

Sustainable Versus Unsustainable Agricultural Intensification in Africa: Focus on Policy Reforms and Market Conditions

Thomas Reardon

Michigan State University

Christopher B. Barrett

Utah State University and Cornell University

Valerie Kelly

Michigan State University

Kimseyinga Savadogo

Université de Ouagadougou, Burkina Faso

Draft, please obtain permission of the authors before citing; comments welcome.

Paper invited for presentation at the AAEA International Preconference on
“Agricultural Intensification, Economic Development and the Environment,”
July 31-August 1, 1998, Salt Lake City, Utah.

Sustainable Versus Unsustainable Agricultural Intensification in Africa: Focus on Policy Reforms and Market Conditions

1. ISSUES

1.1. Intensification of African agriculture is inevitable and desirable

African farmers have traditionally pursued shifting cultivation in response to population growth and declining soil fertility. As population pressure increased, they opened new land by extending farming into forests, wetlands, hillsides, and pastures. This path is still common in land-abundant countries such as the Congo, and can be sustained for a long time, although extensification into permanent pasture, forest and watershed lands may lead to potentially catastrophic loss of biological diversity. Moreover, transhumant and nomadic livestock systems that gradually pushed into new areas opened up by drilling boreholes, eradicating rinderpest, etc. Such practices are still common in some areas in the Sahel and Eastern/Southern Africa.

Nevertheless, the extensification path is quickly becoming unsustainable or is no longer practical in much of Africa mainly because of rapid population growth (the highest in the world and projected to continue into the 21st century) that leads to increase in rural population density and arable land scarcity for most of the rural population of Africa (Binswanger, 1986). That scarcity is increasing as the forest or wetland margin is exhausted or the farmer is barred from using it, or when soil degradation in the "extensive margin" reduces crop yields over time. Rangeland disappearance is due to uncontrolled urban expansion, to the gazetting of lands for parks and protected areas, and to range degradation from overgrazing. (Scoones, 1996.). Increasing rural population density and urbanization reduce marketing costs and input prices, increase land constraints, and drive farm wages down initially, and land prices up.

There is thus a pull and a push on farmers to intensify agriculture by using more labor and or capital (broadly defined as chemical inputs, organic matter, equipment, and land-conservation infrastructure) per hectare of land (as predicted by the theory of induced innovation; Boserup, 1965; Hayami and Ruttan, 1985). Similarly, loss of pastures constrains pastoralist mobility and forces intensification-sedentarization of livestock production.

In the longer term, as industrialization proceeds (and/or trade increase allows for import of inputs), manufactured

input prices decline, farm wages are driven up by the demand for labor in the nonfarm sector, farm capital prices are driven down, and access to output markets increases. Hence, urbanization, economic opening, industrialization, and increasing rural population density all tend to create the conditions for labor-using intensification of agriculture in the short-run, and capital-using intensification in the medium-long run. Moreover, urban and export market growth, coupled with growing incomes, drives a shift in the composition of diets, hence in agricultural output mix, toward fruit, vegetables, dairy, meat, and oilseeds -- as Bennett's Law dictates. The technological change and the product composition change mutually reinforce as these types of products (with the possible exceptions of meat and oilseeds) tend to be produced intensively in labor and capital.

1.2. Technology Issues: What kind of intensification: sustainable or unsustainable?

As African farmers are driven by land constraints to intensify, however, the key emerging issue is what type of intensification technology they use -- sustainable or unsustainable. We define "sustainable" agricultural intensification (SAI) by three criteria: (1) protects or enhances the resource base of the farmer and thus maintains or improves land productivity; (2) meets production goals of the farmer (for food and/or cash); (3) is profitable. We list these three strands (environment, human needs, and profitability) because that puts the sustainability issue squarely in the farmer behavior realm -- and it will be in this realm and this realm only that the requisite farm investments will take place (or not) to ensure productive and sustainable farming in Africa.¹

We begin with a summary discussion in this paragraph of the justification for these three criteria and then return to the points with a more detailed discussion. Risking over-generalization, environmentalists tend to focus on a supply-side definition of "appropriate technology" as sustainable when and if it is "soft on the ground," with an image of LISA (low-input sustainable agriculture) as the model. This sidesteps the fact that absent sufficient inorganic fertilizer, most of these systems still spell soil mining at the degrees of intensity that are needed by African farmers to survive. Furthermore, we have observed that "desirability" ("farmers 'should' want this because it helps their soils) tends to take precedence of sheer profitability in sustainability discussions steeped in the supply-side or technology design perspective; but this

¹1. We have merely combined sustainability cum adoption criteria set out by others: in particular Lynam/Herdt (1989) definition's of sustainability of the resource base as the maintenance of total factor productivity, combination of ecological sustainability and the meeting of human needs in CGIAR TAC (1988), and the profitability criteria for adopting and maintaining a technology, discussed for example in Feder et al. (1985).

sidesteps the strong manifest interest of African farmers in short-term profitability as a key criterion for adoption (whether the technology is “sustainable” or not). That is, African farmers are just regular business-persons -- and just as realistic with respect to the ‘bottom line’ as anywhere. Finally, the environmentalist discussions of technology also are not, we observe, sufficiently realistic about demand-side considerations in farmers’ technology choices. Even if the technology is sustainable in that it enhances or protects the resource base and is profitable in a narrow sense -- if it is not sufficiently productive (at a level to meet the needs assigned to it by the farmer for cash generation and/or in-kind production), then the farmer will find him/herself pushing out onto the extensive margin to make up the gap in production. That will undermine the environment (in the fragile margin), driven by demand-side considerations.

In practice, to meet the first two criteria will require “capital-led intensification” as compared to merely labor-led intensification (Reardon et al., 1997, Clay et al. 1998). Capital-led intensification entails substantial use of “capital,” the latter broadly defined to include nonlabor variable inputs that enhance soil fertility (such as fertilizer) and quasi-fixed capital that protects the land (such as terraces): (1) land conservation infrastructure (grass strips, anti-erosion ditches, hedgerows, and terraces), (2) organic inputs (composting, manure, green manure, mulch), and (3) chemical inputs (especially inorganic fertilizer). If one classifies the planting of perennials as a long-term capital investment, one can also say that planting and maintaining cash perennials such as coffee and bananas fall under the capital-led intensification path. In turn, this capital is either acquired through purchase, often with substantial labor input, or “produced” on-farm (for example, anti-erosion ditches are dug using farm labor and other farm capital such as hoes or tied-ridges using animal traction equipment).

By contrast, intensification that makes little or no use of “capital” (as defined above) we refer to it as *labor-led* intensification or “capital-deficient” intensification if the farmer uses some capital but in an unbalance fashion (such as the Senegal Peanut Basin case depicted in 4.2). Characteristically, farmers following this path will merely add (unaugmented) labor to the production process on a given unit of land, allowing them to crop more densely, weed and harvest more assiduously, and so on. “Low-input sustainable agriculture” is a variant of labor-led intensification or perhaps better-said, capital-deficient intensification that involves little use of chemical fertilizer or other chemicals and intensive use of certain kinds of capital (land conservation structures and organic matter).

Why is capital-led intensification more sustainable than labor-led intensification from the viewpoint of the first two criteria, environmental and productive (meeting needs)? First, because insufficient use of capital (or unbalanced use,

eschewing inorganic fertilizer but using organic matter), combined with the intensity of land use (periodicity of fallows) that characterize most of the semi-arid tropics and hillside tropics in Africa today, leads to soil mining and degradation. Weight and Kelly (1998) review soil science evidence that shows overwhelmingly that inorganic fertilizer is a necessary component for sustainable growth in productivity, even in fragile soils and low rainfall zones. Matlon and Spencer (1984) note that it is crucial for inorganic and organic fertilizers to be combined to maintain soil fertility and integrity in intensification. We present in section 4.2 the sad story of the Senegalese Peanut Basin where capital-deficient intensification is rapidly undermining soil fertility and productivity. Moreover, going the “organic matter path” alone, as advocated in LISA, requires huge amounts of organic matter to substitute for a small amount of inorganic fertilizer (Weight and Kelly show calculations of 20 tons to 100 kgs), which is increasingly impractical where the density of animals per square mile has been steadily declining in many land-constrained areas of Africa -- itself the fruit of disappearing pasturelands.

