PN-ABT-341

Winrock International Environmental Alliance

Environmental & Natural Resources Policy & Training Project

EPAT

Winrock International Environmental Alliance

Center for Policy Negotiation

Development Assistance Corporation

The Futures Group

Institute for International Research, Inc.

Iowa State University Center for Agricultural and Rural Development Resource and Environmental Policy Division

The Johns Hopkins University

KBN Engineering and Applied Sciences, Inc.

The Keystone Center

Management Systems International

New York University Institute for Economic Analysis

The RAND Corporation

Resources for the Future

Tellus Institute

Tropical Research & Development, Inc.

Tufts University Program for Study of Sustainable Change and Development

Tuskegee University

University of Maryland International Institute for Ecological Economics

University of Rhode Island

Winrock International Institute for Agricultural Development

Yale University School of Forestry and Environmental Studies

The Office of Environment and Natural Resources of the Bureau for Global Programs, Field Support, and Research of the U.S. Agency for International Development sponsors the Environmental and Natural Resources Policy and Training (EPAT) Project. The Winrock International Environmental Alliance has responsibility for EPAT's applied research and technical assistance activities.

1611 North Kent Street, Suite 600, Arlington VA 22209 - USA
Telephone (703) 525-9430 FAX (703) 516-0481

PN-ABT-341

Contract Number DHR-5555-Q-00-1085-00
Delivery Order 6

Sustainable Agricultural Development in Africa

Pierre Crosson
September 1994

Prepared as part of the Natural Resources Management Activity 1 for the U.S. Agency International Development's Africa Bureau by:

Environmental and Natural Resources Policy and Training (EPAT) Project
Winrock International Environmental Alliance (WIEA)
Arlington, Virginia
USA

4

Contents

Introduction 5

1. Recent Performance and Potential 7

2. Conceptual Issues 8
   Definition of Sustainable Agriculture 8
   Concept of Total Productivity 8

3. Sources of Productivity Growth 12
   Introduction 12
   Productivity Potential from NRM Improvement 12

4. Obstacles to Realizing Productivity Potential 18
   Importance of Incentives 18
   Rapid Population Growth as an Obstacle 20
   Institutions as Obstacles 21

References 23

Introduction

In the fall of 1992, the Environmental and Natural Resources Policy and Training (EPAT) team of Winrock International, in response to an initiative from the Africa Bureau of the U.S. Agency for International Development (USAID), began three lines of work on the role of natural resources management (NRM) in African economic development. One of the lines was designed to show how economic analysis can be used to improve the design and impact of natural resources policy initiatives and programs.

As the work evolved, a decision was made to focus the economic analysis line on two especially important issues in Africa: achievement of sustainable agriculture and protection of biological diversity. This report, written in four parts, discusses what the team had learned as of September 1993 about sustainable agriculture and offers some ideas for future work. The report's main objective is to provide a brief account of the evidence for assertions about Africa's agricultural potential and a preliminary discussion of conditions that must be satisfied to enable its realization.

Section 1 provides a brief account of recent agricultural performance in Africa and comments on the continent's potential for improvement. Section 2 focuses on two conceptual issues: 1) definition of sustainable agriculture and 2) changes in total productivity over time as an indicator of whether an agricultural system is on a sustainable path. Section 3 considers sources of total productivity growth in agriculture, distinguishing between improvements in NRM and new commodity technologies. It then asks what is known about the potential contribution of these sources to future productivity growth in African agriculture. Section 4 discusses the various obstacles that presently impede realization of the productivity potential of improvements in NRM and new commodity technologies.

It must be emphasized that this report is an account of a process of work aimed at helping USAID's Africa Bureau and missions continue to improve their programs of assistance in building sustainable agricultural systems in Africa. This paper, therefore, should be read as a progress report, not a final product, on that process of work.

1. Recent Performance and Potential

Agricultural production per capita has declined in Africa over the last two decades, while imports of food, including food aid, have increased significantly. This combination suggests that agriculture in Africa is not on a sustainable path. Of course, if Africa's per capita income had been rising satisfactorily, one could argue that the performance of agriculture, despite its sluggishness, nevertheless reflected a generally successful overall development strategy. In fact, real per capita income in Africa has not increased at a satisfactory rate over the past decade. In a number of countries, it has declined. This is judging income performance as it is measured in the national income accounts. If natural resources depletion and environmental damage attributable to agriculture were taken into account, agricultural performance might be judged even more negatively.

Despite this dismal picture of African agriculture, there are grounds for believing the continent can do much better. After an extended examination of agricultural prospects in mid-Africa, Seckler, Gollin, and Antoine (1989) concluded that the region has the potential to become the breadbasket of sub-Saharan Africa. The Food and Agriculture Organization (FAO) (1986) asserts that Africa has the potential to make many African countries food self-sufficient. In support of this assertion, FAO notes that many small-scale maize producers in Malawi and Zimbabwe work under agroecological conditions no better than those in many other parts of Africa yet find it profitable to use modern, high-yielding varieties of maize with high levels of fertilizer. Côte d'Ivoire achieves cocoa and oil palm yields that are among the highest in the world, yet growing conditions are no better than in more than 200 million hectares (ha) of currently cultivated or potentially cultivable land in humid west and central Africa. Similarly, according to FAO, more than 100 million ha of land in the sub-humid and semi-arid parts of the continent, if cultivated at all, yield less than 1 tn. of maize/ha/year; yet these areas are agroecologically comparable to those of Zimbabwe, where average maize yields are about 5 tn./ha/year. Cameroon, Côte d'Ivoire, Malawi, Niger, Swaziland, and Zimbabwe, for a decade or more through at least the mid-1980s, achieved average annual growth rates in agricultural output of more than 4%. Zimbabwe's wheat yields were among the highest in the world. Seckler, Gollin, and Antoine (1989) also present evidence in support of their argument that central Africa has the agroecological potential to substantially increase both yields per ha and total production.

