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9. ABSTRACT

A planning framework for Integrated Sustained Yield Arid Land Agricultural Production Systems (ISYALAPS) based on limitations of natural resources was created and tested for the Sahel-Sudan region of west Africa. This six-country region (Chad, Mali, Mauritania, Niger, Senegal, Upper Volta) suffers from a harsh, variable climate which, with the traditional agricultural system, has contributed to widespread ecosystem degradation in the past decade. From north to south agriculture varies from oasis culture and nomadic and transhumant livestock production (camels, goats, sheep, and cattle) to sedentary cereal crop (mainly millet and sorghum) and export crop (cotton and peanuts) production.

Conclusions were made as follows: (1) the climate will continue to be variable but without major change, (2) the environment has been greatly harmed, (3) wildlife potential as a food source is limited, (4) the existing agricultural system cannot continue to support the present human and animal population, (5) the region can be more productive, (6) broadly conceived and adequately implemented programs will be required, (7) the ISYALAPS planning framework is workable for this and other arid regions, and (8) lack of data severely limits detailed analysis.

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A FRAMEWORK FOR EVALUATING LONG-TERM STRATEGIES
FOR THE DEVELOPMENT OF THE SAHEL-SUDAN REGION

VOLUME II

A FRAMEWORK FOR AGRICULTURAL DEVELOPMENT PLANNING

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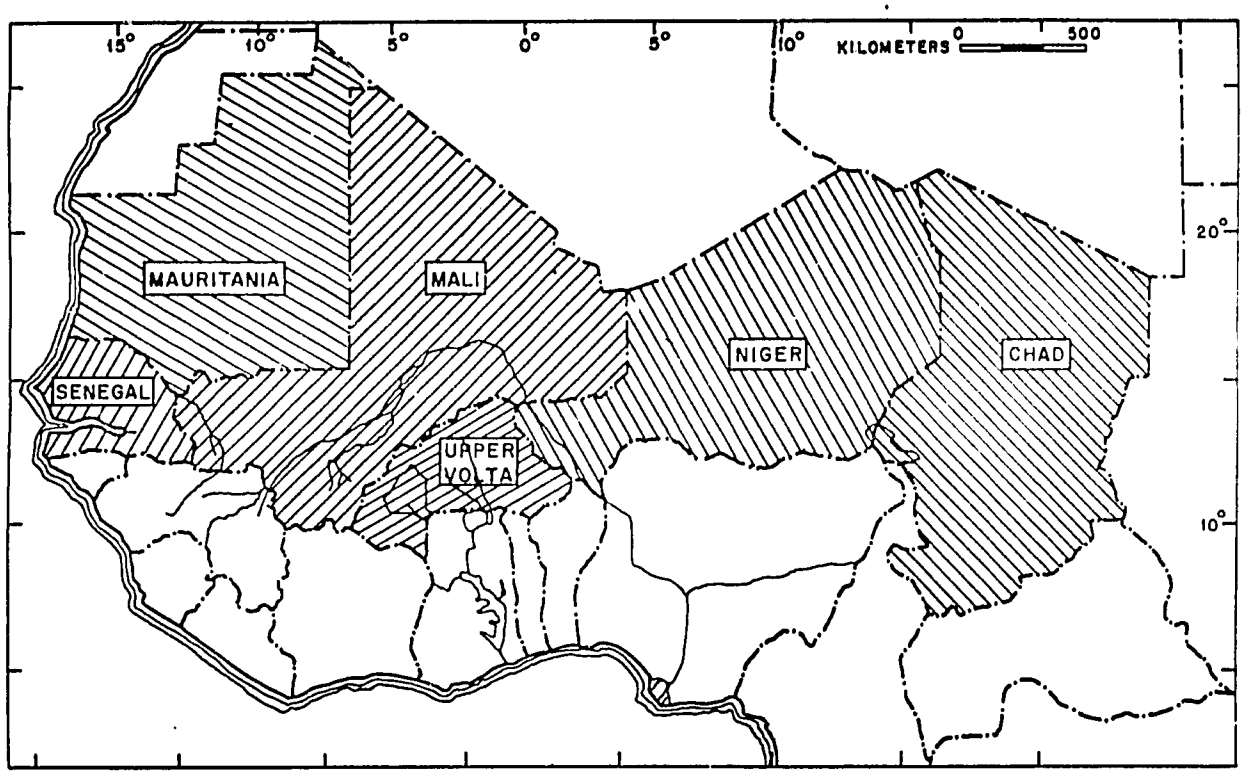

Volume 1. Summary Report: Project Objectives, Methodologies and Major Findings

Volume 2. ISYALAPS, A Framework for Agricultural Development Planning

This work was supported by the United States Agency for International Development under contract afr-C-1040 and was administered by the M.I.T. Office of Sponsored Programs. This report represents tax-supported research.

The contents of this report reflect the views of the Sahel-Sudan Project at the Massachusetts Institute of Technology and do not necessarily reflect the official views or policy of the Agency for International Development.

FOREWORD

This report results from a one-year effort by a multidisciplinary team of analysts to establish a framework for evaluating long-term development strategies for the African Sahel-Sudan area.

By June 1973 it had become evident that the suffering caused by the drought was the most severe the area had experienced in the last half century. A meeting of donor organizations and U.N. agencies, called by the U.N., was held in Geneva to discuss the problem. It was clear that, while the area required immediate assistance to meet the problems of drought relief, there was also need for long-range assistance if the region were to become self-sustaining and begin an era of positive economic development and widespread improvement in the quality of life of its people. The U.S. delegation offered to undertake the first steps necessary to "identify the methodology, the data requirements and the possible alternative lines of inquiry from physical, economic, social and cultural points of view" on which to base "a comprehensive examination of technical problems and the major alternative development possibilities" for the region.* The United States Agency for International Development (A.I.D.) offered to take responsibility for this task and determined that it should enlist the assistance of the academic community in carrying out the work. A.I.D. then approached M.I.T., and a study effort was formally initiated with the signing of a contract covering the period September 1, 1973, through August 31, 1974. This contract was subsequently extended to January 1, 1975.

The goal of the U.S. effort is to develop a methodology for evaluating long-term development strategies for the Sahel-Sudan region. The

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* Final Report on the Meeting of the Sudano-Sahelian Mid- and Long-Term Programme 28-29 June, 1973, Geneva. Special Sahelian Office, United Nations, New York. Statement by Donald S. Brown.

specific focus of the M.I.T. study has been on the development of an effective framework within which to appraise specific projects and programs. The term framework, in this context, refers to the accumulation, development, organization, integration, and analytical evaluation of information on the natural resources, economic resources, and human resources, including the social and political institutions, of the region. The framework is constructed in such a way that alternative strategies for the region can be identified and evaluated, in terms of both their requirements and their impacts, intended and unintended. The M.I.T. study has not been oriented toward detailed sector studies, prefeasibility studies, or project studies. Nevertheless, in the process of developing a methodology we have examined many kinds of information and a number of specific projects and have identified areas requiring further research to fill information gaps that impede long-range planning and evaluation of specific development proposals.

It is hoped that this framework will assist decision-makers in the Sahel-Sudan countries and in donor organizations in arriving at informed judgments concerning strategies for the long-term (20 to 25 years) social and economic development of the region.

The study was conducted under the direction of the M.I.T. Center for Policy Alternatives and was carried out by a multidisciplinary group. The Summary Report and the volume on agricultural development planning have drawn upon a number of working studies on specialized aspects of the problem prepared by the staff, i.e. (1) Economic Considerations for Long-Term Development, (2) Health, Nutrition, and Population, (3) Industrial and Urban Development, (4) Socio-Political Factors in Ecological Reconstruction, (5) A Systems Analysis of Pastoralism in the West African Sahel, (6) Technology, Education, and Institutional Development, (7) The Role of Transportation, (8) An Approach to Water Resource Planning, (9) Energy and Mineral Resources, and (10) Listing of Project Library Hold-

ings and Organizations Contacted. The basic elements of these studies have been drawn together in the two volumes of the final report.

In addition to M.I.T. personnel, individuals from a number of other organizations participated in the effort. Participants from the University of Arizona, in particular, made major contributions; they had primary responsibility for developing the analysis of the agricultural sector strategy. Professor John Paden of Northwestern University was a major contributor to the work on socio-political factors. Members of the Société d'Etudes pour le Développement Economique et Social (S.E.D.E.S.) in Paris provided valuable insights into various aspects of the Sahel-Sudan area. Several members of the Centre de Recherches en Développement Economique (C.R.D.E.) in Montreal developed sections on monetary policy, urbanization, and relationships between Niger and Nigeria. A list of individuals who participated in the study is included in Volume 1 of this report.

Numerous other individuals acted as consultants to the project, provided advice as the study progressed, and reviewed draft material for the reports. Help and advice were given by officials of the governments of the Sahel-Sudan countries, the Comité Permanent Inter-Etats de Lutte Contre la Sechèresse dans le Sahel (C.I.L.S.S.), members of United Nation organizations, members of the International Bank for Reconstruction and Dévelopment, and, especially, officials of the Secretariat d'Etat and various socio-economic and technical study groups in France. Finally, representatives of A.I.D. arranged meetings in Africa and reviewed the the progress of the study. All this assistance is gratefully acknowledged.

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PREFACE

The problems of drought in the Sahel-Sudan region have been discussed extensively in the news media in recent months. The seriousness of the situation has focused world attention on the region and brought new and renewed offers of emergency and technical assistance. The multiplicity of offers emphasizes the need for a strong and well-coordinated effort from the donor agencies and the recipient countries themselves.

This agricultural sector analysis was one of several pursued in the Massachusetts Institute of Technology Sahel-Sudan Project which was sponsored by the Agency for International Development to develop new planning concepts. It was ultimately selected for analysis as an example of the use of the methodology created by the overall project because:

(1) Agriculture is the most important activity in the region from the standpoints of number of people involved and effect on the economy and will continue in that role over the next few decades.

(2) The problem of drought is inseparable from agriculture.

(3) The agriculture sector lends itself to a comprehensive, integrated approach, and data for the sector, although not always exact, are more available.

(4) The resource base for extractive industrial development is

extremely limited.

(5) The educational and training level of the populace of the region does not provide a substantial basis for modern industry.

Development is known to be an unending task. For the last three decades people have sought simple solutions to the problems of development. But there are no quick and easy solutions; progress comes in small steps and only after much struggle, effort, and time.

This study presented an opportunity to break out of the familiar development assistance mold. Seldom has an opportunity been afforded to take other than a project-oriented look at the agricultural sector, and to propose unique ideas and concepts for development, particularly of such a vast region.

Much has been learned, not the least of which are the following:

(1) Analysis of and preliminary development of a planning framework for the agriculture sector of a region two-thirds the size of the United States is an immense task, particularly within the time constraints of the project.

(2) A lot of people, including many working in technical assistance or agricultural development, are still "looking for a miracle," some breakthrough or dramatic solution to the problems of arid land agriculture. This is extremely unlikely.

(3) At the same time, the traditional project-oriented approach, e.g., proposing large-scale irrigation schemes, is assumed by some to be the most desirable form of agricultural planning. Caution in this regard is looked on as negligence by some critics.

(4) A new idea or approach is subject to a lot of criticism especially during the formative stages. Constructive criticism has been useful.

(5) Little arid lands expertise has been applied to the Sahel-Sudan region. European or humid climate thinking has predominated.

(6) The French influence in the region is the most significant. Economic and agricultural policies have been shaped by it.