Second, merely labor-led intensification is insufficiently productive to meet the African farmer’s productivity and output goals and needs; in the medium-long run this will force a return to extensification onto fragile margins as the farmer fights to survive. LISA has the potential to increase food output by only about 1 percent a year, which falls far short of meeting Africa's 3.0 to 3.5 percent annual growth in food demand (Ruttan, 1990). Ruttan’s estimate for LISA actually roughly matches the poor performance from the current predominance of merely labor-led intensification in African farming (with growth rates of about 1 percent in most areas and the common range of yields for cereals is 200-400kgs per hectare, Yanggen et al., 1998). The capital-deficiency of African agricultural intensification is underscored with a few simple facts about inorganic fertilizer use: 9 kgs per hectare in 1995 (Weight and Kelly 1998), down from 10 kgs per hectare in 1993 -- compared to 83 kgs per hectare in all developing areas in 1993 (Heisey and Mwangi, 1997). Rather than cause for celebration, the low use of chemical fertilizer is a major reason for worry, both from the environmental and from the food-production perspective: outside Africa, as much as 75 percent of crop yield increases since the mid-1960s are directly or indirectly attributable to fertilizer use (Viyas 1983). Even manure, a key component in most LISA systems, is in short supply in many countries such as Rwanda, Malawi, and Zimbabwe because of increasing population pressure and clearing of pasture lands for farming, showing the potential contribution of fertilizer to an intensification strategy.

That this capital-deficient strategy, far from being the environmental answer, can drive environmental disaster is the inverse lesson from the success story in Asia noted by Tribe (1994), who notes that if a LISA food-production

strategy rather than the Green Revolution food-production model had been pursued in South Asia in the 1960s, 44 million hectares that are now under forest would instead be plowed and cropped. The upshot is that the capital-deficient, unsustainable intensification widespread in Africa today is a major force behind farmland degradation and thus productivity loss.

However, the third criterion we have assigned to sustainability -- that practices are profitable to the farmer -- is the thorniest issue, and leads to the focus of our paper on policy issues. Practices can be good for the environment or meeting needs, but if they do not start and continue profitable, the farmer will just ignore them. There is accumulating important evidence on this that needs to have a major impact on the policy and technology and even environmental debates.

On the one hand, there are emerging stories of SAI technologies on the shelf (for some time) but the farmers did not use them until the profitability/marketing conditions became right (as in Zambia with hybrid maize, see Howard and Mungoma, 1997 for example). Moreover, there is increasing evidence from field surveys that African farmers tend to use very little organic matter or chemical fertilizers, or labor-intensive soil conservation measures on low-return, subsistence-food crops -- even if agronomists or environmentalists recommend that they do so. Evidence (from such diverse settings as Burkina Faso, Ghana, Kenya, Rwanda, Tanzania, and Zimbabwe) shows that most use of manure, chemical fertilizer, and even land-improvement measures are on commercialized crops (food or nonfood) with relatively high and stable returns (Reardon, 1998). This is discussed further in 4.1.

On the other hand, labor-led intensification that adds labor-intensive land conservation practices may relieve the farmer of nonlabor input purchases but uses labor in a way and to an extent that may not be profitable. LISA techniques such as hand weeding, recycling organic matter, and alley cropping are labor intensive. The evidence is mixed on the farm profitability of these practices (Low, 1993) and can run into severe intra-seasonable labor shortages which are common in African agriculture (Byerlee, 1980) -- even in zones with high overall labor abundance (Hopkins and Berry 1994) and compared to alternative uses of labor off-farm (Reardon and Islam, 1989).

1.3. Policy Issues: How did recent policy reforms affect the extent of SAI, and what further policy action is needed?

Above we argued that capital-led intensification should be considered synonymous with SAI for much of Africa -- and furthermore that much of African agricultural intensification is capital-deficient (either using some capital but in an

imbalanced way, for instance using organic matter but too little inorganic fertilizer, or using very little of either). This implies that many African farmers are intensifying, but veering away from SAI and steering a course of environmental and productivity disaster. Technology designers can make available appropriate technologies for SAI “on the shelf,” but policy researchers must still address the thorny questions of (1) what role recent policy reforms (mainly those associated with structural adjustment) have had in creating a gap between SAI and actual intensification practices of many farmers, and (2) what policy actions are needed to correct for this gap.

This paper focuses on those policy research questions and shows how inappropriate policy reforms and weak markets can lead either to failure to undertake necessary intensification or to unsustainable forms of intensification. Appropriate policies and reasonably well functioning markets, on the other hand, can promote environmentally and economically sustainable intensification. We proceed as follows. In section 2 we lay out a simple conceptual framework that casts the behavioral choices leading to or away from SAI in terms of the incentives facing the farmer and his/her capacity to respond to them, and the role that policy reforms and market conditions have in influencing incentives and capacity. In section 3 we discuss how macroeconomic and sectoral policies affected farmer incentives for SAI in Africa. In section 4 we present illustrations of cases where African farmers are on the SAI path, and where they are on unsustainable intensification paths, and why. Section 5 concludes with policy implications.

2. CONCEPTUAL FRAMEWORK

This section presents a model with four links: (1) policy changes, which induce changes in (2) market conditions and the price distributions in markets, which in turn affect (3) farmer behavioral choices, which then influence (4) environmental outcomes.² This is used as the framework for illustrative discussion in the subsequent section.

2.1. Policy changes

The main policy changes common in the past decade are the following macro and sectoral policy reforms:

- currency devaluation
- liberalization of markets hence change in market conditions (with effects on price levels and variance depending on the degree and type of private sector participation)

²The heuristic model is drawn from Barrett and Carter (1994), Reardon and Vosti (1992), and Reardon et al. (1995).

- removal of fertilizer and seed subsidies
- removal of marketing subsidy for crop outputs
- reduction of farm input financial services subsidies

2.2. Price formation

Farmer behavior with respect to technology/input and crop/output choice (discussed further in the next subsection), hence SAI, is determined by several price variables facing the farmer in a given period:

- level and variance of output prices of crops
- level and variance of prices of nonlabor variable inputs (e.g., fertilizer, seed, and manure)
- the opportunity cost of labor outside cropping (the nonfarm wage)
- farm labor wage

In a multiperiod context, investment in quasi-fixed inputs is influenced by the following prices:

- price of quasi-fixed inputs (such as farm equipment)
- the interest rate

Note that the above prices can either be explicit, market prices, or implicit, effective prices. It is the implicit price that matters in situations where the household is forced into autarchy for that input or output: where transactions costs and risk drive a wedge between sales and purchases prices, endogenously inducing households to opt out of a particular market, shadow prices -- and shadow price risk -- become household-specific (de Janvry, et al. 1991, and Omamo, 1998).

The above prices are solved for (analytically) in a system of demand and supply equations for outputs and inputs. The reduced form shows prices influenced by market conditions, in turn shaped by: (1) policies (such as those listed above), and (2) non-policy factors affecting demand and supply such as rainfall, GDP, world prices, infrastructural quality and density.

2.3. Farmer Behavior

The two key decisions that affect SAI are: (a) crop output choice, and (b) technology /input choice. The two are closely related in practice because a given crop mix can be grown with only a certain range of technologies and be technically feasible and profitable in a given physical and economic (price and market condition) context. Both of these choices are

driven by the (1) incentives facing the farmer and (2) the capacity of the farmer to act on those incentives.

One can derive crop output supply and input demand from a profit function specification.³ The vector of profits is a function of the vector of output and input price levels and variances, quasi-fixed inputs, and other shifters such as nonfarm income (Lau, 1976).⁴ From Hotelling's lemma one can derive the (product) vector of output supply and the (input) vector of input demand functions from the profit function, differentiating the profit function by the vector of output prices and the vector of input prices. The functions have the same arguments as the variables in the profit function. These two sets of equations determine the product mix and the inputs used, hence the activity and technology combination as a function of policy and nonpolicy factors. The production and marketing behaviors of farmers reflect implicit, if not explicit, comparison of expected returns and associated risks across an array of alternative techniques. In an environment of imperfect and idiosyncratically missing markets, the effective price distributions faced by different decision-makers can vary markedly. Thus, differences in endowments and opportunities commonly lead to status-conditional optimal production and marketing strategies (Goetz, 1992, Barrett, 1996, Omamo 1998). Furthermore, where asset poverty constrains smallholder liquidity, yielding a high shadow price of capital, and market imperfections cause complementary variable input (output) prices to be high (low) and volatile, investment in quasi fixed factors that contribute to SAI (e.g., erosion and water control, machinery) will be discouraged (Newbery and Stiglitz, 1981, Reardon and Vosti, 1995).

2.4. Impacts of farmer behavior on the environment

Changes in the input use vector modeled in (3) can induce changes in the environment, thus linking intensification choices to environmental sustainability. For example, a land price increase and a capital price increase can induce labor-led intensification that can mine the soil. A labor price increase and a land price decrease can induce a shift from intensive to extensive practices in the fragile commons or marginal lands.

