have long recognized this as a major problem, soil erosion continues to be a major issue in most developing countries (de Haen 1991), and threatens to undermine nascent productivity-enhancement and Green Revolution in many parts of Africa (e.g for West Africa, see Matlon and Spencer 1992; for Southern Africa, see Whitlow 1988).

From the mid-1980s, the quests in the international agricultural research community, unspecific to region, appear to be (i) to make 'GR' practices sustainable in high-potential/high-performance zones, where they have been adopted; (ii) to extend 'GR' technologies that are highly productive (given proper conditions such as input availability) to high potential zones where they have not yet been adopted; (iii) to identify technologies to raise productivity modestly in low-potential zones; and (iv) to control degradation and alleviate poverty in both high and low potential zones, working toward agricultural sustainability. (TAC-CGIAR 1988) The TAC-CGIAR (1993) is calling for a renewal of effort in the international and national research communities to launch a second Green Revolution, this time with an emphasis on combining productivity increases with sustainability.

In Africa the sustainability challenge is especially important. For new varieties and inputs to spread, for yields to increase, the resource base must be protected through household and village level conservation investments and sustainable land-use practices. These investments include watershed management, organic matter amendments, and water flow diversion.

The challenge will be to reduce growing degradation in high-potential zones and zones where there has already been adoption that currently produce the bulk of agricultural output or are expected to make the largest and fastest contribution to agricultural growth; and (ii) to mitigate severe degradation in low-production/low-potential areas so that modest productivity gains can be preserved.

It is important to understand how these conservation investments/practices differ from the more familiar or traditional Green revolution components that focused on short-term productivity increases. Does encouragement of new conservation activities just imply the usual prescriptions of better credit, more roads, more extension, better prices, and so on? Or are new sets of policy prescriptions and a modified framework for analysis required? Are the constraints to adoption of these sustainable practices and conservation investment different from the adoption constraints discussed above for the more traditional GR components?

(b) From the adoption and investment perspective, what is different about conservation investments?

To determine whether the constraints and policy prescriptions are different, one must first ask what are the differences are between what we can call "productivity investments" (PI) and "sustainability or conservation investments" (CI) that have implications for constraints and how to solve them. (Although these are only polar or center-of-gravity concepts or terms because each can produce results in the realm of the other.) This topic is discussed in Reardon and Vosti (1992) and the points summarized below. We keep the same 'investment perspective' in this section as we did when discussing the initial adoption constraints above.

At the household level, farmers face the same sorts of constraints to long-term strategies and potential contradictions between short-term growth and longer-term sustainability goals, that we identified for PI's (competition between short term food security goals and long term investments, competition for resources between off-farm investments and farm investments.) To alleviate poverty, mitigate income risk, or take advantage of short-term production opportunities (e.g., before property rights are defined, as in the case of squatters in common lands), households push cropping onto fragile soils, or push insurance mechanisms such as livestock herds beyond the carrying capacity of the land. Both can result in a renewed cycle of degradation, bringing renewed threat of poverty and risk, and their attendant mitigation strategies. Similarly, risk and low returns that hurt investment in GR components also undermine desire and capacity to invest in conservation investments.

Productivity and conservation investments can be conceptualized as a spectrum of alternatives that:

(i) increase productivity but damage the underlying resource base such as a modern variety that depletes key soil nutrients; deep-plowing that reduces the integrity of the soil; irrigation methods that salinize or waterlog the soil;

(ii) increase productivity but have ambiguous effects on the natural resource base, such as intensive fertilizer use;

(iii) improve the natural resource base but have ambiguous effects on productivity, such as some crop rotation and agroforestry schemes;

(iv) improve natural resource base and increase productivity, such as tied-ridging that prevents fertilizer runoff and conserves top soil, or nitrogen-fixing high-yielding varieties).

(v) improve the natural resource base but harm productivity (perhaps the 'zero tillage' practice could be included in this category in some circumstances; moreover, if a conservation investment or practice severely reduced time/resources available to perform other production activities, the net effect could conceivably be to decrease productivity).

What are the similarities in these three sets? In the short term, productivity investments/practices are similar to conservation investments/practices in three ways. These similarities are based primarily on things that are required for farmers to undertake investments or modify their agricultural practices. Both types of investments/practices require household expenditures on variable inputs (labor and non-labor) and liquidity. Both types of investments/practices require external inputs of goods and services from the private sector and the government: technical and socio-economic research; extension; manufacturing and distribution of inputs; credit; appropriate institutions; and infrastructure.