We have been materially aided in this study by our colleagues at the University of Arizona: Robert E. Dennis, Roger W. Fox, E. Lamar Smith, Jr., and C. Brent Theurer. Mr. Jean Tyč of the Society for Studies of Economic and Social Development (S.E.D.E.S.) Paris, was extremely helpful. Much of the data collection was done at M.I.T. by Athar Ahmad, Robert Hecht, Subodh Mathur, Tony Picardi, Carlos Selva, and Robert Verhaeghe. E. C. Hutchinson, Gustav F. Papanek, and R. L. Matlock read the manuscript in draft form and made many helpful suggestions. For the assistance of those identified above and others, we express our grateful appreciation.

We approached this project with enthusiasm and still retain that feeling. In retrospect, the effort seems more than worthwhile. For this opportunity we are grateful, and hopeful, also, that we have in some measure risen to the challenge presented.

The Authors

ABSTRACT

A planning framework for Integrated Sustained Yield Arid Land Agricultural Production Systems (ISYALAPS) based on limitations of natural resources was created and tested for the Sahel-Sudan region of west Africa. This six-country region (Chad, Mali, Mauritania, Niger, Senegal, Upper Volta) suffers from a harsh, variable climate which, with the traditional agricultural system, has contributed to widespread ecosystem degradation in the past decade. From north to south agriculture varies from oasis culture and nomadic and transhumant livestock production (camels, goats, sheep, and cattle) to sedentary cereal crop (mainly millet and sorghum) and export crop (cotton and peanuts) production.

The analysis procedure which constitutes the ISYALAPS planning framework involves a sequence of about 25 steps depending on the complexity of the planning area. Included are disaggregation of the area into climatic zones, assumptions of land use, choice of activity levels (levels of implementation), selection of a strategy (arbitrary mix of activity levels for the segments of the agricultural sector), calculation of production, and conversion of production into human carrying capacity for the planning area.

Five east-west oriented climatic zones ranging from desert (less than 100 mm annual rainfall) to woodland (over 900 mm annual rainfall) were defined for the Sahel-Sudan region. The irrigable and urban areas

make up a sixth zone. Long-term average potential production from the agricultural sector was calculated under four optional activity levels described as: Level A--minimum activity (achieve ecologic balance), Level B--extensive management (increase producing area), Level C--intensive management (increase technology and management), and Level D--maximum activity (apply all available technology).

An integrated strategy was selected for use as an example of the application of the ISYALAPS framework. It emphasizes resource management, utilizes all possible productive capacity, and can be implemented with low activity levels in the drier zones and higher activity levels in the wetter zones where potential for success is greater. This same strategy was also applied to Mali as an example, as was an activity level of Level B in all zones.

Comparison of potential and existing production in the regional example showed that the integrated strategy has the potential in an average year to increase calories by 30 percent, cash and export crops up to 400 percent, wood production by 140 percent, and human carrying capacity (at a nutrition level greater than World Health Organization minimums) by 30 percent. Employment in agriculture, however, would be reduced by almost 60 percent, but there would be increased employment opportunities in infrastructure occupations.

Similar comparisons for the Mali example showed that the integrated strategy has the potential to increase calories by 100 percent,

cash and export crops up to 900 percent, wood production by 240 percent, and human carrying capacity by 100 percent. Employment in agriculture would be reduced by 50 percent.

The strategy of implementing at Level B in all zones shows by contrast a 10 percent decrease in calories, an increase up to 180 percent in cash and export crops, an increase of 280 percent in wood production, but a decrease of 10 percent in human carrying capacity. Employment in agriculture would be reduced by 40 percent.

Necessary steps for implementation of the various activity levels are suggested for governments, the private economic sector, individuals, and donor agencies. Needs for inputs, infrastructure, and trained personnel are identified. The time required for implementation and achievement of the potential production discussed above cannot be exactly determined but would probably be from 25 to 50 years.

Impacts of implementation are examined. Benefits of the integrated strategy include increased food production, improved quality of life for rural families, ecosystem stabilization, increased exports, increased opportunities for industrial employment and entrepreneurship. Benefits from the strategy of implementing at Level B in all zones include improved quality of life, ecosystem stabilization, and increased opportunity for industrial employment. Cost factors are discussed, but actual costs were not determined. Impacts on social-political, economic, water resources, and transportation sectors are discussed.

There is an impact from non-implementation (the "do nothing different" strategy) because of the population-agricultural production-natural resources vicious circle existant in the region. Greater ecosystem degradation, starvation, and conflict between nomads and sedentary farmers are predicted. Support at present levels by governments and donors will not break the vicious circle.

Four representative projects which fit the ISYALAPS planning framework are introduced. A matrix for evaluation of projects takes into account the size, variability, diversity, and fragmentation of the region and recognizes financial limitations.

Conclusions were made as follows: (1) the climate will continue to be variable but without major change, (2) the environment has been greatly harmed, (3) wildlife potential as a food source is limited, (4) the existing agricultural system cannot continue to support the present human and animal population, (5) the region can be more productive, (6) broadly conceived and adequately implemented programs will be required, (7) the ISYALAPS planning framework is workable for this and other arid regions, and (8) lack of data severely limits detailed analysis.

Sensationalism in reporting the plight of the region has contributed several unsupported statements. There is no substantial evidence that (1) vast reservoirs of easily available groundwater are waiting to be tapped for irrigation, (2) the region can be the breadbasket for half of Africa, (3) the Sahara desert is encroaching at 30 miles per year, or

(4) the nomads will not consent to reduce their herds.

Many unresolved issues arise from the analysis including need for grazing limitations, inadequate tenure for farmers, inequitable income distribution, weak or missing infrastructure and reduced employment in agriculture.

Recommendations are made concerning steps to be taken in and for the region, for needed agricultural research, and for refinement of the ISYALAPS planning framework.

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1. INTRODUCTION

A brief description of the project is presented to orient the reader to the material which follows. Some of the major physical characteristics of the Sahel-Sudan region, which serves as the example area in subsequent analysis, are identified.

1.1 Project Description

The major objective of the agricultural sector study was to construct a comprehensive planning framework to assist decision makers, in the west African countries of the Sahel-Sudan region and in donor organizations, in making sound judgments concerning alternative strategies for the long-term agricultural development of the region. The collection, organization, evaluation, and integration of information on the agricultural resources of the region were necessary procedures. Much information was also drawn from the results of the analysis of the other sectors in the M.I.T. Sahel-Sudan Project.

1.1.1 Agricultural development planning: The importance of agriculture in economic development has emerged in recent years. No nation can truly develop until its people can be adequately fed, clothed and housed. Few of the developing countries have any base other than agricultural production to provide these necessities, at least in the early stages of development, and the Sahel-Sudan countries are not

exceptions. Unfortunately they have neither extensive mineral wealth nor an educated human resource base for value-added industries.

Further, the Sahel-Sudan and other developing countries are poorly endowed with the natural resources needed for agriculture. The shortage of readily available energy is another constraint. Thus the need for sound agricultural development planning becomes critical. Plans must provide a set of realistic expectations within the physical (and other) constraints of the region. Planning and policy making is a macro-economic process, but the micro-economics must not be overlooked.

Agricultural development plans do not stand alone; they form only a part of the total and therefore must be consistent with overall plans. Too often, however, little attention has been given to the agriculture sector in country planning with consequent disastrous results. The viewpoint that agriculture will somehow survive, and perhaps prosper, unassisted is untenable.

1.1.2 Procedure: The method of attacking the formidable problem presented by the Sahel-Sudan region follows, although not necessarily in chronological order, the form of this final report.

It was immediately apparent that a major problem facing the region is the imbalance between natural resources and their use by man. Exploitive overutilization is common. A systems analysis approach to rational natural resources utilization was evolved to create a framework for more detailed planning. Long-term sustained yield from agriculture

and integrated use of arid and wetter climatic zones are the guiding principles of the ISYALAPS* framework.

Considerable time was spent in becoming familiar with the region and its agriculture through library research and discussions with several consultants and colleagues. Field trips were made to Europe and west Africa to aid in identification and quantification of the problem.

Data concerning the climate of the region were analyzed to determine climatic characteristics and long-term trends. Ecological conditions were examined and the process and results of desertification described.

The agricultural system of the Sahel-Sudan region was analyzed to determine the method of operations and practices of crop and livestock raising in addition to production, productivity and areas utilized. The characteristics of each of the ecologic zones and their effect on productivity were established.

The systems analysis method of the ISYALAPS planning framework was then applied to predict potential agricultural production and other impacts using arbitrarily selected strategies in the west African countries. First the Sahel-Sudan region was considered as a whole; then the country of Mali was analyzed separately. Comparisons of the results of

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*Integrated Sustained Yield Arid Lands Agricultural Production Systems (see Section 2 for details).

these examples were made with the existing situation. Implementation steps are suggested.

A matrix was prepared to permit examination of the whole spectrum of choices for action programs in climatic zones, social arrangements, political subdivisions and activity levels (levels of implementation). Examples of projects which can be tested within the matrix are given.

Conclusions based on the analysis and recommendations for the future development of the agricultural sector and for further study are made for some of the identified needs. A list of selected references is presented.

1.1.3 Scope: Just as planning for agriculture is only a part of overall planning for economic development, this effort does not encompass the whole gamut of agricultural development planning. It is not a complete analysis or full illustration of program analysis and planning. It is a first step, an important step, but only one of many on the way to an agricultural plan.

The intent here is not to make prescriptive decisions for the six countries. That is clearly their responsibility. What is sought is a method which will assist them in making rational decisions to insure that the "means" proposed will accomplish the "ends" desired. In addition to government economic and agricultural planners, and donor agencies, the ISYALAPS planning framework can serve as a guide for commercial investors and large scale farm corporations or individual operators.

Individual activities can be tested for conformity with the ISYALAPS planning framework. Goals can be set and then progress toward the goals measured. Policy can be developed and priorities established. Constraints to development can be identified and evaluated. Since a planning framework must have flexibility, adaptability to change is built into the method.

1.2 Geographic Setting

The Sahel-Sudan region consists of six nations, Chad, Mali, Mauritania, Niger, Senegal, and Upper Volta. Until their independence in 1960 all were French colonies. Chad was administratively a part of French Equatorial Africa, the others were part of French West Africa. All six are contiguous, and encompass part of the southern Saharan Desert and adjacent sub-Saharan semi-arid savannas.

The terms Sahel and Sudan have been variously used as pertaining to this and other regions. Both are Arabic words. Sahel means shore or coast and is used in connection with coastal zones in Morocco, Tunisia and elsewhere. Sudan means black.

The application of the word "Sahel" to a zone south of the Sahara appears to have its origins in the days when Arab camel caravans crossed the "sea" of the Sahara southward and arrived at "shore" points at Gao and Tombouctou. Sudan presumably referred to the lands south of the Sahara where black people lived.

Sudan has been used as a geographic term by the British for the country of Sudan and by the French, as Soudan, as an administrative division of former French west Africa. For a short time after independence, Soudan was applied to the country now known as Mali.

Auberville, according to Cocheme and Franquin (1967) used "Saharian", "Sahelian" and "Soudanian" as names for climatic and vegetation zones in west Africa. Further subdivisions resulted in such terms as "Sahelio-Saharian," "Sahelio-Soudanian," "Soudano-Guinean," and even "Soudano-Sahelian."

As used herein Sudan is more or less equivalent to the savanna and Sahel is more or less equivalent to steppes of some authors.