3. MARKET CONDITIONS AND POLICY REFORMS: MIXED SIGNALS

Too often in policy discussions concerning African agriculture there is a tendency to assume policy effects on output and input prices facing farmers, prices which constitute the incentives for SAI. For example, "liberalization will raise farm

³ ... without necessarily positing profit maximization as the objective of the farmer, Sadoulet and de Janvry (1995)

⁴There are recent examples of using profit functions to model intensification processes (see Adesina and Djato, 1996 for Cote d'Ivoire, and Savadogo et al. 1995 for Burkina Faso, as examples).

profitability” is a common phrase/assumption heard in policy debates. Commonly lost amid the ‘ceteris paribus’ assumptions are the complex means by which policies actually affect prevailing price distributions, i.e., the movement between links (1) and (2) in the chain of our conceptual framework. In this section, we contend that the effects of the major economic reforms -- macro and sectoral policy changes associated with structural adjustment -- are ambiguous and often have not been what was expected of them, and thus one should expect a mixed set of farm-level impacts of these policies on SAI. The common combination of devaluation and liberalization merely magnifies the indetermination in price formation. Section 4 then illustrates these mixed results with cases of SAI compared to those of unsustainable intensification, linking them back to the mixed effects of the policy reforms on the incentives themselves, as well as on the capacity of African farmers to act on the incentives.

3.1. Macro-level policies on incentives for SAI

Macro-level policy reforms (such as devaluation or trade and domestic market liberalization) tend to have analytically and empirically indeterminate effects on the incentives facing farmers, either enhancing or reducing net profitability and the relative risk of sustainable-intensification crops and technologies.

On the one hand, devaluation could raise the output price of an ‘intensification crop’ such as rice or maize or cotton, more than the increase in input prices. This depends on (1) the extent of tradeability of the outputs and inputs, (2) government “pass through policies,” that is, how much of a trade gain do they tax away versus pass on to the farmer, (3) private commerce margins. The Malian rice case in section 4.1 illustrates. Similarly, trade and domestic market liberalization could reduce commerce margins through competition and drive down farmgate input prices improving profits. (An illustration from Tanzania is found in Kaufmann and O’Connell 1991). Or, devaluation-induced increases in the prices of tradeables that are perceived to hurt consumers or farmers may be counterbalanced by governments who take “accompanying measures” to reduce the price increase in tradeables, such as reduction of tariffs on fertilizer in Mali and rice in Senegal following the 1994 devaluation of the franc CFA (Kante et al., 1995).

On the other hand, devaluation can raise farmgate prices of imported inputs more than farmgate output prices and thus lead to loss of profitability. (The Senegal rice case illustrates this.⁵) Similarly, devaluation and market

⁵ The devaluation also lowered incentives to produce irrigated rice and to use urea in the Senegalese River Basin. On the one hand, the government limited increases in rice prices to only 7 percent in the year after devaluation (1994-95)

liberalization can lead to increased *enclavement* of interior markets, raising transport costs, imported input prices, and price risk. Limited available evidence suggests that where state intervention lowered the mean and variance of agricultural product prices, liberalization has increased not only expected prices, but also price variability (Krueger et al., 1988, Barrett, 1997). The Madagascar rice case illustrates this in section 4.2. This can undermine farm investment even where it raises average medium-term output prices, because price instability discourages investments in quasi-fixed capital (Reardon et al., 1992 and Barrett and Carter 1994) Price instability also reduces rates of technology adoption, reducing the speed of inter- and intra-farm diffusion of yield-increasing technologies (Kim et al., 1992).

Hence, the effects of macro policies on SAI via output and input price changes will depend on the market structure (concentration of commerce sector, entry barriers from market and physical conditions, and so on). The evidence in a variety of African rural areas points to concentration and market entry barriers that tends to produce greater price instability with liberalization and ambiguous effects of devaluations on farm profitability of input use for intensification.

3.2. Sectoral policies' impacts on farmers' incentives for SAI

Taken out of the macro policy reform context, the effects of most sectoral price policies (taxes, subsidies, price controls) on output or input prices are unambiguous. But placed in a stabilization context the effects are uncertain. Sectoral policies (that go in a direction opposite to the intended effect of the stabilization policy) can counterbalance stabilization policies - and may even be formulated to do so. Moreover, the past generation of policy reforms have tended to celebrate macroeconomic policy (which is necessary but not sufficient), and to subordinate sectoral policy, ending sectoral interventions in the interest of fiscal balance, achieving border parity pricing, etc. Sectoral interventions, however, may have important, overlooked 'crowding-in' effects, encouraging private investment in sustainable technologies. The empirical evidence reveals several important cases where termination of sector-level interventions has led to environmental and food security retrogression.

to protect real incomes of urban consumers. On the other hand, unlike peanut fertilizer which is produced using large amounts of local phosphates and smaller amounts of imported nitrogen and potassium, urea is entirely imported, and import prices increased 90 percent due to the combination of the devaluation and changes in world market prices. The increase in urea costs, when combined with smaller but important increases in seed, pesticide, and irrigation costs (primarily imported fuel for pumps), caused net income per hectare of irrigated rice to fall from a pre-devaluation level of 139,000 FCFA to a post-devaluation level of 69,000 FCFA (BAME/ISRA, 1995).

3.2.1. Fertilizer/Seed Policy

We noted in the introduction that African fertilizer use is the lowest in the world and has even decreased over the past decade and a half -- the same period in which fertilizer and seed subsidies and cheap input financial services programs have been reduced or eliminated. The effective interest rate for input acquisition rose sharply, as did fertilizer and seed prices. Case study evidence points to a connection between the reduction in fertilizer use and these rising input and financial services prices.⁶

Moreover, there is growing evidence that private fertilizer and seed merchants have responded much less than was expected to liberalization of input markets (elimination of fertilizer and seed parastatals) (Rukuni, 1996, Dembele and Savadogo 1996, Rusike et al. 1997). Fertilizer markets in African are plagued by a series of fundamental problems such as risk, seasonal demand, high transport costs, underdeveloped financial services markets, and cash-constrained farmers. Small markets add to the problem by limiting economies of scale and product differentiation to meet diverse needs. Moreover, economies of scale in fertilizer production make domestic production inefficient in most African economies, so domestic fertilizer prices are sensitive to macro trade and exchange rate policies, and to volatile international fertilizer prices. While fertilizer subsidies and domestic fertilizer production schemes have generally proved ineffective in Africa, it appears clear that private market conditions in rural Africa cannot presently support necessary fertilizer deliveries, so some role for government is inevitable in the short-to-medium term. Given the considerable costs of delivering fertilizer to farmers on time and the restricted physical availability of fertilizer to most farmers, investment in improved private marketing infrastructure seems one of the most promising roles for the state (Ahmed, Falcon and Timmer 1989, Rusike et al. 1997).

3.2.2. Financial Services Policy

We noted above that financial services policy for farm inputs was intimately connected to parastatal distribution of seed and fertilizer, and that the elimination of the public distribution increased costs reduced access to those variable inputs for small farmers in a variety of zones. But the elimination of financial services that raised interest rates also made it

⁶ For example, in Senegal, see Kelly et al., 1996 and the Senegal illustration in section 4.2, and in Zimbabwe and Zambia, see Rusike et al., 1997; for seed issues see Maredia and Howard, 1997.

difficult for merchants to establish new private markets in these inputs without bringing along their own financial services schemes (Rusike et al., 1997 for the Southern Africa case).

There is a crucial, if subtle, difference between subsidizing credit and subsidizing the fixed/sunk costs necessary to establish microfinancial institutions. The former too often crowds out private finance, while the latter crowds it in. Moreover, in many cases, the latent excess demand is for financial savings opportunities (in part to save toward acquisition of physical capital) not for financial borrowing opportunities (Barrett, 1997c, Machethe, 1997).

It is interesting to note that some of the impact of financial services policy is compensated by own-cash sources of farmers, in their majority, nonfarm income sources. These constitute on average about 45 percent of farm household incomes in Africa. Nonfarm income has been shown to be important to farm investment and variable input purchase in various countries. However, these income sources are also usually poor distributed, with high Gini coefficients, which means that with the removal of the “great equalizer” of public input and equipment financial services, access to substitute cash is concentrated — which can lead and there is some evidence that it already is leading to concentration of the capacity to follow SAI (for general reviews, see Reardon et al., 1994, Reardon 1997, and Clay and Reardon 1997 for a Rwanda illustration related to SAI and nonfarm income links).