These similarities suggest possible competition under some circumstances, in particular for household resources, and possibly for external inputs.

What are the distinctions between conservation investments and traditional components of GR?

(i) Risk associated with conservation investments/practices may be perceived to be greater by farm households. The impact on production (e.g., increasing soil integrity) may be less observable by the farmer than is the case for productivity investments/practices.

(ii) Timing of returns to conservation investments/practices can be quite different from productivity investments. Fallowing, for example, eliminates returns for at least one cropping season, and may do so for up to eight seasons in poor soils.

(iii) Timing of input requirements for conservation and productivity investments can differ.

Conservation investments often need to be made in the dry season. The latter is misnamed the slack season, as much off-farm activity takes place then. Building bunds can compete with this activity. The investments might also have to be made in the rainy season, when e.g., labor on alley cropping can compete with fertilizer application or weeding. The opportunity cost of time to the farm household can be high (Reardon and Islam (1989); Sangui and Kerr, 1991).

(iv) Externalities associated with both short-term productivity investments and conservation investments/practices produce spillover and free rider problems that may reduce incentives to make them. For example, if one farm constructs bunds but the neighbor does not, the runoff from the second can overwhelm the conservation measures of the first. Or, watershed management investments by a given farmer might obstruct soil deposition efforts by another (Sangui and Kerr 1991).

(v) Many conservation investments are difficult to undertake incrementally and therefore require substantial and very 'lumpy' expenditures of labor or cash, or both. They often do not merely require changes in agronomic practices. Even if they only imply new practices (not physical private or public infrastructure), many of these require outlays by the State for extension and other services, and substantial increases in own-labor outlay on the farm (e.g., alley cropping; see (Spencer and Polson 1991)) (Reardon and Islam 1989).

For some types of conservation investments, there may be constraints to availability of own-labor and own-liquidity. This would make it difficult for individual households to make the investments, if sufficient credit (to hire labor for example) were not available, hence relegating them to the village or the State (Swindale 1988).

(vi) There are also potential credit constraints for conservation investments (as compared to more typical productivity investments), particularly where (geographically) they may be most needed, for the following reasons: The loan size to construct large items such as bunds, terraces, or the establishment of perennial tree crops might exceed the capacity of local creditors or even village credit groups

(Swindale 1988), especially if many households require loans at once. The externalities associated with many conservation investments/practices (as opposed to most productivity investments/practices) and the implied free-rider problems can cause credit market failure. Borrowers and creditors may not perceive (and indeed there may not be) a clear immediate payoff to conservation investments/practices, hence the risk of default may appear greater. Investments in traditional GR components, particularly in capital goods, require but also create loan collateral (e.g., animal traction equipment). This is often not the case with conservation investments/practices (e.g., creditors cannot reclaim bunds or windbreaks).

(vii) Some conservation investments/practices require specific equipment for which there is no market or little availability, such as is the case with tied-ridgers (Sanders 1985); this equipment might be too expensive for an individual household to buy, or of a nature inappropriate to local conditions. Some tree-cropping schemes require mass production of seedlings, and few banks are willing to lend for such activities. (Ohm and Nagy 1985)

(viii) To be effective in the medium run, many conservation investments require maintenance. Assuring the needed cash and labor inputs over long periods may require a longer planning horizon than is typical of farm households in fragile areas of the tropics. The costs of failure to maintain conservation investments may exceed (and last longer) costs of failure to undertake (often repeated) productivity investments/practices.

In sum, there are important differences between the 'traditional GR components' and the conservation investments and land use measures proposed for sustaining a GR. Thus, researchers should not expect the same sorts of immediate impacts of policy changes designed to encourage and enable households to undertake conservation investments/practices as they would for typical productivity investments/practices. Policy options to overcome the above obstacles may require special and innovative institutional arrangements, extension approaches, and factor market interventions. Finally, there is a need for an appropriate analytical approach/framework to take into account the distinct nature of the type of investments/practices they are targeting.

E. CONCLUSIONS

The challenges for creating and sustaining a GR in Africa are fourfold. We phrase them as obstacles/problems to solve and things to emphasize:

E.1. Strategy for Creation of a Green Revolution

In general, a major priority is to have a long term commitment on the part of donors and national governments to build African research capacity to create and sustain Green Revolution in Africa. Adequate attention to support institutions is critical.