1.2.1 Extent and area: The Sahel-Sudan countries of west Africa range from 27° 30' N latitude (northern Mauritania) to 7° 30' N latitude (southern Chad), a distance of some 1,950 km, and from 17° 30' W longitude (western Senegal) to 24° E longitude (eastern Chad), a distance of about 4,400 km. The total area is about 1.7 times that of western Europe and about equal to 67 percent of the area of the United States (Table 1.1). Areas of the individual countries also are given in Table 1.1 and geographic relations are shown in Figure 1.1.

The region is sparsely populated in comparison with most temperate regions of the world. Countries in the more moist southern zones (Senegal and Upper Volta) have denser populations than the countries with greater areas of desert. Note the extremely low density in

TABLE 1.1

Area, Population, and Population Density of the Sahel-Sudan Region and Selected Reference Areas

	Area (hectares) X 10^6	Population X 10^6	Population Density (persons per hectare)
Chad	128.4	3.710	0.03
Mali	124.0	5.020	0.04
Mauritania	103.0	1.117	0.01
Niger	126.7	4.020	0.03
Senegal	19.7	3.930	0.20
Upper Volta	27.4	5.380	0.20
Total	529.2	23.117	0.04
Arizona	29.5	1.752	0.06
Western Europe	300.3	319.663	1.06
India	326.8	547.000	1.67
Australia	768.6	12.550	0.02
U.S.A.	782.7	207.483	0.27
U.S.S.R.	2,240.2	243.900	0.11

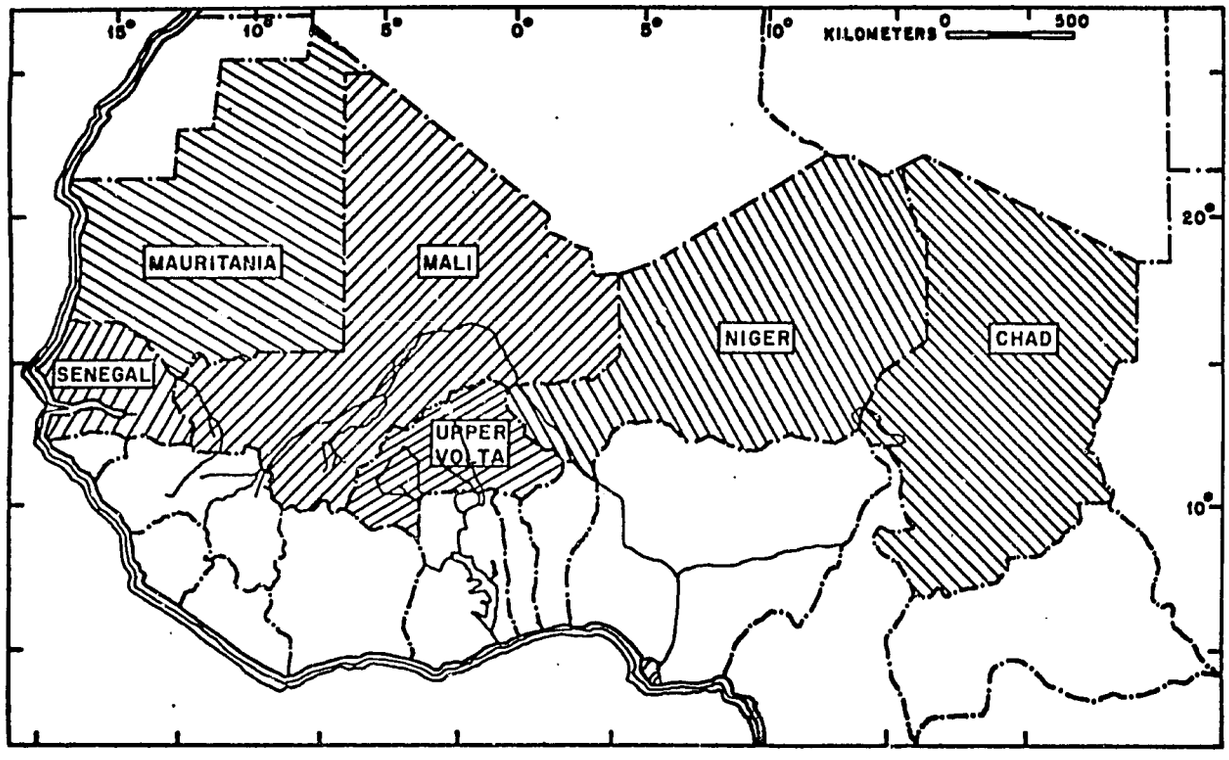

FIGURE 1.1 Countries of the Sahel-Sudan Region

Mauritania. The State of Arizona in the arid southwestern part of the United States also has a low population density, intermediate between the highest and lowest densities in the Sahel-Sudan region.

1.2.2 Topography and drainage: The Sahel-Sudan region ranges in elevation from sea level on the Atlantic coast of Senegal and Mauritania to 3,417 m on top of the volcano, Emi Koussi, in the Tibesti mountains of northern Chad. There is an east-west oriented trough running through the central part of the region with higher elevations to the north, east and south.

Little rain falls in the north so no perennial streams arise there. Four major river systems traverse part of the region. The Senegal flows into southwestern Mali and then northwestward to the Atlantic Ocean. It forms the boundary between Mauritania and Senegal. The Niger River enters southern Mali and flows northeastward to "The Bend of the Niger" where it flows eastward and then southeastward into Nigeria and then southward into the Atlantic Ocean. Most of Upper Volta is drained to the south by the Volta River complex (White Volta and Black Volta).

The Logone-Chari system originates in the moist areas to the south and the southeast of Chad and flows northwestward to Lake Chad. Lake Chad is a fresh water lake with no continuous surface outflow although occasional large floods pass through to adjacent desert areas.

1.2.3 Arable land: The characteristic of the arid and semi-arid climates of the region combine to make little of the land arable. As

shown in Table 1.2 only 7.9 percent of the total land area of the region is classified as arable. In contrast 24.3 percent of all of Africa and 24.1 percent of all of the continents are classified as potentially arable. Twenty-six percent of the arable lands of the region are cultivated.

TABLE 1.2

Arable and Cultivated Lands of the World in the Mid 1960's

Continent	Area 10^9 hectares Total	Potentially Arable	Percent of Total	Cultivated (mid 1960's)	Percent of Arable
Africa	3.02	0.733	24.3	0.158	21.6
Sahel-Sudan region	(0.53)	(0.042)	(7.9)	(0.011)	(26.0)
Asia (except USSR)	2.74	0.627	22.9	0.518	82.6
Australia and New Zealand	0.82	0.154	18.8	0.016	10.4
Europe (except USSR)	0.48	0.174	36.3	0.154	88.5
North America	2.11	0.465	22.0	0.239	51.4
South America	1.75	0.680	38.9	0.079	11.6
USSR	2.23	0.356	16.0	0.227	63.8
Total	13.15	3.168	24.1	1.388	43.8

Source: President's Science Advisory Committee, 1967

2. THE ISYALAPS PLANNING FRAMEWORK

New methods and new techniques are required to solve the urgent problems of the less developed countries. More than twenty-five years of disappointing project-oriented development activity emphasize the need for a fresh approach.

Decision makers need a means for evaluating the probable results of various alternatives, and a methodology was created to meet that need. The basis of the proposed planning framework for integrated sustained yield arid lands agricultural production systems (ISYALAPS) discussed below is the quantification of the natural resources available for agricultural production in the planning area according to the following facts:

a. Productivity varies in different ecosystems, primarily because of moisture availability during the growing season,

b. Productivity can be exploited without any environmental degradation,

c. Productivity can be increased by application of technology, management, and various other inputs.

Constraints to development are identified, and then a potential for sustained agricultural productivity is established with four optional activity levels for implementation.

Finally impacts of an arbitrarily selected agricultural strategy are

evaluated. The method involves determination of human carrying capacity by calculating both the caloric and protein content of the total agricultural production (animals and crops) of the region. Since agricultural productivity varies with activity level, a whole spectrum of carrying capacity values can result. Thus the long term effects of various action programs can be evaluated.

The emphasis is on natural resources and productivity but economic impacts and cost-benefit analysis are not ignored. In preliminary planning, however, details for sophisticated economic analysis are commonly lacking.

A comparison is made with the existing situation to establish the compatibility of the strategy. A basic incompatibility, for example, between existing and proposed land uses can cause insurmountable difficulty in implementation.

An evaluation matrix to assist planners in completeness of analysis for action programs (projects) is proposed. Project evaluation criteria are identified and discussed.

2.1 Nature and Purpose of Planning

Planning is a vital part of modern economic life. It is the essence of management and is a way of looking ahead and taking account of future happenings. Planning for development is aimed at transforming a traditional or subsistence economy into a more modern one.

Planning must account for various constraints and reduce or eliminate their influence. Planning involves setting priorities even though such action may not be politically or socially popular. Effective planning resolves such conflicts in ways that provide maximum social benefits.

> Planning is an aggregation of inter-related development proposals based on critical analysis, on a constant approximation to the facts, and a constant revision of targets in the light of a better understanding of these facts or of a substantial modification thereof and is essentially a question of hard thinking and unremitting intellectual vigilance (FAO 1970).

In less developed countries planning must be adjusted to the existing human and economic situation and available resources and must not copy, unthinking, the planning in developed countries.

Hillman and Martin (1972) point out that optimum combinations of resources may be "efficiently" allocated without being "equitably" allocated. Equity implies that economic and psychic benefits from land must be shared by all citizens. The goals and constraints of resource allocation must be reflected in politically (and socially) acceptable combinations of efficiency and equity.

2.2 Constraints

Every planner would like to prepare plans which will transform a desert or similarly difficult area into the "Garden of Eden." Realistically, the resources--natural, human, and economic--to make such a

transformation seldom are available.

2.2.1 Ecologic and climatic constraints: A number of principles must be considered in efforts to develop an arid or semiarid region. Most of the following have been discussed in more detail by a number of authors, including Talbot (1972) and Dregne (1970). Not only are droughts a part of the normal climate, but also the basic physical conditions vary in other ways, including:

> The facile belief that all the arid regions need to solve is their problems in water no longer is widely accepted by knowledgeable people. Strong winds and intense solar radiation, with all their accompanying problems, will be there whether the supply of water is small or large. The irrigating of a calcareous soil does not make it into a humid-region soil. At best, limitless water would turn the arid regions into numerous oases. Land in much of the arid regions is too shallow, too rocky, too steep, or too salty to be used for anything except the production of a sparse flora and fauna, military ranges, or similar developments (Dregne, 1970).

Probably the most important single factor in agricultural production is climate. The effects of climate can be modified to a certain extent, however, the process is exceedingly expensive.

2.2.1.1 —Variability in arid-semiarid regions: For the relatively short times involved in development projects (even periods up to one hundred years), there is little likelihood that climate will undergo any measurable shift. However, variability in weather is so great that generally a record of at least fifty years is necessary to compute a relatively stable mean value of components. Annual variability (deviation

from average) of weather parameters is greater in arid-semiarid climates than in more moist climates, and droughts occur with more frequency and severity in such regions. Furthermore, even within a given rainfall zone, local variations in soil, slope, and other physical features result in large variations in ecological conditions. Thus, development plans cannot be based simply on short term average weather conditions.

2.2.1.2 —Fragility of ecosystems: Ecosystems in arid and semiarid regions are extremely fragile. Their destruction is quick and easy but reconstruction is slow and difficult. Natural rates of restoration are not well known, but in some cases are estimated to range from more than 200 years to perhaps more than 1,000 years. The time for recovery is directly associated with the degree of degradation of the ecosystem.