3.2.3. Infrastructure and Agrarian Capital Formation Policy

While empirical study of the link between the demise of public financial services and the use of seed and fertilizer is in its incipience, even less is known about how the changes in the market for financial services have affected physical capital formation. It is well established that the strong hypothesis would be that the effective interest rate increase undermines such farm investment (Lipton 1996) but there have been few if any studies of this effect.

Moreover, prices of physical capital items that are mainly imported in much of Africa (mainly of animal traction equipment, irrigation pumps, spare parts for vehicles, and tractors) are driven up by currency devaluation. This translates into higher costs for irrigation schemes, transport, and land conservation investments. We do not know of any studies of the price elasticity of farm investment; most capital formation studies are done with aggregate data or are cross section studies, with a few exceptions such as Dione, 1989 for Malian, or Savadogo et al., 1998 for Burkinabe animal traction equipment investment, or soil conservation investments such as Shiferaw and Holden 1998 or Gebremedhin 1997 in Ethiopia or Clay et al., 1998 in Rwanda.

Despite the gap in information, there is increasing evidence that it makes a great difference to supply and SAI response to changes in incentives created by macroeconomic policy reform as to whether agrarian capital formation had occurred before the reform, capacitating the farmers to respond. Two cases of this are discussed further in section 4.1 – that of irrigation investments in Mali’s Office du Niger before the 1994 devaluation, and animal traction investments before macro policy reforms in Burkina Faso’s cotton/maize zone.

3.2.4. Labor and Wage Policy

In theory, wage policy would have an effect on incentives for SAI: lower rural wages increase the incentive for labor-led intensification and discourage capital-led intensification. The effect on potential extensification is ambiguous, however: cheaper labor could simply encourage staying on one’s own land and intensifying, or cheaper labor could reduce the cost of clearing the forests to farm.

However, in Africa most wage policy covers only the formal sector, which means mainly urban workers. But are there transmission effects of urban wage policy changes on rural workers, hence on incentives that face farmers? There are few if any studies of such a direct link, but we expect it to be weak.

However, one can hypothesize indirect transmission effects of policies that affect urban labor on rural wages. Before discussing those links, it is best to note what kinds of recent policy reforms might cause changes in urban wages: (1) reduction of foreign aid, identified by Edwards and Wijnbergen (1989) as a prime example of a donor-induced Dutch Disease creating an ‘artificial boom’ in the urban sector and pushed up African wages relative to Asian wages; (2) structural adjustment, which has downsized the urban public sector, with probable repercussions on tertiary sector spinoff employment and wages, as well as direct public sector wage cuts.

We expect that the transmission effect would be negative on rural wages in both cases -- mainly via the reduction of demand for migration labor from rural areas. The net effect of the reduction of remittances and the reduction of rural wages would point to an increase of labor-led rather than capital-led intensification, at least from this angle. Remittance decreases would reduce liquidity for farm capital formation (the reverse of the central Kenya case documented in Collier and Lal, 1984), and to reverse the labor flows back to rural areas. Both of these point to the spurring of labor-led intensification (coupled with overcrowding in some rural areas).

3.2.5. Land Policy

Land policy in the past decade has mainly involved some titling schemes, gazetting of public areas, and some very limited land redistribution. The former would tend to drive up land prices (spurring intensification and long-term land improvement investments, Place and Hazell, 1993), and the latter would tend to increase the marginal value product of land use through a higher labor/land ratio, as smaller farmers would supplant larger farmers (van Zyl et al., 1995, Barrett, 1996 in Madagascar, and Byiringiro and Reardon, 1996 in Rwanda).

However, at issue is whether this is labor-led versus capital-led intensification in a situation where redistribution is coupled with dismantlement of state support for agriculture in the form of marketing depots and cheap input loans, and cash sources such as nonfarm income are unequally distributed. See, for example, Clay and Reardon (1998), who show a bifurcated path of intensification among small farmers, labor- and capital-led, depending on access to infrastructure and nonfarm income as a cash source.

Finally, the past decade's burst of activity in gazetting lands for protected areas increases tenurial insecurity for those living in environmentally sensitive areas. If farmers are less certain than before that the state will not appropriate their land for parks, reserves, etc., then they have less incentive to invest in conservation measures required for SAI. The bitter irony is thus that pressures for environmental conservation may induce environmental degradation by threatening current operators' control over the land.

3.2.6. Back to the Future: Projects in Lieu of Policy?

While public involvement in agriculture is de-organizing with the dismantlement of financial services and input parastatals, it is re-organizing as public or NGO projects which are, essentially, mini-packages of policies that affect smaller groups, for (usually) temporary terms, than was the case with public schemes. It is interesting that these packages of policies basically reproduce at least a subset of the pre-structural adjustment policies -- extension as a public good, subsidized financial services ("micro financial services"), subsidized equipment and inputs and marketing services (at least insofar as the projects cover the transport and risk of inputs and/or outputs, even if they maintain "market prices"). These projects are often presented as "demonstration projects" in areas where diffusion might eventually have a chance (if the general conditions change) -- such as the Sasakawa Global 2000 projects in e.g., Ethiopia, Ghana, Tanzania, Mozambique (see Putterman, 1995, and DE/MAP and DNER/MAP, Mozambique, 1998); others are related to contract

farming schemes (e.g., barley for breweries in the Vakinankaratra of Madagascar, or see Little and Watts, 1994).

Many of these have succeeded in sharply increasing yields on participating farms, but only by circumventing the structural obstacles that often impede adoption of SAI methods. That is, projects have delivered appropriate inputs directly to farmers on a timely basis, often with financial services, obviating potential bottlenecks in commercial distribution systems. However, results then often prove nontransferable outside the scheme, unsustainable once the scheme ends, or both. And the schemes themselves are not fiscally sustainable on any significant scale. Such projects demonstrate that African smallholders can achieve higher yielding, environmentally sustainable agricultural production. They also implicitly demonstrate how the weak state of rural factor and product markets mutes both incentives to intensify sustainably and the ability of governments and donors to alter those incentives effectively through macro or sector-level policy.

The discussion in this section 3 signals the importance of being able to trace empirically the effects of policy changes on output and input prices in order to provide evidence of a link between policy reforms and changes in the nature of intensification. While we presented a number of hypotheses and some illustrations, it is striking how rare are empirical studies on these links -- rather, assumptions and assertions tend to underpin the policy debate. That suggests an important policy research agenda ahead. In the meantime, however, policymakers want whatever evidence is available on what are our best guesses as to how policy changes are affecting the nature of intensification. We turn to the latter in the next section.

4. ILLUSTRATIONS OF THE LINKS BETWEEN POLICY AND THE NATURE OF INTENSIFICATION VIA IMPACTS ON FARMERS' INCENTIVES AND CAPACITY

We noted in the conceptual framework section that policies affect the incentives and capacity of farmers to intensify sustainably — which, in order to meet both productivity and sustainability criteria, means using sufficient “capital” (in our broad sense) inputs to protect soil fertility and achieve productivity goals. That implies use of inorganic fertilizer, organic matter, and soil conservation measures such as bunds or agroforestry. The productivity goal, in particular agroclimates, also requires use of farm equipment such as animal traction and irrigation. Below we present illustrations of the effects of policy change on these incentives and capacity for farm investments and input use in various countries,

contrasting cases of SAI with unsustainable intensification.⁷

4.1. Illustrations of SAI

The overarching point is that there is some initial intervention to solve problems in the market conditions (product, input, or factor) or to establish an agrarian capital base to set the incentives and capacity for SAI.

4.1.1. The Bottom Line: Profitable Crops

Although the following is a theme that will run through section 4.1, we want to isolate and emphasize the point that was made in the discussion of the criteria for SAI in the introduction, namely, that it is crucial that the crop and/or technique be profitable for farmers to adopt and maintain it. This point is evident to the technology adoption crowd, but goes against the grain for much discussion part of the environmentalist/sustainability agenda that has recently (as in the Quebec Forum in 1996) pointed to the need for a return to food first, to subsistence agriculture, in the motto “reducing food miles”. But the evidence points the other way: that it is profitable, commercial agriculture (even if small-scale, and of food or nonfood products) that induces investment by African farmers both in inorganic fertilizer use and animal traction - but even in organic matter use and soil conservation investments. For example, in Burkina Faso, farmers use 13 times more manure on cotton and maize (the cash crops) than on sorghum and millet (the main subsistence foodgrains) (Savadogo et al., 1998). In Zimbabwe, farmers mainly use improved tillage practices and fertilizers where there are profitable cash crops (Mudimu, 1996). In northern Ghana, fertilizer use is low on average and very variable over farms, but tends to be applied only to crops-for-sale (hybrid maize, cotton, rice), and not on the subsistence-food crops (sorghum, millet, cowpea) (al Hassan et al., 1996). In the highland tropics of Tanzania, farmers confine fertilizer and soil conservation practices to cash crops (Semgalawe, 1998), as they do in Rwanda (Clay et al., 1998), and in Kenya (Tiffen et al., 1994).

