PD-AAW-252
52006

INSTITUTIONAL CONSTRAINTS ON THE TRANSFER OF AGRICULTURAL AND COMPLEMENTARY RESOURCE-CONSERVATION TECHNOLOGIES APPROPRIATE FOR SEMI-ARID AFRICA

Prepared by:

James T. Thomson, Ph.D.; Alfred S. Waldstein, Ph.D.; and Karen Wiese
Associates in Rural Development, Inc.
110 Main Street, Fourth Floor
P.O. Box 1397
Burlington, VT 05402
U.S.A.

Under AID contract no. PDC-0000-I-00-4104-00, work order 11.

Date: April 1987

CONTENTS

Section		Page
Preface		i
I.	Executive Summary	1
II.	Introduction	9
	A. Illustrative Technologies	12
	1. Response Farming	13
	2. Improved, Drought-Resistant Seed Varieties	15
	3. Alley Cropping	16
III.	Economic Characteristics of Semi-Arid, Low-Resource Agricultural Production Systems	18
	A. Risk Perceptions as Determinants of Low-Resource Production Systems	20
	B. Institutional Possibilities for Risk Mitigation	21
	C. Technological Approaches to Risk Mitigation	22
IV.	Appropriate Technology Generation and Adaptation Systems	27
V.	Political Constraints	36
	A. Central Level	36
	B. Local Level	39
	C. Local Organizations	41
	D. Illustrations	41
	1. Response Farming	41
	2. Improved Seed Varieties	42
	3. Alley Cropping	43
VI.	Land Tenure	47
	A. Background	47
	B. Forms of Landholding	49
	C. Tree Tenure	52
	D. Illustrations	53
	1. Response Farming	53
	2. Improved, Drought-Resistant Seed Varieties	53
	3. Alley Cropping	54
	E. Research Issues	56

VII. Legal Constraints 58

A. Introduction 58
B. Analyzing Impacts of Rules on Behavior 59
1. Authorized Relations 59
2. Authoritative Relations 60
3. Determining Powers 61
C. The Costs of Recourse--Is Litigation Worthwhile? 62
1. Identifying Violations 63
2. Forums 63
3. Convoking Cases 64
4. Arguing Cases 65
5. Enforcing Judgments and Recovering Compensation 66
6. Preventing Recurrences 66
D. Illustrations 67
1. Response Farming 67
2. Improved, Drought-Resistant Seed Varieties 67
3. Alley Cropping 68

VIII. Marketing Institutions and Marketing 71

A. Staple Food Grains 72
B. Perishables 75
C. Industrial Crops 77

IX. Financing Systems 80

A. Staple Food Grains 80
B. Perishables 82
C. Industrial Crops 84
D. Conclusion 84

X. Infrastructure Systems 86

A. General Agriculture 86
B. Staple Foods 88
C. Perishable Foods 90
D. Industrial Crop Marketing Institutions 91
E. Conclusion 93

References 94

PREFACE

Dr. Ken Swanberg, formerly of the U.S. Agency for International Development's (AID) Science and Technology Bureau/ Office of Rural and Institutional Development, developed the basic idea for this concept paper. He viewed it as a vehicle to explore possible problems with the induced innovation theory advanced by Drs. Yujiro Hayami and Vernon Ruttan (1984a). That theory asserts that if an appropriate new agricultural technology is developed, such as the Green Revolution package of improved seeds coupled with high inputs and reliable water supplies, the technology will be adopted by farmers. Furthermore, Hayami and Ruttan maintain that individuals who are interested in fully exploiting new opportunities will develop the institutional changes necessary to support a new technology.

Dr. Swanberg wanted to explore the possibility that institutional constraints might be more powerful than Hayami and Ruttan assume in their model. In particular, he wanted an analysis that focused on institutional problems constraining agricultural innovation in Africa's semi-arid areas. The analysis was intended to treat the full range of institutional constraints, including those associated with the economics of producer units, problems of risk, and facilities to generate and adapt appropriate new agricultural technologies, as well as political, legal, land-tenure, marketing and financial institutions. This paper seeks to provide such an analysis.

A three-person team from Associates in Rural Development, Inc., undertook the task of writing this concept paper. The members of the team and their responsibilities were:

- Dr. James Thomson, ARD senior associate--team leader and responsible for the sections on land tenure, political and legal constraints, and local organizations;

- Dr. Abe Waldstein, ARD senior associate--wrote the sections on credit, marketing and infrastructure institutions; and

- Ms. Karen Wiese, ARD agricultural economist--with support from Dr. Swanberg, authored the sections on economics of institutional and technological mitigation of risk.

I. EXECUTIVE SUMMARY

This report focuses on institutional constraints that may dissuade farmers in the semi-arid regions of Africa from accepting proposed low-resource, low-cost, drought-resistant agricultural and natural resources technologies. It addresses institutional issues primarily from the perspective of individual farmers as potential adopters, rather than the viewpoint of government agencies, extension services or farmer organizations The report is intended to serve agricultural and natural resources project planners, implementers and evaluators as an instrument for assessing the feasibility of particular technologies. In particular, it should help users focus on critical institutional areas where agricultural or natural resources technologies proposed for semi-arid African areas may encounter either resistance or significant interest from potential adopters.

The fundamental issue for individual farmers is whether any new technology will leave them better off given the constraints they face. That is, will the probable gains to farmers of adopting a new, low-resource, low-cost, drought-resistant agricultural or natural resources technology, when appropriately discounted for risk, outweigh the costs of circumventing or overcoming the technical and institutional constraints they face?

To focus attention on this issue, the report proposes a series of frameworks for analyzing potential institutional constraints to be used in evaluating the feasibility of proposed technologies at the farm level. Institutional constraints addressed by the frameworks include those inherent in the microeconomics of existing production systems as well as the generation, adaptation and diffusion of new agricultural and natural resources technologies. Additional frameworks concentrate on the political, land tenure, legal, market, credit and infrastructure systems that often also create severe risks or powerful constraints, but which much of farming systems research does not deal with specifically.

In light of the frameworks, technologies that can be expected to encounter constraints should not automatically be rejected. Further analysis, field experimentation and (quite possibly) policy dialogue will be required to determine whether identified constraints can be eliminated or reduced to a point where farmers find the target technology attractive enough to adopt it.

Most of the farming systems in semi-arid Africa are marginal systems that are currently based on extensive, rather than intensive, methods of crop and livestock production. Most have, at best, impoverished and eroding resource endowments and face

severe pressure from growing populations. Farmers in these systems do not produce a full year's food supply in many years, much less a surplus for market.

The extensive agricultural and natural resources technologies now used in many of these systems further deplete the resource base with each growing season. Some were formerly highly appropriate and economically rational--e.g., regeneration of soil fertility through simple fallowing, with no attempt to ensure regrowth of trees and grasses. However, at present, this and similar techniques are no longer adequate because they do not preserve or rebuild soil fertility rapidly enough in systems where fallows have been drastically shortened or eliminated altogether due to population pressure. Other agricultural technologies, such as animal-traction cultivation, that were introduced during or after the colonial era, wreak havoc with fragile soils if they are not properly applied. Plowing down slopes instead of on the contour is a common example of misapplied technology. Still other agricultural technologies (for example, terracing or intensive cultivation) were used systematically in some precolonial societies, but have since been abandoned for various reasons. Some of these are now being revived with very good results.

The problem of reestablishing resilient and productive agricultural and natural resources systems in semi-arid Africa, that are capable of sustaining growing populations, has two elements:

- stabilization of the existing resource base, and
- intensification of agricultural production technologies.

These can be separated analytically, though in practice, they are inseparable.

Stabilizing the existing renewable resource base--soils, woodstocks, pastures, surface waters and aquifers--is now the first priority. It involves buffering existing resources, especially soils, against further degradation and enriching them, wherever possible. This can be done through the application of water-harvesting techniques, promotion of nitrogen-fixing trees, reintegration or fuller integration of livestock into crop production systems (primarily to increase organic fertilizer inputs and improve transportation capacity) and similar techniques.

Buffering renewable resources against further degradation first requires careful farming systems research to identify the strengths and weaknesses of individual production units in particular geographic settings. This involves microeconomic

analysis of their ability--in terms of resource endowments, labor availability and capital--to incorporate new, low-resource, low-cost, stress-tolerant agricultural and natural resources technologies. It also involves resolving institutional constraints at many critical points that prevent farmers and local people from doing a better job of land-use management and agricultural husbandry. Without better institutional frameworks for land-use management, many of the known and easily mastered natural resources management techniques become unattractive because it is impossible to realize hoped-for results within existing technical and institutional constraints.

The second element involves developing agricultural technologies that will meet basic subsistence needs more reliably and produce a surplus to be sold on local, national or international markets. This includes creating more attractive market incentives for existing or new, low-resource, low-cost, stress-tolerant agricultural crops by identifying new markets, removing unwarranted subsidies of imported food grains that depress demand for local grains, and providing the credit facilities and infrastructure necessary to facilitate and encourage the production of staple grains, commercial export crops and, especially, perishable fruits and vegetables for in-country consumption as well as export, in some cases.

Farmers trying to wrest a living from low-resource agriculture in African marginal environments face many forms of risk. Some are physical, such as uncertain rainfall. Others are biological--e.g., species that ill-adapted to local ecologies and prone to local disease or drought stress. Still others are institutional in nature. Prudent farmers, whose welfare and survival depend on using agricultural and natural resources technologies that keep these risks within acceptable levels, will not easily adopt new techniques which they suspect will fail in their local situations.

Farmers in semi-arid Africa inhabit a very precarious environment and are extremely sensitive to risk in all forms. They prefer to maximize stability of yield, as opposed to yield per se or net income. They are understandably reluctant to acquire farm capital, if it involves incurring debt that may be difficult to repay in subaverage years. They avoid confrontations with authorities over natural-resource and land-use issues that might earn them reputations as troublemakers because they may require support from such powerful patrons in the future to resolve personal, family or drought-induced problems.

Farmers adopt new agricultural and natural resources technologies only when they believe the change will leave them better off. The marginal farmers on the generally poor lands of semi-arid Africa tend to be highly skeptical of new agricultural

and natural resources technologies simply because they lack the cushion of security necessary to take risks, even if the potential rewards for success are high. Judging whether an agricultural or natural resources technology will leave one "better off" is a complex process. Individual users must generally experiment with a technology to fully understand its consequences in their specific, personal production system, as it exists in the surrounding context of institutional regulations and constraints.

Pronounced variability in the biophysical and social systems in semi-arid African regions, and thus, in the technical and institutional constraints and risks inherent in each, means that few technologies will be broadly appropriate throughout these regions. Instead of a single technical package, farmers (even those in quite small areas) should be offered a variety of potentially useful technological options.

It is widely accepted that low-resource, low-cost, stress tolerant agricultural and natural resources technologies cannot be devised and disseminated entirely from the outside, any more than renewable natural resources can be adequately managed without help from local people. Local farmers of both sexes must become entrepreneurs in technology adoption. They should be encouraged, through institutional incentives that promote experimentation and entrepreneurship, to choose and test agricultural and natural resources technologies which seem appropriate to their circumstances to determine whether they are, in fact, suitable.

This report particularly highlights the kinds of institutional problems that farmer-entrepreneurs are likely to face in adopting any new technology. In some cases, it also suggests solutions that might usefully be considered in any effort to design or implement interventions to promote local adoption of new agricultural and natural resources technologies.

It is a truism (easily forgotten) that the agricultural and natural resources technologies which create the least disturbance in established behavior patterns are most easily adopted. A technology that meets this criterion will have the following characteristics:

- technically reliable in the sense that it is stress-tolerant (e.g., certain seed strains, intercropping, alley-cropping) or serves to increase the stress tolerance of associated agricultural technologies (water harvesting, windbreaks, organic manuring);

- requires little additional production inputs (labor, tools, fertilizer);

- can be implemented on existing landholdings;
- unlikely to generate disruptive disputes or only ones that are easily resolved;
- as a condition for implementation, does not involve high transaction costs with other actors, either private or public (for instance, government authorization can easily be obtained to organize a land management unit empowered to make and enforce resource access and use rules, or government permission is not required to prune or cut trees used in agro-forestry applications); and
- a strong, reliable market or auto-consumption demand exists for the product.

A technology that produces results rapidly--i.e., within a single growing season--will be preferred to one which only produces results after a year or several years. Improved, drought-resistant seeds exemplify the former type of technology, while the trees in most agro-forestry operations clearly illustrate natural resources management technologies where results are delayed until the trees mature. Technologies, such as soil-conservation terraces or water-harvesting bunds, that produce observable, albeit modest, results within a year and gradually increase productivity over time will be preferred to those where productivity increases are delayed. Fruit trees used in agro-forestry applications are an example of the latter as they must grow and be properly nurtured and protected for three or four years, at least, before they come into bearing. Further, a technology that produces results directly (e.g., drought-resistant seeds) will be preferable to one which affects output levels only indirectly (windbreaks). If a technology stabilizes yields in a situation where production is decreasing, as windbreaks often do, the prospects for adoption will be reasonable. However, if it increases the output of desired products (crops, forage, building materials), the chances for adoption will be even better.

It is difficult to generalize about which new technologies will create the least disturbance in existing institutions, because institutions vary markedly across very small geographic and social spaces. However, systematic attention at the project planning and evaluation stages to the kinds of factors mentioned here will go a long way toward focusing attention on the issues that are salient for farmers. Since they are the key individuals in the process of integrating new or known technologies into the agricultural production systems of semi-arid Africa, their perspective should be accorded special weight.

This report is organized in 10 sections, including this executive summary. Section II contains the introduction. It presents the problem and outlines the approach to the analysis. This introductory section also describes three technologies that are used to illustrate the report's arguments at various points. These agricultural and natural resources technologies--response farming, improved drought-resistant seeds and alley-cropping--are briefly discussed below.

Section III begins with a cursory review of the economic characteristics of low-resource production systems in semi-arid Africa and then provides a detailed examination of institutions and strategies adopted by producers in these systems to mitigate the very high levels of risk under which they typically operate. Included here is a discussion of the Hayami-Ruttan theory of induced institutional innovation and reasons why it does not apply directly to the situation in contemporary semi-arid Africa. Section IV examines the germination, adaptation and diffusion institutions needed to ensure that existing ("shelf") and new agricultural and natural resource technologies, which are potentially appropriate for use in the low-resource production systems of semi-arid Africa, are effectively tested and adapted to field conditions.

Sections V to X deal with political, land tenure, legal, marketing, credit and infrastructure constraints that frequently impinge on farmers' decision-making about integrating or reintegrating new or known agricultural and natural resources technologies into their production systems. These constraints do not influence adoption patterns for every technology. Market demand for a staple crop may be largely irrelevant if subsistence demand is strong enough. In some production systems, land tenure patterns are both clear and also conducive to investments by those who actually farm fields because they assure them long-term control over improved land, regardless of whether their property claim is freehold or subordinate to some form of group control.

However, other crops will be produced only if farmers can market them because demand exists, credit for inputs is available at attractive interest rates and necessary marketing infrastructures are in place. In most cases, individuals will not terrace fields, plant windbreaks or protect nitrogen-fixing trees on lands they farm if they believe others will either destroy their work or reap the benefits of their efforts. If such constraints exist in any given case, it makes analysis of these institutions imperative in every case. Failure to identify and effectively address possible institutional constraints may doom an otherwise attractive technology to nonacceptance by farmers who clearly see the advantages, but must first deal with the constraints preventing adoption or risks that adoption may entail.

Section V focuses on political constraints. Many of the natural resources management technologies that are highly appropriate for semi-arid Africa are technically simple, but require the capacity at the local level to modify existing patterns of pasture, woodstock, soil and water exploitation. In much farming systems research, the need for the capacity to modify patterns of renewable resource use is often either ignored or assumed to exist at the local level. Thus, this section outlines the background of national and subnational laws, particularly those limiting the ability to take collective action at the local level necessary for more effective land-use management. It indicates how inappropriate laws can drive up the costs of organization to the point where farmers simply cannot adopt certain agricultural or resource management technologies with any hope of success. It also briefly examines the role of producer organizations and suggests why they have been less than effective in much of arid and semi-arid francophone Africa.

Section VI addresses land and tree tenure rules as they influence conditions for productive renewable resource management and agricultural activity in semi-arid Africa. The role of planted trees in establishing usufructuary property rights is a case in point, especially where tenants plant on borrowed lands. Section VII, on legal constraints, presents a framework for the analysis of procedural issues that are likely to arise if disputes arise during the course of adopting or implementing new agricultural or natural resources technologies. This framework is then used to show the types of costs and exposures that technology adopters may have to anticipate if they try to resolve such disputes. The problems of potential uncertainty concerning effective recourse against rule-breakers are highlighted. An example of this type of problem is the difficulty farmers often encounter in the francophone areas of semi-arid West Africa in establishing a property right to trees that they may allow to regenerate in their fields, as opposed to those they plant.

Section VIII deals with marketing institutions. It stresses the highly variable nature of market arrangements that are required as a function of the differing technical profiles of food-grain, perishable and industrial crops. Section IX addresses the issues of obtaining credit, again by commodity subsector, and suggests that food grains require relatively little financing, while perishables demand considerably greater investment. At present, financing is a serious constraint on expansion of the perishables subsector in semi-arid Africa. Industrial crops, insofar as international markets are available and offer attractive prices, are typically financed by para-statal organizations or private-sector companies, so credit poses less of a constraint for these crops. Finally, Section X considers infrastructure constraints and opportunities relative to the adoption of innovative agricultural technologies in the target areas. The main opportunities here are again in the

perishables subsector because these crops are much more heavily market-oriented than food grains. Of particular importance are better food-processing and transportation infrastructures.

The three technologies used to illustrate the analysis of constraints at various points in the report are response farming, improved drought-resistant seeds and alley-cropping. Response farming is an agricultural technique involving the prediction of intra-seasonal rainfall totals sufficiently early in the growing season to allow farmers to adjust their cropping patterns to get the greatest productivity under predicted good, average or poor precipitation conditions. To be effective, this technique requires reliable, long-term, rainfall data and fairly complete information about soil conditions and crop behavior under different soil and moisture regimes.

Improved, drought-resistant seeds are drought-tolerant and adapted to some subset of the highly variable and generally impoverished African soils. Of the three techniques, this one mimics, to an extent, the classic green-revolution procedure of increasing the productivity of seeds. However, it is quite distinct from the green-revolution approach, which emphasizes massive increases in productivity by reducing genetic variability and stabilizing water and fertilizer inputs at high levels. Drought-tolerant seed that improves the probability of some production on poor soils in areas with highly irregular rainfall regimes must be genetically structured to respond positively in production terms despite the high variability and low quality of inputs.

Alley-cropping involves a variety of techniques that associate trees and field crops to improve the overall productivity of a given arable area. Constraints that affect alley-cropping also often impinge on the broader category of what might be termed agro-forestry technologies, such as windbreaks, live fences and the use of trees which regenerate in fields to modify microclimates for crops.

These three technologies concern natural resources management and agricultural <u>production processes</u> and, hence, are used frequently to illustrate the arguments in Sections III to VII. In Sections VIII to X, the analysis of marketing, credit and infrastructure is organized by crop type. The three technologies could potentially be used in production processes for any of these crop types, but do not illustrate the institutional constraints associated with marketing, credit and infrastructure. Rather, it is the different crop profiles of food grains, perishables and industrial crops that structure demand and the technical requirements of processing. For this reason, the analysis shifts from the three illustrative technologies to the three generic crop types in these sections.

II. INTRODUCTION

This concept paper presents a framework for analysis of institutional considerations affecting the adoption of new agricultural and natural resources technologies in semi-arid African environments. It focuses specifically on institutional factors that encourage or impede the introduction and dissemination of low-resource, low-cost, environmentally appropriate, stress-tolerant technologies. The framework is intended for use by those who design, implement or evaluate agricultural and natural resources management projects in the target areas. It should help them more easily identify obstacles to and opportunities for better management of the natural resources base and increased agricultural production in semi-arid African areas.

Dissemination and adoption of new technologies in these environments has proven particularly difficult. They differ sharply from areas in South and Southeast Asia where Green Revolution technologies have dramatically improved outputs. The Asian areas have generally young, fertile, highly uniform soils. Regular irrigation ensures reliable water regimes. By contrast, in most semi-arid African environments, soils are old, depleted and highly variable in composition, even over short distances. Water regimes are based on rainfall and are unreliable in the extreme, by Green Revolution standards. Socio-political organizations, legal systems governing access to natural resources, and judicial, economic and financial systems also vary markedly within small areas. The extent of variability and relative poverty of farmers in these areas make it extremely difficult to apply the fundamental strategy of the Green Revolution. This strategy involved the creation of stable agricultural regimes through selective plant breeding to reduce genetic diversity, high chemical inputs, and adequate, controlled water supplies. Technical packages were backed by relatively effective institutions that ensured reliable supplies of inputs and attractive markets for outputs.