2. Conceptual Issues

Definition of Sustainable Agriculture

Definitions of sustainable agriculture vary widely. They are never right or wrong, only more or less useful. The author finds the following a useful definition of sustainable agriculture: a production system that indefinitely meets rising demands for food and fiber at economic and environmental costs consistent with rising per capita welfare of the people served by the system. The word "indefinitely" indicates that the system must perform sustainably across successive generations. "Rising demands" are part of the definition because, on a global scale and in Africa, demand for food and fiber is, in fact, likely to continue to rise indefinitely. "Rising per capita welfare" is included because the welfare of so many people around the world, particularly in Africa, presently is so low.

Note that this definition does not require that economic and environmental costs of agricultural production must remain the same or decline over time. Conceivably, the welfare of the people of a region, country, or continent would be best served by a development strategy that emphasized non-agricultural sectors of the economy, even at some increase in costs of agriculture. However, African agriculture, upon which so many people depend, is so important in the economies of most African countries that it is unlikely, at least over the next several decades, that rising economic and environmental costs of agriculture would be consistent with rising per capita welfare of the great mass of the African people. As a practical matter, therefore, the definition of sustainable agriculture for Africa implies that the combined economic and environmental costs of agricultural production must not rise over time.

Note also that this definition requires neither the economic nor the environmental costs of agriculture to rise. Some rise in either type of cost is consistent with sustainability if the other type declines enough to offset the increase. It is the *combination* of costs that must not rise.

Note finally that this definition does not mean that depletion of natural resources in agriculture or the environmental costs of agricultural production must be reduced to zero. Some natural resources depletion and environmental costs are acceptable as long as they are consistent with rising per capita welfare.

Concept of Total Productivity

Total productivity is the ratio of all the outputs of a production system to all the inputs used in producing the outputs. As used here, the outputs include not only priced agricultural commodities and services (i.e., those that are exchanged in market transactions) but also unmarketed (therefore unpriced) services of the environment, such as wildlife habitat values. The inputs include not only those purchased in markets, such as fertilizer, and labor provided by the farm family, but also unmarketed environmental services, such as those provided by neighboring streams in which farmers dump sediment, agricultural chemicals. and other effluents of farm operations. Changes in the value of natural resources used in production also are part of the inputs, whether or not the changes are reflected in market prices of the resources. For example,

the value of land productivity losses because of soil depletion is counted as a cost of production whether or not the losses are reflected in declines in land prices. If land is exchanged in markets, land prices presumably would reflect any significant losses of soil productivity. A correct accounting for all production costs requires that the value of the losses be included on the input side of the measure of total productivity. By the same reasoning, any improvements in land productivity resulting from farm management practices, such as mulching to build organic matter in soils degraded by erosion, would be included as a negative entry on the input side, reflecting an increase in the value of the soil resource. Such soil improvements thus produce a decline in total inputs, hence an increase in total productivity.

Because total productivity, as defined here, is the ratio of *all* the outputs of agriculture to *all* the inputs used in production, changes in total productivity over time can be taken as an indicator of whether the agricultural system is on a sustainable course. Should per capita productivity remain the same or increase, this would indicate sustainability; should it decline, the opposite would be indicated.

Because agriculture typically produces multiple outputs and uses multiple inputs, total productivity always is measured as the ratio of an index of outputs to an index of inputs. The output and input indexes are calculated separately. The output index, in its simplest but still representative form, is calculated the following way: the quantities of each output in some base year are multiplied by their respective prices and the products are summed. The result is simply the total value of output in the base year. Next, the quantities of each output in some given year are multiplied by base year prices and the products summed. The result is the value of given year output as it would be if output prices were the same in both the base year and given year. The total output value in the given year is then divided by the base year value. The result is multiplied by 100 to express it as an output index. Because the same prices are used to value the components of output in each year, the index shows the relative change in the quantity of output between the base year and the given year. If, for example, the quantity of output increased 20% between the two years, the output index in the given year would be 120.

Construction of the input index is comparable. Thus, the input index for the given year shows the relative change in the quantity of inputs used from the base to the given year, with each input in each year weighted by its price in the base year.

The total productivity index in any year is the ratio of the output index to the input index for that year. The total productivity index thus measures the relative change in the quantity of output between the two years in relation to the relative change in the quantity of the inputs used in production. For example, if the quantity of output increased 20% from the base to the given year, the output index in the given year would be 120. In addition, if the quantity of inputs increased only 5%, the input index in the given year would be 105. The total productivity index for that year would be 120 divided by 105 or 1.14. The inputs used in the given year were able to produce 14% more output than the inputs employed in the base year. This is a measure of the increase in productivity of the resources employed in the agricultural system.

It is then clear that, if changes over time in total productivity are to serve as a measure of the sustainability of the agricultural system, it is critical to have accurate measurements of both the quantities and prices of outputs and inputs in a succession of years. It is sometimes difficult to obtain these data for marketed outputs and inputs, even though the transactions in these generate an "information trail" of quantities and prices. For example, in all African countries, much food production is directly consumed by farm families, with only the balance sold in markets. Market data thus miss a significant amount of the quantity of production. Similarly on the input side, most on-farm labor is provided directly by the farm family, although hired labor may generate some market information.