2.2.1.3 —Population pressures and exploitation: Most arid and semiarid regions are not underpopulated by either humans engaged in agriculture or domestic animals, and parts appear to be overpopulated by both. Herdsmen, whether nomadic or sedentary, appear never to have existed voluntarily in equilibrium with their environment. Rather, exploitative over-utilization long has been recognized by range management specialists as being widespread.

Long-term continued over-utilization by grazing and especially browsing results in massive ecosystem destruction and desertification.

The buildup of animal and human populations during a period of a few wet years results in an extremely rapid ecological degradation when followed by average or drought conditions.

Because of population pressures rain-fed crops are sometimes planted in semiarid areas where adequate rainfall occurs only during exceptional "wet" years. The destruction of the native vegetation which results from such planting not only reduces available forage for animals but also permits wind and water erosion leading to desertification in average or drought years.

2.2.1.4 —Ecological balance: Esthetic considerations are of minimal importance to starving people, however, ecological balance is of prime importance for their survival. No scheme to increase productivity of foodstuffs for human consumption is likely to succeed unless it takes into account the ecology of the region. Some form of animal grazing offers the best potential for a long-term sustained yield in areas in which the water supply is inadequate for crops. Developmental schemes that remove environmental limitations on animal numbers (such as water development, veterinary activities and predator control) and that are not associated with an immediate control of animal use and/or range improvements result in range degradation and reduced sustainable carrying capacities.

2.2.2 Time constraints: Time is a crucial element in agricultural development. Quick solutions are sought for difficult problems

but past experience shows that such development occurs slowly. An example taken from the history of agricultural development in the United States will serve to illustrate the point.

Many constraints to increased productivity in the less developed countries resemble those of the arid and semiarid southwestern United States and adjacent northwestern Mexico. There, many procedures have been applied to increase productivity, including:

a. Range management, improvement, and restoration

b. Soil and water conservation

c. Land leveling, irrigation, and drainage

d. Use of fertilizers, pesticides, and herbicides

e. Development of crop varieties and animal breeds adapted to higher productivity in the ecosystem.

This system for agricultural production was not established quickly. Pressure from farmers and ranchers through their elected representatives was important. Further, sustained agricultural research and development (variously associated with universities, government agencies such as the U.S. Department of Agriculture, private corporations and even some individual owners) result in continuing improvements.

Much of the development of agriculture in the United States has been directly related to a series of Federal laws providing funds for education and research, regulating land use and conservation, and establishing credit and other assistance for farmers. Some of the major

events were:

1862 - U.S. Department of Agriculture established. In 1889 USDA was given Cabinet status.

1862 - Homestead Act distributed millions of acres to farmers and ranchers.

1862 - Morrill Act provided for the establishment of the Land Grant Colleges of Agriculture.

1881 - Forestry Division established. In 1891, the Timber Cutting Act was repealed and forest reserves were authorized. By 1905, the Forest Service had evolved.

1887 - Hatch Act established support for state agricultural experiment stations.

1894 - Irrigation was provided under state auspices. In 1902, the Reclamation Act put the Federal government directly into irrigation development.

1914 - Smith-Lever Act established the Cooperative Extension Service.

1916 - Federal Farm Loan Board established to provide long-term credit to farmers at low interest rates. In 1933, Federal land banks were created to provide additional credit; the Farmers Home Administration provided credit and supervisory assistance for small farmers. The Bankhead-Jones Tenant Act authorized loans for the purchase of small farms in 1937.

1933 - Soil Erosion Service founded to combat erosion problems. In 1935 it became the Soil Conservation Service and was moved to the Department of Agriculture.

1933 - Taylor Grazing Act brought public range lands under responsible control and conservation.

From the above, it is evident that the development of the present southwestern United States system covered somewhat more than 100

years. However, many of the basic principles that were established in this period could be applied to another region in a much shorter period of time. In fact, in large areas of northwestern Mexico, many of the U.S.-evolved procedures are being applied, with significant improvements in productivity. In other parts of northwestern Mexico (as well as on some of the Indian reservations in the southwestern U.S., e.g., the Papago and Navajo-Hopi Reservations in Arizona) these procedures are not being utilized and productivity remains low.

2.2.3 Energy constraints: For each calorie of energy invested in a primitive food production system from 5 to 50 food calories may be obtained (Steinhart and Steinhart 1974). Intensive rice, corn, potato and soybean production is only slightly less efficient, but industrialized food systems may require from 5 to 10 calories of fuel to deliver one food calorie to the consumer.

Energy supply problems at the present time focus concern on energy use. Energy is used directly on the farm, in the processing, packaging and transport industries, and for commercial and home food storage and cooking. A relatively high energy cost is associated with high protein foods and irrigation. "Green revolution" varieties require irrigation, fertilizer, other chemicals, and machinery, all of which increase energy input. However, a natural ecosystem requires no fuel input and subsistence agriculture uses only the energy of farm labor.

Moving from subsistence to a market economy will increase energy input but need not require fossil fuel in large amounts. Use of wind and animal power, animal manure and green manure crops, and limiting chemical inputs reduces energy needs significantly without sacrificing output.

Farm output as a function of energy input shows the familiar S-shaped curve. Additional energy input in the lower ranges increases output markedly but yields little or no increase at higher levels. If development plans fail to consider the availability of energy both present and future, their success will be limited.

2.2.4 Social-political constraints: There are usually many institutional and attitudinal obstacles to development plans. Establishment of priorities for resource distribution may be justified but naturally results in political and social pressures for uniform allocations.

Planning must fit the human needs, but many critical factors are exogenous to agriculture. A need may exist, for example, to provide employment for surplus labor under uneconomic conditions. Manpower might be transferred from agriculture to industry and the service sector, but there is usually a lack of skilled personnel, including administration.

If farmers (and other citizens) are not kept informed of what the objectives of the plans are, their cooperation thereby will be lessened greatly.

2.2.5 Economic constraints: Development plans require financing for implementation and are limited by the resources available. Foreign assistance and food aid often are considered because local capital usually is scarce and foreign exchange limited.

Surplus agricultural production provides for investments in industry and other related sectors while exports supply needed foreign exchange for import of development goods. Caution is required to avoid "skimming off" too much of the farmer's return for this purpose.

The demand for agricultural products is a critical, dynamic factor. Knowledge of annual growth of demand is helpful in planning as is an understanding of how the agricultural economy functions.

Farmers, like other people, respond to economic incentives. Price stabilization, easy credit, availability of inputs, and creation of infrastructure are all necessary. In addition, farmers want to receive a fair share of the final sales price.

2.3 Systems Analysis Approach

Systems analysis is a process, which may involve mathematics and computer technology, for examining a total system, taking nothing for granted. It requires creativity and imagination in the application of quantitative and qualitative methods to determine and define more carefully the relationships among the parts of the system. Models that abstract from reality but which are based on the critical relationships may be used.

As applied to development planning, systems analysis includes the determination of relevant factors, the quantification of relationships and calculation of the effects of following various strategies. Systems analysis does not provide "how to" information, but rather gives insight into "what ought to be or can be done." (Fischer 1972) The framework developed by analysis provides a testing ground for ideas and helps determine priorities.

Using computer technology, systems analysis can provide rapid evaluation of alternative strategies with complex sets of variables. Critical constraints can also be identified through sensitivity analysis.

However, one must keep firmly fixed in mind the axiom that the model of the system being studied is no better than the data used to define it. Assumptions or "educated guesses" must be recognized as only that. Unfortunately, there is an authenticity, often unjustified, but nevertheless almost automatically granted, to computer printout or other tabulated results of model studies.

2.4 Natural Resources Utilization

The natural resource base for agriculture includes not only the sunlight, soil, and water available in an area, which are of prime importance, but also the native plant and animal life (grass, shrubs, trees, wildlife, fish, etc.) and the climate. The quantification of these resources provides an upper limit for the carrying capacity of the region in both human and animal terms.

Adequate evaluation of the resources will help formulate guidelines for administrators regarding things to be considered for development. Decisions cannot be based on a few years of favorable weather but must be solidly based on long-term climatic characteristics. Effective measures must be taken to insure that resources are not over-committed and that any assessment of agricultural productivity is realistic.

The seemingly inappropriate emphasis of the ISYALAPS planning framework on productivity and production based on resources should not be confused with a disregard for the plight of subsistence farmers. On the contrary, full consideration is given to their problems. In an economic system where the rewards are based in large measure on individual productivity, the farmer must produce more if he is to gain a larger share of the proceeds. If increasing the "quality of life" of the rural poor is the "end," then increasing agricultural productivity is a "means" to that "end."

2.5 Description of the ISYALAPS Planning Framework

The analysis procedure which constitutes the ISYALAPS planning framework involves a sequence of about 25 steps depending on the complexity of the planning area. First, the given planning area is divided into climatic zones. Then assumptions are made regarding appropriate land use (certain lands may not be suitable for any intensive uses.) Drier zones are integrated with more humid and irrigated zones

in the total agricultural production system.

Potential productivity is evaluated on the basis of climatic zone and the activity level (level of management, technology, and other inputs) applied to the system. Costs and benefits also are affected by the selected activity level.

Total potential production and other impacts of an arbitrarily chosen agricultural stategy then are evaluated. If results are unsatisfactory the process is repeated with an alternative strategy. Finally production is converted into human carrying capacity.

In the material which follows, the steps in the application of the ISYALAPS planning framework are described in more detail. Examples of the use of the ISYALAPS concept for the Sahel-Sudan region are given in Section 4.

2.5.1 Climatic zones: Water is the basis for the first disaggregation of land area. Climatic zones must be defined on the basis of effective rainfall (that falling during the growing season or at such time as it can be stored in the soil zone for later crop use). Where a water resource (surface or groundwater) suitable for irrigation is found, irrigable land is considered as a separate zone. The quantity and quality of available water limits the magnitude of such zones, which may or may not be contiguous with the water resource. Figure 2.1 is a schematic of a theoretical planning area with various climatic zones.