These conditions cannot be met in most semi-arid African rural contexts. The costs of developing Green Revolution packages suitable for the myriad rural micro-environments would be exorbitant. Instead, new approaches must be developed to improve the capacity of African farmers to preserve or enhance the existing resource base and improve agricultural productivity.

These new approaches will involve reliance on low-cost, low-input technologies. The strategy for diffusion will differ from that used thus far in the standard approach to agricultural extension work in Africa. This approach has emphasized the development of standardized technical packages that are assumed

to improve agricultural productivity for farmers who adopt and apply them consistently.

Typically, these packages have been defined in a relatively narrow, technical sense. In a number of cases, attempts are made to promote farmer organization for produce marketing, adult literacy, etc., but extension systems rarely encourage peasant farmers to modify agricultural packages to fit their own circumstances. They rarely provide technical support for individuals willing to experiment with new approaches. Instead, they try to impose uniform technical solutions in environments where the common denominator is variability.

These approaches also generally fail to confront the issue of fundamental variability in decision-making arrangements at local and overlapping levels. Here again, uniformity and simplicity are the watchwords, not variability and complexity. Farmers are most often organized in quasi-cooperatives based on a standardized organizational form and set up by government agents. The same credit systems are applied in all local communities without much regard for varying local perceptions of the risks involved or reliability of these systems in particular local contexts.

Such approaches to the dissemination of new natural resources management and agricultural production strategies have most often discouraged local entrepreneurship in the search for technologies and institutions that are workable and productive in the specific local contexts where they evolve. Some of these have been based on a broad-based, systemic assessment of farmers' needs. In particular, the extension programs organized in the context of integrated rural development programs have assumed the needs for appropriate infrastructure (e.g., farm-to-market roads, crop storage facilities, and low-cost access to export markets); adequate, reliable credit; organizations to represent farmers' interests; adequate, timely supplies of inputs at prices attractive to producers; and literacy (among other things), in addition to appropriate technical packages.

However, largely due to the complexity of interactions between the distinct elements of integrated programs, the general tendency has been to develop, once again, a single, uniform approach and artificially reduce complexity to the point where technical agents and officials can, in theory, plan and guide development. As often as not, some or all elements of the program are inappropriate for many of the farming units contacted. These attempts to impose simplicity on complex environments have neither eliminated nor suppressed persistent real differences.

Other issues must be addressed, including land tenure; decision-making arrangements at a variety of levels, depending on

the particular activity; profit margins and efficiency; and the often limited responsiveness of government agents to local people. Failure to admit the existence of these issues has simply made it increasingly difficult or impossible for farmers and rural people to grapple with them. As a result, proposed innovations are often not economically attractive to peasant farmers in semi-arid areas of Africa.

For all of these reasons, rural people in these regions have shown themselves to be generally uninterested in most such programs and have met determined state attempts to "modernize" their farming behavior with devastatingly effective passive resistance.

This paper analyzes institutional factors that condition acceptance of new technologies. It assumes that farmers in semi-arid African environments are economically rational, i.e., that they will integrate new technologies, which promise to improve living standards, into their production systems if they can do so with acceptable levels of risk. These calculations will involve crude, order-of-magnitude estimates, rather than highly quantified amounts. While it is difficult, for example, to assess the economic value of readily available judicial recourse within a secure system of tree tenure, farmers clearly understand the value of institutions that can ensure low-cost recourse. The analytic frameworks presented here will not address all institutional factors involved in such situations, but they will highlight critical ones in a number of areas.

The term "institution" is used here in a broad, generic sense. It refers to rules that allocate decision-making power among actors (Oakerson, 1987: 17). These rules structure decision-making arrangements in legal, political, financial and economic activities.

For instance, legal institutions include land- and tree-tenure rules, which specify who can make decisions about access to land and woodstocks. The judicial process rules and organizations for enforcement of land- and tree-tenure rights are also legal institutions. Political institutions include all administrative jurisdictions from the local to national level, as well as autonomous and government-sponsored political parties, youth and similar movements, and the rules establishing the terms of organization and action in those units. Financial institutions include banks, credit unions, patron-client networks and formal credit programs. Examples of relevant decision-making arrangements here are rules that determine who will have access to credit and how, repayment schedules and recourse in the event of default. Economic institutions include the economics of production systems, agricultural pricing systems and policies, conservation and production incentives, institutions that deal with risk in semi-arid African rural areas, infrastructure

systems, marketing institutions and markets for input factors and sales of output, and institutions for the generation of new technologies.

A. Illustrative Technologies

To illustrate the application of the framework developed in this paper, three technologies were tentatively identified that are at different stages of readiness for adoption and use:

- response farming--i.e., basing crop selection on intra-year predictions of rainfall amounts and distribution;
- development of drought-resistant seed strains; and
- alley cropping, which reinforces the existing agro-forestry production systems utilized by many African farmers.

Where appropriate, these technologies will be examined from some of the institutional perspectives mentioned above to identify probable obstacles to adoption as well as opportunities for improved dissemination efforts.

Several preliminary points must be made about the use of these examples to illustrate constraints. First, no judgment is made about the state of readiness of any particular agricultural technology. Second, the three illustrative technologies are not used in the sections on marketing, credit and infrastructure institutions. Instead, the discussion there of institutional constraints is organized by commodity type.

The three illustrative technologies vary by area and farming system in their degree of readiness. Response farming, for instance, is a "ready" technology where rainfall and supporting data have been collected and analyzed, and where reliable data collection and processing networks are in place. Where the networks are not operational and data are not available, response farming must be considered a "proven" technology, requiring further efforts to adapt it to local conditions. Similarly, improved, drought-resistant seeds and alley-cropping systems may be "ready," in some local circumstances, arguably "proven" in others, and only potential "future" technologies in a third set of areas where indispensable biophysical experimentation has not been initiated, to say nothing of working through solutions to various institutional constraints. It is also worth noting that technologies can shift from "ready" status back to "proven," and even to "future" status if necessary supporting conditions can no longer be met, e.g., data collection networks break down, new plant diseases arise in an area, economic conditions change, or

political or legal rules are modified, making a technology less attractive to producers.

Second, in the sections on marketing, credit and infrastructure institutions, discussion of constraints and possibilities has been organized by commodity type--staple food grains, perishables and industrial crops. Each has its own set of constraints, determined by the nature of the crop. The three illustrative technologies could be applied to crops in any of the three categories.

1. Response Farming

As a technology, response farming assumes that rainfall patterns in an area are not entirely random, but rather exhibit certain regularities over time. These regularities concern the probable total amount of rainfall and duration of rains in any given season. They can be identified statistically, based on the date of onset of the rains and amount of precipitation accumulated by a given date within the first half of the "normal" rainy season. This date is set after intensive analysis of statistical records. It can be modified over time, as the data set is amplified and refined.

Such statistical analysis depends for its validity on the existence of accurate rainfall records over a relatively long period of time, plus certain other data. Complete sets of rainfall data over several decades for areas where predictions are to be made are probably the minimal data required for this technique to be effective. Such long data runs exist for many areas in Kenya and India. Other data necessary to develop the model for an area include "evaporation rates, soil depth and water-holding capacity, and growth characteristics of the crop influencing water uptake and yield" (Stewart and Hash, 1982: 477).

This technique apparently enables the analyst (Stewart and Hash, 1982; Stewart, 1986) to project the gross amount of rainfall likely in a given season at a point that is sufficiently early to allow farmers to adjust their crop mix and agricultural practices. In practice, the crop recommendations that flow from the system are fairly simple--e.g., it is safe to plant long-cycle crops this year, or late onset and small amounts of precipitation strongly suggest that long-cycle crops will either fail or produce very inferior yields, so switch to short-cycle crops. In addition, shortly after precipitation starts, rainfall amounts become more predictable. Further recommendations about fertilizer application and plant thinning rates then become possible (Stewart and Hash, 1982: 485-89).

Recommendations of this sort could be of considerable value to farmers in African and other arid areas, if they enable farmers to plant crops having the greatest chance of producing some yield or even a superior yield in a given year. If accurate, such recommendations could provide some hope of avoiding famine. They could also allow farmers to develop a comparative advantage in intra-national or international competition by consistently producing somewhat higher yields of marketable crops.

Response farming has reportedly been used successfully over the past few years in Kenya to predict probable precipitation amounts in selected wet and dry areas with a bimodal rainfall regime (Stewart and Hash, 1982). It has also been used to good effect in India under a uni-modal monsoon regime.* In theory, this technology should be applicable anywhere that the requisite historical depth of rainfall data, and supporting evaporation and soil data are available.

This paper explicitly makes no attempt to determine the value of the response-farming technology, but several caveats seem appropriate. If the technique proves effective over time in some areas, this would presumably create incentives for governments or other agencies to gradually improve the underlying data base by annual additions of current information. This could be done by increasing administrative controls, where necessary, to ensure that the highest standards of data collection, transmission and retrieval are consistently respected. The number of data points could be multiplied to ensure greater coverage, within the limits of administrative or private-sector ability to guarantee accuracy. Particularly in uni-modal rainfall regions in the Sahel and in other arid areas along desert edges, rainfall distributions in even limited areas (e.g., the several square miles of an average village territory) tend to be highly variable. The richer the data set in terms of collection points, the more likely that predictions will be accurate for those who may be staking a year's profits or even their lives on the information. As data sets are developed over time for areas that have not been previously monitored, more detailed predictions might become possible.

In West African Sahel, AID, DDA and the World Meteorological Society have provided technical assistance and financed efforts by national governments in the region to significantly improve the rainfall data base. The motivation is twofold--improve the data base for possible future use in the agricultural sector and permit more effective control of river flows in the Niger-Benue Basin.

---

*Personal communication, J. Ian Stewart, Washington, DC, June 1986.

It is not clear whether response-farming techniques can only succeed if the rainfall regime in a target area exhibits some minimum level of consistency, in the sense that similar gross annual rainfall totals do not reflect widely divergent intra-seasonal rainfall patterns. If so, this could be a serious problem in West African Sahel. There, proper distribution (amount and timing) of sub-"average" amounts of rain (14 to 15 inches in an area that nominally receives 20 inches) often produces good to bumper crops, while the average amount, if it is badly distributed in a small number of deluges separated by long periods of drought, can and often does result in disastrous reductions in crop yields or failures. Even above-"average" rainfall totals can produce such disappointing results. Thus, it is not clear whether the response-farming technique is indeed feasible everywhere.

In any case, the more astute local farmers will have no difficulty understanding the idea. Many have been practicing the essentials of this system for a long period, armed only with rough-and-ready data and calculations learned through years of farming in marginal areas. Hence, user demand for this technology should pose little or no problem, if it proves effective in an area, because it reinforces the existing practices of the best farmers. They could be counted on to adopt the technology, although few would voluntarily proselytize its use by others.

2. Improved, Drought-Resistant Seed Varieties

The concept of drought-resistant seeds is already well-known to farmers in some areas. For instance, in Niger in the late 1960s, following a 15-year moist period, droughts increased again in the country's southern arable fringe. Longer cycle crops suffered with the gradual dessication of the climate, aggravated by extensive clearing of marginal lands. Southern farmers acquired and planted indigenous strains of pearl millet, developed earlier along the desert edge some 100 miles further north by local people cultivating grain under the extremely precarious, drought-ridden conditions there. These desert-edge grains were shorter cycle by 30 to 45 days. Yields are smaller than those of long-cycle millet varieties grown under ideal moisture conditions, but the local short-cycle millet survives and produces under arid conditions.

AID has supported a millet improvement program in Niger since the mid-1970s. On condition that varieties produced do not require expensive inputs of fertilizer and other materials, the program should gradually improve the viability of Nigerien agriculture under the currently severe arid conditions.

This paper proceeds on the assumption that the adaptation of seeds to drought conditions is possible and will occur if demand for the crops produced appears sufficient to justify investment costs both of technical development and overcoming existing institutional constraints. How well particular strains are adapted to local conditions at specific sites is a matter for the technicians who breed them and farmers who use them to decide. In addition, how long it will take to achieve any necessary adaptation to local conditions is an issue that this paper does not address. The paper also assumes that farmers know that plant cycle lengths vary and comparative advantage is to be gained by selecting varieties which are best suited to local conditions, whether they be arid, moist or somewhere in between. Thus, diffusion should largely be a self-sustaining process, once there is sufficient stock of a strain in an area.

3. Alley Cropping

As a technology, alley cropping is far more complex and subject to institutional constraints than either response farming or improved, drought-resistant, low-input, seed varieties. Alley cropping consists essentially of the development of tree and crop associations that are mutually reinforcing. Each then improves the overall productivity of the alley-cropped parcel. Trees in these situations may serve as windbreaks which create turbulence in wind currents and slow their velocity to produce microclimates in the alleys that are favorable to agricultural production. They may reduce the impact of violent rains on interplanted field crops and, by providing needed shade, reduce crop evapotranspiration rates, which is critical for plant survival during periods of drought. However, even during normal weather, reduced evapotranspiration may help conserve and increase soil moisture against the inevitable periods of drought.

In essence, alley-cropping systems increase crop survivability. Because tree roots generally go much deeper than those of crops, trees catch nutrients that leach down through the soil out of reach of crop roots. These nutrients are then recycled in the form of fallen leaves and returned to the topsoil as valuable, water-retaining, often nutrient-rich humus. A few indigenous African trees, such as Acacia albida, drop their leaves at the beginning of the rainy season and so provide precious organic nutrients during the early part of the crop cycle. Many alley-cropped trees respond well to pruning and, if lopped during the rainy season, can provide an additional source of green manure.

Trees may benefit from cultivation of the soil and its enrichment by nutrients from decomposing crop residues or the manure of animals attracted to the residues as forage. Cultivation reduces competition with weeds when seedlings are

beginning to grow. It also breaks up the soil surface, slows surface-water runoff and encourages infiltration, thus recharging the aquifers that trees depend on for water in the dry season(s) between rainy periods. Other symbiotic relationships that are not mentioned here may also exist in particular cases.

This example illustrates (in many ways that are explored in detail below) the class of agricultural technologies that are potentially burdened with land-tenure, legal and political constraints. Like windbreaks, soil- and water-conservation technologies (e.g., bunds, terracing and contour cultivation), and fallow and natural-forest regeneration schemes, alley cropping requires long-term secure access and use rights to land and, in many cases, trees. Because these technologies all require high initial levels of labor input as well as regular maintenance and protection thereafter, they only make sense where these issues can be resolved at a reasonable cost, in light of projected benefits. Benefits include not merely the proceeds from sale of the crop, wood, and secondary and tertiary forest products, but also the preservation of renewable resources capital in the form of soils and their fertility, surface and subsurface water supplies, woody biomass and associated forest products.

Agricultural technologies, such as response farming and improved, drought-resistant seeds, are inherently attractive because the legal, political and land-tenure constraints tend to be less restrictive and returns on the investment are more immediate. The more intangible benefits of long-term agricultural technologies--alley-cropping, windbreaks, soil and water conservation--are harder to evaluate. However, without such environment-stabilizing technologies, agricultural innovation in the semi-arid areas of Africa will be much more difficult to initiate and sustain or even impossible. For this reason, careful analysis of institutional constraints that impede the adoption and spread of these technologies is important.

III. ECONOMIC CHARACTERISTICS OF SEMI-ARID, LOW-RESOURCE AGRICULTURAL PRODUCTION SYSTEMS

Modern agricultural production in semi-arid Africa is not completely restricted to indigenous, small-scale, low-resource systems. Significant agricultural production of both domestic staple and export commodities takes place under irrigated regimes and under large-scale mechanized schemes. However, two important points need to be made with regard to these relatively high-input, market-oriented production systems within the semi-arid African context. First, the majority of the rural population is not touched by or involved with such production systems. Second, the institutional and infrastructure support systems that enable such production systems to exist have been developed and maintained by aggressive and expensive public and private-sector investment. Access to these support systems is not typically extended to the small-scale agriculturist.

Thus, semi-arid Africa is predominantly characterized by small-scale, low-resource agricultural production systems. Within this larger grouping are two distinct types of production organization--sedentary and transhumant. Furthermore, within each of these production organization types, a wide range of specific production systems exist. Hence, small-scale, low-resource agricultural production in semi-arid Africa is characterized by extreme heterogeneity. This situation is further complicated because households within each specific production system are linked horizontally as well as vertically to external resources/institutions/organizations. For many reasons and in many ways, the sedentary and transhumant production systems interact with each other at various points along the vertical linkage--essentially fulfilling the role of these external input supply/service and output demand organizations and institutions, which are ineffective, inaccessible or nonexistent in the supply-demand chain. Similarly, the horizontal linkage among like units within a specific type of production system is defined by the functions of the external resources/institutions/organizations along the vertical linkage that are provided from within the group.

These various linkages are important to understand, in both magnitude and direction, if the economics of semi-arid, low-resource agricultural production systems are to be understood. Such understanding is an indispensable prerequisite to successful new technology generation, adaptation, testing, dissemination, adoption and diffusion. That these functions do not exist or are not effectively carried out by the formal (visible) sector of the economy does not mean that they are not provided and effective in the informal sector of the economy. In most instances, functions that do not take place in the public and private business-sector operations of the economy are provided by interactions within

these systems. The underlying rationale for such an informal economic system is, simply stated, the need for survival in such a harsh yet fragile environment.

The heterogeneity of the low-resource, semi-arid African farming systems stems from many factors, such as proximity to urban demand centers, access to transportation, varying ethnic traditions, and agro-ecological parameters.

The homogeneity that exists among such production systems derives from the characteristics that they share. These commonalities, briefly stated, are:

- the objective function being maximized is stability of yield, rather than yield per se or net income;
- agricultural enterprise production undertaken primarily to provide for one's household consumption, while producing a goal-only surplus for the market, is a secondary contingent;
- the majority of farm production takes place on marginal soils under increasingly erratic rainfall regimes and uncertain surface-water supplies;
- the majority of inputs to production are obtained locally;
- farm-family labor is subject to strict cultural definitions of sex and age roles in the various enterprise production activities;
- the overwhelming majority of agricultural-enterprise production, processing and marketing activities are undertaken by women, although men in many West African arid areas play major roles in production and marketing; and
- the majority of these farm households operate outside of the formal economy.

Each of these characteristics provides important economic information in the analysis of the farming system and should not be relegated to the position of an assumption within any methodological approach to semi-arid Africa. Rather, these characteristics form the basis for the development of new methodologies for measurement of productivity of the factors of production (especially labor and capital). They also offer the possibilities for more accurate specification of objectives, constraints, trade-offs and explicit treatment of risk--probably the single most important factor in semi-arid African agricultural production decision-making.

A. Risk Perceptions as Determinants of Low-Resource Production Systems

Farm-level risk in semi-arid Africa emanates from uncertainties inherent in the natural, economic and socio-political environment. Without doubt, climatic variability (heightened as a consequence of spreading desertification) is the largest source of uncertainty and is, in fact, the major determinant of semi-arid production possibilities. Over the centuries, African farmers have responded to this prevailing uncertainty by seeking out ecological niches and establishing farming systems (e.g., multiple cropping, mixed farming and alley cropping) that spread the risk of failure over a number of enterprises with varying growth cycles and requirements. Risks are further mitigated by part-time, off-farm activities--trade, artisan production, participation in urban service and industrial sectors, etc.

While risk in the economic environment is less pertinent to these "subsistence" farmers who operate largely outside of the formal market economy, the inevitable variability of product and input prices nonetheless discourages deliberate surplus production destined for the marketplace. Theoretically, input and product price variability should reflect domestic supply and demand interactions. However, in the majority of African countries, government "mis-intervention" in the marketplace is responsible for much of the price instability. In many African countries where commercial production inputs must be imported (e.g., chemical fertilizers, soil amendments, insecticides, herbicides and improved seed), government has repeatedly demonstrated an ineptitude in management of commodity planning, procurement and distribution. In response to such mis-intervention, enterprising private-sector entrepreneurs turn to black-market distribution channels and cross-border smuggling. Costs of meeting market demand illegally drive domestic prices above what they would be under unfettered market allocation--or supplies simply dry up.

In addition, the majority of African governments respond to the bulging underemployed urban populations with a cheap-food policy that prices consumer staples (and some luxury items) much below the actual cost of production, as well as below the international border price. Thus, for the small-scale, low-resource farmer, the market economy offers highly variable input prices and supply availability and artificially constrained commodity prices (which shrink even further as market middlemen take their share).

Finally, the socio-political risk that small farmers in Africa face today is clearly visible and pervasive. As governments grow, their tendency is toward the establishment of new administrative structures modeled after those that exist

elsewhere in the world. These administrative structures are superimposed on societies, which are already structured by a plethora of complex, indigenous socio-political organizations. Conflict between these superimposed administrative structures and local and regional structures--coupled with mismanagement and corruption--often leads to a situation of serious social unrest and political upheaval. Such an environment must certainly be viewed as reinforcing a subsistence attitude toward agricultural production, all other factors aside.