Measuring the productivity of African agriculture with respect to marketed outputs and inputs is complicated also because many African farms, particularly in areas of low and unreliable rainfall, are multi-product enterprises. To deal with the risk of climatic variability and to reduce potential damage from insect pests and disease, these farmers may plant several crops simultaneously on the same land or interplant annual crops with trees. They often integrate animal production with crops; the animals feed on crop stubble and other vegetative waste and provide manure to maintain soil fertility. This practice is an effective way of dealing with the many market and natural risks that affect African agriculture. However, it greatly complicates the already difficult problem of measuring total agricultural productivity in Africa (see Peters in Seckler 1993, 69).

With respect to marketed outputs and inputs, these problems pale in comparison to those affecting unmarketed outputs and inputs. Because these are not exchanged in markets, neither quantity nor price information is available for them. Economists have begun to develop techniques to overcome these data problems. But the work is at a primitive stage relative to the scale of the measurement problem, particularly in developing countries and especially in Africa.

So severe are these measurement problems with respect to unmarketed outputs and inputs that it is not now practicable to construct total productivity indexes incorporating environmental outputs and inputs for African agriculture (or the agriculture of any other country or set of countries).[1] The concept of total productivity, nonetheless, is important because it provides a guide for thinking about the sustainability issue in African agriculture. The concept forces one to keep aware of the fact that the unpriced natural resource and environmental consequences of agriculture are just as relevant to assessing the sustainability of agriculture as the priced consequences for marketed outputs and inputs. A focus only on the priced consequences might lead to totally misleading assessments of sustainability.

While the concept of total productivity can play a pivotal role in the assessment of the sustainability of African agriculture, this concept alone, even in principle, does not provide sufficient information for a complete assessment. It does not capture processes of social and political change that must also be taken into account. The importance of these processes is expressed by USAID's Africa Bureau (1992, 27) in the following language:

---

[1] The work done for EPAT by Glenn-Marie Lange and Faye Duchin on natural resources accounting for African countries is beginning to address these measurement issues. The authors' work is not cast in a total productivity framework, but the questions they raise are the same as those discussed here.

Natural resources management must be integrated into broader-based policy dialogue and agricultural and rural development programs to achieve cost-effectiveness, sustainability, and acceptability.

The concept of total productivity obviously cannot capture these broader, non-quantitative dimensions of sustainability. Nonetheless, with population and per capita income growth driving unceasing increases in demand for food and fiber, the productivity of the resources available for agricultural production clearly must increase also if sustainability is to be achieved. The concept of total productivity provides a way of organizing data collection and analysis toward that objective.

Rising total productivity in agriculture is vitally important because of its contribution to enhancing the welfare of so many people dependent on farming for their livelihood, a majority of whom live in Africa. In agriculturally-based African countries, productivity growth in agriculture also is a necessary condition for rising per capita income in the rest of the economy. Higher productivity in agriculture stimulates farmer demand for both consumer and producer goods from the non-farm sectors, thus creating incentives for expansion in those activities. Higher farm productivity also, in time, permits people to move out of agriculture to supply the increasing demand for labor in urban areas. Agricultural productivity growth thus plays an important role in the complex processes by which low-income, rural countries are transformed into high-income, urban ones.

3. Sources of Productivity Growth

Introduction

EPAT's NRM Activity 1 for agriculture focused on how improvements in NRM could contribute to the achievement of sustainable agricultural systems in Africa. Natural resources, however, are only one source of agricultural production. Knowledge embodied in people, technology, and institutions is the other critically important resource. Moreover, knowledge and natural resources typically are integrally related in the processes of agricultural production. The potential contribution of improvements in NRM to productivity growth, therefore, cannot usefully be assessed independent of considering the potential contribution of knowledge resources.

This discussion of sources of productivity growth takes explicit account of the interdependence between natural and knowledge resources. The author begins by reviewing evidence of situations where improvements in NRM, in combination with existing knowledge, car contribute to increased productivity. He then considers situations in which it appears that NRM improvements would be effective only in combination with additional or new knowledge, e.g., that embodied in fertilizer and its use or in a not yet developed, higher-yielding crop variety. To anticipate the outcome, the evidence suggests that, over perhaps a decade, the combination of NRM improvements with existing knowledge could generate significant increases in productivity. Over the longer term, however, the promise of NRM improvements in the absence of new knowledge is probably quite limited.

Productivity Potential from NRM Improvement

NRM improvements can contribute to increased productivity by 1) restoring the productivity of degraded natural resources, as in the example given above of mulching to build organic matter in badly eroded soil; 2) slowing or halting current rates of degradation, e.g., adoption of some form of conservation tillage to reduce or eliminate erosion-induced losses of soil productivity; 3) improving the productivity of a neither degraded nor degrading resource. Irrigation development provides the principal example of the third source of productivity gains; bunding to increase soil moisture by capturing more precipitation runoff is another important example.

As the above examples suggest, the first two sources of productivity growth are those that could be achieved by simple changes in farm-management practices with no significant changes in technology. The third source typically would require some technological change, e.g., the payoff to irrigation investments typically requires a shift to higher-yielding crop varieties combined with increased fertilizer use. Realizing the productivity potential of NRM practices to increase soil water-holding capacity usually would require some increase in fertilizer use.