In regional planning, or for that matter, in some cases of national

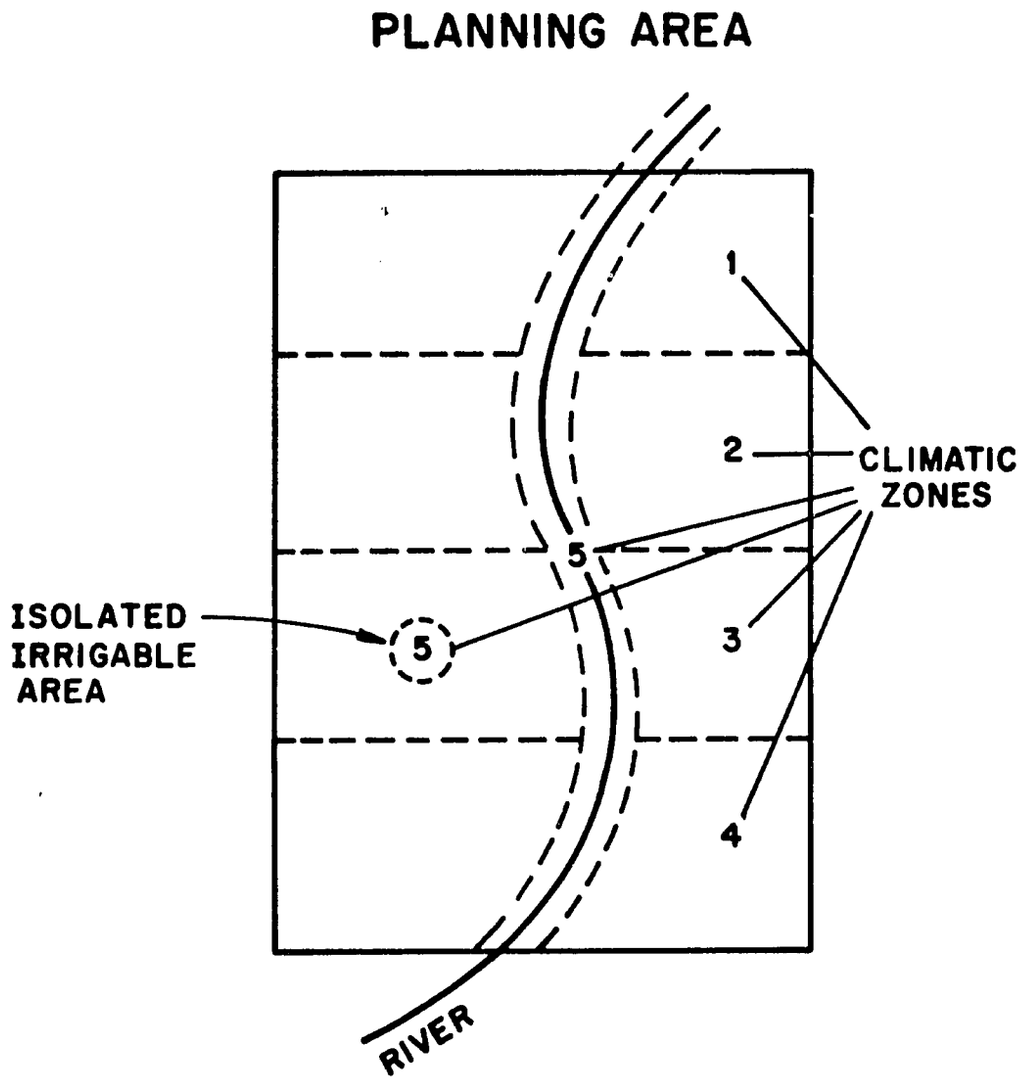

FIGURE 2.1 Schematic of a Planning Area

planning, it may be desirable to consider smaller subdivisions as well as the total area. Such planning areas may lie wholly within a single climatic zone or may encompass several of them. The basic methodology for applying the ISYALAPS planning framework for the agricultural development of an area is the same regardless of its physical size or ecological complexity.

Livestock production is considered possible for all zones except irrigated land. Even there it may be integrated with crop production. Dry land crop production is considered practical only in those zones with sufficient rainfall. Irrigation is limited by the quantity of available water, which, itself, varies with application of technology. Wood production is considered for all but the irrigated zone. Inland fish production is generally limited to perennial streams or lakes but may include intensive pond fish culture. Milk, poultry, and egg production can be included in appropriate locations, usually in or near urban areas.

In some cases certain land areas are unsuitable for agricultural production because of chronic disease caused by insect infestation or other reasons. Such areas can be subtracted from the climatic zones at this point, recognizing that they can be made productive but only with massive eradication programs.

2.5.2 Agricultural production potential: The potential agricultural production obtainable from a given land area, which is a function of many interrelated factors, must now be assessed. Subsistence

agriculture is often exploitive, with decreasing soil fertility and/or actual loss of soil by erosion after some years of operation. Productivity may have been quite high initially, but it also is reduced and when some lower limit is reached, the farmer or herder abandons the land and moves to a new location. Eventually productivity may be partially restored through natural ecologic processes and the cycle begins anew.

Modern agricultural systems recognize the need for maintaining or improving productivity. Management, technology, and various inputs are required.

2.5.2.1 —Activity levels: It is convenient to consider, for comparative purposes, four discrete activity levels (or implementation stages) as they affect productivity in an agricultural development scheme. Funds are never unlimited and by this method a set of options is created for the decision makers. Any activity level can be considered for a given climatic zone although usually there are logical reasons for choosing the activity level appropriate for a given zone as will be discussed later.

Even though the ultimate goal of development might well be to obtain results of the highest activity level, i.e. optimum productivity, such a goal usually exceeds the capabilities of both the donor agencies and the recipient countries or is economically infeasible.' There is a natural progression from the lowest (A) to highest (D) activity level and various segments of the agricultural system within a given country may

be operating at vastly different levels. Activity levels are cumulative--everything done at Level A is or can be a part of Level B, etc.

Briefly described the activity levels have the following characteristics:

Level A - This is the minimum activity with impact and attempts to achieve ecological balance in the planning area by controlling the number of animals, area farmed, and population distribution. Resource degradation is halted while current technology is essentially retained.

Level B - This extensive management activity seeks to increase production by utilizing more area at slightly greater technology levels. Controlled use of all appropriate land areas is permitted.

Level C - This intensive management activity requires the introduction and utilization of improved agricultural technology in crop, wood, and livestock production. Improved varieties and breeds, and soil and water conservation practices are used along with natural sources of nitrogen and animal powered mechanization. Multiple use of land, which implies that alternative uses of the same land are not competitive, is permitted. (At some level of production this principle is violated.)

Level D - This maximum activity level calls for widespread utilization

of intensive agricultural systems, similar to those in developed countries. All available agricultural technology and practices are used to maximize production of crops, wood, and livestock including irrigation and drainage, mechanization, and chemical fertilizers, herbicides and pesticides. Multiple use of land is not permitted where it constrains productivity.

Productivity achievable under each of the activity levels must be estimated. Such estimates are based on productivity attainable in similar regions. Productivities at the high end of the scale (Level D) are thus easier to estimate because they approximate those presently reached in a similar climatic zone (or irrigated area) in a developed country.

There are costs and benefits associated with the implementation of programs at each activity level in the various climatic zones. However, because of the novelty of the activity level concept as applied to agricultural development, the explicit relationships between such costs and benefits cannot be determined from available information.

Figure 2.2 depicts the relationships as they are currently conceptualized. The abscissa is the activity level with the existing activity at the origin which represents a "do nothing different (DND)" alternative at subsistence levels. The ordinate is the dollar value of costs and benefits. No attempt is made to include social and other indeterminate

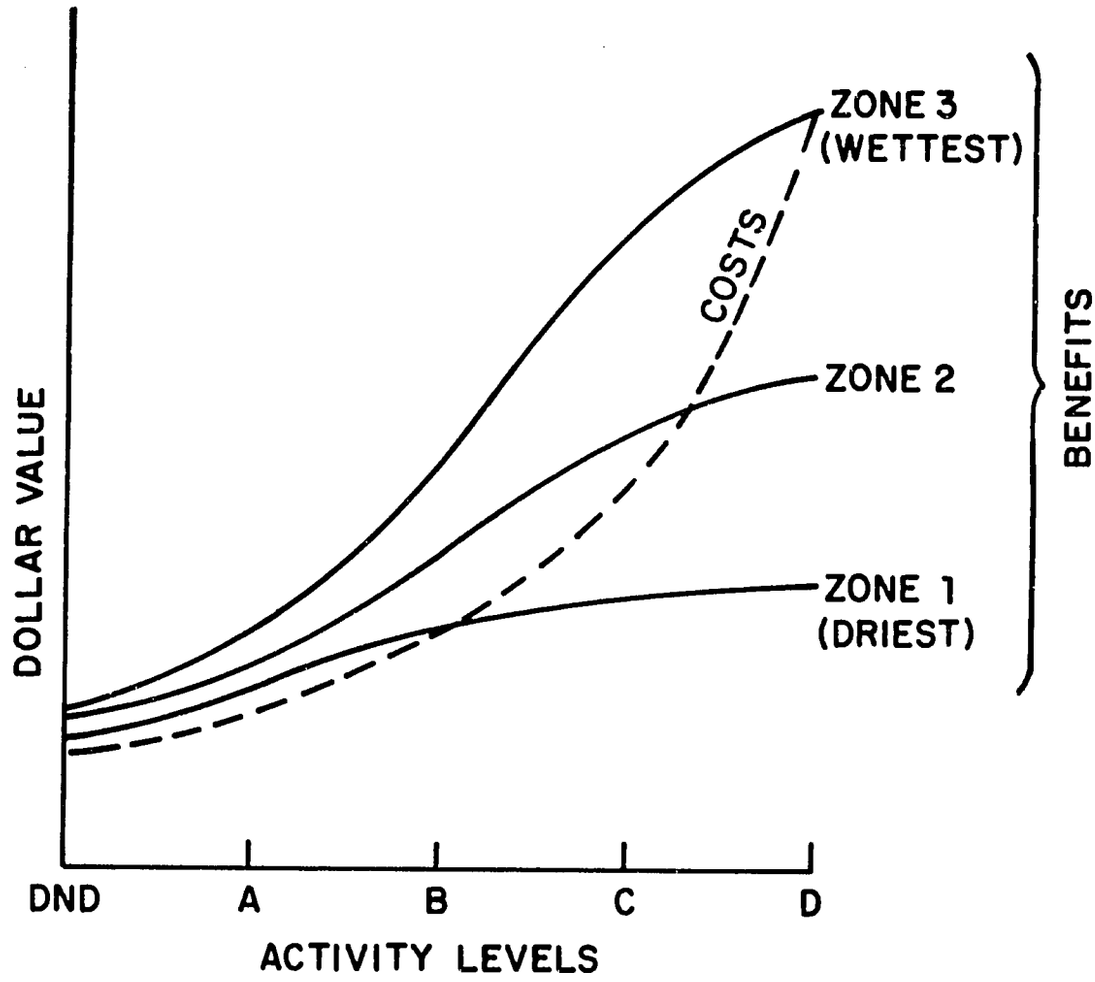

FIGURE 2.2 Theoretical Effect of Activity Level on Direct Benefit-Cost Relationships in Climatic Zones

values.

The cost curve is exponential in shape with rapidly rising costs at the higher activity levels. Only a single cost curve is shown, but costs may be different for the same activity level in different climatic zones. A family of S-shaped benefit curves is shown for sample climatic zones. The "S" shape was chosen to reflect similarly shaped curves for agricultural productivity as a function of inputs.

Existing activities appear to be profitable in all three zones. In the driest zone (1) activity level A results in slightly increased profits, activity level B is possibly profitable, but levels C and D are economically infeasible.

Activity levels A, B, and C are feasible in zone 2, but level D shows costs exceeding benefits. In the wettest zone (3) all levels of activity are profitable but marginal costs exceed marginal benefits as level D is reached.

As previously pointed out, the exact shape and location of these cost and benefit curves are unknown. They seem reasonable as drawn in the light of present knowledge. The relationships are dynamic, continually changing with new knowledge and technology as well as market prices. Costs can be separated into public and private costs. Public costs decrease with increasing activity level as the private sector becomes stronger.

On the basis of direct cost-benefit relationships alone, it would

appear to be most efficient to invest all resources in zone 3 at activity level C. This rather simple example neglects the indirect costs and benefits which, from a social-political standpoint, may have a much higher value.

The following sections indicate specific kinds of improvements which can be made in various segments of the agricultural sector at the four activity levels.

2.5.2.2 —Possible crop production system improvements:

Level A - Crop production within present capacity of the environment.

Save and use best available seed for planting.

Plant in better areas.

Remove competing weeds.

Gather productivity information.

Stabilize farm families in crop production area.

Control fallow/cultivated land ratio to maintain productivity.

Note: Extensive farming, defined as tossing out seeds and waiting to see what happens is considered to be below this activity level because of its low productivity and large land requirements.

Level B - Extensive management of the environment.

Provision of domestic water supplies to permit dryland farming in otherwise unusable areas.