The conjunction of uncertainties from natural, economic and socio-political sources presents a large number of constraints within which farm management decisions must take place. There are a number of institutional and technological means of introducing change in the farming system while mitigating risks that need to be examined and considered thoroughly by African governments, development donors, agricultural research organizations and farmers themselves.

B. Institutional Possibilities for Risk Mitigation

Dillon has reviewed the literature on market-based institutional possibilities for risk mitigation at the farm level in arid and semi-arid regions (1986). The paper is recommended reading for a summary of current knowledge in this area as well as a comprehensive bibliography. The major points made by Dillon are:

- Market-based rural financial (credit) institutions exist but are typically ineffective and inefficient in meeting demand for credit, especially with regard to the subsistence farmer. This is largely the result of government intervention and attempts at regulation.

- Commercial insurance institutions exist but rarely have anything to offer small-scale, resource-poor farmers.

- National crop insurance programs exist in various countries, but none have demonstrated a capacity for longer term self-sustainability. "Successful" programs require consistent subsidization by national governments.

- Marketing systems are underdeveloped and ineffective in structure, conduct and performance. Were the input supply and product-demand channels and transportation, storage and processing facilities more fully functional, farmers would have more options to sell their marketable product at a price

reflecting their cost of production and profit. They would also be able to obtain the changing range of production inputs necessary to modify production strategies in light of intra- and inter-seasonal climatic variation.

Dillon's review of the obvious private-sector institutional sources of risk mitigation leads him to the conclusion that--due either to inappropriate government intervention or to a complete lack of government intervention--the private sector is constrained. Dillon goes on to recognize that there are legitimate and rational roles and functions that government can and should play or provide, to promote the public good. Briefly stated, these institutional interventions are: meteorological/commodity outlook/extension information dissemination services; subsidization of crop, tree and animal insurance programs; capitalization of a rainfall insurance program; input subsidies; commodity price stabilization; income stabilization; income taxation systems; and capital investment in agricultural support infrastructure (irrigation, transportation, market facilities, rural public works, agricultural research facilities).

In summary, low-resource farmers in semi-arid Africa live with risk as a matter of daily life. Generally speaking, African governments are not yet secure enough to consider nonintervention in the marketplace as a viable government strategy. Thus, institutions that have a theoretical role to play in assisting these farmers to develop risk-management strategies are ineffective, inaccessible or nonexistent. African governments and development donors should continue pressuring for the public-sector divestiture of private-sector market functions as an issue for policy dialogue and an action agenda. The comparative advantage of government is found in its raison d'être--to provide for the maintenance of social and political stability needed for economic growth. In the public domain, government can play an important role in risk mitigation by underwriting the enormous capital cost of national infrastructure development to enable economic growth and to subsidize the costs of generating production and market information that is accessible by the public at large.

C. Technological Approaches to Risk Mitigation

Recent advances in economic theory and research methodology have provided the conceptual basis for agricultural researchers to reexamine the basic approach to new technology generation in semi-arid Africa. One of the most significant contributions was that made by Hayami and Ruttan on induced innovation (1984a). Drawing on empirical evidence of technological change in the United States and in Japan over the past century, they observed

that if changes occur in the macroeconomy which lower prices for factor endowments and increase product demand, then investments in research will be induced to develop higher yielding technologies. That is, technological change comes about through research on the factors of production that lower per-unit cost or, conversely, increase yield per unit of input. However, the research initiative will depend on the existence of strong, effective product demand.

An examination of the development of new, higher yielding varieties of wheat and rice, and the conditions surrounding massive adoption of these technology packages in India and in southeast Asia, provides evidence in support of the model. In the Philippines during the early 1970s, irrigated land was fully under production, labor was fully utilized, and the urban populations provided an effective and unmet demand for domestic rice production. The conditions were ripe for the introduction of new high-input packages of hybrid seed and fertilizer, which produced yield responses far in excess of the cost of the new inputs. Furthermore, the existing institutional and organizational/infrastructure rice-production and marketing support system along the vertical linkage was strengthened by appropriate government intervention to remove risks associated with inaccessibility of input supply at stable prices or instable product markets and prices.

Given the circumstances of high effective demand for output, supportive and responsive vertical support systems, and appropriate institutional change enabled by government intervention, adoption of the new, higher yielding fertilizer-responsive production technologies resulted in a significant production response, as depicted in Figure 1.

Where the farmers had been operating at their profit-maximizing point under traditional production technology, at point A the adoption of new technology caused a major outward shift of the production function, representing a much higher input use corresponding to a much higher output response at point A'. The dashed curve (MPF) is what Swanberg refers to as the meta production frontier (1985). That is, adoption of new production technologies (which act to substitute a relatively cheap input for one facing inelastic supply) will shift the production function out along this path, such that MC=MR at each new combination of inputs.

However, application of the Hayami-Ruttan theory to semi-arid Africa does not yield similar values for the key parameters of the model. We do not find a decreasing ratio of input price (P_x) to product price (P_y). In fact, we find the reverse situation, wherein ineffective consumer demand for staple commodities, in combination with artificially low product price ceilings imposed as a result of a cheap urban food policy and

Figure 1. Production Response to Adoption of New High-Yielding Varieties (HYVs)

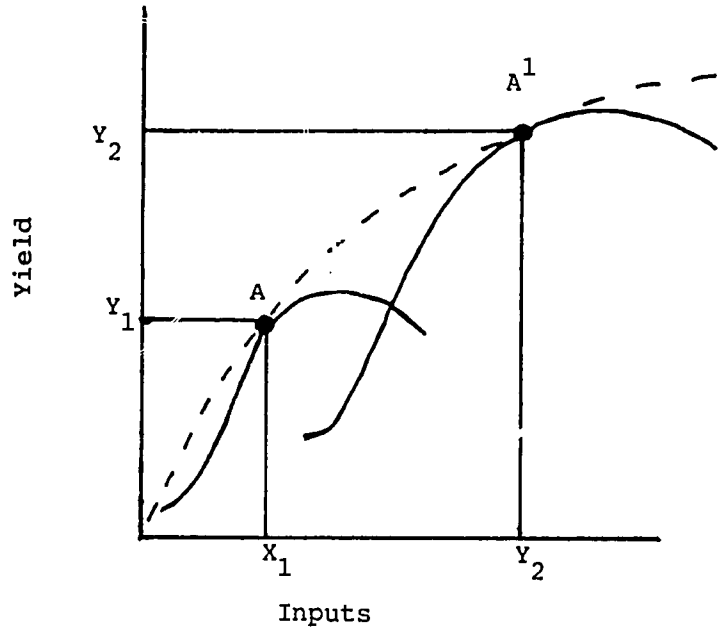
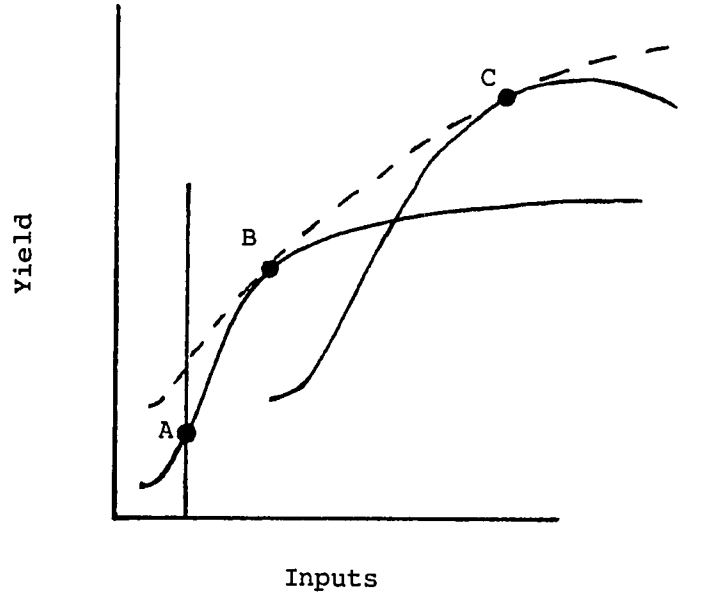


Figure 2. Production Response to Adoption of Improved Management Procedures



— — — Meta production frontier.

ineffectively functioning product markets, results in low product prices. Furthermore, input prices have been high and volatile, especially for imported and petroleum-based inputs.

Finally, the existing institutional, infrastructure and organizational base in many rural areas of semi-arid African countries has not been responsive in making adjustments to agricultural dynamics. In fact, as has been pointed out in other sections of this paper, the incentive structure in most of these African economies has a decidedly urban bias.

What guidance does the Hayami-Ruttan model provide in terms of strategy for new technology development, given the disparities between the economic circumstances of technological change which allowed the embrace of new, higher yielding, capital-intensive technologies in other parts of the world and that which exists in much of semi-arid Africa?

First, Hayami-Ruttan observed that farmers who adopted new, more capital-intensive production technologies were already operating at their profit-maximizing point, where MC=MR. Farmers in semi-arid Africa are probably not now operating at such a profit-maximizing point on their production function because of the resource constraints that they face. This is shown in Figure 2, which presents the semi-arid African farm-production function under traditional technology. The farmers are operating below their optimal point (B) because their access to inputs is constrained (vertical line x_1) such that they operate at a suboptimal point (A) on their production function. It is clear from the figure that without relief from the constrained input situation in which farmers in semi-arid Africa must operate, they can never move to an optimal point on their existing production function. Nor will they be able to adopt new, higher yielding technologies that will shift the production function along the meta production-function expansion path (MPF) to a new optimum, say point C.

In recognition of this situation, Swanberg has suggested a new approach to research and extension organization which embraces the notion that technological advance for this part of Africa must flow from the existing production function. Such advances should be geared toward moving farmers out along their existing production function to the point of optimality, where MC=MR, and then expand iteratively along the MPF.

Although Swanberg's argument seems to carry the proper logic and rationale, there are still many unanswered questions that stem from this suggested reorganization of research and extension with regard to:

- the process of such a reorganization,

- the development of new research methodologies, and
- the inevitable requirements for well-designed institutional intervention supportive of technical change.

The emergence and recent advances made in farming systems research provides some guidance in relation to the questions of process and method.

IV. APPROPRIATE TECHNOLOGY GENERATION AND ADAPTATION SYSTEMS

If the path of technological change within small-scale, low-resource agricultural production systems in semi-arid Africa is to follow an iterative process that moves farmers along their existing or traditional production function to their optimal production and then expands iteratively outward along the MPF, then the first order of business is to create a diagnostic profile of each farming system. The purpose of the diagnostic profile is to determine first the nature of the existing production function and then which resources (inputs) are abundant and which are in relatively scarce supply. Once the factor endowments and production relationships are determined, a process can be set in motion for designing interventions to reduce the identified constraints (Swanberg, 1985).

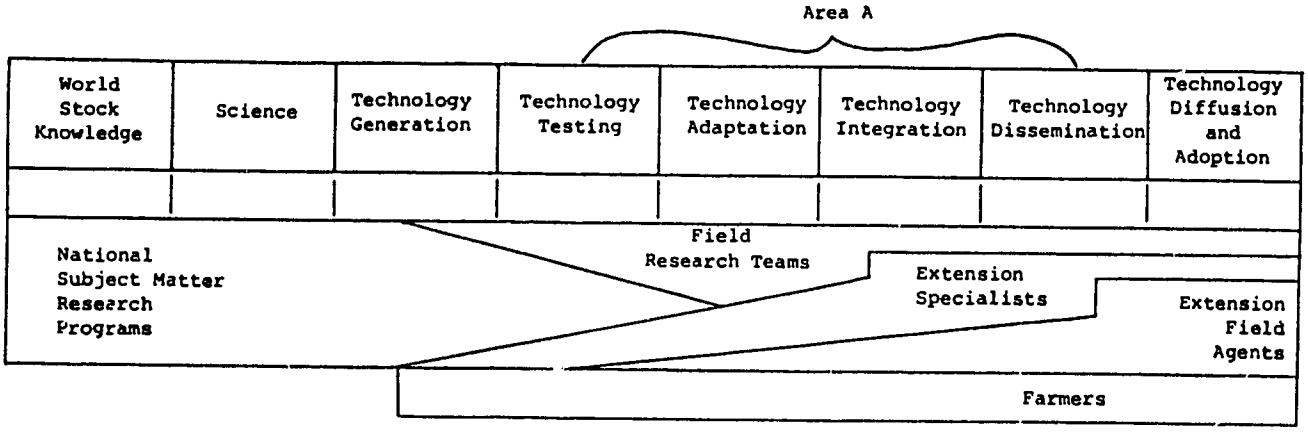
Such a process requires a somewhat different approach to agricultural research than that traditionally followed by the international agricultural research community. Farming systems research (FSR) is a research process or approach that, in the main, takes the objective of conducting on-farm research for the purpose of testing, adapting, integrating and disseminating new technologies for adoption by farmers. FSR, in combination with strong commodity research, offers an increased potential for improving the productivity of the whole farm system and thereby improving the welfare of the adopting farm family and ultimately the larger national economy. FSR, as a research approach, has emerged in response to increasing recognition that the existing national agricultural research systems have been functioning ineffectively in terms of appropriate technology development. Such ineffectiveness has been attributed to:

- an observable lack of understanding of farm production systems in which new technologies are expected to perform; and

- a failure to evaluate the performance of newly developed technologies by the criteria of those systems and the farmer decision-maker.

Figure 3 presents what McDermott conceptualizes as the technology innovation process in agriculture. As suggested by the figure, FSR is regarded as an integral part of the larger research, development and diffusion process.

Figure 3. The Technology Innovation Process in Agriculture



Adapted from J. K. McDermott, "Farming Systems Support Project, VITA-CAR Team Notes," 10/19/84.

Research is commonly associated with science in the search for new knowledge. In this sense, research is an abstract analytical process that seeks to control all independent variables so that new knowledge can be gained regarding the dependent variable.

Technology generation is a creative function wherein something new is conceptualized, designed and put together. Technology is usually generated on an experiment station. The reductionist approach (the "scientific method") is used and, thus, performance can be hypothesized. It is important to note that not all technology generation occurs within any given national system. There is heavy borrowing from other national and international research systems, e.g., the world of stock knowledge.

Technology testing is the testing of a proposed, promising technology for performance. Often the first test (screen) will be on the experiment station. If we keep in mind that a technology will be of value or use only in relation to a production system, such initial experiment station screening is not enough. The new technology must be tested in the system in which it is expected to perform and against the performance criteria of that system. If the public system does not perform during the second-phase testing, then either the process stops or some other entity will pick it up.

Technology adaptation is the function of adapting a technology, which has been tested (and works) in one specific production system, often with minor modifications, so that it performs to standard in other relatively similar systems. This is a very important function from an economic point of view in that, to bring costs and benefits in line with management

expectations and criteria, it is necessary to enlarge the range of sites in which a technology will serve. The need to adjust technology to a range of sites requires extension specialists to be active participants in the technology development process.

Technology integration is a function with multiple aspects. Technology itself is an integration of performance characteristics with other technologies into a single new technology, which must then be integrated with other technologies in the production system. Sometimes a technology is embodied in a commodity that can only be adopted into the production system if larger systems that serve the production system change accordingly, e.g., market distribution systems. It is important to realize that even in the "earlier" stages of technology generation, integration problems can be anticipated, will be important in designing and generating the new technology, and will provide some of the criteria for testing and adaptation. New technologies must be integrated into both the bio-physical production environment and the "agri-milieu" of markets, consumer acceptance, storage capacity, etc.

Technology dissemination is an extension function that requires a conscious, active promotion campaign for the new technology. Although "dissemination" is often used interchangeably with "diffusion," there is a major distinction to be made. One of the most common dissemination techniques is the extension demonstration. Extension field agents and, in some cases (where existing and functioning), other state, para-statal and private-sector agribusiness entities do most of the actual dissemination. It is necessary, therefore, that these dissemination agents be familiar with the new technology. When a national extension service is doing the dissemination, there must be extension personnel--who have participated in the technology testing, adaptation and integration phases--working with the field agents and supervising the farmer-agent demonstrations.

Technology diffusion is a dynamic social process that occurs in every community through farmer membership in various social systems--family, neighborhood, church, civic organizations and cliques. It is a natural process, the dynamism of which emphasizes the importance of working with farmers throughout the technology innovation process.

The objective of FSR is to raise the efficiency of the whole farm system. The FSR task is to identify potential technologies that will increase the productivity of a particular commodity/enterprise or even subsystem, but not lower the productivity of all other subsystems within the whole farm system. This whole-farm-system orientation places great demands for information on the research team, with implications for the types of activities that must be undertaken and the disciplines needed for the research effort.

FSR embodies certain characteristics that differentiate it from so-called conventional on-station research. These characteristics are:

- farmer participation in the research process;
- multidisciplinary research planning, design, conduct and evaluation;
- holistic approach to research problem identification, prioritization and technology evaluation;
- problem-solving research orientation; and
- reduction of natural heterogeneity of farming systems to homogeneous groups for both research and extension purposes.

FSR involves five successive research stages--reduction of natural heterogeneity, description/diagnosis; experimental design; technology testing; and extension. Two points should be made with regard to these research stages. First, there is a great deal of iteration of activity between and among the stages. Second, information feedback is an important element of FSR and is usually obtained by involvement of the farmer in at least the diagnostic, testing and extension stages.

While there are several variants of the FSR concept in practice, it is suggested that on-farm research with a farming-systems perspective (OFR/FSP) is the closest to what is required of African national agricultural research organizations in order to develop appropriate new technology under semi-arid conditions. OFR/FSP begins with the collection of just enough information on the farming system to define the research necessary for step-by-step modification and improvement of the farming system. Most of the research conducted in this style will be on-farm, recognizing that technologies intended to change the performance of the particular system need to be adapted to the circumstances of their farmer users.

Probably one of the most important characteristics of FSR is the insistence that farmers, for whom research is being conducted, must be involved in the research process. Many events and ideas have contributed to this reorientation in research procedures. For many years, it was widely assumed that small farmers were a homogeneous group of inefficient producers, bound in ignorance by the forces of tradition. However, over the past 15 years, research results from all areas of the developing world have shown that:

- small farmers are economically rational in their decision-making regarding resource allocation;
- their objective is not necessarily profit maximization;
- risk and uncertainty are dominant forces in their decision-making;
- the nature of these forces are primarily determined by the economic and natural (bio-physical) circumstances of the individual farmer; and
- the economic and natural circumstances that dictate the type of farming system are widely diverse, even within relatively small geographic areas.

Research scientists have come to recognize that if they are to be successful in developing technologies for adoption by small farmers, they must first come to understand those farming systems, and then evaluate the performance of new technologies against the criteria of those systems. The farmers must be involved in the problem-identification phase to the extent that they give the researchers a sufficient understanding of the whole farm system, the problems they have in increasing the production and productivity of any particular subsystem(s), and an indication of the priorities for problem-solving.

Similarly, the farmer must be involved in evaluation of new technologies designed by researchers to solve farm production problems. Such involvement provides the researchers with information regarding the appropriateness of the technology and its acceptability to the farmer. Also, in cases where problems arise concerning appropriateness and/or acceptability, the farmer provides essential feedback. This feedback can be important not only in improving the "fit" of a particular technology to a particular system, but also in guiding future experimentation and dissemination efforts.

If we accept the need for improved understanding of small-farmer decision-making, in terms of their perceptions of risk and uncertainty as conditioned by economic and natural (bio-physical) circumstances in which decisions are made, then multidisciplinary research is critical to OFR/FSP. At an absolute minimum, multidisciplinary research in the OFR/FSP context demands the collaboration of a research agronomist and an agricultural economist in all of the activities of the research cycle (e.g., site selection, diagnosis, design, experimentation and testing). Norman (1980) has characterized the underlying determinants of any farming system as technical and human, with the human element including both exogenous and endogenous factors. He claims that the technical and exogenous human factors are beyond the control

of the individual farmer. Thus, farmerS will make decisions regarding resource allocation within the farm system according to their perceptions of the constraints imposed by those exogenous human factors. Whereas it is the task of a physical or biological scientist to modify the technical environment to provide the potential for improvement of the production system operating in that environment, OFR/FSP practitioners claim that the technical perspective is not enough. Collinson (1982) states that the most important contribution of the agricultural economist is in providing an understanding of how and why, in managing their farms, farmers will compromise on the optimal technical management of any one enterprise to raise the productivity of the whole system. Thus, a collaborative, multidisciplinary research effort can provide the combination of perspectives and abilities to understand both the technical and human determinants of any given farming system, and thereby provide the possibility of modifying constraints, resulting in the improvement of the whole farm system.

The research approach recognizes the importance of the underlying technical and human determinants of any particular farm system as constraints to increased efficiency of that system. Therefore, OFR/FSP focuses on the interrelationships and interdependencies between the technical and human elements and, as such, is more holistic than conventional agricultural research. In general, the term "holistic" is used to mean bringing a broad understanding (obtained from both primary and secondary data) and appreciation of technical and human elements that constrain the various on- and off-farm production enterprises to the problem identification, research prioritization and technology evaluation activities of the research process.