In the examples cited, the NRM improvements would increase the productivity of the land in agricultural production. It is important to remember, however, that such improvements can potentially contribute to increased productivity of off-farm resources and on-farm resources not involved in agricultural production. For example, NRM improvements that reduce pesticide use may improve water quality downstream from the farm. Decisions not to drain wetlands on the

farm would protect habitat resources for wildlife. In total productivity language, improvements in NRM can contribute to increased output, or reduced input, of both marketed and unmarketed (environmental) resources.

One approach to an assessment of the productivity potential of the first two types of NRM improvements is to ask how severely natural resources have been degraded and at what current rates. If answers to these questions were known (e.g, if it were known that, with existing technology, degradation had reduced crop productivity on X million ha of African land by 30-40%), that knowiedge would permit an estimate of the potential productivity gain through NRM improvements on that land.

The author's review of the literature in connection with this and similar work clarifies that precise answers to these types of questions are not now possible for African countries. For water resources and losses of wildlife habitat, even imprecise answers are not feasible. Most of the evidence relevant to the questions is for land resources, which is briefly reviewed here.[2]

Extent of degraded and degrading land.[3] Discussion focuses on the first two sources of productivity growth mentioned above to consider the productivity potential of measures to restore degraded land or halt current rates of land degradation in the absence of complementary uses of additional technology. The third source of productivity growth mentioned--improving natural resources productivity of neither degraded nor degrading resources, e.g. through investments in irrigation--almost by definition requires complementary uses of added technology. The third category's potential of productivity growth is considered subsequently.

A review of the literature on land degradation reveals two seemingly contradictory themes. One is deep concern that land degradation around the world poses a serious threat to the sustainability of the global agricultural system. The other is the scarcity of reliable information about the extent of land degradation, let alone its productivity consequences. The first theme was given impetus by a report prepared for the United Nations conference on desertification held in Nairobi in 1977 and by a subsequent follow-up paper (Mabbutt 1984). Taken together, the two studies showed that some 4.5 billion ha (about 35% of the earth's land surface) suffered some degree of degradation. Of the 4.5 billion ha, 3,475 million were drylands already at least moderately degraded. This is 75% of all productive land in the world's drylands (Mabbutt 1984, 105). Of the 3,475 million ha, 3,100 million were rangelands (80% of dry rangeland), 335 million were rainfed cropland (60% of rainfed dry cropland) and 40 million were irrigated land (30% of irrigated dryland). Of the 3,100 million ha of degraded dry rangeland, 1,300 million were severely to very severely degraded. This was true also for 170 million of the 335 million ha of degraded, dry rainfed cropland, and of 13 million of the 40 million ha of degraded, dry irrigated land. The studies showed that the areas most affected by land degradation, in descending order, were the Sudano-Sahelian region, Africa south of this region, and South Asia.

---

2 Reminder: This is a progress report on work done in fiscal year 1993 under the EPAT NRM Activity 1. The literature reviewed, therefore, now far from exhaustive, suffices in providing both useful insights into the issues involved and guidelines for subsequent research.

3 Discussion here is based on Crosson and Anderson (1992, 30-34).

The Africa Bureau (1992, 11) asserts (without any supporting evidence) that "soil erosion and declining soil fertility together are Africa's most serious environmental and economic problems." Elsewhere, the Bureau states that "desertification, exacerbated by periodic drought, has severely undermined agricultural productivity in Africa and is a tangible threat to the region's food security" (Africa Bureau 1992, 28).

Nelson (1988) surveyed the evidence for the extent of land degradation, including Mabbutt's 1984 study, as well as one by Lamprey (1975) of land degradation in the Sudan. Nelson noted that the meanings of "moderately," "severely," and "very severely" in Mabbutt's study are subject to varying interpretations. In addition, in 1982, the time of the survey on which the study was based, Africa was at the end of a severe and prolonged drought, which could have affected the judgment of the African officials included in the survey.

Lamprey (1975) apparently was the source for the widely-cited estimate that "the Sahara Desert is advancing south at 5.5 km./yr" (Nelson 1988, 6). Drawing on several subsequent studies of the same area that covered a longer period of time, Nelson concluded that the "advancing Sahara" argument was overdone. The pattern in northern Africa would be better described as desert encroachment in periods of drought followed by retreat when rains returned.

Biot et al. (1993) cite recent evidence from Botswana on vegetation recovery after drought, indicating that trends of rangeland degradation observed during periods of drought are readily reversed once the rains return. The authors assert that most of the research on rangeland degradation tends to indicate that the resilience of the savannas of southern Africa is much higher than has been reflected in official statements on the extent and severity of such degradation.

The imprecision and ambiguity of the information about the extent of land degradation in Africa are suggested by FAO (1986, 94). The report states that little reliable data are available on the extent of land degradation in Africa, but that "the eye of the traveler" reveals that it is "widespread" and serious." Yet, an overview of the problem based on "local experience and on information provided by specialists in the different countries concerned" indicates the following:

- only in Madagascar is gully erosion severe;
- in no country is sheet erosion severe;
- only in Chad and Mauritania is wind erosion severe;
- among 36 countries judged, gully erosion was slight in 19, moderate in 16, and severe in 1;
- among the same 36 countries, sheet erosion was slight in 15 and moderate in 21.