In terms of targeting research, emphasis would best be placed on high potential zones (where conditions allow intensification of production) to promote adoption of new varieties along with investment in inputs and conservation measures. In low potential zones, the emphasis should be on conservation investments and sustainable land use practices. But whether a zone is high or low potential will depend, apart from its agroclimatic characteristics, on policy and research, and how they affect the productivity of resources and the local conditions. Moreover, it is hard to judge from current performance: some areas are currently low performance but considered high potential (for example, Matlon (1990) considers the Guinean zone in semi-arid West Africa to have high potential).

Moreover, the most pressing need for intensification through adoption of GR components is in areas whose land productivity is declining, where there are land constraints. It is tricky to determine unambiguously which these are. There are obvious cases such as Rwanda or Malawi. But Binswanger (199x) cited evidence from the FAO land carrying-capacity study that ranked Niger with Bangladesh in terms of population density per unit of land standardized for carrying capacity. Matlon (1990) notes that there are significant land constraints in the Sahel, in contrast with the traditional image of these areas as land abundant. Thus, land scarce areas may be much more common in Africa than previously thought, and the need for technologies of intensification much greater.

Finally, the choice of crops to research and promote should take into account comparative advantage of the region, and the long-term prospects for intermediate and final demand. Eicher (1992) points out that export crops (traditional ones, such as cocoa, coffee, cotton, and non-traditional crops such as vegetables) need to be objects of mainstream agricultural research. There is a need to rebuild national research capacity in traditional export crops (e.g. cocoa, oil palm) and expand capacity in non traditional crops (e.g. horticulture). A GR in export/cash crops helps grain crops through local linkages (say via liquidity provision), and helps overall food security, trade balance, and overall growth.

But the key point is not whether research should focus on bringing on a GR in food versus cash crops, but rather that research should be oriented by a region's comparative advantage and by a broad range of needs, including growth in food availability, of foreign exchange, and of liquidity for local investments on and off-farm. But a caveat is needed here. Comparative advantage is a fluid and malleable measure; research, public and private investments, and policy can change it.

E.2. Take a Horizontal and Vertical Systems Perspective in Research

A horizontal systems perspective, focusing on the rural household economy, leads research to go beyond a unisectoral viewpoint to a multisectoral viewpoint, and interest in the household's strategy to diversify cropping and overall income, and what impact that has on adoption of innovations. Adoption of GR components 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.

Moreover, given the household's interest in smoothing incomes and consumption, and managing risk from instability of output and prices, the stability of returns to an innovation will be of importance in breeding strategies. Yield stability should be stressed in breeding and agronomic research to protect the interests of the poorest, especially in semi-arid Africa. This is because, in many areas, access to off-farm activities is limited for the poorer groups, and so the latter have to rely on cropping and the vicissitudes thereof.

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 a nascent GR in a particular commodity.

Finally, research needs to emphasize the creation of local 'growth spirals' through upstream and upstream linkages to agriculture, to get maximum growth multipliers. Agricultural researchers need to explore the potential for these linkages, and promote products with potential to create these linkages.

But the research community face a dilemma when thinking about what strategy to pursue, what perspective to take with respect to the diagnosis of and the accounting for constraints. Should they create the 'best technology' and then lobby policymakers to create local conditions appropriate to its adoption? Or should they take local conditions and farmers' strategies in the face of them as given, and create technologies that are attractive and adoptable given those constraints? This paper does not try to resolve that dilemma. How it is resolved differs by situation -- how changeable are the local conditions, what influence researchers have in policy design, how much alteration of local conditions would be needed for farmers to want to use a new technology.

E.3. Facilitating Adoption and Investment

Sequencing of complementary investments and institutional reforms both to support initial adoption and to support maintenance of adoption is critical.

Macro and sectoral policies are 'necessary but not sufficient' for both productivity and conservation investments (Structural Adjustment is not enough). In addition, sector and subsectoral policies, and targeted public investments are needed.

E.4. Sustaining a new Green Revolution

Focus should be on finding 'overlap technologies' that combine productivity and sustainability increases; these can be for example combinations like fertilizer plus bunds plus new varieties. The challenge is the sustainability and adaptability of 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 African research is potentially competitive, as it may displace 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.

REFERENCES ... still partial list

Barker, R. and D. Chapman, "Sustainable agricultural growth in developing countries: An economist's view", World Food Issues, vol. 2, 1990. Center for Analysis of World Food Issues, Cornell University.

Bernsten, R.H. "Implications of Asia's Green Revolution for Sustainable Agricultural Development in Sub-Saharan Africa", mimeo, MSU, 1993.