⁷Note two caveats as we embark in this section on illustrations of policy effects on farmer behavior. Both caveats are related to points made in the above section. The first is that the analysis here is partial equilibrium -- the illustrations are products of general equilibrium processes while they are presented as fruit of a given sectoral and/or macro policy context. We do not know how important the interactions are between the policies, other elements of the general equilibrium, and the agricultural sector. The second is that most of the illustrations are of the short-medium term effects of policy change, not the long term effects. Most policy reforms were undertaken less than a decade ago, and it could be that the results will be different from those described as time goes on and market participants have more time to adjust.

4.1.2. Onions and Rice in Mali: Infrastructure investment as a base for SAI, stimulated by increased incentives from macro policy reform

For years the Office du Niger (ON) irrigation scheme in Mali was run by a government parastatal which attempted to control all aspects of construction and maintenance of irrigation infrastructure, crops cultivated, and input and output marketing. Progressively during the 1980s and 1990s the government withdrew from many of these activities (farmers could grow the crops they wanted rather than being forced to grow rice, they could market to whom they wanted and purchase inputs from whom they wanted, as government controls on imports and exports were gradually reduced). At the same time that the government was withdrawing from functions that could be handled by farmers and others in the private sector, it continued to invest in upgrading the irrigation infrastructure. This set the scene for farmers in the ON to benefit substantially from the 1994 devaluation of the CFA franc. Both the rice and the onions produced by ON farmers became much more competitive within Mali and the West African region.

Onions, produced during the dry season, are not only much more profitable than the dry-season rice production that the government had formerly been imposing on farmers but it is also a crop that women have become heavily involved in, so there are equity benefits as well. Double cropping (rice followed by onions) has significantly increased total farm income, increased the productivity of government investment in infrastructure, increased incentives and capacity of farmers to maintain that infrastructure, and improved cash flow so that farmers are better able to purchase fertilizer (a few even do so without relying on financial services) and farm equipment.

Regarding rice, the CFA franc devaluation increased net returns to rice production, and there was an elastic market for the product, there were cases of intensification with increased use of improved inputs. There was a rise in the profitability of Malian irrigated rice, whose output price was allowed to rise faster than input costs. Net returns per hectare rose 10-35 percent according to the zone and level of intensity of input use (Mendez del Villar and Diakit , 1995; Coulibaly et al., 1995). Rehabilitation of infrastructure would allow the system to function more efficiently and profitably. Expansion of this intensified system would require public investment in new infrastructure (e.g., irrigated perimeters). This increase was less the second year because fertilizer prices went up more -- there were stocks of pre devaluation period fertilizer that kept the fertilizer price increase down the first year after the devaluation.

Although the ON onion/rice story is a SAI success story at this point in time, there are some problems on the

horizon. Much of the infrastructure improvement was financed by loans. The repayment of these loans is costing the government about 300,000 FCFA/ha/year. This is viewed as a subsidy to ON farmers by the WB and there is a movement underway to require farmers to pay these costs. Recent financial analyses suggest that although substantially improved from predevaluation levels, net income per hectare for the principal rice crop would barely cover the 300,000 FCFA subsidy, leaving farmers only the income from their second crop, which is smaller than rice income and currently going primarily to the women of the household. Care must be taken to build on the progress made to date and encourage further increases in crop intensification (additional increases in rice yields, which research indicates are possible if fertilizer doses are increased, and perhaps a third crop) while gradually increasing the share of the infrastructure debt carried by farmers.

4.1.3. Bananas in Rwanda: Happy marriage of agroindustrial opportunities for the poor and SAI

Over the past two decades, there has been a rapid rise in cropping of bananas in Rwanda. Much of the banana crop is processed into banana wine by smallholders. Bananas, as they are grown on the small hillside plots, provides protection against erosion (much more than other food crops), and erosion has become a major concern of Rwandan peasants (Byiringiro and Reardon, 1996).

Moreover, the marginal value product of land under bananas (and coffee) is far higher than alternative uses, and so provides profitable intensification opportunities. Although there is a gestation period for the bananas to be established, food crops can be grown around young bananas, so even the poor can bear the gestation period, which is not true of some other cash perennials. The clincher is that growing one's own bananas provides a ready and cheap source of intermediate inputs for a major small-scale agroindustrial activity of the poor -- banana wine production. This is an important source of income. Moreover, other nonfarm activities have higher entry barriers for the poor. Although in the long-term banana wine will probably be supplanted in the diets of the urban consumer and even the rural resident if incomes grow sufficiently, for the medium term bananas and banana wine is an example of an agroindustrial, cash/food crop opportunity with growing urban demand, and that provides a path for SAI (Kangasniemi, 1998)

4.1.4. Cotton/maize zones in Burkina Faso and Mali: Vertically Integrate systems delivering inputs, promoting an agrarian capital base, and guaranteeing output markets

Animal traction equipment programs and fertilizer and seed subsidies and guaranteed output markets (in vertical coordination assured by mixed public/private firms) in the Sahel in 1960s and 1970s led to expansion of cropped area in the Guinean zone, under cotton in Mali and Burkina Faso in the 1970s-1980s. These programs raised the net profitability of these crops that were at first extensification crops (bringing new land under the plow) and then intensification crops relative to others (as quality-land constraints set in the 1980s, Savadogo et al., 1998), and relatively large amounts of fertilizer, organic matter, and animal traction were used on both cotton and the rotation crop, maize (see the point about Burkina Faso in 4.1.1.).

Dioné (1989) found for Mali that cotton cropping increased the ability of farmers to buy inputs for maize cropping. Through the cotton scheme, farmers had access to financial services to buy animal traction equipment, which increased the productivity of cotton and of maize production. The cash income generated from cotton farming also allowed for purchase of inputs for maize production.

4.2. The Troubling Stories of Unsustainable Intensification or Return to Extensification

The general problem is that there is commonly a dearth of the above ingredients of SAI success (illustrated in the three case studies in section 4.1): (1) public and private agrarian capital such as roads, animal traction equipment, irrigation perimeters; (2) affordable inputs; (3) low-risk output markets; (4) accessible financial services; (5) agroindustrial opportunities that provide value-added and buoyant markets.

Before the recent reforms, longstanding conditions were not, in themselves, propitious to overcome the above gaps. Low population density and high import costs made infrastructure expensive, unstable weather increased output and input market risk, and so on. But at great expense (to the state, to donors, and to bankers) there was a general effort to overcome those gaps basically with subsidies (on output marketing, on inputs, on financial services, on transport). In some situations where there were obviously profitable and stable export (and domestic) market opportunities, companies and cooperatives and parastatals invested to build up markets and enlist producers (e.g., in cotton, horticulture, and of course the traditional exports of coffee and cocoa and tea). The state usually helped with infrastructural investments (such as we illustrated above in the case of irrigation perimeters for the Office du Niger in Mali, or road improvement in the cotton zone of Mali and Burkina Faso).

However, the state's subsidization built up a deficit that was fiscally unsustainable by the mid 1980s. In the

cases of private/public schemes tied to profitable export or domestic markets (cotton, horticulture for example) or to certain producer strata (e.g. the largeholders in Zambia and Zimbabwe, Rusike et al., 1997), there was not much disturbance. There was even growth because the capacity and conditions were in place to take advantage of the new incentives wrought by macro policy reforms.

The evidence is accumulating, however, that the story was very different for the broader swath of producers — smallholders producing grains, roots, and tubers under rainfed conditions for domestic markets. Whereas the cases of SAI among this strata of smallholders before the economic policy reforms were essentially in public imitations of private/public cash crop schemes, when the subsidized element of these schemes was withdrawn, there were cuts in input and output market coverage, increase in input and financial services prices, increase in risk (as we have argued in section 3). The result, as we illustrate again with three cases in this section, was evidence of disintensification (return to extensification, in the Madagascar illustration), and a shift toward capital-deficient intensification (as in Zimbabwe, Zambia, and Senegal illustrations below).