Taken literally, these statements raise serious questions about the accuracy of repeated assertions that soil erosion in Africa is a major threat to sustainability of the continent's agriculture. It is unclear whether the statements are to be taken literally because the meanings of

"slight," "moderate," and "severe" erosion are unclear, as pointed out by Nelson (1988). Thus, a major difficulty in determining the extent and severity of land degradation in Africa and elsewhere is vagueness in definitions of degradation and its various levels of severity. Biot et al. (1993) note that traditional definitions of rangeland degradation have been in terms of changes in vegetation under the pressure of grazing, with savannas losing perennial grasses in favor of annual ones, palatable grass species being replaced by less palatable ones, and encroachment of bush. This pattern of degradation is based on short-term studies of vegetation changes in restricted grazing areas; the authors cite three studies contending that these findings for restricted grazing areas do not necessarily apply to open, communally-held rangelands. Even if the pattern of vegetation change is found on such lands, it does not necessarily mean an irreversible reduction in the land's capacity to produce livestock. Further, "the lack of evidence for decreased livestock production, despite more than 50 years of warnings concerning rangeland degradation, ... tends to support the idea that vegetation changes are not necessarily to be seen in terms of land degradation ...." (Biot et al. 1993, 168.)

This brief review of the available evidence bearing on the extent and severity of land degradation in Africa points to two principal conclusions: 1) there is little firm information about the problem and 2) the available information suggests little support for apocalyptic statements about the severity of the land degradation problem. A common tendency, especially in official statements, is to overstate the present extent of damage and to underestimate the land's capacity to recover from periods of drought, including prolonged ones.

The two conclusions imply great uncertainty about the potential payoff to policies and programs designed to restore the productivity of presently degraded land or to reduce or eliminate present rates of degradation in the absence of complementary measures to increase productivity. If firm information is lacking about the present extent and severity of degradation and rates of degradation, there is no firm basis for committing resources to policies and programs to deal with these perceived problems. Doubts about the wisdom of such a commitment are only reinforced by the suggestion in the scanty available evidence that, because the degradation problem may be much less severe than commonly believed, the potential payoff to corrective policies and programs may be correspondingly small.

This is an important and possibly controversial conclusion. It is important, therefore, to clarify its meaning. First, the conclusion applies at the general level across Africa as a whole. It does not deny that in specific areas the evidence for a "clear and present danger" from land degradation may be sufficient to justify a commitment of resources to corrective action. Second, as the emphasized passage above indicates, the conclusion applies to corrective actions focused only on restoring degraded land or reducing present rates of degradation. The conclusion is consistent with the idea that the potential payoff to such actions may be high when combined with measures to increase the use of presently known or improved technologies in production; i.e., the relationship between improvements in NRM and use of additional technology may often be complementary in the sense that the payoff to one type of improvement may depend, to some extent, on the payoff to the other.

NRM improvements combined with additional technology. The importance of the complementarity between NRM improvements and technology is widely recognized in the agricultural development literature. The following statement by USAID's Africa Bureau underscores this importance:

> Natural resource management activities complement other programs in technology development and transfer and in agribusiness and marketing development to lead to increases in productivity and finally broad-based sustainable growth. Consideration of the complementarity of programs in the broad agriculture and natural resources sector is an important programming principal (Africa Bureau, 1992, 30).

As an example, the Bureau notes that "fertile, well-watered soils will be necessary to exploit the full potential of genetically enhanced food crops" (32). In another report, the Africa Bureau gives a specific example of a farmer in Mali who has managed to move out of shifting cultivation by adopting a set of crop-rotation practices that include nitrogen-fixing legumes, substantial amounts of compost, windbreaks to reduce erosion, and such measures as "judicious doses of mineral fertilizer" that permit him to achieve satisfactory levels of productivity on the same piece of land year after year (1993, 25). Encouraging movement out of shifting cultivation is widely seen as a way of reducing incentives for deforestation, thus easing attendant problems of soil erosion and losses of biological diversity.

Use of animal manure to enhance soil fertility is a widely recommended NRM improvement in Africa and elsewhere. The Office of Technology Assessment (1988, 176) reports experimental work in Burkino Faso, indicating that sorghum yields on land that received neither manure nor nitrogen fertilizer were 1,831 k/ha. The addition of 10 tn. of manure per ha, still without nitrogen fertilizer, raised yields to 2,409 k/ha. On land that received both 10 tn. of manure and 60 k/ha of nitrogen fertilizer, yields were 3,591 k/ha. The addition of the fertilizer to the land receiving the manure thus increased yields almost 50%.

The theme of NRM improvements combined with greater use of mineral fertilizer holds much promise for productivity gains runs through much of the literature reviewed. It receives major emphasis in Seckler, Gollin and Antoine (1989). Indeed, they make greatly increased use of fertilizer, particularly nitrogen, as a necessary condition for achieving the high potential they see for mid-Africa. Fertilizer is so important because, in much of Africa, the soils (predominantly Oxisols and Ultisols) are low in natural nutrients. However, contrary to widely held views, these soils have excellent physical properties and can be intensively farmed to give high yields under proper management and enough fertilizer to overcome the nutrient constraint (National Research Council 1992). On the Oxisols and Ultisols, "the key to continuous production is effective crop rotations and the judicious application of lime and fertilizer" (70).

Seckler, Gollin, and Antoine (1989) stress the importance of increased irrigation as a contribution to realizing the productive potential of mid-Africa. Realization of the productivity potential of investments in irrigation typically involves the substitution of higher-yielding for traditional varieties of crops and greatly increased use of fertilizer. Thus, irrigation is a prominent example of the complementarity between improvements in NRM and additional technology.