Bernsten, R.H. "Sustainable Agriculture in Semi-Arid Sub-Saharan Africa: Reflections on Factors to Consider in Setting Research Priorities", mimeo, MSU, 1993.

Binswanger, H.P. (1986) "Risk Aversion, Collateral Requirements, and the Markets for Credit and Insurance in Rural Areas", in Hazell, Pomareda, and Valdes (editors), *Crop Insurance for Agricultural Development*, Johns Hopkins University Press.

Boserup, E. Population and technological change: A study of long-term trends. Chicago: University of Chicago Press. 1981.

Byerlee, D. "Technical change, productivity, and sustainability in irrigated cropping systems of South Asia: Emerging consensus in the post-Green Revolution Era", in Journal of International Development, Vol. 4, no. 5, 1992.

b

Celis, R, J.T. Milimo, and S. Wanmali (eds.), Adopting Improved Farm Technology: A Study of Smallholder Farmers in Eastern Province, Zambia, University of Zambia, Government of Zambia, IFPRI, 1991.

Eicher, C.K. "African agricultural development strategies", in Stewart, Lall, and Wangwe (editors), Alternative Development Strategies in SubSaharan Africa, Macmillan, 1992.

Eicher, C.K. 1986. "Transforming African Agriculture", The Hunger Project Papers, No. 4, San Francisco, the Hunger Project, 1986.

Hazell, P. and C. Ramasamy, with contributions by P.K. Aiyasamy et al., The Green Revolution Reconsidered: The Impact of High-Yielding Rice Varieties in South India, The Johns Hopkins University Press, 1991.

Herdt, R. and C. Capule. Adoption, Spread, and Production Impact of Modern Rice Varieties in Asia. IRRI, Los Banos, Philippines, 1983

Lele, U., N. van de Walle, and M. Gbetibouo, Cotton in Africa: An analysis of differences in performance. MADIA Working Paper. Washington, D.C. World Bank. 1989.

Pachico, D. "After the Green Revolution: Technical Change in Bean Production in Colombia, Costa Rica, and Guatemala", in Groendfeldt, D., and Moock, J. (eds.), Social Science Perspective on Managing Agricultural Technology, IIMI, 1988.

Reardon, T., C. Delgado, and P. Matlon. "Determinants and Effects of Income Diversification Amongst Farm Households in Burkina Faso", Journal of Development Studies, January, 1992.

Reardon, T., A. Fall, V. Kelly, C. Delgado, P. Matlon, O. Badiane, "Is income diversification 'agriculture-led' in the WASAT? Survey evidence and development strategy implications", presented at the "International Conference on African Economic Issues", West African Economic Association and the Economic Association of East and Southern Africa, and the World Bank, in Abidjan, Cote d'Ivoire, 11-16 October 1992.

Reardon, T. and N. Islam. "Issues of Sustainability in Agricultural Research in Africa", in the Proceedings of the Symposium on the Sustainability of Production Systems in Sub-Saharan Africa, NORAGRIC, Agricultural University of Norway, Ås, Norway, 4-7 September 1989; Noragric Occasional Paper Series C.

Reardon, T. and S. Vosti. "Issues in the Analysis of the Effects of Policy on Conservation and Productivity at the Household Level in Developing Countries", Quarterly Journal of International Agriculture, (4) October-December 1992.

Spencer, D.S.C., "A research strategy to develop appropriate agricultural technologies for small farm development in Sub-Sahara Africa", chapter in Ohm, H. and Nagy, J. (eds.), 1985, Appropriate Technologies for Farmers in Semi-Arid West Africa, Purdue University.

Tschirley, D. and M. Weber, "The determinants of household income and consumption in rural Nampula province: implications for food security and agricultural policy reform", Agricultural Economics Staff Paper 92-96, 1993.

Vosti, S., T. Reardon, and W. von Urff (eds.) Agricultural Sustainability, Growth, and Poverty Alleviation: Issues and Policies; Proceedings of an international conference sponsored by IFPRI and DSE, held in Feldafing Sept. 23-27, 1991; published by DSE, Feldafing, Germany, December 1991.

Wanmali, S. and J.M. Zamchiya (eds.), Service Provision and Its Impact on Agricultural and Rural Development in Zimbabwe, IFPRI, 1992.

Whitlow, R. "Soil conservation history in Zimbabwe", in Journal of Soil and Water Conservation, July/Aug. 1988.