OFR/FSP must have a problem-solving orientation. As pointed out earlier in this section, this is not "scientific" or "basic" research. Rather, OFR/FSP involves technology testing, adaptation and integration (with a varying role in dissemination). The important point here is that research is not undertaken to generate knowledge for the sake of knowledge. Knowledge that is generated through OFR/FSP is applied to production problems of a specific farming system to raise the overall efficiency of that system, as perceived by the farm family, according to its goals.

Once we assume that the economic and natural (bio-physical) environments in which farmers must operate are the most influential forces in their decision-making regarding technologies to be used in production, it is also important to recognize that there is considerable heterogeneity in small-farm agriculture. Technologies must be tested, adapted and integrated into production systems of small farmers who may produce the same commodities but have different preferences and operate in

different market situations. One of the first research activities, therefore, is to reduce the "universe" of heterogeneous farming systems to a set of relatively homogeneous subgroups. The disaggregation is done first in terms of agro-ecological systems or differences in the technical element, then in terms of differences in the human element. The research process can then proceed, depending on development priorities of the national decision-makers and the research resources available.

OFR/FSP recognizes that experiment station results are by no means always predictive of the experience with a technology at the farm level. The objective of OFR/FSP is to create a stepwise modification of the farming system. The activities of this research approach include data collection; data analysis; information feed to "external" organizations, delivery and support systems; on-station experimentation; on-farm experimentation; technology evaluation under farm management; and dissemination.

OFR/FSP offers national research organizations an effective approach to the identification of farm-level constraints and an opportunity to select, test, adapt and integrate new production technologies into an existing farming system. However, OFR/FSP relies to a large extent on the existence of a "shelf" of ready or proven technologies, and this shelf of technologies needs to be known and available to on-farm research teams. At present, this certainly is not the case in most African countries, as government budget and professional agricultural research resources are stretched beyond the limits of effectiveness. Much of this apparent lack of ready or proven shelf technologies is a function of ineffective regional and international dissemination of information. However, the problem is also associated with a somewhat overzealous focus--at both the national and international levels--on the development of "miracle technologies" that will shift the production function outward, rather than following a more iterative approach to technology generation and adaptation. Regardless of the fact that the shelf of technologies is not well known, such technologies do exist, and they await the selection, modification and adaptation process.

The so-called "ready" technologies are those which have been tested against biological, socioeconomic and institutional constraints and have been demonstrated as acceptable to a certain set of farmers and adopted into a certain restricted grouping of farming systems. Intercropping systems, such as alley cropping, are examples of such ready technology. Alley cropping is a production technique that requires growing two or more crops simultaneously in rows. Where a leguminous species is intercropped with a cereal crop, production improves as a result of reduced risk of disease and weed and insect infestation,

increased soil fertility and stabilization, reduced water runoff and soil erosion, and increased yield, to name a few. One of the most successful ready technologies is intercropping of Leucaena leucocephala with various cereal and leguminous species. In such a production system, the food crops are grown in "alleys" formed by hedgerows of trees. This technology has been developed and adopted by farmers in some parts of semi-arid Africa as a greatly improved method of maintaining soil fertility, as compared with the traditional practice of fallowing the land, in some cases for as long as 20 years. Beyond the obvious benefits of the establishment of a sustainable perennial production system, the farmer also benefits from the off-take of the leaves, the branches and eventually the wood itself. Much has been written recently on the subject of alley cropping with Leucaena that need not be discussed here. What is important is to recognize alley cropping as an example of an improved production technology that awaits dissemination.

"Proven" technologies are techniques or improved production inputs that have been demonstrated as technically suitable for integration into existing farming systems, but which either fail or have not been tested against socioeconomic or institutional constraints. "Response farming" can be viewed as such a proven technology. Response farming is the introduction of meteorological information into the farmer's decision-making process. Certainly in semi-arid Africa, where many of the critical crop-production activities such as final seed-bed production and planting depend so heavily on rainfall occurrences, the widespread dissemination of such meteorological data (e.g., weather reports on the radio) would be of tremendous value to farmers in helping to plan and would thus reduce the risks of crop failure due to lack of appropriate soil moisture for seed germination and growth. While it is true that meteorological data collection provides a critical information input to farmers in many of the more developed countries, such technology has not yet been introduced into most African countries because of economic, infrastructure and organizational constraints. The technology depends on the accumulation of large sets of longitudinal data that will require African governments to allocate financial and human resources to the task and to create the infrastructure and organizational capabilities that make such dissemination of public information possible.

There is a third category of production technology--"future" technologies. Future technologies are known technologies that face biological, socioeconomic and institutional constraints. An example of a future technology would be the development of new high-yielding, drought-resistant sorghum or pearl millet varieties. In semi-arid Africa, these two cereals are the dominant food crops because they are relatively more tolerant of low soil moisture conditions than are other cereals. However, yields of sorghum and pearl millet in Africa are, on average,

only one-fifth of yields in Central America and India, respectively.

It has been demonstrated that varietal improvement (genetic change) is responsible for approximately one-third of production increase, whereas the greatest contribution to production comes from agronomic and management factors. Furthermore, plant breeders and agronomists seem to agree that, where farmers operate under the yield-stability objective function (rather than yield maximization), the first limiting component to higher yields often is not variety, but agronomic factors. Examples of these agronomic factors include soil moisture management, nutrients, timely planting, and weed control (Andrews, 1986). However, given that varietal improvement does significantly contribute to improved yield and considering the time factor involved in genetic improvement, development of such improved varieties should be continued. The international agricultural research centers and other breeding research programs (such as conducted by INTSORMIL) will be best suited to this task, given the limited resources of the public-sector research organizations in Africa and the relative comparative advantage of the latter group in carrying out OFR/FSP in an attempt to improve small-farm production through the introduction of ready and proven technologies.

In conclusion, the emergence of on-farm research conducted with a farming system perspective has provided African research organizations with a viable and more practical approach to carrying out their mission of technology generation and adaptation. If, as a result of appropriate retraining of agricultural researchers <u>and</u> improved international and regional information dissemination regarding the existing shelf of ready and proven technologies, perhaps farmers in semi-arid Africa can move toward their optimal production point. However, the assistance of agricultural research organizations to small-scale, low-resource farmers who are shifting their production function out along the MPF will be limited without well-designed and specifically targeted institutional change in support of each new innovation.

V. POLITICAL CONSTRAINTS

This section analyzes the political constraints that may create incentives for or against adopting improved agricultural technologies in contemporary semi-arid African areas. Section V.A addresses problems of political organization that occur in semi-arid areas, as well as in Africa in general. These problems stem primarily from security concerns and the nation-building agenda of the leaders of African states. Implications, in terms of centralization of authority over organization, taxation and expenditure decisions, are then examined. In the second part of the section (V.B), the analysis follows these implications through at local levels and suggests general constraints impeding better organization there. Included here is a brief discussion of the costs of organization. Finally (Section V.C), examples based on the three agricultural technologies illustrate the impact of political constraints on the introduction of new techniques.

Political constraints are often subtle, imprecise in nature and exceedingly difficult to quantify. They create incentives against activities necessary to make new technologies attractive to peasant adopters, but often only indirectly. For all their ambiguousness, however, they can profoundly influence farmers' calculations about the value of new technologies.

A. Central Level

The regimes that control the semi-arid areas of Africa today are generally weak governments. They lack material, monetary and manpower resources. They may face opposition from ethnic, corporate or class groups. As a rule, they fear overt expressions of political discontent. In consequence, these governments tend to control political organizations very tightly (Zolberg, 1966: 42-47).

In most African countries, the civilian successor regimes that replaced colonial administrations established one-party states after independence and outlawed opposition parties. Most were later overthrown by coups and replaced by military regimes.

Officers generally justify their attacks against civilian regimes by pointing out that civilian politicians have been guilty of corruption, mismanagement and abuses of power. On taking control, military governments usually ban all politics and, with it, political organizations. Most military regimes begin operation by publicly asserting that economic action is essential and political organization superfluous. They fear and resist political organization because officers are trained to

view organization in the "enemy" ranks as a sign of dangerous potential to oppose, resist or confront (Decalo, 1976: 24-32).

In the francophone countries, this orientation of military regimes builds on the authoritarian traditions of the French colonial era. French colonial officials sought by all means possible to control public activity within their jurisdictions. They saw rigorous control as the means to prevent anticolonial revolts by disaffected ethnic groups. This danger, which was quite real, continues to weigh in the thinking of many francophone military men turned politicians. At the same time, control reduced the likelihood of sporadic disruptions of the public peace by small organized groups struggling with each other over control of resources, and it sapped the capacity of the population to resist colonial tax collection, military and labor recruitment activities. Controls over economic life and the press were likewise quite rigorous in francophone countries (Hargreaves, 1967: 136-37; Morgenthau, 1964: 1-6).

In the anglophone group, greater reliance by colonial officers on indigenous power structures--and indeed their sustained attempts in many countries to reinforce those structures--created the basis for a somewhat more open political tradition (Hargreaves, 1967: 139-42; Noronha, 1985: 15). Organization is not automatically viewed with suspicion by state officials. Military and civilian regimes have been hostile to a free press, but in some countries, such as Nigeria, they have had great difficulty in reining in a long-standing tradition of lively journalism. No judgment is offered here on the merits of either approach. It is simply noted that stronger countervailing powers exist in some anglophone countries than in most of the francophone group. These powers take the form of local political organizations or indigenous political structures that are much transformed and often far more powerful economically than they were at colonization.

Eventually, most military regimes feel the need to set up their own "popular" organizations. These quasi-governmental organizations are intended to serve as channels of communication with the population and ensure more effective controls on local activity. Once regime-approved institutions are established, any organized activity that occurs outside these institutions is, by definition, illegal. But such "apolitical" organizations almost always remain the creatures of the regimes that create them. They do not serve as vigorous two-way communication channels, by which local people can inform their leaders of local problems and desires, or objections to national policies. They are not meant to serve as organs of political pressure--the important decisions have already been taken at the national level. Despite lip service to the contrary, these regimes are thus not usually much concerned to inform themselves about conditions in local areas, or to act on suggestions from those levels (Decalo, 1976: 33).

Under these circumstances, it is costly--in time, money and effort--for most local people to secure changes in national rules that affect them. Rural farmers, for instance, are hardly likely to propose changes in extension systems or forestry codes when to do so they must either try to work through the system of government-controlled organizations, or take the risk of acting outside the approved framework. They are too exposed to eventual reprisals by officials or powerful, well-connected individuals who might resent their efforts to change the status quo. If there existed legitimate opposition parties strong enough to protect those who openly dissent from regime positions, criticism and lobbying to change existing policies would be more common. Currently, however, and with exceptions, such as Senegal, the game is usually rigged against it (Zolberg, 1966: 93-127).

Fiscal policy in many African states is driven by central government concern to gain control over as many productive tax sources as possible. The kind of economic planning pursued by many of these governments, military as well as civilian, in the first two post-independence decades supported centralization of both revenue collection and expenditure decisions, particularly in francophone areas. This continued colonial practice and, in theory, permits central governments to deal more effectively with problems such as revenue mobilization, foreign debt management, infrastructure investments, resource exploitation and security concerns.

In consequence in many rural places it is illegal, or extremely difficult, for local people to collect taxes. In many ex-French and ex-Belgian states, if local jurisdictions are authorized at all to impose taxes by collective decision, they are usually limited to the least lucrative tax bases (Cochrane, 1983, p. 5). Central officials, often with little input from local representatives, decide on tax bases, allocate them among jurisdictions, and fix tax rates.

While local officials may be involved in tax collection operations, funds collected must be transmitted in whole or in very large part to the central treasury. Local people cannot earmark proceeds of specific tax bases for specific operations they judge beneficial. Local people know that they cannot control tax monies once they are turned over to the national administration, so they resist national levies. Resistance is muted--it does not often take the form of outright refusal to pay taxes. Instead, taxable activities and items (trade figures, amounts of land owned, number of family members or livestock owned) are consistently underreported. This seriously reduces taxes produced from the base in question.

Central officials also make expenditure decisions, again frequently with little effective village-level input. Top government officials are generally aware of this, because

inappropriate investment decisions are made so frequently. Despite their efforts to force central and regional civil servants to pay more heed to local advice and desires, allocation decisions continue to be highly centralized.

B. Local Level

To ensure that people behave in desirable ways--respecting resource use rules, paying their share of costs involved in provision of public services, etc.--there must be institutions to make, modify and enforce collective decisions. Rules do not enforce themselves. People must do that, and the activity takes time and resources. Leadership and day-to-day operation of institutions likewise require regular human effort.

Who will support these costs? This is a critical but regularly overlooked issue. It is often assumed, for instance, that local units of government at the hamlet, village or district level can shoulder these additional burdens. It is even more frequently assumed that "the villagers" will do it. Such feckless solutions to complex issues beg too many questions and should never be allowed to pass unchallenged.

The dilemma is this: If a local government accepts an additional burden without a corresponding increase in revenues (own source, e.g., taxes or user fees; donations; or grants from other governing agencies), either local officials will agree to work more for less, or--as is more likely--the job will be done badly or not at all. If "the villagers" agree to do the task, but no firm provision is made to support costs--through labor contributions, new rates or grants by outside agencies--then implementation of the activity will depend on voluntary inputs. Voluntarism may work if volunteers receive separable side payments through participation in the activity. It is often thought that social prestige is associated with community service, but that may well be problematic over the long run. Volunteers ultimately recognize that others are riding free on their efforts. To avoid earning a reputation as pushovers by continuing to volunteer (rather than winning the social prestige that outsiders like to believe is associated with voluntarism, because it simplifies the knotty problems of institutional support), volunteers cease to participate.

While the benefits to be derived from political power at the national level generally justify risks and costs of organizing to win and maintain control there, political action may not be so profitable at the local level.

The rig, or bias, of the game at the community level, against the backdrop of overlapping political and administrative systems, strongly affects local people's sense of whether

organized collective action makes sense in any given instance. The term "rig of the game" refers to the way the local, working rules of politics bias outcomes. If rural villagers know from experience that local officials will take their interests into account in making decisions (generally because villagers have low-cost, formal or informal means to express dissatisfaction and to veto officials' initiatives of which they disapprove), then they may be willing to commit themselves to necessary collective action. If, on the other hand, people believe that decisions are likely to be biased--and that they will systematically give an advantage to one set of local people at the expense of others--those who stand to gain will support collective action, and those who stand to lose will resist it if they are able. This is frequently the case in mixed ethnic communities, in those where factional strife is persistent, or where caste and class systems empower some groups while reducing the influence of others--or depriving them of political power altogether.

In the former case, power can be exercised at the local level subject to effective checks and balances. This tends to ensure that collective action will leave most people in the group or jurisdiction better off in the long run. Thus, proposals for collective action will be judged on their merits. By contrast, where the rig of the game is strongly in favor of some at the expense of others, those who expect to suffer from political decisions will generally seek by all feasible means to resist or impede collective action. Their desire to resist does not guarantee success, however.

Those who lack power may resist any sort of collective action, even policies and activities from which they might benefit in the short-run, on the grounds that any successes will simply strengthen those who already dominate. Those wary of the outcome of any competition for power--which they might win, but equally might lose--may also consider agreeing to collective action too risky.

These concerns are heightened by other considerations. Controlling public funds is difficult in polities where competition among ethnic or kin groups can be intense for access to lucrative positions in the civil service, military and political organizations. Many local people are not interested in authorizing local taxation because they believe themselves incapable, under prevailing political conditions, of controlling use of the funds. Rather than see tax monies disappear through corruption and embezzlement, they would prefer to do without additional services. This often discourages creation of the institutional infrastructure necessary to establish conditions conducive to adoption of new agricultural technologies.

C. Local Organizations

Local organizations that can successfully defend rural producers' and consumers' interests do not exist in many parts of semi-arid Africa. This is particularly true in the francophone countries. Reasons for this apparent dearth of local organizations have just been outlined:

- fear by central-government officials of uncontrolled opposition at local levels, which leads to suppression of most autonomous groups;
- capture by central regime forces of the remaining ones through legitimization only of government-controlled organizations;
- concentration of taxing and spending authority at the central level (a policy strongly supported by the IMF) so that local groups, even where they do enjoy taxing authority, have few productive tax bases they can tap; and
- in many local communities, skepticism about fairness of the political game at that level and resistance to authorizing policies, actions or taxes that might give opponents even more power than they have now.

These reasons explain to some extent why local organizations that might defend or promote producer interests are so rare in much of semi-arid francophone Africa. Their relative absence constitutes a major constraint on potential producer initiatives to secure agricultural credit, arrange agricultural input supply for themselves, and bulk and market crops. These problems add to the difficulties caused by national policies and practices that sharply restrict the operational power of local jurisdictions.

Local organizations are more prevalent, and play more important roles in local life, in many parts of semi-arid anglophone Africa, e.g., Kenya, Sudan, and the northern tier of states in Nigeria. Just how effective these organizations are in assisting with agricultural technology transfer remains to be determined. Future operational research efforts should be directed to fuller exploration of this issue.

D. Illustrations

1. Response Farming

Response farming should encounter few direct political constraints at the local level, simply because it does not

require collective action there. If predictions are broadcast regularly over public radio or television stations, individuals may use the information if they wish. Constraints, in terms of planting crops adapted to local farming conditions and projected moisture totals, will occur instead because of inappropriate financial and marketing institutions.

At the national level, the major potential constraints will concern capacity to collect reliable rainfall data and access to air time in a reliable media network to broadcast the information at times when the target audience is likely to listen consistently. If radio and television programmers judge rainfall data less important than material available for competing programs, then response-farming technology may not have a chance to work.

2. Improved Seed Varieties

Development and diffusion of drought-resistant seed strains will potentially face political constraints at national, intermediate and local levels. The critical issue in development of improved seed strains will be the political priority given to applied agricultural research. Research is a long-term endeavor. Even if trained manpower is initially in short supply, given sufficient funding, competent scientists and technicians can be produced. Donors have demonstrated, over the long haul, willingness to provide training. They have also been willing to finance capital and operating costs of agricultural research stations. However, most donor and lending organizations require counterpart funds from host governments, and often these are not forthcoming. Reasons are complex. They have to do in part with overall spending priorities of central governments. The much discussed urban bias of most African regimes is clearly a politically driven phenomenon. Potential for expression of popular discontent, for instance, over rising food prices (as opposed to the absolute dearth of food experienced during the last five years in many semi-arid African areas), is much higher in urban centers than in the countryside, and potentially much more damaging. In consequence, governments tend to give greater weight to urban problems than to rural problems. Despite sometimes evident desires to do more in the countryside, officials also have to calculate the per capita cost of providing a given level of public services to individuals in cities and in rural villages. Economies of scale and often enormous economies in distribution costs in favor of urban areas reinforces the general urban bias.

The concentration of power and economic elites in cities consolidates the urban bias. These groups have better contacts with high government officials (indeed, many of them are high

government officials). Not surprisingly, their interests loom large in the allocation of government funds.

The greater amenities, the higher standards of living, and the more reliable social security nets available in the cities of semi-arid Africa count as strong disincentives dissuading promising young people from choosing careers in agricultural extension work. Individuals who intend to raise families--and who still (accurately) see children as their major hope for old-age social security--must worry about the quality of primary and secondary education available in rural areas, by comparison with the education their children might well receive in an urban setting. Inadequate preparation at the primary or secondary level will sharply reduce chances of students moving on to any type of higher education and, eventually, high-paying and/or secure jobs in the private sector or public service. Health services are generally of lower quality in rural areas. Given high infant and child mortality rates, this will be a legitimate cause of concern to parents. Cultural life in rural areas may also be perceived as impoverished. The range of consumer goods available will be restricted in rural areas, and costs correspondingly higher for everything but staples. Finally, salaries for work in remote posts rarely reflect the family and personal hardships entailed.

If handled through government-organized extension networks, local-level distribution of improved drought-resistant seed varieties will tend to be skewed in favor of local power and economic elites. These people will acquire as much as they can of improved varieties, both for their own use and to consolidate political and economic ties with their clienteles. This does not mean that others will be excluded from access to the new varieties, but their access will be restricted. Particularly if hybrids degrade over several growing seasons, less well connected farmers may have to be satisfied with consistently lower quality seeds.

3. Alley Cropping

Alley cropping, as a biological technology, will likely suffer from many of the same national-level political constraints as improved seed varieties. This will hold for research in general. Furthermore, if the trees proposed for alley-cropping systems serve mainly to stabilize the environment, reconstitute soil fertility, create micro-climates favorable for agriculture, and produce browse as a dry-season forage for livestock--rather than generating valuable export products--research will tend to be neglected even more. To some extent, donors can influence this. However, it is not clear that many donors see the logic of promoting low-cost, low-resource biological technologies--given the long-standing emphasis on promoting export crops that can

help finance needed imports. The indirect but politically derived constraints on extension service mentioned above clearly apply as well to diffusion of alley-cropping technologies.