The literature reviewed strongly suggests substantial productivity potential in more widespread exploitation of the complementarity between improvements in NRM and presently known technologies (e.g., Seckler, Gollin, and Antoine 1989; National Research Council 1992; Office of Technology Assessment 1988). Seckler, Gollin, and Antoine (1989) conclude this with respect to maize, sorghum, and other crops currently grown in mid-Africa. The Office of Technology Assessment asserts, with respect to sorghum, that yield gains "of between 50 and 100% are possible on fertile soils with moderate rainfall simply by using existing improved varieties" (1988, 216).

Antoine reports that a World Bank study in which he participated concluded that, with few exceptions, the productivity potential in existing varieties of maize, sorghum, millet, cassava, and rice was not a problem in achieving substantial yield increases for these crops. "We did a review of all the major crops [those just listed] and for very few were we able to identify severe problems in germplasm" (see Seckler 1993, 65).

Antoine concludes from this that, for Africa, plant breeding to develop higher-yielding crop varieties has been overemphasized and that the real problem is getting the existing varieties to farmers on a sufficient scale and on sufficiently attractive economic terms that they would adopt them widely. Nothing in Antoine's discussion suggests, however, that he believes that research to develop new crop production technologies can be indefinitely downplayed in Africa. The literature reviewed also indicates that eventually [with no clear indication of when "eventually" may arrive] the productivity potential of the combination of improved NRM and present technology would be exhausted, and that continued advances would require development of new technology. In recognition of this, the Africa Bureau states that USAID "... will continue a strong commitment to agricultural research and technology development" in Africa (1992, 32). The Office of Technology Assessment argues that the payoff to increased investment in crop breeding in Africa would be high relative to other development areas because, thus far, the investment in such research has been low in Africa. Seckler et al. (1989), while emphasizing the productivity potential from exploiting the complementarity between improved NRM and existing technology, nonetheless argue that, in time, this potential will be exhausted and new technologies will be required to ensure continued needed advances in productivity. Because of the time lag between the beginning of research and the availability of economically attractive new technology to farmers, the research effort should be expanded without delay.

This brief review strongly suggests considerable potential for expanding agricultural productivity in Africa through more widespread exploitation of the complementarity between improvements in NRM and present new technology. One may note that the review reflected almost exclusively the productivity potential measured by the ratio of traditional outputs, e.g., maize and sorghum, to traditional inputs, e.g., land and fertilizer. Little reference was made to environmental outputs, e.g., improvements in wildlife habitat, or environmental inputs, e.g., use of streams as a dump for farm effluents. This imbalance in treatment reflects both the lack of credible literature dealing with these environmental aspects of agriculture in Africa, as well as time limitations in preparation of this report.

4. Obstacles to Realizing Productivity Potential

Importance of Incentives

Various analytical approaches are used to understand the obstacles to realization of the productivity potential of improved NRM practices and additional technology in African agriculture. For an economist, the most fruitful approach begins by asking two questions: 1)how do the existing institutional and policy structures affect the incentives of farmers to manage their resources the way they do; and 2) how might the structures be changed to strengthen incentives to adopt the higher productivity potential of NRM practices and technologies? The incentives questions are important in understanding why farmers adopt the NRM practices and technologies included in traditional measures of total productivity. The questions are critical to understanding why farmers tend to undervalue the environmental output and input aspects of total productivity.

USAID has developed a framework for analysis of the institutional and policy conditions affecting farmers' incentives to adopt improved NRM practices (Figure 1). This framework can easily incorporate increased use of existing and new technology, as well as NRM practices. An advantage of the USAID framework is that it provides for analysis of conditions affecting the behavior of non-farm actors in both the public and private sectors that, in turn, affect the adoption incentives of farmers. Level 1, for example, includes public and private decisions to invest in research to develop improved NRM practices or new technologies. Level II includes, for example, the effect of land-tenure institutions on farmers' incentives to adopt the fruits of such research.

The brief review of the literature mentioned below suggests that in terms of the USAID framework the critically important conditions for realizing the higher productivity potential of improved NRM practices and additional technology are captured in Levels I, II, and III. It appears that, if the conditions at those levels are satisfied, the wanted biophysical changes (Level IV) and increases in productivity and income (Level V) will follow.

Because the team lacked experience working with the USAID framework, it did not use it to organize its discussion of the literature bearing on farmer incentives to adopt improved NRM practices and additional technology. The team did find the framework useful, however, in thinking about the incentives issue.

Because of time limitations in preparation of this report, the author focuses here on only two categories of obstacles to providing farmers positive incentives to adopt improved NRM practices and technologies: rapid population growth and institutions. Even for these categories, the discussion is far from exhaustive. The intent is to provide the flavor of the arguments in the literature about how population growth and institutions affect farmer incentives.[4]

---

[4] At the time of this study, the team recommended that a more comprehensive treatment of these and other obstacles to more positive farmer incentives be undertaken.