4.2.1. Rice in Madagascar: Liberalization leads to a return to extensification

Madagascar's economy is dominated by its rice sector. Until economic reforms in the 1980s, the state controlled rice prices, keeping them low and stable, like most low-income countries (Krueger et al. 1988). With reforms, prices were decontrolled, rose, and became more volatile, due in part to sharp exchange rate devaluation and in part to the weakening state of private marketing infrastructure and financial markets (Barrett 1994, 1995, 1997a,c). The same factors led to reduced fertilizer use. Fertilizer distribution has long been highly erratic, and most smallholders have faced serious liquidity constraints that impede fertilizer use. Devaluation, contractionary monetary policy, termination of rural finance programs, more volatile output market conditions, and fiscal cutbacks that have effectively ended rural roads maintenance, all created further disincentives to use of imported modern inputs like fertilizer. Nonetheless, the increased mean and variance of rice prices induced malagasy rice producers — most of whom are net rice buyers — to stimulate output by expanding the area in cultivation through further shortening of fallow periods and extensification into fragile forest margins (Barrett 1998a,b). Madagascar's unique ecosystems make the prospective environmental costs of extensification or unsustainable intensification particularly high. Absent significant improvements in production technologies or application of modern inputs, farmers continue to shorten fallow periods, to bring new land into

cultivation, and to further degrade already fragile and erosive soils. Economic reforms in the 1980s appear to have exacerbated this unsustainable trajectory.

4.2.2. Maize in Zambia and Zimbabwe: a shift from a “public cash crop scheme” to liberalized markets and capital-deficient intensification

Zambia and Zimbabwe maize subsectors present interesting cases where pre-SAP policies created conditions in the early 1980s for smallholders to finally adopt hybrid maize varieties that had been a technology ‘on-the-shelf’ since the mid 1970s, but the output market profitability for smallholders (including stable access to output markets, cheap loans, access to subsidized inputs, and extension) only came in the early 1980s. This technology was essential to SAI in the smallholder sector (in the most fragile areas of the country), and there was a boom, a local Green Revolution. However, neither Zambia nor Zimbabwe could afford the public expenditures demanded by depot provision and subsidies to seed and fertilizer and financial services, and the system was dismantled in the second half of the 1980s and early 1990s. Following that was a shift away from fertilizer use on maize by smallholders in both countries, which meant that to the extent maize production was intensifying, it was happening with much less fertilizer and thus was ‘labor-led’ and dangerous for sustainability and soil fertility. At present, the smallholder output and input market is slowly resurrecting in the private sector but it is too early to tell how widespread and successful this will be to bring profitability and market stability back to a point that induces a return to SAI (Howard, 1995; Eicher, 1995; Rusike et al., 1997)

4.2.3. Peanuts in Senegal: a vicious circle of capital-deficient intensification and soil degradation

Senegal’s Peanut Basin provides a telling illustration of farmers’ soil mining as a response to two things: (1) decreases in expected profitability of improved input use due to changes in subsidy and financial services policies in the 1980s; (2) a risky and deteriorating physical environment, the result of low and variable rainfall, as well as decades of continuous peanut/millet cultivation with limited use of fallow, organic matter, and chemical fertilizers. Kelly et al. (1996) show that the seed and fertilizer subsidies, financial services subsidies, and animal traction equipment programs, greatly reduced input and equipment costs to peanut farmers in the Senegalese Peanut Basin in the 1970s and early 1980s, leading to extensification at first as new land was brought under the plow for peanuts, but then intensification as high levels of

inputs per hectare (by African standards) were employed to produce this cash crop, sold in a guaranteed (export) market. Removal of subsidies and dismantling of programs led to a relative dis-intensification of peanut production (with a precipitous decline in fertilizer use).

Following the sharp drop in fertilizer consumption during the 1980s, farmers began increasing peanut seeding densities to improve yields and incomes, at least in the short run, and to compensate for the declining soil quality which they believed was slowing down the growth of peanut ground cover and therefore causing weed problems. The practice has become widespread; survey data show that many farmers are using more than twice the recommended quantity of seed per hectare. Although raising peanut seed density appears to be a logical short-run solution (Kelly et al., 1996), agronomic research suggests that it is not a sustainable practice (Gaye and Sène, 1994). Without supplementary fertilizer and organic matter, increased seeding densities will not only lead to further soil mining but also undermine seed quality over time -- hence a vicious circle.

The fifty percent devaluation of the CFA franc in January 1994 did not break the vicious circle in the Peanut Basin, mainly because producer prices did not rise sufficiently to offset the increased costs of imported inputs. The government raised producer prices for peanuts twice -- a combined increase of 71 percent over pre-devaluation levels, but less than the 100 percent increase in the CFA value of the world price. Passing on only a portion of the increase in the export price was a common strategy of Sahel governments after the devaluation for subsectors with strong government intervention (Dioné et al., 1997); in general, the strategy is explained as a means to raise revenue to decrease deficits and finance public investments. Despite the 71 percent farmgate price increase, and smaller increases in the cost of peanut fertilizer (47 percent by May 1995), economic incentives to intensify peanut production with fertilizer remained inadequate in the Peanut Basin. Linear programming analysis (Diagana et al., 1995) shows that the devaluation has not reversed the pre-devaluation problem of low fertilizer use and movement toward higher peanut seeding densities. The analysis shows that the "optimal" (net income maximizing) peanut production technology is to forego fertilizer and increase peanut seeding densities well beyond recommended levels. The lack of incentive for fertilizer use results from the worsening price ratio between peanut and fertilizer prices, and from insufficient liquidity at the farm level for purchase of fertilizer. Diagana et al. (1996) note that constraints to access to peanut seed, fertilizer, equipment, and financial services have limited the post-devaluation supply response in the peanut subsector in Senegal.

5. CONCLUSIONS

Our main contention in this paper is that sustainable agricultural intensification in Africa requires capital-led intensification, broadly defined as adequate use of inorganic fertilizer, organic matter, and agrarian capital such as soil conservation structures and equipment and irrigation. Capital-deficient intensification merely leads to soil mining and a return to extensification because it does not meet productivity nor sustainability goals.

Policy reforms profoundly affect market conditions, which in turn influence the incentives and capacity of farmers to intensify with adequate use of capital. We have laid out arguments and evidence to show the mixed record of these reforms on incentives and capacity for the needed investments. That mixed record of effects on incentives has translated into a mixed record of intensification — from a return to environment-damaging extensification practices in Madagascar, to a shift from sustainable to unsustainable, capital-deficient intensification in Senegal, Zambia, Zimbabwe. By contrast, where infrastructure (and agrarian capital formation in general), reasonably stable input and output markets, financial services, and agroindustrial opportunities are available, one finds persistent instances of sustainable intensification — made even more successful by having been able to take advantage of the incentives wrought by the macro policy reforms.

The troubling aspect is that the market and infrastructural conditions present in the persistent or new cases of sustainable intensification just serve too few African farmers: they are linked to the lucky few who have the capacity to produce for the dynamic and profitable export and urban markets. The issue then is how to reverse the decline in conditions for the broad mass of smallholders producing cereals, tubers, and roots under rainfed conditions for local markets.

To a large degree this will involve policies that spur private investments, supported by public infrastructure, institutions, and goods, to improve the condition of rural factor and product markets. Heavy-handed state interventions in marketing systems proved fiscally unsustainable failures in most of Africa. But necessary state support services for private marketing have too often been thrown out with the parastatal bathwater in the course of economic reform programs. We have contended that the state needs to steer a middle course between relying solely on liberalization, which has not delivered the goods, and heavy interventionism. The selection of the needed public investments in physical infrastructure and institutional change will need to be made in a country by country fashion, supported by cost-benefit analysis that has been only rarely undertaken since the macro policy reform period.