At local levels, two sorts of political constraints on alley cropping can be foreseen. The first concerns the general level and efficacy of political organization possible in a given rural setting. The second concerns potential conflicts with national forestry codes--alley-cropped trees may themselves have to be cropped at regular intervals to prevent them from shading out field crops (Majjia Valley Project). If forestry codes prohibit harvesting or even pruning of planted trees without prior approval by foresters, as is the case in many francophone semi-arid areas, individual farmers may be reluctant to plant, fearing that permission would be expensive or impossible to get.

In areas of transhumance and where livestock are allowed to forage freely after the harvest on crop residues, grasses and browse, it may only be feasible to establish trees in an alley-cropping system if policies on dry-season livestock movements can be modified. National governments, however, may find it easier to deal with potential conflicts between livestock owners and alley croppers by upholding the status quo and vetoing such policy changes. They may do this by directly refusing to change national rules on the question or to enact appropriate legislation that gives local communities the option to make their own rules in the matter. Or they may refuse to authorize the sort of local organizations necessary to enforce restrictions on livestock movements.

Even if general national or local-option enabling legislation is passed, local people may be unwilling to make the necessary decisions or to tax themselves to finance implementation. If taxation to fund organization is impossible, the whole idea of policy change on this point may be moot. If local people anticipate high levels of conflict over proposed changes, they may consider the costs simply unacceptable. Finally, they may simply see no need for the changes sufficient to justify the costs of change.

Failing national authorization in centrally controlled systems, political constraints may prevent the powerless from adopting alley-cropping systems. Local elites might, however, be able to work within existing legislation--for instance, national forestry codes--or work out schemes to avoid national rules. The former often provide that tree planters own the trees they plant. The latter might take the form of agreements with field-level forestry, livestock or general government agents to enforce against livestock owners special "outlaw" rules prohibiting animals from browsing on trees planted in the fields of the powerful. Such agreements could be based on deference or bribes in cash or kind.

Even if such rules were generally observed and enforced by local officials, prohibitions on cutting might still be enforced by foresters. They might enforce the restrictions to protect the environment. However, they would also have monetary incentives to enforce regulations--either because they can legally claim a portion of the fine as personal income, or because they can use the authorization to extract illegal payments from would-be cutters, and bribes from those caught in violation of the prohibition.

Political Constraints

National Level:	Response Farming	Improved Seeds	Alley Cropping (agro-forestry application)
Authorization Required	Broadcasting rainfall data.	Applied research	Land-use management jurisdictions, rules, local taxation to finance.
Political WCS* Activity (allocation of human and budgetary resouces)	WCS rainfall, soils, crop behavior research and data collection (training, salaries, equipment, ensuring data quality control, etc.).	WCS research, given competing demands.	WCS appropriate changes to empower local jurisdictions to manage woods, to check resources and control land-use patterns.
Intermediate Level:			
Authorization Required	As above.	As above.	As above.
Political WCS Activity	As above.	WCS distribution of varieties or allow private-sector distribution.	As above.
Local Level:			
Authorization Required	None required.	None required.	Land-use management (enforce, finance, sustain land-use management activties and rules to control stock movements, mobilization and payments of guards, etc.)
Political Support	None required.	None required.	

*WCS = willingess & capability to support

VI. LAND TENURE

Land tenure rule systems* play a major, if often unseen, role in defining the risks and benefits of adopting new agricultural technologies. Land tenure regulations--the rules that govern access to and utilization of lands, including agricultural lands--always influence the views of farmers and potential users regarding innovative agricultural technologies.

This section begins with background comments on African land tenure, as a context for the subsequent discussion of tenure-related constraints and opportunities. Next, the discussion analyzes advantages and disadvantages of various forms of landholding, specifically freehold and usufructuary variants of "private," open-access and common property at the family, extended family, quarter, village and higher levels. A discussion of tree tenure systems follows, including implications for various types of agricultural technology transfer and resource management. Illustrations of land tenure implications for the three target technologies conclude the section.

A. Background

African land tenure systems were never "tradition-bound." Long before the advent of European colonialism, African groups developed land-use rules to meet their needs, changing them through various mechanisms when new conditions warranted. New agricultural technologies, increased population concentration, exploitation of comparatively richer or more marginal areas, war and other factors produced land tenure changes. After colonization, however, land tenure rules, which were merely one stage in continuously evolving systems, were often solidified by colonial and postcolonial administrative decisions and practice, through codification and through nonjudicial changes in political arrangements (Bruce, 1985: 10-11).

Flexibility has long been the salient characteristic of African land tenure systems. The two factors that explain this continue to influence the evolution of tenure arrangements in semi-arid areas. First, climates have never been stable. Historically--from at least 15,000 B.C.--unpredictable, but recurrent, droughts imposed periods of hardship, just as they do today. Land-use practices had to accommodate these fundamental changes in land productivity, in part by authorizing different types of activity in a particular area as rainfall changed over the course of years.

---

*This section draws heavily on two recent works (Bruce, 1985 and Noronha, 1985).

Second, different agricultural production systems often shared the same piece of land, using it in different ways over the course of the annual cycle. Arable lands devoted to crop production during the rainy season, and riverine lands used for rice production or gardening during or after the annual floods, were often grazed by local or transhumant herds once those areas had been harvested (see, for example, Cissé, 1982: 182-183; Bruce, 1985: 90). To accommodate these predictable changes in use patterns was somewhat easier than dealing with drought. Still, it required a significant ability to coordinate behavior on the basis of changing liberties of access to and use of land resources.

Although many of these complex use patterns persist today, population pressures are creating pressures for change in land tenure regulations. Most tenure systems in semi-arid Africa developed under conditions of abundant land and labor shortages. Man-to-land ratios have deteriorated seriously since 1900 (see World Bank, 1985, for estimates of carrying capacities in the arid, semi-arid and semi-humid zones of West Africa).

However, sharply skewed land distribution patterns are still the exception rather than the rule. Generally, everyone has access to some land, even if only on a temporary, usufructuary basis. Most own at least small parcels. Subdivision of land into units of uneconomic size has led to the breakdown of land management systems in some areas and can be expected to create increasing difficulties in the future. Fragmentation may already pose problems in some areas, if it severely inhibits farming efficiency by increasing travel time between homestead and fields. But this danger must not be confused with the tenure results of deliberate risk-spreading strategies. Farmers often seek widely separated plots, to increase chances that at least some fields will receive adequate moisture in any growing season, and to gain access to differential soil types in the highly variable soils found in most African areas. This holds true even for areas that are not hilly (Eicher, 1982).

Indigenous African land tenure systems are supposedly "communal" in nature. Some analysts assert that such systems should be replaced by privatized landholdings. Supporters of this contention often stress the need to create incentives, through private ownership of land, that will encourage rural people to invest in land improvements and farm inputs.

Most indigenous African land tenure systems define the need for security, John Bruce argues, not in terms of a clear freehold claim to property in a piece of land, but rather in terms of security of access and a stable usufructuary right to productive land, and thus to a subsistence living. This system makes economic sense--both from the perspective of individual rural migrants and from a systemic viewpoint--in stagnating economies

such as those which have prevailed in most semi-arid African areas. In these areas, urban industries and mining operations have foundered, rather than developing and creating new employment opportunities for peasant farmers rendered redundant by on-farm improvements in productivity (Bruce, 1985: 32-33).

Nonetheless, the issue of whether particular land tenure rules dissuade efforts to gradually upgrade farm productivity merits attention on a case-by-case basis. Rules may provide insufficient security for investments in soil conservation and land use management, which take years to mature.

One issue of great significance for programs promoting low-resource, low-cost, stress-tolerant agricultural technologies concerns rules determining use rights to fallowed lands (Bruce, 1985: 25-27). As population pressure restricts or eliminates true shifting cultivation systems, the possibility of fallowing land without losing control over it becomes critical. In most contemporary settings, 10-year fallow will be considered of long duration and adequate to integrate trees into the process of rebuilding soil fertility. But in some situations, land left "unused" for as little as three years can be appropriated by another person, who, through cultivation, establishes a legitimate usufructuary claim (Niger). Such limited periods need not eliminate the value of fallowing, but they may severely restrict its usefulness.

Land tenure and tree tenure are often governed by separate legal systems, unlike the situation in most Western legal systems, where property rights in land generally include ownership of trees growing on the land.

B. Forms of Landholding

A mistaken impression exists that most rural lands in Africa are held "in common" by "people." Commons do exist. They continue to be very important in the overall scheme of land management in semi-arid African areas. However, most rural African rural farmers consider that they "own" the land they cultivate as well as land they have fallowed. This was true in much of precolonial Africa as well (Noronha, 1985: 12-13). In fact, many indigenous tenure and inheritance systems consolidate in individual farmers very significant degrees of control over their fields and fallows. They decide what to plant and when, how to cultivate, and when and how to harvest. Often, land can be loaned, either against a symbolic rent or on a sharecropping basis; mortgaged; given irrevocably to offspring and non-kin; and sometimes sold outright.

Individually owned private property almost never escapes some degree of regulation by others, however, and this clearly

holds in semi-arid areas of Africa. For instance, national legislation or administrative regulations may set the period(s) when farmers are permitted to raise crops without fencing them against livestock and, conversely, may establish periods when livestock owners may allow their animals to forage freely over all unfenced areas. They often fix dates when crop residues cease to be the private property of the farmer and can be collected freely by anyone. They may proscribe the burning of cropped lands or fix dates during which burning is legal. Regulations may determine that certain species of trees cannot be cut without official permission, even if planted on cultivated land, or that certain grasses belong to those who plant them during a fixed period after the growing season.

The extent of collective control over land use may vary dramatically among various land tenure systems. Where collective control is limited, landowners can invest with considerable security. Where it is more extensive, investments will be conditioned on the landowner's belief that personal goals can be achieved within the limits set by existing regulations.

Open-access lands--unmanaged commons, in this context--are those that anyone is at liberty to use without restriction. The operative legal principle here is that no one can deny others access to the land or prevent them from using it as they please. Such tenure systems may or may not be authorized. Many herding areas formerly managed by specific groups of users have been converted, by administrative fiat and action, to open-access properties. Such changes in pastoral-area tenure systems have occurred as a matter of deliberate public policies (Thomson, 1981: 234-235). They have been implemented by declaring that water in state-drilled wells is free and available to all. This effectively undermines the common-property pasture-management systems that formerly prevailed in semi-arid African areas, by making it impossible for officials of the erstwhile management group to continue controlling access to pastures in the area by refusing long-term watering rights.

Open-access tenure rules offer the advantage, where abundant resources are underutilized, of encouraging beneficial use by making the resource available to all comers. However, where resources are scarce, they often promote destructive use by making it extremely difficult to regulate exploitation rates when demand for resources in an area exceeds supply. Hardin's (1968) analysis of the tragedy of the commons highlights this disadvantage, although his examples of "commons" concern primarily unmanaged, open-access properties. This is a severe disadvantage in much of contemporary semi-arid Africa, because growing populations have brought many resources, especially land, under increasing pressure.

Common-property lands are managed to some extent by the named and known group that shares joint access and use rights to particular resources. This may merely involve attempts to keep unauthorized users from exploiting the resource, or it may involve more complex efforts by the joint owners of the common property to apportion supply and demand. This is done by the yearly establishment of a stint--a given amount of the resource that can be used or harvested--consonant, at least in theory, with the annual increment of productivity or use units, e.g., of soil fertility.

Lands held in common occur at many different scales. The smallest are generally lands farmed by restricted family units, e.g., nuclear monogamous or polygamous families. A large portion of the land is farmed by all members, under management by the family head. Each wife and unmarried son also controls their own separate parcel. These parcels may be changed over time.

At the next level, an extended family may work lands in common, while according each constitute nuclear family its own parcel. Quarters, villages, and loose inter-village associations typically share pasture commons and may also have separate areas where residents of these units harvest firewood and build poles and other secondary forest products.

At levels above inter-village associations, common properties may exist, but they are likely to come under the aegis of overriding jurisdictions (districts, cantons, counties, provinces, departments, states, regions and national states). An example would be the public livestock corridors through cultivated lands. Management of these lands is frequently the responsibility of officials of the organizing jurisdictions. Experience suggests that often these responsibilities are not fully met. Officials lack the manpower, funds or appropriate incentives to implement effective management operations.

National, regional or local legislation and regulations (the formal rules) on one hand, and local practice (the working rules), on the other, may or may not coincide. Where they diverge, most local users will guide their conduct in light of the working rules, which they know to be applied most of the time. Divergences between local working rules and formal rules of overlapping jurisdictions may render land tenure rules problematic. This in turn may make it difficult for local people to plan their farming strategies, because of the uncertainties involved in deciding which rule will apply in a given circumstance. Frequently, these disputes are resolved at a procedural level, when decisions are about which court will decide a given land tenure case.

Assume for the moment that land tenure rules governing common lands are clear. Common lands are preferable to private

freehold or usufructuary arrangements under certain circumstances. Other things being equal, joint exploitation of common lands is more efficient in labor-intensive production systems because, during periods of high labor demand, sickness and injuries are less likely to impede accomplishment of critical tasks (e.g., cultivation, sowing, weeding and harvesting) than they are in smaller production units such as nuclear families.

Commons systems also permit economies of scale, for instance, in fencing lands or patrolling them to protect against depredations by wandering livestock or people intent on illegally appropriating renewable resources associated with the land.

Disadvantages may include, first, higher management costs than those incurred in exploiting private holdings, simply because the group of users must agree on and support a common set of rules if sustained-yield management of the land is to be possible over the long term. Second, technologies that involve investments of labor or materials (including trees), in land may raise tenure issues because, under prevailing indigenous systems, such acts may establish a claim to ownership (Noronha, 1985: 12; Bruce, Fortmann and Riddell, 1984: xi).

Third, changes in multiple, overlapping patterns of use will evoke conflict unless all interested parties accept the changes. This is particularly important for new agricultural technologies that require earlier planting or longer growing seasons, or impede existing land-use patterns such as dry-season pasturage of crop residues (stubble, stalks, vines, leaves).

Finally, technologies (and infrastructures) that enhance land values may evoke dormant claims, particularly by the locally powerful (Bruce, 1985: 31-33, 88). Extinguishing those claims by legislation rarely changes the situation unless the consensus among users supports those changes.

Rules can be changed through community legislation (sometimes under the aegis of "project law"), project land law, and contract and economic incentives, as well as through state or national legislation (Bruce, 1985: 139-144).

C. Tree Tenure

Two points are important here. First, in most indigenous tenure systems, naturally occurring trees and shrubs are considered open-access resources which anyone is free to exploit. This rule has been modified in some parts of semi-arid Africa by the imposition of forestry codes that protect certain species wherever they occur. Second, deliberately planted trees are usually considered a crop. Like crops, their ownership is often separated from that of the land on which they grow (Noronha,

1985: 78-79; Bruce, 1985: 114-117). People can plant trees to establish tenure claims. Once planted trees have become established, the owners can prevent others from cutting them. They can exploit the crops (nuts, fruits, leaves for condiments, browse and wood) that the trees produced. At the same time, their control of the trees enables them in great measure to control the use of the land n which the trees grow. For this reason, those who loan, lease or rent land to others tend to prevent those who enjoy a temporary usufructuary right from planting trees.

D. Illustrations

1. Response Farming

Response farming will face few constraints on the basis of land tenure problems. Individual farmers can react to information made available through response-farming broadcasts without having to coordinate their behavior with other farmers. As long as they have secure access to a piece of land for the duration of a farming season, they can profit from the information about probable total rainfall accumulations by sowing and cultivating drought-resistant or drought-sensitive crops in accordance with projections of dry or wet years. Once farmers have mastered the system and understand the modifications required in their farming strategy in any given year, they can continue to put that knowledge to good use whenever they farm where response farming information is publicly available. Unlike terracing, response farming produces the greatest results within the space of a single farming season. It does not depend on secure long-term access. Even individuals farming on a sharecropping basis have a strong incentive to increase (or maintain) production at high levels to derive the most profit from their own efforts, regardless of how much of the crop they turn over to the field owner.

2. Improved, Drought-Resistant Seed Varieties

Land tenure constraints will have little impact on this technology, unless the seeds are adapted only to certain types of soils, the distribution of which is skewed in favor of certain categories of farmers because of tenure regulations. For example, tenure rules and inheritance proceedings might consistently allocate richer soils to descendants of the earliest settlers in the area, to the oldest farmers, or to the most politically powerful, and seeds developed for such soils would, all other things being equal, be more likely to benefit individuals in those categories than others. By contrast, drought-resistant seed varieties developed for use in poorer

soils would probably benefit late settlers and their descendants, younger farmers and the less politically powerful, because these individuals are likely to occupy poorer quality lands.

3. Alley Cropping

Land tenure and tree tenure regulations can be expected to influence strongly adoption patterns of alley-cropping technologies (Thomson, 1981b). This general class of biological technologies differs sharply from those involved in response farming and improved, drought-resistant seed varieties. Benefits of alley cropping are not generally apparent at the end of a single growing season. Particularly in semi-arid Africa, where trees generally grow less rapidly than in more humid regions, positive results begin to be noticeable at earliest only three or four years after the trees have been planted.

An individual who intends to create an alley-cropping system must be able to accept a substantially deferred return on investment. Furthermore, to make the investment of money, time and energy worthwhile, individuals must believe they have a high probability of continued control over the land, crops and trees in the system during the productive cycle of alley cropping. (Exogenous variables, such as changing levels of demand and prices for crops and tree products produced by the system, will also affect calculations, where farmers think that they can predict stability or change in these factors.)

Ability to defer return on investment in nursery stock purchased for development of an alley-cropping system will not generally pose a problem. If it does, it may be possible to substitute natural regeneration or trees started from seed for planted seedlings. However, land tenure-related costs of protecting alley-cropped trees to the point of productivity and beyond may be significant. This will be particularly true in parts of semi-arid Africa where privately cultivated fields revert after the agricultural season(s) to managed commons or open-access properties. To prevent animals and herders from damaging or destroying trees for browse, it will be necessary to guard the alley-cropped areas. Depending on the level of surveillance of fields that are managed commons during non-agricultural periods, it may be possible to start alley-cropping systems there at little or no additional outlay. In the case of an open-access property, this would involve a costly new outlay even if it is legally feasible.

The issue of control of crops, land and trees is a more difficult one. Crops typically belong to those who plant them. Except in extreme cases of confrontation over property rights in fields, field crops pose little problem. Even when land is

sharecropped, the split is established beforehand and is typically accepted by both parties.

However, African tenure rules view planted trees as crops as well. In consequence, until they are cut, die or are alienated through sale, pledge, mortgage or other legal procedures, tree planters retain property rights. For this reason, most landowners are loathe to allow renters or borrowers to plant trees--and, although temporary usufructuary rights of this sort can be terminated and the land reclaimed for agricultural purposes, trees once planted cannot be cut or uprooted without the planter's permission.

Another serious impediment in some parts of semi-arid Africa is the assertion of power by forestry services, relying on forestry code provisions, to determine when and how trees (even trees planted by individuals on farmed fields) may be harvested. The danger here is that farmers would find it expensive, illegal or impossible to trim trees that have begun to shade out crops, or remove them from their fields altogether. Farmers who have had confrontations with foresters over this issue, or who know individuals who have, will think twice about allowing trees produced by natural regeneration to grow in their fields--to say nothing of deliberately planting trees as part of an alley-cropping system. A related issue--treated in greater detail in the section on legal impediments--is the burden of proof of establishing that a given tree was planted, rather than "merely" protected in a field after having sprouted through natural regeneration. If farmers are assigned the burden of proof, as is presently the case in most of francophone Sahelian Africa, this represents a serious obstacle. Unless low-cost procedures are established, farmers in effect have to make sure that foresters visit the area while it is still clear (from soil condition, etc.) that a tree has been planted. Even if the foresters then issue papers certifying that the trees have been planted by the individual, it will still be necessary to map the location of individual trees so that they can be identified in later years. This process will be costly, uncertain and unattractive.

Control over borrowed land may pose difficulties if it is clear that usufructuary rights can be withdrawn at the initiative of the owner. Farmers working borrowed land or sharecropping will see little sense in investing to start an alley-cropping system (assuming for the moment that tree tenure issues can be resolved satisfactorily) if they do not think they can recover investment costs and reap additional benefits besides. Long-term control over the trees and their products will probably not, by itself, justify the investment. Yet trees in most alley-cropping systems are likely to become productive just when establishment costs start to taper off rapidly. At that point, the owner of a field loaned to a prospective alley-cropper would have a strong incentive to reclaim the land. This sort of maneuver need occur

only once or twice in an area before all sharecroppers will lose all interest in alley-cropping schemes, even though they may well recognize their considerable technical value within the agricultural production system.

E. Research Issues

Further research on several issues would be valuable. An inventory of existing types of contracts or land tenure agreements that effectively address the problems of long-term security for strategies that enhance resource productivity, such as alley cropping, would be very much in order.