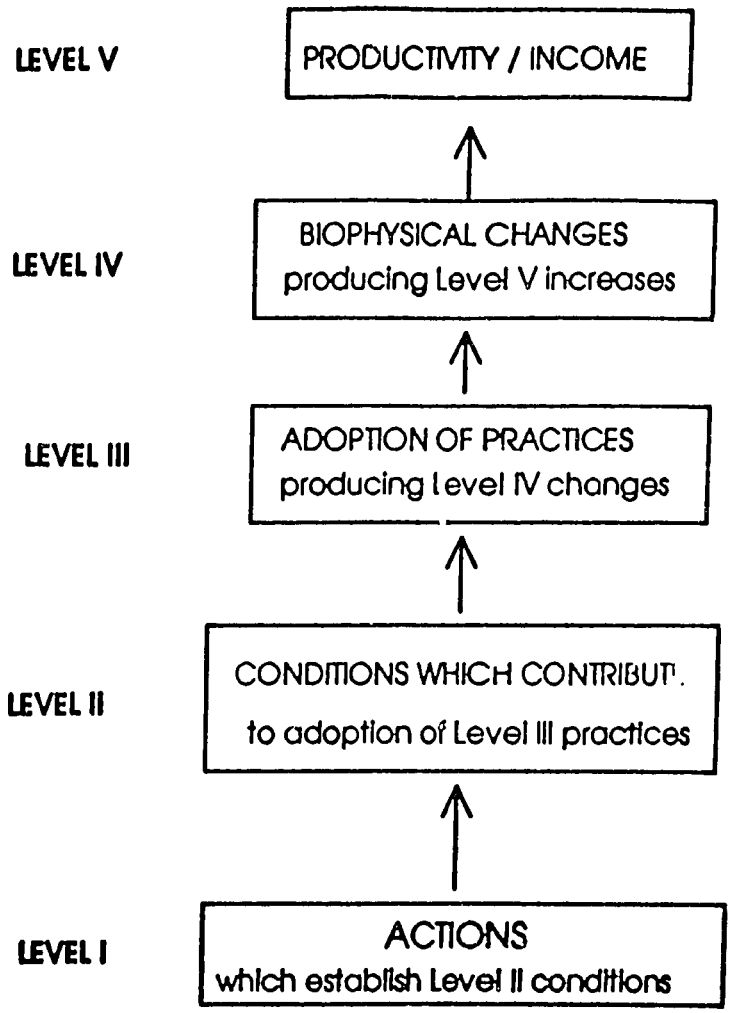

Figure 1. NRM organizing framework

Rapid Population Growth as an Obstacle

Rapid population growth in relation to the supply of natural and knowledge resources is widely viewed as a major cause of unsustainable patterns of agricultural production in Africa. The Africa Bureau (1992), for example, states with respect to its perception of soil erosion as a major threat to sustainability, that "the underlying problem is population growth and increasing pressure on the land, which induces increasingly intensified use of the fragile land resource" (11). A frequently mentioned aspect of the negative consequences of rapid population growth is its effect in shortening fallow periods in shifting cultivation. As the number of people per ha increases relative to the productivity of the shifting cultivation system, farmers are induced to shorten the fallow period to keep more of the land in crop production at any given time. The shortening of fallow then results in declining soil fertility and productivity.

Rapid population growth is sometimes cited as a reason why farmers may be induced to engage in practices that deplete natural resources, even though they may recognize that these practices are not sustainable over the long run, and even though sustainable practices, but with long-run payoffs, are available to them on otherwise favorable terms. In this argument, the necessity of feeding increasing numbers of family members is so pressing that farmers in this situation cannot afford to wait for higher, longer-term increases in productivity that could be achieved by present adoption of sustainable practices (e.g., see Africa Bureau 1992, 39 and the literature cited therein).

Without denying that rapid population growth may sometimes have these negative consequences, the literature suggests that, under some circumstances, population growth may actually encourage a shift from non-sustainable to sustainable systems. For example, the Africa Bureau states that "sometimes the diffusion of sustainable systems is linked positively to demographic pressures. In the Sahel, farmers are switching from extensive to intensive practices in areas where the availability of land has become limited. In some areas, land markets are developing for sites that were once degraded but have been reclaimed. Rwanda has the highest population density in Africa and some of the most intensive farming systems" (1993, 24).

Feder and Noronha (1987) argue that population growth in sub-Saharan Africa, in combination with emerging technologies and commercialization of agriculture, is stimulating shifts in land-tenure systems toward more secure property rights in land, which give farmers incentive to invest in the technologies. Tiffen and Mortimore (1992) found similar processes at work in the Machakos District of Kenya between 1960 and 1980. During this period, Machakos farmers achieved "steep" increases in productivity, even though population growth in the region increased to 3.4% annually, one of the highest rates in the world (Tiffin and Mortimore 1992, 365). The authors found that this high growth combination of productivity and population was achieved without depleting natural resources or seriously damaging the environment. In fact, they report that the most intensive environmental degradation in Machakos occurred in the 1930s and 1940s when population densities in the District were much lower than in the 1960-80 period.

With respect to the effects of rapid population growth on farmers' incentives to adopt improved NRM practices and technologies, the evidence appears somewhat ambiguous. Feder

and Noronha (1987) and Tiffen and Mortimore (1992) suggest, however, that the population growth-innovation relationship is a dynamic one that must be examined over a period of years (probably several decades) to be properly understood. Their and other work not cited here also suggest that the socioeconomic context in which the relationship evolves must also be taken into account. Clearly, the issue needs further investigation.

Institutions as Obstacles

Both public and private institutions are critically important in shaping farmers' incentives to adopt improved NRM and technologies. The literature reviewed strongly suggests that the incentive effects of both types of institutions have generally been negative over the last several decades; public institutions and the policies they have pursued have been especially culpable. Wolgin provides an especially forceful expression of this view:

> Part of what has happened in Africa over the past 25 years has been the total destruction of the capacity of government to do almost anything, and in particular to maintain roads, to do agriculture research, to maintain credit institutions, to do policy. (Seckler 1993, 67)

The view that government institutions and policies create negative incentives for farmers is widely represented in the literature, although the view usually is not as strongly expressed as in the quoted statement of Wolgin. The Africa Bureau, citing a substantial body of literature, refers to the weak management capacity of governments throughout sub-Saharan Africa as a major bottleneck in providing services to farmers. The perhaps extreme case of Uganda is cited as an example "where the tumultuous events of the last 20 years have severely degraded public-sector capacity to carry out the most basic of government functions" (Africa Bureau 1992, 33).