REFERENCES

- Adesina, A.A. and K.K. Djato. 1996. "Farm size, relative efficiency and agrarian policy in Cote d'Ivoire: profit function analysis of rice farms," *Agricultural Economics*, 14 (2), July, pp. 93-102.
- Ahmed, J., W. Falcon and P. Timmer, "Fertilizer Policy For The 1990s," Harvard Institute For International Development Discussion Paper No. 293 (1989).
- BAME/ISRA (Bureau d'analyses macro économiques/Institut Sénégalais de Recherches Agricoles) (1995) Etude de l'impact de la dévaluation du franc CFA sur les revenus et la sécurité alimentaire au Sénégal: contribution du BAME/ISRA. Paper presented at the Atelier Régional du PRISAS sur Impact de la Dévaluation du Franc CFA sur les Revenus et la Sécurité Alimentaire en Afrique de L'Ouest, Bamako, Mali, June.
- Barrett, C.B. 1995. "Madagascar: an Empirical Test of The Market Relaxation - State Compression Hypothesis," *Development Policy Review*, 13 (4) Dec.: 391-406.
- Barrett, C.B. 1996. On Price Risk and The Inverse Farm Size-Productivity Relationship," *Journal of Development Economics*, 51 (2) December: 193-215
- Barrett, C.B. 1997. "Liberalization And Food Price Distributions: Arch-m Evidence From Madagascar," *Food Policy*, 22(2), April: 155-173.
- Barrett, C.B. 1997b. "The Effects of Real Exchange Rate Depreciation on Stochastic Producer Prices in Low-income Agriculture," Mimeo (January)..
- Barrett, C.B. 1997c. "Food Marketing Liberalization And Trader Entry: Evidence From Madagascar," *World Development*, 25 (5): May: 763-777.
- Barrett, C.B. 1998. "Immiserized Growth in Liberalized Agriculture" *World Development*, 26 (5), May: 743-753.
- Barrett, C.B. Forthcoming. "Stochastic food prices and slash-and-burn agriculture," *Environment and Development Economics*.
- Barrett, C.B., and M.R. Carter. 1994. Microeconomically Coherent Agricultural Policy Reform in Africa. University of Wisconsin-Madison. Madison: Dept. of Agricultural Economics. Mimeo
- Binswanger, H.P. (1986) Evaluating Research System Performance and Targeting Research in Land-abundant Areas of Sub-Saharan Africa. *World Development* 14, 469-476.
- Boserup, E. 1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. Chicago: Aldine.
- Byerlee, D. 1980. "Rural labor markets in West Africa with emphasis on the semi-arid tropics," *Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-arid Tropical Agriculture, 19-23 February 1979* (Patancheru: ICRISAT).
- Byiringiro, F. and T. Reardon. 1996. "Farm productivity in Rwanda: effects of farm size, erosion, and soil conservation investments," *Agricultural Economics*, 15(2) November: 127-136.
- Consultative Group for International Agricultural Research (CGIAR), Technical Advisory Committee (TAC). 1988. *Sustainable Agricultural Production: Implications for International Agricultural Research*. CGIAR meeting at FAO, May.

Clay, D.C. and T. Reardon. 1997. "Population and Sustainability: Understanding Population, Environment and Development Linkages" in G. D'Souza and G. Gebremedhin (editors), *Sustainability in Agricultural and Rural Development*. Hampshire, England: Dartmouth Publishing Company.

Clay, D., T. Reardon, and J. Kangasniemi. 1998. "Sustainable Intensification in the Highland Tropics: Rwandan Farmers' Investments in Land Conservation and Soil Fertility," *Economic Development and Cultural Change*, 46 (2) (January): 351-78.

Coulibaly, B.S., Sanogo, O., and Mariko, D. 1995. Cas du coûts de production du paddy à l'Office du Niger. Paper presented at the Atelier Régional du PRISAS Sur l'Impact de la Dévaluation du FCFA sur les Revenus et la Sécurité Alimentaire en Afrique de l'Ouest, Bamako, Mali, June.

Dembele, N.N. and Savadogo, K. 1996. "The Need to Link Soil Fertility Management to Input/Output Market Development in West Africa: Key Issues." Paper presented at the International Fertilizer Development Center Seminar, Lomé, Togo, November 19-22.

Diagana, B.N., Kelly, V. and Fall, A.A. 1995. Dévaluation du franc CFA et décisions de production agricole: une analyse empirique de l'impact de la dévaluation du franc CFA sur les choix de culture et de technologies de production par les ménages ruraux du Bassin Arachidier du Sénégal. Paper presented at the Atelier Régional du PRISAS sur Impact de la Dévaluation du Franc CFA sur les Revenus et la Sécurité Alimentaire en Afrique de L'Ouest, Bamako, Mali, June.

Diagana, B., Kelly, V., and Kébé, M. 1996. L'offre agricole suite à la dévaluation: pourquoi une réponse si faible au Sénégal? Policy Brief, Institut Sénégalais de Recherches Agricoles, Institut du Sahel, and Michigan State University, October.

Dioné, J. 1989. *Informing Food Security Policy in Mali: Interactions Between Technology, Institutions, and Market Reforms*. Ph.D. Thesis, Michigan State University, East Lansing, Michigan.

Dioné, J., J-C Le Vallée, J. Staatz, J. Tefft, M. Yade, A. Chohin, B. Kanté, T. Reardon, V. Kelly, 1997. "Lessons from the Impact of the Devaluation of the CFA Franc on Agri-Food Subsectors in West Africa," Policy Brief, PRISAS, Institut du Sahel, Mali. June.

Direcção de Economia (DE)/Ministério de Agricultura e Pescas (MAP)/Direcção Nacional de Extensao Rural (DNER)/MAP. 1998. "Is Agricultural Intensification Profitable for Mozambican Smallholders? An Appraisal of the Inputs Subsector and the 1996/97 DNER/SG2000 Program," Paper presented at the IFA Regional Conference for Africa, Maputo, Mozambique, 8-12 June.

Edwards, S. and S. van Wijnbergen. 1989. "Disequilibrium and Structural Adjustment," in H. Chenery and T.N. Srinivasan (eds.) *Handbook of Development Economics, Volume II*, Amsterdam: North Holland.

Eicher, C.K, 1995. "Zimbabwe's maize-based green revolution: Preconditions for replication," *World Development*, 23(5): 805-18.

Feder, G., R.E. Just, and D. Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey," *Economic Development and Cultural Change* 33 (2): 255-298.

Gaye, M. and Sène, M. 1994. Les fortes densités de semis de l'arachide au Sénégal: motivations paysannes et interprétation agronomique. mimeo, Kaolack: Institut Sénégalais de Recherches Agricoles..

Goetz, S. "A Selectivity Model of Household Food Marketing Behavior in Sub-saharan Africa," *American Journal of Agricultural Economics*, 74, 2 (May 1992): 444-452.

al Hassan, R., J. Kydd, and M. Warner. 1996. *Review of Critical Issues for Natural Resources Policy in Ghana's Northern Region*, Briefing Paper 4, Project on the Dynamics of Smallholder Agriculture in the Guinea Savannah Zone of West Africa, with particular reference to Northern Region Ghana (Ashford Kent: Wye College).

- Hayami, Y. and V. Ruttan. 1985. *Agricultural Development: An International Perspective*, 2nd Ed. (Baltimore: Johns Hopkins University Press)
- Heisey, P.W. and W. Mwangi. 1997. "Fertilizer Use and Maize Production in Sub-Saharan Africa," in Byerlee, D. and C.K. Eicher (Eds.). *Africa's Emerging Maize Revolution* (Boulder: Lynne Reinner).
- Hopkins, J., and P. Berry. 1994. Determinants of Land and Labor Productivity in Crop Production in Niger. Report to the United States Agency for International Development, Niamey, Niger (November). Washington, D.C.: International Food Policy Research Institute.
- Howard, J. and C. Mungoma. 1997. "Zambia's Stop-and-Go Revolution: The Impact of Policies and Organizations on the Development and Spread of Maize Technology," in Byerlee, D. and C.K. Eicher (eds.). *Africa's Emerging Maize Revolution* (Boulder: Lynne Reinner)..
- de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained," *Economic Journal*, 101: 1400-1417..
- Kangasniemi, J. 1998. People and Bananas on Steep Slopes: *Agricultural Intensification under Demographic Pressure and Environmental Degradation in Rwanda*, Ph.D. Dissertation, Dept. of Agricultural Economics, Michigan State University.
- Kante, B., T. Reardon, and A. Keita (1995) Devaluation du franc CFA: analyse typologique des mesures d'accompagnement," December; Working Paper no. DT 95-11. PRISAS, Institut du Sahel, Mali.
- Kaufmann, Daniel and Stephen A. O'Connell. 1991. "The Macroeconomics of the Unofficial Foreign Exchange Market in Tanzania". In *Economic Reform in Sub-Saharan Africa*, eds. Chhibber, Ajay and Stanley Fischer. Washington, D.C.: The World Bank.
- Kelly, V., B. Diagona, T. Reardon, M. Gaye, E. Crawford. 1996. *Cash Crop and Foodgrain Productivity in Senegal: Historical View, New Survey Evidence, and Policy Implications*, MSU International Development Paper, no. 20.
- Kelly, V., T. Reardon, D. Yanggen, and A. Naseem. 1998. "Fertilizer in Sub-saharan Africa: Breaking the Vicious Circle of High Prices and Low Demand," Policy Synthesis Number 32, Food Security II Project, Michigan State University, February.
- Kim, T.-K., D.J. Hayes, and A. Hallam. 1992. "Technology Adoption under Price Uncertainty," *Journal of Development Economics*, 38 (1), Jan.: 245-253.
- Krueger, A.O., M. Schiff, and A. Valdés. 1988. "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economywide Policies," *World Bank Economic Review*, 2: 255-271.
- Lau, L.J. 1976. "A Characterization of the Normalized Restricted Profit Function", *Journal of Economic Theory*, 12(131-163)
- Lipton, M. "Market Relaxation and Agricultural Development," in C. Colclough and J. Manor, Eds., *States or Markets? Neo-liberalism and the Development Policy Debate* (Oxford: Clarendon Press, 1991).
- Little, P.D. and M. Watts. 1994. *Living Under Contract: Contract Farming and Agrarian Transformation in Sub-Saharan Africa*, Madison: University of Wisconsin Press.
- Low, A. 1993. "The low input, sustainable agriculture (LISA) prescription: a bitter pill for farm households in Southern Africa," *Project Appraisal* 8 (2), pp 97-101.