Examination of the evolution of forestry legislation, forestry codes and forestry jurisprudence in semi-arid Africa as these various rule systems bear on the issue of individual, family, group and local control and management of woodstock resources (both in field and fallow and in natural bush areas) would be highly desirable.

Land Tenure Constraints

	Response Farming	Improved Seeds	Alley Cropping (agro-forestry application)
National Level:			
Rule-Based Constraints	None.	None.	Existing land-tenure codes (national) precluding, e.g., long-term fallowing without loss of usufructuary right, authorizing stock to rove at will during dry season(s), overgrazing young trees. Forestry codes precluding farmers from cutting/lopping prime agro-forestry tree species.
Intermediate Level:			
Rule-Based Constraints	None.	None.	Working rules of indigenous and Islamic land-tenure systems may compete with national systems, creating insecurity of access and use rights. Insecurity of tenants' rights may discourage investment in alley-cropping/agro-forestry.
Local Level:			
Rule-Based Constraints	None, assuming farmer access to land assured for growing season.	None, assuming applied research focuses on all soil types equally, not just best types owned by most powerful/ richest families.	Difficulties establishing ownership claim to naturally regenerated trees and planted local species. Landowners' fear that tenants will establish property claims by planting trees on borrowed lands may preclude agro-forestry.

VII. LEGAL CONSTRAINTS

A. Introduction

This section highlights the elusive, as well as the more obvious, legal constraints that can impede transfer of agricultural technologies. The discussion begins with a framework for the analysis of legal relationships. In Section VII.C the implications are explored in the context of costs that plaintiffs may face when they initiate legal actions.* Finally, in Section VII.D, consequences for the three illustrative arid-land agricultural technologies are examined.

Legal issues arise in two general categories: substantive rules governing behavior in a particular domain or sector, and procedural rules, which govern judicial aspects of dispute resolution. Relevant substantive rules are covered in other sections of this report, e.g., land tenure, political constraints and marketing institutions.

This section focuses more on procedural rules. Boiled down to basics, procedural issues concern recourse. Substantive rules are important, if enforceable. But unless substantive laws can be predictably enforced, they are either uncertain, ambiguous, unreliable guides for behavior, or largely meaningless. Enforcement difficulties can cut both ways. They may make "bad laws" less onerous. They may emasculate "good laws," or render them meaningless. In the former case, they make it difficult to calculate probabilities and future outcomes. In the latter, the law is irrelevant because it is never enforced and, thus, does not influence people's decisions, nor channel their future behavior.

---

*The plaintiff's perspective is adopted in the analysis of costs only because they initiate legal proceedings. If the costs are too high, potential disputes will never be joined in a legal context. This often means that an action is dropped, perhaps after some verbal fireworks--it becomes a legal nonevent. Nonetheless, the incident may have an impact on future behavior, if it suggests that the plaintiffs know the rules and what constitutes violations, and may initiate judicial action in the future. In these situations, "plaintiffs'" reactions put "defendants" on notice that problems and legal costs to defendants will follow, if behavior does not change. The approach adopted involves no presumption that plaintiffs are always in the right.

B. Analyzing Impacts of Rules on Behavior

1. Authorized Relations

If procedural rules of enforcement are important, how can they be analyzed? An answer to this question starts with a brief discussion of substantive rules. They crudely divide imaginable activities into the permitted and the prohibited. In this manner they facilitate calculation of future behavior. Substantive rules allocate rights, duties, liberties and exposures* among those involved in using a good or service. Rights and liberties are advantageous and valuable to the individual. Right holders can control others' actions within the limits of their right. Official backing can be invoked if necessary to achieve authorized control of others. Liberties constitute a weaker but nevertheless important form of official support for individuals' actions: official support can be invoked to prevent others from interfering with liberty holders as they engage in legally protected behavior. Duties and exposures are disadvantageous and costly to those burdened with them. Duties subject one's conduct to control by others. This is likely to be costly or onerous. Those burdened with exposures cannot invoke official action against damages that they might suffer as a result of others' behavior.

Rights and the duties associated with them are correlative. They are also equal in extent. In other words, the extent of a right is mirrored by its correlative duty--both concern the same set of controlled behavior. Neither rights nor duties are unlimited, however. Where official support and official compulsion end, exposure and liberty begin. Exposure is the reciprocal of right, and its limit. Liberty is the reciprocal of duty, and its limit. Where a right ends, right holders cannot invoke official support to protect themselves against damages that they might suffer because others are no longer subject to their control, but are at liberty to act as they wish. To the contrary, liberty holders can invoke official protection for their conduct even though it may damage exposed individuals.

---

*Rights--the ability to control the conduct of others, that is, what they must or must not do; duties--subjection to control by another over one's conduct, that is, what one must or must not do; liberties--those areas of conduct where the indivdiual may act as they wish without interference from others; and exposures--those areas where one is exposed without recourse to injury from the actions of others (Commons, 1959: 83-100).

2. Authoritative Relations

Procedural rules concern interpretation and enforcement of rights, duties, liberties and exposures. The following example illustrates the relationship between the authorized relationships just mentioned and authoritative relationships that underlie them and give them meaning through interpretation and enforcement proceedings. The individual who asserts a right, for instance a property right (whether fee-simple or some form of usufructuary right) to a piece of land, claims control over access and use of that good. The asserted control will never be absolute--family, group or state claims to regulate access rights and use patterns to some degree will persist. Nonetheless, those who assert the right will argue that they have dominant control, e.g., over farming, grazing and wood-harvesting activities. As part of this control they can prevent others from entering the land. They can order trespassers to vacate. All others are under a correlative and equal duty to stay off the land unless specifically authorized to enter it for some purpose by those asserting control. The same holds for a group that controls a common-property resource--farm land, pastures, watershed, watercourse or woodstock--as far as use by nonmembers of the owning group.

The positive and negative values, respectively, of these rights and duties depend on whether they can be enforced. A livestock owner puts animals into a farmer's field of ripening millet, and the animals destroy half the crop. The farmer accosts the herder and demands damages. The herder refuses. The farmer could try to attack the herder, or his animals, but that approach involves risks. Instead, the farmer complains to an authority he/she believes can judge the case. A trial is held. The judge renders a verdict--compensation in some amount. The verdict determines the value of the asserted right in that situation: crop damages will be compensated exactly, or half compensated, or doubly or triply compensated.

The authority might return a verdict of no compensation, however. This latter decision would establish at law that the owner's asserted property right, and the correlative and equal duty of the herder to avoid use of that land without permission, were none such. Instead, the judgment would create or confirm an exposure for the landowner. Following that decision, others could legally use crops on the property as forage for their herds, without the field owner's permission. A correlative and equal liberty for herders follows--they can help themselves to the fruits of others' labor, and the officials will prevent others (the field owner, in this case) from interfering with them.

By this rule, the farmer must bear, without recourse, the costs of herders' actions in taking the farmer's crops. If judges in crop-damage cases regularly require herders, whose

animals have foraged without prior authorization, to reimburse farmers for half the value of their crop losses, the right-duty/liberty-exposure relationships shift to a position midway between full recourse ("property means property") and no recourse ("land and unstored crops are open-access resources").

The same analysis can be applied to use disputes concerning common properties. Attempts by common-property owners of pastures or wood stocks to invoke recourse against unauthorized users may be rejected. The resource in question is then better understood as an open-access or unmanaged common property than as a managed common property where users/managers try to apportion demand to supply. In the former situation, common-property "owners" stand exposed to others using the resource without their permission, and all others are at liberty to run down the resource without hindrance.

Authorized relationships--rights, duties, liberties and exposures--depend for their content on the interpretations of officials acting as judges or enforcers. When a complaint is brought before a judge, the judge must determine whether the power of the jurisdiction or group--a "going concern," in Commons' terminology (1959: 143-53, especially 145)--can be invoked by the claimant of the asserted right in support of the claim, or whether the claimant is instead exposed and the concern's officials are under a disability to act in the claimant's support. Simultaneously, the decision establishes whether concern officials have a responsibility to enforce a duty, e.g., that herders keep animals out of crops or are liable for damages, on one hand, or whether, on the other, herders are at liberty and concern officials immune from the putative right-holder's claim that they help impose a duty of avoidance on livestock owners.

3. Determining Powers

Once the legal judgment is made on the complaint, the next problem is whether it will be enforced. Judgment and enforcement should be clearly distinguished: winning a judgment is not tantamount to recovering damages. Nor does a legal victory automatically prevent livestock owners from damaging crops in the future, assuming the plaintiff was seeking that sort of guarantee as the outcome of litigation. Officials, even lowly ones, retain often substantial degrees of discretion in the exercise of their interpretation and enforcement powers. These "determining powers" (Commons, 1959: 121-26) bulk large in defining the "working rules" of going concerns (134-42). The working rules determine:

> . . . what individuals must, must not, may, can and cannot do, if the authoritative agency that decides

> disputes bring [sic] the collective power of the community to bear upon the said individuals. (Commons, 1959: 138).

Critical in this context is the word "if." Formal laws may be enforced, and the working rules may conform quite exactly to the formal rules, but formal laws are not self-enforcing and working rules can diverge dramatically from formal laws. When they do, people will shape their conduct in light of the working rules, not the formal ones, because they know the former are the ones officials will apply in disputes. A few may seek to challenge and change rules. In general, however, people will predict future conditions and plan future behavior based on their understanding of the working rules. The costs of trying to effect changes generally far exceed amounts most peasants can afford to invest in litigation. Since loss of control over land, crops, woodstock, or valuable services would be catastrophic for most peasant households, the rule of prudence for most farmers is to live by the working rules.

C. The Costs of Recourse--Is Litigation Worthwhile?

The costs that peasants will face and calculate carefully, if they decide to try to get recourse and damages when they feel they have been wronged, can be foreseen. The six basic categories of costs, each associated with a phase of dispute resolution, include:

- identifying a violation of right or liberty,
- selecting a forum,
- convoking a case,
- arguing the case,
- enforcing the ruling or collecting damages awarded, and
- preventing recurrences in the future.

Each of these has multiple cost components. Some involve out-of-pocket costs. Others may take the form of more subtle status changes in other areas of the litigant's life, e.g., changes in social "credit rating"; or increased likelihood of future support or retaliation from fellows, political officials, judges and strangers. Each cost may vary depending upon the circumstances of the case and the character of the contested rights.

1. Identifying Violations

This may be relatively simple, especially when frequent, systematic or semipermanent patterns of land use are involved. Crop production, or reclamation of loaned land, for instance, will be sufficiently overt incidents that interested parties will be informed without any effort on their part. Disputes will arise here over asserted violations of sharecropping arrangements or land loan agreements, percentage of the crop claimed by the landowner or duration of the loan and terms of revocability. Such cases will turn on establishment of the legal facts via a legal process, but detection of the "violation" will not normally pose a problem.

Other violations, e.g., crop damage or illegal harvesting of wood, may be more problematic to resolve. Such incidents may be easy to identify after the fact. But identifying who is responsible may be much more difficult. A potential plaintiff must balance costs of discovery proceedings and other expenses of the judicial process against the value of the compensation they will likely receive. It may be possible for a farmer who has suffered crop damage, or lost large branches lopped from valuable trees by local or passing herders, to hire a tracker or personally spend time following trails to catch up with the pastoralist responsible. But is the game worth the candle? Merely identifying a potential defendant does not bring them before a court competent to judge the issue. Getting them there may involve significant additional costs, noted in the section below (VII.C.3) on convoking cases.

2. Forums

Most societies have regular patterns of dispute resolution. Sometimes this involves a single hierarchy of dispute resolution institutions. More often, choices exist--informal negotiation within family or local settings such as quarters, camp units or villages; negotiation or arbitration through recognized third parties such as religious figures, elders or people with recognized skills in judicial matters; formal administrative courts; and formal civil courts.

The language of dispute resolution is to some extent a matter of symbols. Tactics and strategy are heavily involved. A litigant's choice of legal forum will communicate something of the litigant's intentions to their opponent. Taking the case before a local dispute resolution specialist may signal a willingness to seek an amicable settlement at the least cost, so that the parties can get on with their lives. In effect, a plaintiff informs the defendant that they are seeking a decision that will be self-enforcing because both parties will accept it. On the other hand, a decision to initiate formal legal

proceedings may be considered an aggressive escalation designed to overwhelm the opponent or strain their resources. It may also serve notice that the plaintiff intends to ignore local working rules about the issue in question.

The reputation of the elder, cleric, arbitrator, administrative official or judge--as honest, efficient and impartial or, on the contrary, corrupt, ineffective or biased--also says something about the intentions of the plaintiff. In certain local courts, customary joking relations, defined on the basis of interethnic categories, may place one litigant in a privileged position vis-à-vis the judge, giving them a tactical advantage. Judges are not likely to remove themselves for cause. The disadvantaged litigant's options are to make the best of the situation or appeal to another court, shouldering the costs involved in that process.

Decisions about where to initiate dispute resolution proceedings thus telegraph something about how a case is likely to be decided in that forum, the likelihood of escalation and appeal, and the probable costs of litigation to the defendant. This is information that local people, or local legal specialists, will know. It may or may not be more widely available. In any case, it will be difficult for outsiders to obtain quickly.

3. Convoking Cases

The decision to convoke a case will almost certainly cost the plaintiff something. The judge, arbitrator or informal mediator must be informed, and must agree to hear the trouble case. Court costs in one form or another will be involved. Bribes may be required in some systems if the plaintiff wants to improve the likelihood of winning. The defendant will have to be convoked. It may be necessary as well to bring witnesses.

If the dispute is to be resolved locally and informally, these costs will be generally low. The plaintiff may convoke the defendant, or go with the judicial figure to resolve the trouble case on the defendant's property. Court costs will probably be limited to petty cash or gifts of food. Bribery may be a problem, but if either party can easily appeal the case, overt attempts to suborn the judge will, if successful, likely result in an appeal by the other party.

Convoking all of the relevant parties may be quite simple, even in incidents where the responsible individual is not known. Unknown defendants can sometimes be flushed out through reliance on a fetish. If belief in the supernatural powers of the fetish is widespread, a defendant will appear upon learning that the perpetrator of the contested act must appear before the named

authorities or face the evil consequences which the fetish (e.g., mask, idol, Quran or other item) will unerringly mete out. To achieve the desired end, the plaintiff must simply take adequate pains to publicize the charge.

If this procedure is not available because of conflicting belief systems, or if appeal to the supernatural is proscribed in resolution of these types of cases, convoking the case may be quite expensive. It may involve outlays for detective work that far exceed any value that could be recovered. Such circumstances arise frequently--women collecting firewood; herders seeking browse for their animals during the dry season; and men desperate for thatching grass, building poles or silo supports and too poor to buy them, may all take resources from others' lands without asking. In most cases, the amount taken will be small, and the owner or responsible party decides against making a case. In the aggregate, however, the threat to security of investment in these resources becomes significant, particularly because everyone knows that surreptitious harvesting will not be detected if minimum precautions are taken.

4. Arguing Cases

Any litigant has three options in arguing cases in the circumstances of concern here. First and most commonly, litigants, or more senior or experienced relatives, argue their own suits. Second, litigants can also hire "bush lawyers." These are individuals who lack formal legal training but make up for it in practical experience, forensic skills learned on the job, and a knowledge of relevant procedures and personalities. They have demonstrated capacity to win cases or defend client interests. Third, litigants can hire professionally trained lawyers.

Costs rise as one moves up the scale from personal toward professional representation. In many parts of arid Africa, a trained lawyer would never be hired except to defend an accused individual in a criminal case. In others, land litigation might involve values sufficient to justify the outlay. Litigation over trees probably would not justify engaging even a bush lawyer.

The second set of costs incurred in actual litigation, as opposed to initiating the case and convoking the parties, are those involved in maintenance during the trial. These will be negligible if the dispute is argued locally. However, if appeals are taken to higher level courts, in distant district or county towns, considerable travel and living expense may have to be envisaged. Depending on local practices, additional court and customary payments may have to be provided by the appellant at each level, if the individual wants to ensure a fair or favorable hearing.

5. Enforcing Judgments and Recovering Compensation

A judgment rendered does not a working rule make. Defendants may be judged liable for damages. They may be declared under duty to change their behavior, for instance by no longer cultivating a contested field awarded the plaintiff, or by ceasing to collect wood on the plaintiff's land. Compliance is another matter, and it is always problematic. Civil cases of the sort likely to arise in the course of agricultural technology transfer will not generally involve jailing of defendants. The latter will be at liberty to move about. The plaintiff, if forced to compel a defendant to comply with the terms of a judgment, may have to again request the assistance of officials. This will involve outlays, in time and money, for living expenses and to ensure that officials actually enforce the ruling. Police officers often receive an advance from the plaintiff against their own costs in traveling about to contact a defendant or others involved in the case. Under the locally accepted working rules, they may be able to claim a percentage of damages awarded as a commission for enforcing the verdict, whether or not this is formally permitted.

This underlies the importance of official determining powers--if officials can do a halfhearted job of enforcement without fear of reprimand, they have bargaining power they can use against plaintiffs. Plaintiffs may have to supply small gifts to other court officials, arbiters or dispute settlers at various stages in the dispute settlement process to demonstrate good faith and respect for authority. While none of these items is itself a major outlay (unless the plaintiff tries to bribe officials to obtain their help), together they can add up to a considerable sum.

6. Preventing Recurrences

In a certain sense, the entire discussion of this section is merely a prelude to this point. Working rules are the guides for daily conduct. These rules are set and changed by officials exercising their determining powers, within the limits allowed to each by the authoritative relations among judges, police, political and administrative authorities, clan and family leaders. The problem, from the perspective of this paper, is how to create situations in which the working rules give rise to decision-making arrangements--institutions--which in turn support stable patterns of behavior favorable to the introduction of new agricultural technologies. Conflicts cannot be constantly resolved through dispute resolution procedures. Instead, they should give rise to rules, and modifications in rules, that permit people to avoid conflicts.

This is the intersection between political and legal constraints on the introduction of new agricultural technologies. Court judgments will not prevent recidivism if the chances of being caught remain small. In the absence of preventive patrols, violations of rules against harvesting wood without permission or allowing animals to roam unattended will continue. The costs at each phase of the judicial process are sufficiently high that most potential plaintiffs will opt not to act, because the value at stake in each particular incident is too small to justify the effort and outlay. In such circumstances, only if the users are authorized to tax themselves or finance patrol activities by other means (e.g., by user fees or by assuming policing chores on a rotating basis within the community) will the likelihood of detection be great enough to dissuade potential violators from ignoring the rules.

D. Illustrations

1. Response Farming

Response farming as a technology will, at most, face indirect legal constraints. These might arise first at the national level, in terms of obtaining authorization to broadcast meteorological information. However, if political constraints in this regard are overcome, legal barriers will probably not be used to hinder application of the technology. At the field level, response farming would confront legal constraints only if land-tenure relationships were generally so insecure that farmers could not count on being allowed to harvest the crops they plant. While livestock damage to standing crops is always a threat, it seems unlikely that it would become so severe as to deter farmers from planting.

2. Improved, Drought-Resistant Seed Varieties

Legal constraints will have little impact on introduction of drought-resistant seed varieties. So long as new varieties can be openly marketed, those who are interested and have the necessary cash can purchase them. If they are distributed through administrative or political/organizational channels, access will be more problematic for the less well connected. Courts might offer a legal remedy, to force officials to adopt a more equitable distribution pattern. Remedies could also be sought through political action, increasing dependence of officials on the people they are formally required to represent and serve.

3. Alley Cropping

Wherever there are legal constraints of the sort mentioned above in the discussion of costs engendered by the various phases of legal action, they can be expected to weigh heavily against acceptance of alley-cropping techniques. The value of tree crops and the positive environmental effects of raising trees in association with field and garden crops are significant. However, development of such systems demands long-term investments. Most trees do not start bearing fruit before they reach five years of age. Most do not attain their full production potential until they are closer to 10 years old. In addition to the impediments posed by land and tree tenure authorized relations, serious problems concerning enforcemen could easily arise in many arid African areas.

The first set of problems concerns the cost-benefit calculus of controlling unauthorized browsing or harvesting of trees planted or protected in an alley-cropping production system. If one or several large landowners commit themselves to alley cropping, they might find it advantageous to organize some sort of private patrol system. But most peasants may be able to create alley-cropping systems only slowly, over a period of years. Some may rely largely on natural regeneration, rather than intensive tree planting. If the trees are relatively few in number and widespread, the reduced level of benefits that the tree-crop association will produce during the early years of its existence may not justify consistent efforts to protect those trees from unauthorized use. If that is the case, then tree densities may never reach the point where systematic protection is a cost-effective operation.

If local jurisdictions cannot legally organize to patrol lands within their boundaries, and if they are precluded from raising taxes locally, on consent of the members of the jurisdiction or their representatives, then chances are slim that voluntary action will suffice to police and control unauthorized harvesting of alley-cropped trees. The same applies to special districts that might be organized to protect trees--if enabling legislation and back-up taxing authority are in place, individual farmers interested in alley cropping might be able to create the necessary organization.