Protection (fencing) of cultivated areas.

Native seed increased (perhaps in developed country) to

improve germination, purity and seed size.

Simple on-farm demonstrations.

Limited nitrogen added in wetter or irrigated areas.

Level C - Intensive management of the crop environment.

Improved varieties and species introduced.

Limited use of commercial fertilizer, especially nitrogen where moisture is adequate.

Use of animal manure and green manure crops.

Multiple use (water, wood, livestock, crops, wildlife, etc.) is permitted.

Level D - Environmental management with economic crop production maximized.

Today's best technology utilized.

Chemical fertilizers are applied.

No multiple use is permitted.

Contract or corporate farming in irrigated zone.

Labor intensive practices in drier zones.

2.5.2.3 — Possible plant protection improvements:

Level A - Fallow system to permit natural reduction of pests.

Level B - Crop rotation to prevent buildup of pests.

Selection of crops which are not "hosts" to pests of other crops.

Provide information and training in identification of problems.

Level C - Use of resistant varieties.

Hand application of chemicals.

Level D - Mechanized chemical application of herbicides, pesticides, etc.,

Use of integrated pest and disease control.

2.5.2.4 —Possible wood production system improvements:

Level A - Harvest limited to sustained yield.

Restrictions on use of fire.

Level B - Firebreaks.

Control of fire use.

Regulate use which may affect reproduction, e.g., by browsers.

Encourage selection of particular types.

Rudimentary surveys, e.g., of productivity.

Level C - Fire prevention and control (firefighting).

Reforestation in depleted areas.

Prescribed burning.

Eradication of diseased growth.

Control of competing species.

Selective harvest, animal power.

Cutting and thinning systems, special procedures, e.g., for posts.

Forest surveys.

Level D - Use all available technology.

Plantation production units.

No competition, remove undesirable species (no multiple use)

Fertilizer, spray insecticides, etc.

Alternate host control.

Exotic species.

Mechanical harvest.

2.5.2.5 —Possible range management improvements:

Level A - Livestock use within present longterm capacity.

Investments only to maintain the environment in presence of grazing and browsing.

Level B - Extensive management of the environment.

Fencing and water development (wells, catch basins, water spreading, etc.) to obtain livestock distribution and maintain plant vigor. Full utilization of available animal unit-months of grazing. Fire (controlled burning) may be used as a management tool.

Level C - Intensive management of the environment.

All available technology is considered.

Management to increase livestock forage.

Manual brush control, seeding, pasture development and fertilization on best areas.

Existing vegetation may be replaced by higher quality varieties through improvement in growing conditions.

Provision for multiple use.

Level D - Environmental management to maximize livestock production.

Stewardship of soil and water.

Mechanized removal of brush and timber.

No multiple use in designated range areas.

Maximum technology input.

Intensive pasture management.

Mechanized reseeding and fertilization.

2.5.2.6 -Possible livestock production system improvements:

Level A - Control of livestock numbers.

Collection of information on numbers, productivity.

Veterinarian control to contain major disease outbreaks.

Dissemination of extension information in appropriate field areas.

Use of certain animals for milk production rather than entire herd or flock.

Level B - Extensive management of livestock.

Control of parasites--establishment of dipping vats.

Control of diseases--implement vaccinations and sanitary practice.

Control of breeding season.

Technical assistance in managing cows at parturition and calf management to minimize death losses.

Simplified corrals and chutes for livestock handling.

Salt and mineral supplementation distribution (phosphorous primarily).

Watering facilities--catch basines, etc.

On-farm demonstrations of improved management techniques.

Level C - Intensive management of livestock.

Supplemental feeding and/or pasture rotation, use of cropland residues.

Provision of corrals, chutes, and scales.

Some confined feeding systems.

Milk production units around cities.

Improved breeding systems; improved sires, crossbreeding, etc.

Establishment of appropriate shelters and shade.

Disease diagnostic laboratories.

Chemical laboratories to determine chemical composition (nitrogen, phosphorous, etc.) of feedstuffs.

Level D - Use of all management, nutritional and breeding practices

with maximum input of available technology.

More emphasis on milk production units around cities and intensified confined feeding systems.

Environmental control systems for dairy animals.

2.5.2.7 —Possible poultry production improvements:

Level A - Unorganized production for family use.

No grain feed used.

Level B - Family production units.

Protection from predators, etc. at night.

Feed from surplus grain, garbage.

Surplus marketed.

Level C - Commercialized farm flocks.

Fenced areas.

Prepared feeds used.

Rudimentary disease prevention.

Organized marketing systems.

Level D - Confinement housing.

Improved breeds.

Vaccination and disease control.

2.5.2.8 —Possible fish production improvements:

Level A - Harvest limited to sustained yield of natural waters.

Traps, net and pole fishing.

Level B - Extend fishing to all reaches of streams.

Minimum size restrictions.

Family fish ponds in wetter areas.

Surplus marketed.

Level C - Stocking natural streams, irrigation and drainage canals and ponds (control by nets).

Government hatcheries.

Organized market system.

Level D - Pond culture.

Commercial feed used.

Disease control.

2.5.2.9 —Possible water management (irrigation and drainage) improvements:

Level A - Water dipped manually from stream when available.

Level B - Improved manually operated water lifts.

Small, unlined distribution ditches.

Water available if stream flows.

Land corrugated or furrowed for water control.

Level C - Water pumped by animal or wind power.

Unlined distribution ditches.

Small diversion works, water delivery on time schedule (if stream flows).

Open ditch drains.

Level D - Supplemental irrigation used.

Engine or motor driven pumps.

Dams and reservoirs, lined canals.

Lined distribution ditches.

Subsurface and well drainage.

Water management systems (sophisticated irrigation and drainage systems).

Irrigation based on soil moisture (crop needs).

Soil and water conservation practiced (erosion control, etc.)

2.5.2.10 —Possible mechanization improvements:

Level A - Provide information on use and care of existing hand tools.

Level B - Introduction of improved and new hand tools.

Level C - Animal mechanization of tillage and cultivation.

Powered mechanization introduced at community or cooperative level.

Level D - Small and large scale mechanization from land preparation to harvest and processing.

2.5.3 Alternative strategies: The user must now decide what strategy (or strategies) will be tried, i.e., what mix of activity levels will be selected for the various segments of the agricultural sector in the different climatic zones. It may be useful to consider a single activity level for all aspects of an area's agricultural development. This is a rational decision since the needs of crop and livestock production

for inputs, infrastructure, etc., are similar at equal activity levels in most climatic zones. From an efficiency standpoint, however, a more logical mix would be to apply relatively low activity levels (A and B) in the drier zones where the marginal returns from the higher levels (C and D) are negligible and use the higher levels in the more productive, wetter zones where the returns are great.

In any case the selection of a strategy (mix of activity levels) for the agricultural sector involves tradeoffs in terms of factors (any one of which might be maximized) such as total food production, export crop and livestock production, employment generated and inputs required for the selected strategy in comparison with the multitude of other possible strategies. The entire process must be repeated for each alternative strategy to be tested.

In selecting an agricultural strategy the principles of comparative and actual advantage should be followed. Actual advantage means that in a particular area, production from certain crops or livestock systems has an economic advantage over the same crop or livestock product produced in another area. Crops should thereby be grown in the areas of most efficient production, defined as highest productivity per unit cost. For example, it is probably wise for the Central American republics to grow bananas for the U.S. market although they probably could be grown (with some difficulty) in the southernmost parts of the United States. Basic food needs are then imported for the banana producing areas.

Comparative advantage means that production of a particular crop has an economic advantage over other crops which can be grown in the same area even though they also can be produced profitably. Selection of strategy on this basis is generally in contradiction with the idea of establishing food self-sufficiency in the area.

The question becomes one of economics. Exploitive export market systems may give an agricultural product an apparent comparative advantage. Care must be taken to insure that the effects of the "advantage" filter down to the producers. They should receive a just share of the market price of the export product and furthermore should be able to purchase food needs at a reasonable cost.

2.5.4 Land allocation: Allocation is used here in the sense of classifying land for its most appropriate agricultural use and not as a decree handed down from a planning authority to the producers, who are certain to object under that circumstance. However, farmers and herders must be encouraged, with adequate incentives, to use land under their control within its ecologic constraints. Hopefully the allocations of the planners will not be in serious contradiction with uses already existing.

A decision must be made regarding the capability of land for crops, livestock, wood production or other uses in each climatic zone. Although such a decision has elements of arbitrariness, certain lands are more suited for one use than any other. Also some is barren, i.e., unsuitable for production (e.g., too steep, too rocky), and some must be

devoted to towns and villages, roads, and other miscellaneous uses. Lack of dependable water supplies for people and animals may eliminate some potentially productive land.

Different allocations of land for various purposes will affect total production and experience may show that another allocation will be more appropriate. Optimization techniques may be used if the accuracy of the data available justifies such detailed scrutiny.

Mixed crop and livestock farming may be practiced in more favorable areas. Variations may include dairy and poultry production. Wood production is included primarily as an energy source, but other uses should not be overlooked.

In some cases policy makers may decide to emphasize a particular segment of the agriculture sector, for example, livestock production. If such a decision is made, land allocations must be made accordingly.

2.5.5 Crop and wood production factors:

2.5.5.1 —Fallow/cultivated land ratio: A fallow system is usually used in dryland crop production in the developing countries to restore soil fertility and moisture and decrease losses to pests. The fallow/cultivated land ratio must be sufficient to permit complete recovery or a gradual deterioration in productivity will result. A matrix of different ratios for the various climatic zones and for different activity levels must be prepared.

2.5.5.2 —Possible crops: For each climatic zone

certain crops are ideally suited. Usually they are the crops already being grown although there is often the possibility of introducing a new crop or crops. A listing of such crops guides the decision maker.

2.5.5.3 —Crop assortment: An assortment of crops must then be selected for each climatic zone. This is a completely arbitrary decision based in part on existing crops and should not be confused with sophisticated linear programming techniques to optimize farm income. Such methods might be used but data are probably not sufficiently accurate or available at this stage of planning. Crop production is usually not possible for those zones at the bottom of the water availability scale.

2.5.5.4 —Effect of activity level and climate: Productivity of each crop will be different in each climatic zone for each activity level. Productivity in the irrigated zone at activity level D is assumed to be the maximum attainable for any crop under the best currently available agricultural practices and is assigned a value of 100 percent. A productivity matrix is then prepared with decreasing values along the activity level axis and along the climatic zone axis. Decreases because of climate are based on water availability information. Those resulting from activity level changes are estimates.

2.5.5.5 —Crop productivity: The productivity matrix is used to calculate crop and wood productivity for each crop with each activity level in each climatic zone.

2.5.5.6 —Crop production: Production of each crop in each climatic zone in the planning area then can be calculated. Production is calculated in kilograms and then converted to calories and grams of protein for later determination of human carrying capacity.

2.5.5.7 —Total food crop production: Total production for a planning area (calories and grams protein) is obtained by adding the production of each crop. In those cases where animal power is used in the production system or poultry production is included, the consumption of crop yield by draft animals or poultry must be subtracted from the total to determine net crop production.

2.5.5.8 —Non-food crop production: Production of non-food crops can be included in the analysis if, for example, they already contribute substantially to the agricultural economy, of if planners deem desirable their inclusion. Referring to the previous material the procedure would be as follows:

(1) Is production of the crop possible?

(2) What percentage of crop land should be allocated to the crop?

(3) What is potential productivity of the crop at activity levels A, B, C, D?

(4) What is potential total crop production?