- Lynam, J.K. and R.W. Herdt. 1989. "Sense and sustainability: sustainability as an objective in international agricultural research," *Agricultural Economics*, 3: 381-98.
- Machethe, C.L. 1997. *Determinants of Credit Constraints on Micro- and Small Enterprises in the Northern Province of South Africa*. Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University.
- Maredia, M. and J. Howard. 1997. "Facilitating seed sector transformation in Africa: Key findings from the literature" Policy Synthesis no 33, Dept. of Agricultural Economics, Michigan State University.
- Matlon, P., and Spencer, D.S.C. 1984. "Increasing Food Production in Sub-Saharan Africa: Environmental Problems and Inadequate Technological Solutions," *American Journal of Agricultural Economics*, December.
- Mendez del Villar, P. and Diakité, L. 1995. Impact de la dévaluation du franc CFA sur la filière irriguée au Mali. Paper presented at the Atelier Régional du PRISAS Sur l'Impact de la Dévaluation du FCFA sur les Revenus et la Sécurité Alimentaire en Afrique de l'Ouest, Bamako, Mali, June.
- Mudimu, G. 1996. "An Analysis of Incentives for Adopting Soil and Moisture Conservation Tillage Practices by Smallholder Farmers in Zimbabwe: a Case Study of Kandeya Communal Land," mimeo, Dept. of Agricultural Economics and Extension, University of Zimbabwe.
- Omamo, S.W. 1998. "Transport Costs And Smallholder Cropping Choices: an Application to Siaya District, Kenya," *American Journal of Agricultural Economics*, 80, 1 (February): 116-123.
- Newbery, D.M.G. and J.E. Stiglitz. 1981. *The Theory of Commodity Price Stabilization: A Study in the Economics of Risk* (Oxford: Clarendon Press).
- Place, F. and P. Hazell. 1993. "Productivity Effects of Indigenous Land Tenure Systems in Sub-Saharan Africa," *American Journal of Agricultural Economics* 75 (February): 10-19.
- Putterman, L. 1995. "Economic Reform And Smallholder Agriculture in Tanzania: a Discussion of Recent Market Liberalization, Road Rehabilitation, And Technology Dissemination Efforts," *World Development*, 23, 2 (February): 311-326.
- Reardon, T. 1998. "African Agriculture: Productivity and Sustainability Issues," in C. Eicher and J. Staatz (editors) *Agricultural Development in the Third World* Third Edition (Baltimore: Johns Hopkins University Press).
- Reardon, T., E. Crawford, and V. Kelly. 1994. "Links between nonfarm income and farm investment in African Households: adding the capital market perspective", *American Journal of Agricultural Economics*, Volume 76, No. 5, December; pages 1172-1176.
- Reardon, T., E. Crawford, and V. Kelly. 1995. *Promoting Farm Investment for sustainable intensification of African Agriculture*. International Development Paper No. 18. East Lansing: Michigan State University.
- Reardon, T., J. Hopkins, and V. Kelly. 1992. "Structural adjustment impacts on real incomes and demand patterns of urban and rural households in the Sahel," selected and presented at the 29th Seminar of the European Association of Agricultural Economics, 'Food and Agricultural Policies Under Structural Adjustment', Sept. 21-25, Hohenheim, Germany.
- Reardon, T., and N. Islam. 1989. "Issues of Sustainability in Agricultural Research in Africa," chapter 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; NORAGRIC Occasional Paper Series C.
- Reardon, T., V. Kelly, E. Crawford, B. Diagana, J. Dione, K. Savadogo, D. Boughton. 1997. "Promoting Sustainable Intensification and Productivity Growth in Sahel Agriculture After Macroeconomic Policy Reform," *Food Policy*, 22(4), August: 317-328.

- Reardon, T. and S. Vosti. 1992. "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*, 31 (4), October-December: 380-396.
- Reardon, T. and S. Vosti. 1995. "Links Between Rural Poverty and Environment in Developing Countries: Asset Categories and Investment Poverty," *World Development*, 23 (9), Sept: 1495-1506.
- Rukuni, M. 1996. "a Framework for Crafting Demand-driven National Agricultural Research Institutes in Southern Africa," Dept. of Agricultural Economics Staff Paper no 96-76, Michigan State University.
- Rusike, J., T. Reardon, J. Howard, V. Kelly. 1997. "Developing Cereal-based Demand for Fertilizer Among Smallholders in Southern Africa: Lessons Learned and Implications for Other African Regions," Policy Synthesis No. 30, Food Security II Project, Michigan State University, November.
- Ruttan, V. 1990. "Models of Agricultural Development," in C. Eicher and J. Staatz (eds.) *Agricultural Development in the Third World*, Second Edition (Baltimore: Johns Hopkins University Press).
- Sadoulet, E. and A. de Janvry. 1995. *Quantitative Development Policy Analysis*, Baltimore: Johns Hopkins University Press.
- Savado, K., T. Reardon, and K. Pietola. 1995. "Mechanization and Agricultural Supply Response in the Sahel: a Farm-level Profit Function Analysis," *Journal of African Economies*, 4 (3), Dec.: 336-377.
- Savado, K., T. Reardon, and K. Pietola, 1998. "Adoption of Improved Land-use Technologies to Increase Food Security in Burkina Faso: Relating Animal Traction, Productivity, and Nonfarm Income," *Agricultural Systems*, October.
- Scoones. 1996. *Hazards and opportunities: Farming livelihoods in dryland Africa*. (London: Zed Books, 1996).
- Semgalawe, Z.M. 1998. *Soil Conservation and Agricultural Sustainability: The Case of North-Eastern Mountain Slopes, Tanzania*, Doctoral Dissertation, Dept. of General Economics, Wageningen University, Netherlands.
- Shepherd, A. 1989. "Approaches to The Privatization of Fertilizer Marketing in Africa," *Food Policy*, 14, 2: 143-154.
- Shiferaw, B. And S.t. Holden "Resource Degradation And Adoption of Land Conservation Technologies in The Ethiopian Highlands: a Case Study in Andit Tid, North Shewa," *Agricultural Economics*, 18, 3 (May 1998): 233-247.
- Tiffen, Mary, M. Mortimore, and F. Gichuki. 1994. *More People, Less Erosion: Environmental Recovery in Kenya*. Chichester: Wiley.
- Tribe, D. 1994. *Feeding and Greening the World: The Role of International Agricultural Research*, (Wallingford: CAB International).
- Viyas, V.S. 1983. "Asian Agriculture: Achievements And Challenges," *Asian Development Review*, 1 (1): 27-44.
- Weight, D. and V. Kelly. 1998. "Restoring Soil Fertility in Sub-Saharan Africa: Technical and Economic Issues," Policy Synthesis number xx, Food Security II Project, Dept. of Agricultural Economics, Michigan State University.
- van Zyl, J., Binswanger, H. and Thirtle, C. (1995) The relationship between farm size and efficiency in South African agriculture, Policy Research Working Paper 1548, The World Bank, Agriculture and Natural Resources Dept., November.
- Yanggen, D., V. Kelly, T. Reardon, A. Naseem. 1998. *Incentives for Fertilizer Use in Sub-Saharan Africa: A review of empirical evidence on fertilizer yield response and profitability*, International Development Working Paper no. ??, Michigan State University.
- World Bank. 1993. *World Development Report 1992*. Oxford University Press.

Zeller, M., G. Schreider, J. von Braun, and G. Heidhues, 1997, *Rural Finance for Food Security for the Poor: Implications for Research and Policy*. International Food Policy Research Institute Food Policy Review no. 4.