The incapacity of government institutions to provide services to farmers includes, critically, the capacity to do agricultural research and to provide the results to farmers in a timely fashion. Both agricultural research and extension institutions are notoriously weak throughout Africa, a theme that runs throughout the literature reviewed. (Two of the many examples are Office of Technology Assessment 1988 and Tabor, Papafio, and Haizel 1992.)

Where services are provided, it often is with a heavy hand. This is especially true with respect to government management of forest resources. These resources have an especially important role to play in development of sustainable NRM systems because, in much of Africa, farm production of crops and animals is intimately linked with the use of trees. Throughout Africa, forest resources are considered state property or are so treated by governments. In asserting state-property rights in forest resources, forest management agencies typically have viewed their role as the policing of rules and regulations limiting farmers' access to the resource (Africa Bureau 1992, 32 and the literature cited therein). The result, predictably, has been to weaken farmer incentives to adopt improved NRM practices in the many instances where this would involve integrating forest management with crop and animal production.

Land-tenure institutions and their effects on African farmers' incentives to innovate probably have received more attention from researchers than the effects of any other set of institutions. Literature concerning land tenure in Africa is now vast; no attempt is made here to review it in

detail. For a small but reasonably representative sample, one may refer to Feder and Noronha 1987; Migot-Adholla et al. 1991; Barrows and Roth 1989 (and related publications of the University of Wisconsin's Land Tenure Center); Atwood 1990; Seckler 1993 (especially the discussion on pp. 156-57); Tiffen and Mortimore 1992; Africa Bureau 1993; and Biot et al. 1993.

A major thread running through most of this literature is that the widely held view that land tenure systems in Africa are rigidly set and tend generally to weaken farmer incentives to innovate is overdone. The evidence is strong that, in many parts of sub-Saharan Africa, these systems are undergoing substantial change under the pressure of population growth and the emergence of technical and market opportunities for profitable production. Where these conditions exist, local people are finding ways to modify existing tenure systems where these impede seizure of new opportunities. This is happening even in areas where laws and public policies forbid it. The evidence in this respect now seems sufficiently strong to suggest the need for revising the traditional view of land tenure systems in Africa as they bear on farmer incentives to innovate. Without denying that these systems may still impede innovation in some parts of Africa, their capacity to change in a direction favorable to innovation now seems an established fact.

REFERENCES

Africa Bureau. 1992. *Implementing natural resources management policy in Africa: Review of literature.* Office of Analysis, Research, and Technical Support. Washington, D.C.: USAID.

_____. 1993. *Toward a sustainable future for Africa.* Technical Paper No. 5. Washington, D.C.: USAID.

Atwood, D. 1990. Land registration in Africa: The impact on agricultural production. *World Development* 18(5):659-71.

Barrows, R. and M. Roth. 1989. *Land tenure and investment in African agriculture: Theory and evidence.* Madison, Wisconsin: Land Tenure Center.

Biot, Y., P. Blaikie, C. Jackson, and R. Palmer-Jones. 1993. *Rethinking research on land degradation in developing countries.* Overseas Development Group. Norwich, U.K.: University of East Anglia.

Crosson, P. and J. Anderson. 1992. *Resources and global food prospects: Supply and demand for cereals to 2030.* World Bank Technical Paper No. 184. Washington, D.C.: The World Bank.

Feder, G. and R. Noronha. 1987. Land rights systems and agricultural development in sub-Saharan Africa. *Research Observer* 2(2):143-69.

FAO. 1986. *African agriculture: The next 25 years, executive summary.* Rome: Food and Agriculture Organization of the United Nations.

Lamprey, H. 1975. Report on the desert encroachment reconnaissance in northern Sudan: October 21-November 10. UNESCO/UNEP Consultant Report.

Mabbutt, J. 1984. A new global assessment of the status and trends of desertification. *Environmental Conservation* 11(2):103-13.

Migot-Adholla, S., P. Hazell, B. Blarel, and F. Place. 1991. Indigenous land rights systems in sub-Saharan Africa: A constraint on productivity? *The World Bank Economic Review* 1(1):155-75.

National Research Council. 1992. *Sustainable agriculture and the environment in the humid tropics.* Washington, D.C.: National Academy Press.

Nelson, R. 1988. *Dryland management: The land degradation problem.* Environment Department Working Paper No. 8. Washington, D.C.: The World Bank.

Office of Technology Assessment. 1988. *Enhancing agriculture in Africa: A role for U.S. development assistance.* Washington, D.C.: Congress of the United States.

Seckler, D., ed. 1993. *Agricultural transformation in Africa.* Proceedings of the seminar on agricultural transformation in Africa held in Baltimore, Maryland, May 27-29, 1992, pp. 65, 67, and 69. Arlington, Virginia: Winrock International.

Seckler, D., D. Gollin, and P. Antoine. 1989. *Agricultural potential of mid-Africa: A technological assessment.* Morrilton, Arkansas: Winrock International.

Tabor, S., H. Quartey Papafio, and K. Haizel. 1992. *Structural adjustment and agricultural research in Ghana.* Discussion Paper No. 92-15. The Hague, Netherlands: International Service for National Agricultural Research.

Tiffin, M. and M. Mortimore. 1992. Environment, population growth, and productivity in Kenya: A case study of Machakos District. *Development Policy Review* (vol. 10, pp. 359-87).