Production of non-food crops obviously does not enter directly into computation of human carrying capacity. Its worth can be determined in terms of the value of domestic or export consumption.

2.5.5.9 —Wood production: Potential production of wood in each climatic zone of the planning area can also be calculated. Wood may be considered for timber or fuel uses.

2.5.6 Livestock production factors:

2.5.6.1 —Carrying capacity: Range livestock production is a function of the carrying capacity of the land. Carrying capacity itself is related to the resource base of the area, particularly the soil and the precipitation. However, man's stewardship of the environment can increase carrying capacity through technology, management, and other inputs.

Estimates of carrying capacity for each activity level in each climatic zone must be made, based on existing data for the area, data from similar areas, and subjective evaluation. "Animal units" (or other consistent system) are used for convenience. One animal unit (A.U.) is considered herein to be a 450 kilogram cow with calf. Other animal types must be converted to the equivalent in these units.

2.5.6.2 —Livestock system parameters: The most important factor in livestock production is the quantity of meat (or other product) produced each year. A number of controlling parameters must be quantified to be able to make a total production estimate. They include fertility (calving percentage), mortality, replacement cows per year, age of animals at sale, offtake (percentage of herd removed for consumption or sale), and dressing percentage.

In primitive range livestock production, dead or dying animals are often consumed because the herders are in such close contact with the animals that this practice can be followed without harmful effects on humans. When this is the case, estimated offtake must include this utilization of animals.

2.5.6.3 —Livestock production: Production of meat in the planning area can then be calculated. Production is calculated in kilograms of meat and then converted to calories and grams of protein for calculating human carrying capacity.

2.5.7 Other products: The animal sector also supplies other products such as milk, poultry, eggs, and fish. Similar procedures are used to estimate the potential productivity and production from these sources. Agricultural byproducts like hides and skins, cotton seed, etc., can have a significant value and also must be included.

2.5.8 Summation: The production from each segment of the agricultural sector is then summarized. The totals represent the potential production in calories and grams of protein for food products and kilograms of non-food crops, wood, and byproducts for a planning area under a selected strategy (set of activity levels).

2.5.9 Carrying capacity, surpluses and shortages: Agricultural production is ultimately used to feed people or as a raw material in some manufacturing or processing activity, either in the area where it is produced or in another area to which it is exported. In many developing

areas, particularly in those described as least developed, food shortages are chronic. Yet agriculture is asked to produce raw products for the export market.

The planner is faced with the dilemma of choosing between food production and loss of essential foreign exchange or export production and the need to import food supplies. Some degree of balance between the two choices is usually the result.

Knowledge of the relationships between the potential for production of food and other agricultural output and the population (existing or projected) of an area is necessary in making these planning decisions. Population must be considered from the dual standpoints of the number of people who can be supported by the potential production and the number of people who can be meaningfully employed in agricultural production. The latter number is usually inversely related to the increases of technology, management, and other inputs.

Losses of agricultural production occur in transit and storage. Assessment of these losses must be made before surpluses or shortages can be determined. But they, too, are an inverse function of the activity level.

Assumptions must also be made regarding the minimum daily calorie and protein requirements. If wood is used for fuel, it also has a daily requirement per family or user group.

The human carrying capacity of a planning area under a selected

alternative strategy can now be calculated. Analysis of the results can be used to determine surpluses and shortages.

2.5.10 Comparison with existing situation: Before the impact of an alternative agricultural development strategy can be measured, production must be compared with that obtained under the existing strategy (or lack of strategy). Two problems occur in making comparisons. One is the generally poor quality of the agricultural statistics in many of the developing countries. Productivity usually is overestimated; production is often underestimated because of a failure to account for local consumption and storage and transportation losses.

The second problem can be more serious. Production under exploitative management may, for a time, be greater than that obtained under long term sustained yield management. When this occurs a simple comparison of numbers is misleading.

2.5.11 Steps for implementation: Certain steps must be taken to implement an agricultural development strategy, and the details of the required actions vary for different activity levels selected as part of the strategy. Constraints to development must be identified so they can be overcome.

Implementation asks the questions, "What needs to be done?" and then "Who will do it?" and finally, "When will it be done?" Additional questions then arise concerning the subsidiary needs, for example, numbers of trained people required and costs. Implementation of a strategy

can, of course, be considered for parts of a planning area or can be done in stages.

There are four groups which can take steps to implement a particular agricultural strategy: local and national governments, the private economic sector, individuals, and the donor agencies. Their actions are not necessarily required in unison in all cases, but such unified effort usually is more effective.

Government and donor agency action usually has to be stronger at the lower activity levels (A and B). Private sector and individual action is more readily obtained at the higher activity levels (C and D) when the possibilities for success (economic reward) are much greater.

The needs for inputs, infrastructure and trained personnel can also be related to the selected activity levels.

2.5.11.1 —Government: Government implementation actions can be considered in the areas of policy, legislation and programs. Policy provides the governmental directions, guidelines and philosophy for action. Natural resources policy promotes wise use, conservation, and reclamation. Economic policy attempts to provide stability and disaster relief; an assistance policy is concerned with both technical and social help. Legislation permits implementation of policy. Laws usually relate to specific programs or controls. Programs are the activities carried out by government agencies to implement the policy.

Examples of the types of possible government actions required in

these three categories are illustrated in Table 2.1.

2.5.11.2 —Private economic sector: The private sector does not become deeply involved in country development at the lower activity levels. In any case as much of the action of development should be shifted to the private sector as possible. (As individual farmers become a part of the market economy, they join the private economic sector.) Actions by this sector include research, the supply of needed agricultural inputs, and infrastructure facilities development. The private sector responds to the profit motive but typically needs a "push" from the government and/or donor agencies.

Some illustrative examples of the types of action which can be taken by the private economic sector are given in Table 2.2.

2.5.11.3 —Individuals: Individual farmers or herders are limited in their possible response, but can be actively involved in the implementation process. The individual operator is a manager and as a manager must make certain decisions. He uses what technology is available and responds to incentives.

At low activity levels (A and B) he will apply low level technology but perhaps can be encouraged, e.g., to use the best land available, and accept governmental controls on animal numbers and land use. At high activity levels (C and D) he will make more sophisticated decisions to optimize his position in society; he will actively seek new technology and will actively participate in government.

TABLE 2.1

Possible Government Actions for Implementation*--(local and/or national)

Action arena	Activity level			
	A	B	C	D
Policy	Reduce livestock numbers, stabilize cultivated area, share risk. (can be implemented for entire country or subunit)	Promote rural community development, protect cropped areas from grazing.	Permit individual land tenure (ownership?)	Permit contract or corporate farming.
Legislation	Grazing laws, tenure for farmers, price support law, funds for agriculture (credit, tech assistance, etc.)	Tenure for herders, pure seed laws, increased support for agriculture.	Increased support for agriculture.	Increased support for agriculture.
Programs (Tech assistance, education and institutional development, research, information & data collection, credit, price supports	National ext. service (range mgt. livestock, on-farm storage), awards for high yield, supply of inputs, resource and economic base studies, price supports, range survey & study plots, collect production data.	Weather information service, improvement loans, water development, fencing, distr. improved seed, livestock sanitation, Inst. of Agric. Tech. (seed producers, general agric, short courses) seed certification, foreign training for professionals.	Meat & milk grading systems, animal mechanization assistance, Col. of Agric. (professional, extension agents, aides), experiment farms, disease diagnostic laboratory, plant composition laboratory, market information.	Vocational agriculture in high schools, veterinary school, central experiment station.

*Activity levels are accumulative from A to D.

TABLE 2.2

Possible Private Sector Actions for Implementation*

	A	B	C	D
Research	None	None	Product marketing	Machine design
Inputs	Supply traditional inputs	Increase supply	Production and supply of modern (new) inputs	Agricultural chemical industry
Infrastructure Markets	Provide urban markets	Development of rural marketing system	Modern markets	Marketing boards
Storage	None	Development of low cost storage systems	Permanent farm storage	Commercial storage
Transportation	None	None	Ox-cart transportation companies formed in local areas.	Trucking companies.
Credit & Savings	None	None	Farm savings and loan companies	Full service banks

*Activity levels are accumulative from A to D.

2.5.11.4 —Donor agencies: Several types of donor agencies are active in promoting agricultural development; each operates in a different "arena". Multilateral organizations act on a government to government level as do most of the bilateral assistance programs. They thus assist developing country governments in formulation of policy and model legislation as well as in action programs. Significant assistance can be given to countries in planning and setting priorities as well as in financing development projects which fit the ISYALAPS planning framework.

Some donor agencies interact with the private economic sector in the developing countries; usually this also is done under government auspices. Such activities as consulting services and financing infrastructure may be undertaken under the higher activity levels.

Religious groups and some bilateral aid programs, for example, the Peace Corps, attempt to provide assistance directly to individual farmers and herders. Properly coordinated, this type of assistance can be effective in transferring low level technology improvements (activity levels A and B). A training program in range management for local groups is one example of this type of assistance.

2.5.11.5 —Inputs: Implementation of an agricultural strategy, at any activity level, requires the availability of certain inputs necessary for the production system. The need increases with the higher activity levels (C and D). Specific inputs can be identified on a project

by project basis but are difficult to quantify otherwise. Expendable inputs, such as fuels and lubricants, fertilizers, etc., will have to be supplied on a continuing basis.

Not related directly to agricultural production but certainly essential as incentives to farmers and herders are consumer goods and services. At low activity levels these are often the only incentives.

2.5.11.6 —Infrastructure: Agricultural development can be materially aided by the concurrent growth of a supporting infrastructure. Existing systems must be strengthened and new systems developed. At low activity levels the infrastructure (other than what already exists) probably will have to be provided by the government. In zones where higher activity levels are practical, the private sector will play an important role. Requirements include storage, transportation, marketing, credit and savings, water resources development; and other institutions which support the agricultural sector.

2.5.11.7 —Trained personnel: The single most important requirement for effective implementation of an agricultural strategy is trained personnel. At activity level A personnel requirements are low in terms of educational level yet significant in terms of numbers. Trained range managers and livestock and agricultural extension agents, many of them at the local level, are needed. Top level personnel are required in planning and program supervision.

With increasing activity levels the personnel needs change.

Requirements at the various activity levels can be spelled out in terms of agricultural production units, e.g., farm or ranch families, land under cultivation, number of animals.

2.5.11.8 – Time frame: Implementation of any selected strategy will require a certain time. Lower activity levels (A and B) can be implemented more rapidly in general than can activity levels C and D, not only because of the lower level of technology used but also because of lesser needs for inputs and infrastructure. Determination of exact time required for implementation of a complex strategy involving different activity levels in the various segments of agriculture and climatic zones is complicated further by the fact that implementation in many cases does not start from a zero level nor even from a definite activity level.

2.5.12 Determination of impacts: Planners need to know more than just the production potential of an agricultural strategy. They also must be aware of the effects such increased (or decreased) production will have, not only on the agriculture sector, but also on the other aspects of the society in or for which change is being sought.

Impacts of a strategy can be beneficial or detrimental. If they can be measured in monetary units, determination of their results on society is relatively straightforward. The allocation of resources (funds) between competing activities requires a complete analysis of the benefits as well as the costs involved. In most instances, however, neither the monetary value of impacts nor a clear cut indication of their position on

the benefit-detriment scale can be ascertained readily.

A substantial caution must be exercised in assessing the impacts of a planning strategy. As stated by King (1972):

> The development of planning or decision making models is outstripping the availability of input data and the ability of planners to use them properly. There is a strong impetus for quantification of decision making and, where quantification is obviously impossible, to express non-quantifiable decision elements as constraints. This can be dangerous because it gives the appearance of a greater reduction in uncertainty and subjectivity than is actually the case.