The second set of issues concerns the costs of reacting effectively to violations. In the absence of state legislation providing for double or triple damages, individual plaintiffs will probably not be able to justify the costs of prosecuting those who ignore tree tenure rules, or of litigation to change those rules. And even triple damages may be insufficient to finance litigation at anything other than the most local level. This is clearly the situation in litigation against minimal impact, low-value harvesting incidents (a branch here, a couple

of fruits or nuts there). However, over the long run, repeated occurrences can destroy the value of an alley-cropping effort.

It will only be possible to finance the costs of litigation if several well-to-do landowners, or local organizations of the types suggested above, exist. Private entrepreneurs might conclude that a few precedent-setting decisions that effectively uphold the rights of tree planters to collect damages for unauthorized use would increase security of investment in alley-cropping technologies, reduce their long-run exposures, and increase the attractiveness of the activity. Collectively financed litigation, like collectively financed prevention, can reduce the costs to each individual by having one private individual representing a large personal interest, or an official representing the will of an entire community, make the case.

Legal Constraints

	Response Farming	Improved Seeds	Alley Cropping (agro-forestry application)
National Level:	No legal recourse available against inappropriate or bad response-farming data. Farmers who use it exposed to negative consequences of poor quality or incomplete research/diffusion effort.	No legal recourse available against distribution of inappropriate seeds, poor extension work, etc. Farmers use seeds at own risk.	Costs of appeal.
Intermediate Level:	Same as above.	Same as above.	Costs of appeal or trial if local judicial process cannot hear case because, e.g., foresters resolve all tree litigation.
Local Level:	None.	None.	Cost of legal recourse against those who damage/destroy alley-cropped seedlings or mature trees, if available at all--identifying violations, selecting forum, convoking and arguing case, enforcing ruling/collecting damages, preventing recurrences. Costs of land litigation.

VIII. MARKETING INSTITUTIONS AND MARKETING

In this section, the focus of the discussion is refined. The previous sections have analyzed the political, legal and tenurial institutions that establish a framework within which the farm family will make its production, technology and innovation choices. This section and the two that follow pose the problem that once the framework enabling innovation is in place, where are the incentives for the producer to take advantage of it?

The most important incentives to increase agricultural production through use of innovative technologies are imbedded in the behavior of the marketplace. In the first place, producers will keep an eye firmly fixed on prices and demand for the commodities they are producing as they work through their production decisions. At the same time, however, they will pay close attention to the cost and availability on the market of the inputs they need to produce the commodities in question.

These next three sections, therefore, treat first, input and product marketing institutions as such, then focus on one particular input, credit, and end with a discussion of infrastructure, the state of which largely determines the performance of both input and product marketing institutions.

The discussion to this point has focused on the relationships between three specific technologies and several institutions whose activities enable or disallow their application. Now, when talking about the incentive institutions of input and output marketing and their support institutions, the focus of the discussion must shift. At this point, not a technology, but rather the use of the technology to produce something with a particular value at a particular cost, is the issue. Hence, the question becomes not one of technological innovation as such but one of what innovative technologies can produce and what the incentives to that production are. The answer to this latter question holds the key to the adoption of innovative technologies.

Marketing institutions play a critical incentive role in promoting innovation in agricultural production. Among other things, they transmit information and signals that producers must receive and interpret to determine the allocation of their land, labor and capital for the agricultural season. Under the proper market conditions, producers can be induced to expand production and even to adopt technological innovations to do so. The most effective incentives that the market can communicate are long-term prospects for continuous short-term gains.

Each agricultural commodity has its own technical profile. Commodities vary according to demand, perishability, seasonal

availability, transportability, location of demand centers in relation to supply centers and so on. It is therefore most helpful to analyze marketing institutions by commodity subsector. Marketing institutions for agricultural commodities (excluding livestock) in semi-arid Africa can be divided into three general classes of commodities:

- staple food grains--millet, sorghum, maize and rice;
- perishables--carrots, lettuce, onions, potatoes, tomatoes, mangoes, bananas, okra, cayenne pepper, eggplant, turnips, etc.; and
- industrial crops--sugar, peanuts and cotton.

In semi-arid Africa, the impact of marketing institutions on each of these commodity classes differs. Each class has different institutional requirements to promote adoption of appropriate agricultural and technological innovation.

A. Staple Food Grains

National institutions often intervene in the marketing of staple food grains in semi-arid Africa through para-statal agencies. These agencies have generally pursued several objectives, including:

- development of stocks for national food security and
- control of the profits of private grain traders by intervention in the producer and consumer markets at a given price level and in large enough volume to force private merchants to be competitive.

At present, these marketing institutions are in retreat; thus, it is not necessary to review the general critique of these para-statal organizations. However, it is important to note that the pricing and marketing rules instituted by national governments, principally through the para-statal marketing bodies, have not transmitted any significant incentive to producers to increase their production through innovative technologies.

Most of the countries in semi-arid Africa have organized producers into cooperatives--on one hand, to feed staple grains to the para-statal and, on the other, to put producers in a strong bargaining position in relation to private merchants. In theory, producers grouped together in a cooperative will reap the benefits of quantity discounts in buying inputs cooperatively as well as benefits from assembling output for sale in cooperative lots. Here, as above, it is not necessary to reconstruct a comprehensive critique of African cooperatives. For purposes of

this report, it need only be noted that selling staple grains through the cooperative does not give the producer any advantage. Because of the position of the cooperative in national marketing institutions, the price paid provides no incentive for the producer to increase production of staple grains or to adopt technological innovations for that purpose.

The bulk of staple food grains that transit the market in semi-arid Africa pass through informal market institutions. These institutions are arranged in hierarchical relations, with countless local markets scattered throughout the region at the base. Women most often bring a loose portion of their family harvest to the local market to sell.

Assemblers buy grain on the local level, pack it into standard sacks and take it to the regional markets. These assemblers, both men and women, often come from families of local notables. Market activity is only one of several economic activities, chief of which is still usually agriculture. The families of notables are usually the only ones with the resources to maintain commercial activity. In some Sahelian countries, these notables are disproportionately drawn from the Muslim clerics, who accumulate their stocks of grain in exchange for religious services provided to their clientele. This mechanism provides one explanation for the fact that, for centuries, clerics have been identified with commercial activities in the Sahel. At the regional markets, the assemblers meet large-scale grain merchants (Jones, 1967).

The large-scale grain merchants are the only actors in the system who concentrate on cereals commerce as their sole economic activity. These men run a crew of full-time employees and often own their own vehicles for transporting grain to the major demand centers from the major supply centers. In a country such as Niger, where the major consumption center (Niamey) is 600 to 700 kilometers from the major supply centers (Maradi and Zinder), the market is concentrated in relatively few hands (Cullen and Waldstein, 1983). A grain merchant must invest a considerable amount of capital to reap economies of scale in hauling grains over such distances. In other countries, such as Burkina Faso, the production and consumption centers are closer together and the market is much less concentrated.

Studies in Niger by S&T/RD's Small Farmer Marketing Access project (Cullen and Waldstein, 1983) and by Elliott Berg Associates in 1982 and 1983 have established that, by and large, producers grow staple grains for family consumption. Less than 10 percent of family production finds its way to market. Most families sell some staple grains, but most sell relatively little overall and, on average, only a small amount at each transaction. The only large transactions are likely to be just after harvest. The cost per transaction is therefore high, and the assembly

function a prerequisite to redistribution. Long-term mercantile relations among actors at different levels of the system are rare.

Staple-grain marketing institutions often straddle frontiers. An ongoing study financed by CILSS is examining institutions in a series of so-called free trade areas strung out along the interface between the semi-arid Sahelian countries and the wetter coastal countries in West Africa. Coastal countries are exchanging staple foods for labor in many cases. Nigeria and Ghana are acquiring hard currency in trading staples with Niger and Burkina Faso respectively.

To improve the performance of informal staple-grain marketing institutions in semi-arid Africa, two important questions must be addressed:

- How can savings be realized in the cost of transactions to increase the producer price while leaving the consumer price untouched?

- What limits the volume of staple grains that the marketing institutions handle at present and how will they adapt to an increase in the volume of commodities they must handle?

The greatest constraint on the ability of marketing institutions to expand the volume of production that they handle is the shortage of commercial credit. There is virtually no source of formal institutional credit for commerce in staple food grains in semi-arid Africa. Credit, such as it is, is scarce and expensive. The most common sources are relatives and the large-scale merchants.

From the viewpoint of staple-food marketing institutions, the following are needed:

- an analysis of where the costs of transacting business can be reduced, and

- the creation of institutions that can channel credit into the system.

A further need may be improved circulation of marketing information. There is some debate about how well-informed staple-grain producers are about current conditions at the most promising receiving market for their production.

B. Perishables

In a number of ways, marketing institutions for perishables in semi-arid Africa are very different from those for staple food grains. The differences in the institutions are linked to the technical characteristics of the commodities under production:

- These crops are exotic to the region and therefore require cash outlays for seed, special hand tools, fertilizer and other occasional inputs.

- The crops are generally grown off-season under a locally adapted water management technology. These are necessarily low-resource technologies. Their use is expanding rapidly throughout semi-arid Africa, and the conditions and limitations of their success deserve systematic study.

- With the exception of potatoes, none of these off-season crops is a food staple. Rather, they are grown to some degree as dietary supplements, but more importantly for market.

- Almost all of these crops must be consumed within a matter of days after harvest. Potatoes can be stored up to six weeks under proper conditions. Onions can be dried and stored longer. None of these crops has a storage life comparable to staple grains unless some transformation process is undergone. At present, the main transformation technology accessible to small-scale producers in semi-arid Africa is sun drying.

- Linked with the perishability of these off-season crops is their vulnerability to damage during transport. This in effect means that most profitable sites for perishable production lie in a ring around major consumption centers, notwithstanding the technical production potential of areas farther afield.

- National-level marketing institutions play a very small role in the marketing of perishables. They generally are active only in those few cases in which perishables are being produced for the international market, such as mangoes in Mali and green beans in Burkina Faso. Otherwise, marketing institutions are simply what the producer(s) arrange themselves.

Although national-level institutions are comparatively rare in perishables marketing, cooperative groupings are quite common.

Their existence often depends on the strategy for capitalizing perishable production and the technology chosen to carry it out. In general, these cooperative groupings are not formally registered with the government. Most often they are loose-knit groupings of family members, villagers, co-members of voluntary associations or business partners. Often, the association carries a name. Members cooperate mainly on maintaining technology, sharing association expenses and assembling loads of produce for transport to market.

Because of the technical characteristics of these off-season crops--particularly their perishability and fragility--institutions for marketing them take on a distinctive profile. Except for potatoes and onions, off-season crops do not travel nearly as well as do grain staples. Therefore, there are not as many layers in the hierarchy of marketing institutions. The most common case is for producers or representatives of producer associations to come to market with the produce and sell it to consumers directly in exchange for cash. In larger markets, assemblers are present who will bulk produce from several clients on consignment. They pay the producers after a day or two for what they are able to sell. There is a fair amount of spoilage in the system. The producer takes almost all of the risk.

Producers use production inputs for perishables more readily than for staple food grains. Perishable production is intended primarily for market. It generates cash for producers, and producers willingly channel a portion of that cash to purchase seeds, fertilizer and hand tools. These inputs are usually available on the open market in areas where off-season crop production is concentrated. In some countries, such as Senegal, there are shops devoted exclusively to horticultural provisioning in several cities. There are otherwise relatively few extension programs through which perishables producers can get instruction and input supplies. SENPRIM in Senegal is one of the few.

Steps to increase the volume of staple grains transiting marketing institutions by increasing consumer demand will probably lead to frustration. Throughout semi-arid Africa, cereal is now consumed at a rate of 180 to 200 kilograms per capita per year. With increasing prosperity, the demand for perishables and animal proteins will probably increase at the expense of the demand for staple grains.

On the other hand, demand for perishables has grown dramatically in recent years and has potential for considerable further growth. The growth in market demand has impelled thousands of producers in semi-arid Africa to identify, adapt and implement new agricultural technologies. What steps, then, could be taken to further increase demand for perishables? A program of social marketing, such as that used to drive up fish production in Djibouti (Waldstein and Lampe, 1986) in the early

1980s, might have a positive impact on innovation in agricultural technology.

As with staple grain marketing, steps to lower marketing costs would have a positive impact on consumer prices and presumably also on demand. Increasing demand will at some level induce innovations in agricultural technology. A major cost factor in perishable marketing is the high rate of spoilage. Low-cost, decentralized transformation technologies could thus have a positive effect on marketing costs.

C. Industrial Crops

Industrial crops are grown overwhelmingly for market. Moreover, most often they are grown for the international market. Input supply and output marketing are therefore usually handled through formal national-level institutions. As with the former ONCAD in Senegal, these para-statal production and marketing organizations very often effectively contract with producers to act as "out-growers" in a sort of contract-farming scheme. In the case of ONCAD, the para-statal supplied peanut seed, fertilizer, hand tools, extension advice and pesticides, if necessary, as well as sorting, shelling and bagging equipment. In return the producer had to sell virtually all of his or her crop through ONCAD at prices set by the national government. In contrast to the case of staple-grain marketing institutions, there are virtually no parallel marketing channels for producers of industrial crops. The only significant exception to this generalization is cross-border trade, which some merchants practice to profit from the differentials in official prices for industrial crops between neighboring countries.

This situation does not encourage innovations in agricultural technology. As with staple-grain marketing, the prices for industrial crops are so low that the opportunity cost of industrial crop production is prohibitive in an economic environment where realistic alternative revenue-producing activities exist. In fact, production of industrial crops has dropped off much more dramatically than production of staple food crops during the drought years of the past 15 years. Producers have felt that it is more important to have secure food supplies than to have the level of cash they anticipate from industrial crop production.

Innovation in industrial crop production is linked to changes in national and international institutions, principally pricing institutions. As a first step, para-statal marketing institutions will have to relax their grip on industrial crop marketing. This has begun to happen in several countries in semi-arid Africa. Second, prices for industrial crops will have to rise considerably to reach a level where producers are

encouraged to invest in new technologies to achieve and maintain higher levels of production. Current trends in the international markets for primary products do not portend such price levels.

In short, it is difficult to identify incentives that could realistically be built into the industrial-crop marketing system that would induce innovations in industrial crop production.

Marketing Institutions

	Staple Grains	Perishables	Cash Crops
National Level:	Road network, storage systems, system of redistribution of commodities, circulation of information.	Distribution network for processed commodities.	Road network, storage and transformation systems, system of input distribution, processing and transshipment systems production credit.
Regional Level:	Assembly system.	Road network, transformation systems, circulation of information.	
Local Level:	Marketplaces, points of input distribution production credit.	Marketplaces, points of input distribution, production credit.	Commodity collection and and input distribution points, extension support.

IX. FINANCING SYSTEMS

The relative scarcity of agricultural credit and its high cost when available comprise perhaps the greatest bottleneck constraining the expansion of agricultural production and, by extension, the adoption of new agricultural technologies in semi-arid Africa. People are simply hard-pressed to find or afford the resources to underwrite innovative activity.

As already discussed, the needs and available channels for financing vary according to the crop. In addition, the status of the producer very often influences whether certain channels for financing are open.

When financing is accorded through informal institutional arrangements, the effective charge for the money is often very high--many writers claim as high as 30 to 40 percent. Such a charge is not simply an interest charge. Rather, it may represent the discount a creditor must insist on when, in effect, making advance purchases of crops at the beginning of the cultivation season. It may also simply represent, in the process of repaying loans from relatives and friends, an acknowledgement in kind of gratitude for the loan. On the other hand, it can be argued that the charges are the cost of capital, determined more or less by market forces, in an area where capital is scarce.

A. Staple Food Grains

Both formal and informal financial institutions act in support of staple grain production in semi-arid Africa. The formal institutions tend to be national agricultural credit banks, para-statal marketing institutions and cooperatives. Informal institutions are relatives and friends for the most part.

National agricultural credit banks such as found in Niger and Burkina Faso are autonomous banking institutions that must adopt elaborate application procedures and qualification criteria for evaluating loan application packages to survive. Historically, the criteria for the bank in Burkina Faso have been more stringent than those for the bank in Niger (Dofman and Waldstein, 1981). Formal institutional credit goes disproportionately to producers with above-average agricultural incomes. The point is that national agricultural credit banks are not at present a source for direct financing of agricultural production for the average rural producer. Very often, however, a cooperative acts as an intermediary in securing loans for its members from these credit institutions. This is often the case in Niger, for example.

Para-statal organizations involved in staple grain production and marketing also generally work through cooperatives. Therefore, the average rural producer has access to credit, through membership in the local grain producer cooperative. The credit line available per producer, through this mechanism, is relatively low.

The most common use for these credits is the purchase of seed, according to a study carried out recently in Niger under S&T/RD's Rural Credit for Capital Mobilization Project (Cuevas, 1986). Most credits are given in kind rather than in cash. In addition to seed, the credits may be given as draft animals, plows and carts or other material.

According to the Niger study, over 80 percent of rural farmers benefit from informal credit. The bulk of these producers get their credits in kind from family or friends. There are income differentials in the rural areas, but they are not sufficiently pronounced to make large amounts of capital available through these informal financial institutions. In fact, financing of staple grain production is acquired in large part through remittances from migrant labor.

There is probably no longer very much forward contracting of grain production in semi-arid Africa, although the practice is discussed widely in the literature. It is often maintained that merchants make loans to producers at planting time for production to be delivered at harvest at the discounted price. This arrangement is often presented as a loan at high rates of interest. Rainfall has been too problematic for merchants to continue to take the risk of forward contracting without an almost prohibitively heavy discount, from the producers' point of view, on the harvest. Conversely, producers would resist obligations to surrender any significant portion of their hard-won harvests. The role of family and friends as informal credit institutions, therefore, has probably grown in recent years.

The availability of credit is a prerequisite for adoption of any innovation in agricultural technology. Producers already, to a significant degree, acquire their seed on credit from formal institutions. This same credit mechanism would support the acquisition of drought-resistant seed strains as well as present varieties.

However, there is a larger problem here. Access to agricultural financing may not be the controlling factor limiting staple food grain production. To what degree would producers with easier access to credit implement new technologies to secure and/or increase their production of staple food grains? This question links back to issues raised in the previous section on marketing institutions and marketing--where is the motivation,

and to what degree do producers perceive their material interest in increasing their efforts in staple grain production.

Decisions on implementing programs for increasing producers' access to agricultural credit focusing on staple grain production should be held in abeyance pending the outcome of two issues:

- what signals about increasing staple grain production are being sent by the market; and
- what is the opportunity cost of increasing staple grain production, even with more favorable access to agricultural credit?

One hypothesis is that, even under favorable conditions for agricultural credit, demand for staple food grains has a natural plateau of 180 to 200 kilograms per capita per year. This per capita demand is dropping in the main consumption centers where rice and wheat often substitute for millet and sorghum. Therefore, producers generally have higher marginal returns by channeling their marginal efforts to other pursuits.

B. Perishables

Perishable food production has greater capital investment requirements to develop and operate than staple food production does. Perishable foods are commonly grown in semi-arid Africa during the dry season. This means that some sort of water management technology is necessary for operations. Throughout the area, that technology very often involves using diesel pumps to lift water from wells or rivers into a canal network.

Perishable food production installations require considerable investments in labor and equipment before they can be put into production. In practice, the investment funds come from several different sources:

- In many areas, such as along the Senegal River and on the Mossi Plateau in Burkina Faso, the main source of funds is remittances from migrant labor.
- With the expansion of interest, in recent years, in off-season perishables production, a number of PVOs have been promoting the establishment of village schemes. The PVOs then offer credit from their project funds to villagers.
- There is some sharecropping of perishables, but this is a relatively rare occurrence. Under this arrangement a lender, often a merchant, establishes a title over a plot of land, buys the equipment and

brings in the labor, sharing the harvest or the proceeds from the harvest.

- Self-financing is most common. Any number of people, from three or four to a whole village, will pool resources to establish title over a plot of land, buy the equipment, etc.

- In Senegal and Niger, credit is available through formal government institutions whose objective is to promote perishable production.

- A certain amount of credit for perishable production is available through formal credit institutions.

Formal credit institutions have been more supportive of perishables production than staple-grain production. There are several reasons for this:

- Production of perishables is possible only on certain kinds of land. The proper types of land are scarce and, therefore, have market value themselves.

- Production of perishables presupposes title to the land cultivated. Even conservative credit institutions have confidence in the security of the lien that they can require on the title.

- Production of perishables requires the purchase of equipment and a certain amount of land improvement, all of which can be repossessed by the institutions.

- Production of perishables is primarily for the market. The credit institution can estimate the cash flow from the operation.

The production of perishables is expanding rapidly in semi-arid Africa. Compared with staple food grains, market demand is also expanding rapidly, and perishable production may be the most promising remunerative dry-season activity in many areas. The incentives for the producer are incontestable.

Perishables are generally cultivated by low-resource, low-cost, environmentally appropriate and stress-tolerant technologies. The installations are usually small, dispersed, and under individual or small group management. Shortages in the availability of credit have slowed down their further development. Since the incentives for producer adoption of the technology already exist, it will be relatively easy to diffuse more refined technologies that conform to progressively resource-conservative standards.

Thanks to the characteristics of perishable production, formal financial institutions will be able to develop lending criteria to support them relatively easily. One element in refining and expanding perishable production technology, therefore, will be the creation of perishable production loan windows at formal financial institutions throughout semi-arid Africa. Access of entrepreneurs and/or entrepreneurial groups to these loan windows is prerequisite to the diffusion of the technology.

C. Industrial Crops

Financing for industrial crop production usually comes from the para-statal or private firm that is engaging the producer in the system. Industrial crop production often stresses quality production. It therefore often incurs heavy expenses for production inputs, field services, postharvest handling, packaging and transportation.

In general, the para-statal or private firm makes all of these supports available on credit to the producer, from whose production the amounts are deducted when the company and the producer settle up at the end of the season. There are a number of arrangements under which producers are engaged in industrial crop production--contract farming, sharecropping, wage laboring. The general rule in all of these arrangements is that the producer receives credits through the para-statal or firm and makes reimbursement to it.

The para-statal or firm extends credit either from its own resources or as an intermediary between a private credit institution and the producers. In either case, the para-statal or firm has primary responsibility for collecting the reimbursement from the producers. Since it controls the marketing of production, it has control over a considerable share of producers' income. Therefore, the para-statal or firm has a reasonable expectation of much higher rates of reimbursement than staple-grain production and marketing entities. Producers cannot store and consume large quantities of industrial crops as they can staple grains.

At present, the mechanism for delivering financial support to producers of industrial crops appears adequate.

D. Conclusion

Credit institutions have a much greater potential role to play in diffusion of agricultural technology in semi-arid Africa than they now play. For example, staple grain farmers often buy their seed on credit. Credit institutions, therefore, would

necessarily be involved in the diffusion of drought-resistant seed strains. Production of perishables is experiencing dramatic growth in semi-arid Africa at the present time. In view of the technologies that must be put into operation, development of lands for perishable food production requires relatively heavy financial support. Further expansion of perishable food technologies cannot take place without considerable expansion of the capacity of financial institutions.

X. INFRASTRUCTURE SYSTEMS

Innovation in agricultural production technology is often induced by the need of producers to respond to changes in the social, political, economic and/or natural environment. Viewed in this way, it is noteworthy that a considerable number of producers in semi-arid Africa have responded to the drought years of the past decade and a half by adapting, installing and operating low-technology water management systems.

Technological innovation is induced in response to two opposing forces:

- the constraints that are emerging in the environment, and
- the opportunities that are opening up in the environment.

Infrastructure generally plays a role of opportunity in the environment. People will not innovate without an incentive. Very often that incentive is an opportunity to meet a growing need for cash at a low opportunity cost. Another common incentive is the need to maintain a standard of living in the face of growing competition for scarce resources, or of a deterioration of the resource base, or of prejudicial political or economic changes.

Most often, agricultural innovation involves a change in relations between producers and the market. Infrastructure systems play their most important role in inducing agricultural innovation because they are a pivotal element in agricultural marketing systems. The level of development and operations of infrastructure systems conditions the performance of commodity subsector-marketing systems and, thereby, the incentives for innovation in the technology of agricultural production. It is therefore most useful to organize the discussion of infrastructure systems according to the three general classes of commodities presented in the preceding sections. Before embarking on the discussion by commodity subsector, a general discussion of the conditions that infrastructure systems lay down for agricultural production is needed.

A. General Agriculture

The question here is, what kind of support do infrastructure systems give, in general, to agricultural production to encourage producers to reach higher production levels to the point at which they will have an incentive to adopt innovative technologies to assure the new production levels? Infrastructure systems provide

channels of two-way communication between producers and consumers. But they have a certain cost. The object of developing infrastructure systems is to reduce the transmission losses in this communication. Losses and inefficiencies in transmission occur in several different areas:

- Transportation of produce, agricultural inputs, buyers and sellers--Travel by road in much of semi-arid Africa is slow and arduous. The slowness adds vehicle and personnel time to each trip. The relatively poor state of the road network means that vehicle owners must amortize their vehicles in one-third to one-half the time that American owners do, for example. These twin factors reduce the efficiency and effectiveness of the transmission of demand from consumers to agricultural producers.

- Storage, spoilage and transformation of produce--Agricultural commodities are produced seasonally. The challenge is to move from seasonal production to year-round consumption. All commodities are perishable. The least perishable crops--staple grains--can be kept for years in family granaries under proper conditions. Other commodities must be transformed to last longer than a week or two. Still others do not respond well to transformation at all. Spoilage losses are another source of disturbance of transmission of demand to agricultural producers. They burden that transmission with costs that could be reduced by low-loss, low-cost storage or by low-resource transformation technologies.

- Transmission of accurate, up-to-date marketing information--To what degree producers are not receiving current pricing data in accessible markets is a matter for discussion. Producers interviewed in various activities of S&T/RD's Small Farmer Marketing Access Project always seemed to have a good idea of current prices in accessible markets as well as in several large inaccessible ones. Marketing information travels by word of mouth along the main-road axes from the marketing centers. Telephone, telex, print media and radio play little role in transmitting marketing information to the average producer. Whatever the resolution to this debate, it is a truism that the perfect market depends on perfect circulation of information to drive production and consumption. Imperfections in the circulation of marketing information have to be identified and addressed.

- Convenient transaction points with established channels for shunting produce through a distribution hierarchy to eventual customers--producers need a convenient point for buyers and sellers to assemble. The marketplaces themselves play an important role in transmitting messages from consumers that have an impact on producer efforts. The design of the marketplaces is critical to attracting produce buyers and sellers. The main design elements that must be considered are: location in relation to major markets, internal accessibility, shelter from sun and rain, drainage, access to freshwater, and accessibility by various-sized trucks from major routes. In fact, in the past 10 to 15 years, a common local-initiative development project in semi-arid Africa has been the establishment or upgrading of village markets. The evolution of the local economy in the zone has been toward more and more market activity as people's needs for cash expand in tandem with their need for consumer goods.

B. Staple Foods

Because staple food grains store and travel fairly well, the staple food grain market operates on a national scale. Therefore, national transportation infrastructure is vital to the operation of marketing institutions for staple food grains. Likewise, circulation of grain marketing information on a national scale is an important support to marketing institutions.

Storage poses a problem, however. For example, it is not clear where grain is being stored at present to feed the market through the dry season until the new harvest.

In many semi-arid African countries, para-statal marketing institutions buy and store cereals in their own warehouses. OFNACER in Burkina Faso and OPVN in Niger have been severely criticized for poor management of their stocks and high storage losses. None of the other para-statals are doing any better.

On the other hand, there is a widespread belief that grain merchants are buying and storing large quantities in secret caches near major consumption centers. This belief has never been confirmed by observation. Moreover, economic theory would call into question the wisdom of grain merchants storing large quantities of grain for more than a few weeks at a time. There are too many actors in the grain markets; the markets are too competitive and, consequently, too unpredictable to risk long-term storage of large quantities of stocks. In addition, money is too expensive in rural Africa to tie up large quantities in stocks for which the long-term marketing prospects are too risky

(See Blaine, et al., 1983; and Waldstein, 1984). The conclusion of S&T/RD's Small Farmer Marketing Access Project was that the majority of long-term storage of staple grains takes place at the village level in the granaries of producers or local assemblers. Once it leaves the village, it moves quickly through the marketing system to the consumers (See Cullen and Waldstein, 1983; and Waldstein, 1984).

Burkina Faso has been experimenting over the past few years with the establishment of village cereal banks. During the colonial era, village cereal banks were common features throughout the Sahel. The colonial government obliged producers to participate. Producers resented the policy, and village cereal bank programs were dropped by independence. As autonomous local institutions, however, village cereal banks can play several valuable roles (Blaine, et al., 1983):

- They can make credit available to rural farmers on the security of the commodities stored in the facility. Producers could deposit grain in the storage facility in exchange for a cash payment. Should they find themselves in need of grain later on, they would have to pay back the loan for the grain that they are repossessing at the original price level plus a service or operating charge.

- They insure against local food shortages by keeping stock on hand for distribution in time of need.

- They cut transport costs to supply local farmers who have not produced enough grain to cover their families' grain consumption needs. Since the grain that they will have to buy does not have to travel, in effect, from the village to the national distribution centers and back, the village consumers will cut out a major cost factor in the local price and benefit from the impact of this savings in the price that they pay.

- They act as a special-purpose cooperative group for grain marketing. In principle, the storage center could market stocks in bulk and reap the assembler's profits, should the membership of the village grain storage center so decide.

Village grain banks could play any of several roles in encouraging expansion of agricultural production to the point of inducing producers to adopt innovative production technologies for increased benefits from new opportunities. The technologies themselves must be reviewed for their impact on the natural resource base. However, an effective village grain bank depends

on effective local institutions. The crystallization of such institutions presents a challenge.

C. Perishable Foods

Infrastructure support for production and marketing of perishables is somewhat different from that of staple grains. Perishables do not travel or store as well as staple grains do. Yet production of perishables is much more oriented to the market than staple grain production is. Therefore, perishables have the following infrastructure needs:

- well-built, well-maintained roads that can take produce to market relatively rapidly with minimal losses;
- relatively large centers of consumer demand relatively close to the production zone;
- refrigerated holding areas to prolong the shelf life of fresh produce at market sites; and
- low-resource technologies for transforming unsold fresh produce for future consumption.

As already mentioned, the widespread adoption of off-season perishable production systems throughout semi-arid Africa is the most remarkable innovation in agricultural technologies and practices since independence. This trend owes its success to the conjunction of two other phenomena--the increasing circulation of cash in the economy, particularly in towns and cities; and the need to find remunerative activity, preferably at home, to replace the decrease in rainy season production that has accompanied the drop in the annual rainfall averages of the past 15 years or so.

S&T/RD's Small Farmer Marketing Access Project did a study of perishable production and marketing in northwest Burkina Faso (Waldstein and Masson, 1983). The study team found that producers had identified three varieties of potato that yielded well under local conditions. The interest in potato production centered around the following:

- the ability of local producers to adapt and master the necessary water management technologies for potato cultivation;
- the relatively high productivity of potatoes per hectare (people were harvesting roughly five to eight tons per hectare);

- the high demand for potatoes in urban markets.

- the suitability of potatoes as a substitute for staple grains whose production has fallen--potato production fits into the local farming system without competing for land or labor with staple grain production, yet potatoes themselves are a staple, and they permit families to stretch out the consumption of their grain stores during January, February and March; and

- the good travel qualities of potatoes and their sustained freshness for several weeks after harvest, under proper conditions.

In terms of infrastructure, potato producers had two major problems:

- lack of low-cost, low-loss storage; and

- very expensive, time-consuming and bruising transport to the large consumption centers, due to the state of the roads.

Experimentation with potato production is also currently taking place in Mali, Niger, Mauritania, Chad and Senegal.

Infrastructure support is a prerequisite to further adoption of technology packages for production of perishables. The greatest needs are for transport systems and postharvest handling systems to prolong the shelf life of produce. Removal of severe contemporary constraints through infrastructure support in these two areas will help to cut farmers' losses and, thereby, costs to consumers. At some point the market for perishables in semi-arid Africa will be saturated, but it is hard to determine where that point is until postharvest handling losses and, by extension, retail prices are cut considerably.

D. Industrial Crop Marketing Institutions

As with the other two crop categories, industrial crops have their own peculiarities and their own infrastructure support needs. The essential features of producing industrial food crops are:

- export crops are grown overwhelmingly with the market, especially the export market, in mind;

- promotion of industrial cropping is normally in the hands of a private company or para-statal organization--expansion of industrial cropping is

rarely a spontaneous occurrence, as expansion of perishable or staple food grain cultivation has been; and

- the private company or para-statal concerned with industrial crop development generally extends a whole package to producers from production credits to seed, cultivation inputs, extension services, postharvest treatment, packing, pricing and marketing.

Certainly, the adoption of industrial crop production means, by definition, the adoption of innovative agricultural production systems. The extent to which these technologies are resource conservative is a discussion that must be held between a national government and the private company or para-statal promoting the crop package. Only in the case of industrial crops can the technology for production be a matter for negotiation between the policy-making arm of national governmental institutions and the promoter. In the Casamance and Senegal Oriental regions of Senegal, for example, the national government has obliged two private companies to extend rice cultivation technology along with its cotton production package.

The large-scale private or public institutions involved in promoting expansion of industrial crop production need infrastructure support in several areas. Presumably, they will pass along benefits from the infrastructure to out-growers, either voluntarily or after negotiation with the national government. Support is needed in the following areas:

- road systems--the industrial crop production institution needs a well-developed, well-maintained road system to channel its production to the port; and

- telephone and telex communication systems--the industrial crop production institution may well have agents and producers scattered over a wide area, so its ability to keep in touch with them is a factor that has an important impact on the efficiency and, hence, cost of its operations.

The other infrastructure support systems such as marketplaces and postharvest handling and treatment facilities are either unnecessary in the industrial crop production system or are already internal to the system.

E. Conclusion

Infrastructure facilitates the transmission of messages from the marketing system to the producers. The more well-developed and efficient the infrastructure support system, the lower the transmission losses for messages from the marketing system. Cutting the losses is essential to demonstrating to producers where their best interests lie and to inducing them to adopt innovative agricultural technologies in pursuit of them.

Infrastructure support systems vary somewhat depending on the class of crop under consideration--staple food grains, perishables or industrial crops. Each of these crop classes has its own technical characteristics and particular institutional support system. Improved transport systems are a need common to all three. Beyond that, expanding marketplaces, improving the circulation of market information, and improving postharvest handling techniques and technologies play an important role with one crop class or another.

REFERENCES

Andrews, David. January 1986. "Current Results and Prospects in Sorghum and Pearl Millet." World Bank Agriculture Symposium.

Bahl, Roy, Jerry Miner and Larry Schroeder. 1984. "Mobilizing Local Resources in Developing Countries," Public Administration and Development, Vo. 4., pp. 215-30.

Becalo, Samuel. 1976. Coups and Army Rule in Africa: Studies in Military Style. New Haven and London: Yale University Press. 284 pp.

Blaine, Diane, Philip Boyle, William Garvey and Alfred Waldstein. 1983. "Evaluation of the Rwanda Local Crop Storage Project," U.S. Agency for International Development, Kigali, Rwanda.

Bruce, John W. 1985. "Land Tenure Issues in Project Design and Strategies for Agricultural Development in Sub-Saharan Africa." Madison, Wisconsin: Land Tenure Center, University of Wisconsin.

Bruce, John W., Louise Fortmann and James Riddell. 1985. "Trees and Tenure: An Introduction." In Louise Fortmann and James Riddell, Trees and Tenure: An Annotated Bibliography for Agroforesters and Others. Madison, Wisconsin: Land Tenure Center, University of Wisconsin; Nairobi, Kenya: International Council for Research in Agroforestry. Pp. vii-xvii.

Cissé, Salmana. 1982. "Les leyde du delta central du Niger: tenure traditionnelle ou exemple d'un aménagement de territoire classique?" In Enjeu fonciers en Afrique noire. Edited by Emile Le Bris, Etienne Le Roy and François Leimdorfer, with Emmanuel Grégoire. Paris: ORSTOM/ Karthala. pp. 178-89.

Cochrane, Glynn. 1983. Policies for Strengthening Local Governments in Developing Countries. World Bank Staff Working Paper no. 582. Washington, DC: World Bank.

Collinson, Michael. 1982. "Farming Systems Research in Eastern Africa." Paper no. 3. East Lansing, Michigan: Department of Agricultural Economics, Michigan State University.

Commons, John R. 1959. Legal Foundations of Capitalism. Madison, Wisconsin: University of Wisconsin Press. 394 pp. First published 1924: Macmillan, New York.

Cuevas, Carlos E. 1986. "Financial Markets in Rural Niger: Formal and Informal Transactions at the Household Level," Studies in Rural Finance, Agricultural Finance Program, Department of Agricultural Economics and Rural Sociology, The Ohio State University, Columbus, Ohio.

Cullen, Michael A. and Alfred S. Waldstein. 1983. "Grain Markets in Niger," Africa and Middle East Branch, International Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

Dillon, John. January 1986. "Institutional Possibilities to Minimize Risk at Farm Level." World Bank Agriculture Symposium.

Dorman, John and Alfred S. Waldstein. 1981. "Evaluation of the Rural Development Cell of the Entente Fund." Regional Economic Development Services Office for West and Central Africa, U.S. Agency for International Development, Abidjan, Côte d'Ivoire.

Eicher, Carl K. Fall 1982. "Facing Up to Africa's Food Crisis." Foreign Affairs. Council of Foreign Relations.

Fortmann, Louise, James Riddell, et. al. 1985. Trees and Tenure: An Annotated Bibliography for Agroforesters and Others. Madison, Wisconsin: Land Tenure Center, University of Wisconsin; Nairobi, Kenya: International Council for Research in Agroforestry.

Hardin, Garrett. 1968. "The Tragedy of the Commons." Science, 162, pp. 1243-48.

Hargreaves, John D. 1967. West Africa: The Former French States. Englewood Cliffs, N.J.: Prentice-Hall. 183 pp.

Hayami, Yujiro and Vernon Ruttan. 1984a. "Toward a Theory of Induced Institutional Innovation." Journal of Development Studies 20, p. 4.

Hayami, Yujiro and Vernon Ruttan. 1984b. "The Green Revolution: Inducement and Distribution." The Pakistan Development Review, 23, p. 1.

Jones, William O. 1967. Staple Food Marketing Systems in Tropical Africa, Stanford, California: Stanford University Press.

Morgenthau, Ruth Schachter. 1964. Political Parties in French Speaking West Africa. Oxford: Clarendon Press. 445 pp.

Norman, David. 1980. "The Farming Systems Approach: Relevancy for the Small Farmer." Michigan State University Development Paper no. 5.

Noronha, Raymond. 1985. "A Review of the Literature on Land Tenure Systems in Sub-Saharan Africa." Washington, DC: Research Unit, Agriculture and Rural Development Department, Operational Policy Staff, World Bank, (report no. ARU 43). 340 pp.

Oakerson, Ronald J. 1987. "A Model for the Analysis of Common Property Problems." In Proceedings of the Conference on Common Property Resource Management, prepared by Panel on Common Property Resource Management, Board on Science and Technology for International Development, Office of International Affairs, National Research Council. Washington, DC.: National Academy Press. Pp. 13-29.

Stewart, J. Ian. 1986. "Mediterranean-Type Climate, Wheat Production and Response Farming." Paper presented at the Workshop on Soil, Water and Crop/Livestock Management Systems for Rainfed Agriculture in the Near East Region, Amman, Jordan, 18-23 January 1986. 30 pp.

Stewart, J. Ian and Charles T. Hash. 1982. "Impact of Weather Analysis on Agricultural Production and Planning for the Semi-Arid Areas of Kenya." Journal of Applied Meteorology, 21, 4, pp. 477-94.

Swanberg, Kenneth G. 1985. "A Framework of Analysis for Agricultural Technology Development and Utilization in Semi-Arid Africa: A Short-Run Solution to Sub-Saharan Africa's Food Security Crisis." Paper reporting on work supported by the Food Security in Africa Cooperative Agreement between USAID and Michigan State University (DAN-1190-A-00-4092-00). East Lansing, Michigan: Department of Agricultural Economics, Michigan State University.

Thomson, James. 1981. "Nigerien Herder Associations: Institutional Analysis and Design." Report prepared for USAID/Niger Range and Livestock Project (contract no. 683-A-10002). Maradi, Niger. 269 pp.

Thomson, James T. 1981b. "Public Choice Analysis of Institutional Constraints on Firewood Production Strategies in the West African Sahel," in Public Choice and Rural Development. Washington, DC.: Resources for the Future. Pp. 119-52.

Waldstein, Alfred. 1984. "Where Is All That Food Storage We Hear So Much About Anyway?" Paper presented at the annual meetings of the Society For Economic Anthropology, University of California, Davis.

Waldstein, Alfred S. and Frank Masson. 1983. "Vegetable Marketing in Upper Volta," Small Farmer Marketing Access Project, Office of Rural Development and Institutional Development, Bureau of Science and Technology, U.S. Agency for International Development, Washington, DC. (mimeographed).

Waldstein, Alfred S. and Harlan Lampe, 1986. Djibouti Fisheries Development Project, Technology Transfer Impact Evaluation, Center for Development Information and Evaluation, Bureau for Program and Policy Coordination, U.S. Agency for International Development, Washington, DC.

World Bank. 1985. Desertification in the Sahelian and Sudanian Zones of West Africa. Washington, DC: World Bank.

Zolberg, Aristide R. 1966. Creating Political Order: The Party-States of West Africa. Chicago: Rand McNally. 168 pp.