He went on to emphasize the impossibility of eliminating uncertainty and value judgments. Planners must recognize such value judgments explicitly so they can be adequately tested.

2.5.12.1 —Benefits: Economic benefits of an agricultural strategy can be measured in terms of per capita income increase, improved balance of trade, etc. Such items as increased food production, achievement of ecosystem stability, increased export earnings, and development of agriculturally based industries are some quantifiable benefits.

Subjective evaluation of the impacts also must include the abstract measures of an improved "quality of life" for people in agriculture. Impacts on the social system also are difficult to quantify. An increase in agricultural production may be beneficial to society in general, but may result in loss of income to a food importer. An increase in prices of agricultural commodities may benefit producers but have a negative impact

on urban consumers.

2.5.12.2 —Costs: Determination of costs associated with implementation of a particular strategy which uses the activity level concept is an immense problem. Some items can be identified easily and costed accurately. Others can hardly be identified, let alone costed. Nonetheless the results of an attempt to evaluate costs can be useful in comparing alternatives.

In thinking about costs it is useful to maintain two considerations in mind:

(1) The distinction between public and private costs. Public costs are those that will normally be paid by governmental units (local or national governments, international agencies, etc.). The private costs will be borne by the individual entrepreneurs. Each activity level must be examined to determine what are the explicit and implicit public costs. As many actions as possible should be left for private sector development. In this way economic feasibility can be insured. No doubt the governments involved will also want to consider the nature and magnitude of social or secondary costs.

(2) The possibility of substituting labor for capital in public projects. The use of labor intensive methods can save on scarce foreign currency and increase employment. Each proposed action should be examined from this aspect.

Activity level A indicates the need for range management

specialists, veterinarians, and extension agents. The training can be based on the development of the training capacity locally (institution building), or training in the developed countries. In each case the costs will be different and important timing questions will be involved.

The support of the trained technician is another issue that involves choice. Will the support be local or national, or a combination of the two?

Choices between national researchers, foreign teams or a combination exist. The costs and the quality of the results will vary depending on the approach selected. In any case the research effort will require public expenditures. Choices involving private costs and labor intensive methods exist. The requirement for fencing and water development under activity level B is a good example. Can the costs be shared between private and public entities? Should labor intensive methods of construction be encouraged?

Probably it is unwise to attempt at this time to measure exact activity level costs or the total costs for implementation of an agricultural strategy in a large planning area. The potential for error is tremendous, and no estimate may be better than a wild guess.

When assessing costs of implementing a particular strategy (at the project stage) in this incremental method of analysis, the existing facilities, equipment, infrastructure, etc. which support the project should be subtracted from projected costs.

Some of the items for which costs must be determined in project evaluation include such things as fencing, wells and pumps, mineral supplements for livestock, improved seeds, fertilizers and other chemicals, hand tools, machines and implements, and construction of facilities for livestock or water management. As an example of what needs to be done Table 2.3 lists possible mechanization requirements for activity level D in a given planning area. This is the first step in cost determination and a similar procedure can be followed for other identifiable project needs.

2.5.13 Iteration with alternative strategies: The first trial of the use of the ISYALAPS planning framework with a selected agricultural strategy cannot be expected to result in a completely satisfactory solution to a given development problem. Several attempts probably will be necessary, and moreover, because planning is a dynamic process and conditions change over time, the process should be repeated regularly to verify the validity of decisions previously made.

One of the advantages of the systems analysis method of problem solving is its flexibility in testing various alternatives. It also lends itself to the use of digital computer techniques for obtaining speedy results.

2.6 Matrix for Project Evaluation

Choices are needed for action programs resulting from use of the

TABLE 2.3

Possible Mechanization Requirements*

(Activity Level D)

Machine	Requirement
Tractor	1 per 100 hectares
Combine harvester	1 per 230 hectares
Farm truck	1 per 267 hectares
Pumps, etc.	1 HP per 2.6 hectares
Cultivators (powered)	1.2 HP per hectare
Electricity	150 kwh per hectare

*Minimum land unit 100 hectares.

ISYALAPS planning framework which can be immediately considered by policy and decision makers and which will have a significant long-term impact on agricultural development. Specifically the question might be, "What kinds of things can be done which will make the net result something different than what has happened in the past?" The choices to be considered for project activities and further detailed planning must be consistent with the selected strategy and previously determined natural resource limitations. Such analysis also helps determine priorities.

2.6.1 Matrix parameters: A matrix for project evaluation can be constructed to insure completeness of the examination (Figure 2.3). Dimensions of the matrix include: (a) a geographic (location and climate) component, (b) a mode of social and/or land use arrangements, (c) an activity level (level of implementation, and an economic dimension), and (d) a political unit (not shown).

The matrix thus takes into account the physical size and consequent geographic variability of an area, the diverse possible social arrangements, the political structure, and recognizes that financial and other resources are limited. Each of these dimensions has various subsectors. Flexibility allows the matrix to be entered along any axis (dimension) for development of project activities.

2.6.2 Use of matrix: Proposed project ideas can be identified with a particular subcube of the matrix for project evaluation and tested for conformity with the agricultural strategy of the ISYALAPS

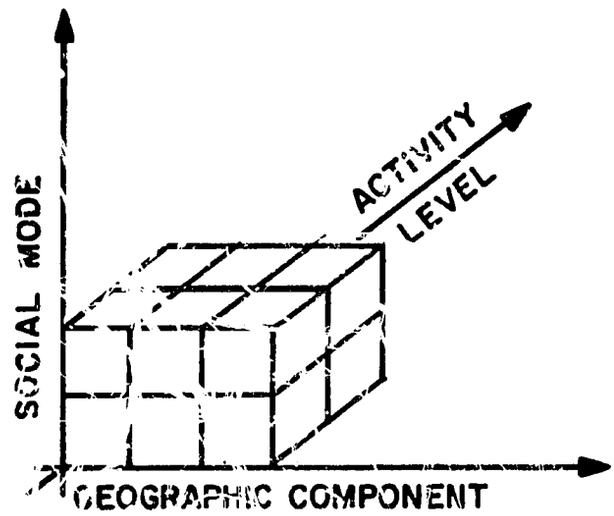

FIGURE 2.3 Matrix for Project Evaluation

planning framework. This allows the planners and decision makers a wide range of latitude in planning within a complete framework. Proposals which "fit the framework" can then be further examined in terms of impacts, costs, etc. By considering several of the subcubes, each of which contains project proposals, priorities can be set and those projects with greatest possibility for success can be identified and set apart.

2.7 Evaluation Criteria

Evaluation of proposals for activities to be carried out in a region must be, in the final analysis, a subjective process. An administrator of either a donor agency or a host country has to make the decision for approval or rejection. There is an aspect of quality in evaluation in that the probable degree of success or failure must be determined. In addition, time is an important consideration, not only from the point of view of number of years required for project completion but also in the sense of past, present, and future. What occurred in the past, what is going on now, what will happen in the future?

2.7.1 Goal definition: Development of exact evaluation criteria is impossible without having well defined, realistic goals. This means not only goals for agriculture but also goals for the other sectors of the economy. Examples of the kinds of goals which might be set are as follows:

- Agriculture will produce a larger share of the GDP in the future economy.
- More people will be educated professionally and technically in agriculture.
- Agricultural production will provide adequate protein and abundant food for internal demand.
- Production of cash crops for the export market will be maintained at current levels.
- Employment in agriculture and agriculturally related industries will be increased.
- Environmental degradation will be halted.
- The infrastructure in support of agriculture will be strengthened.

2.7.2 Guidelines: In addition, projects must be acceptable to the donor agencies and to the political and social mores of the recipient otherwise they will probably fail or not be implemented. Guidelines against which proposed projects can be measured in a multi-objective analysis will include, but not necessarily be limited to, the following:

- Is the project in conflict with any of the goals listed above? If so, what features are included to minimize the conflict?
- Have similar projects been implemented in the past? To what degree were they successful? Why? Have provisions been made to avoid the mistakes of the past?
- Are the financial and other demands of the project compatible

with the resources of the donor agency and the recipient? Can the project be adjusted to fit resources?

- How much will the project cost? What are the benefits? Is the project economically viable and will it remain so after assistance stops? What is the impact per unit cost?
- What inputs will be required to have a significant impact and who will supply them? (Consider capital, technology, equipment, supplies, etc.) What is the most desirable time sequence of inputs?
- What infrastructure will be required to support the project? (Consider transportation, communications, markets, storage, education and training, government policy, tax and price structure, etc.)
- What indicators will be used to measure the success of the project? (Consider improved quality of life for rural poor, agricultural productivity, new or stabilized jobs, income per capita, growth rate of GDP, etc.)
- When will the project be started? Completed? How soon will impacts be seen?
- What are the restraints to project success? Have provisions been made to minimize them? (Consider the policitical, legal, and social aspects as well as limits of physical, human, and other resources.)

3. THE AGRICULTURAL PROBLEM OF THE SAHEL-SUDAN REGION

The severity of the climate in the Sahel-Sudan region is a contributing factor in the current disaster and limits potential productivity. However, characteristics of the traditional agricultural production system have combined with decreasing rainfall since the late 1960's to intensify the problem.

3.1 Climate

The climate of the Sahel-Sudan region varies from that of a hot desert to that of a dry subtropical woodland. Rainfall ranges from less than 100 mm/yr in the north to more than 1250 mm/yr in the south. Throughout the region, rainfall is essentially unimodal, falling in a single season. In the northern Sahel the wet season is in July and August. Farther south the wet season becomes progressively longer, lasting from May into September. A general "rule of the thumb" is that as one goes northward from the southern coastal forests (with a rainfall of about 2400 mm/yr) toward the Sahara, the average annual precipitation decreases 1 mm per kilometer traveled.

Temperatures range from warm to hot, with only stations in the highest mountains of northern Chad ever recording temperatures below 0 C. Stations in the northern areas have recorded maximum temperatures in excess of 50 C (122 F), usually in the months of April, May and June. Frost is unknown in most of the region. Most stations have a

bimodal distribution of lower temperatures, generally in December-January and again during the wet season of June to September.

Winds in the region are seasonally variable. During the dry season, the region is under the influence of dry northeasterly trade winds, called the harmatten. At the beginning of the wet season violent winds associated with thunderstorms are common. Later in the wet season, southerly monsoon winds dominate.

The level of solar radiation is high, with few cloudy days recorded other than during the wet season. Relative humidity is generally low. Evaporation rates are high, with annual potential evapotranspiration values in excess of 2400 mm common in the north.

3.1.1 Weather patterns:

3.1.1.1 —Intertropical convergence zone: On a world-wide scale a series of discrete tropical anticyclones forms belts on each side of the equator. In these zones, descending air north of the equator results in hot dry air at the surface, moving southward as the north-east trade winds. Where the northern and southern belts converge near the equator, the air rises and cools, resulting in rainfall. The area of convergence is known as the Intertropical Convergence Zone (I.T.C.Z.).

3.1.1.2 —Monsoon rainfall: Most of the region receives its rainfall from a monsoon system, a seasonal north-south oscillation of the I.T.C.Z. Mitchell (1973) gave a concise summary of the operation of this system in west Africa. An annual cycle of a

northward penetration and a southward withdrawal of a warm, humid airmass controls the rainy season and the rainfall. In cross section, this airmass is wedge shaped, of limited vertical extent in the north and deeper to the south. At the leading edge is a sharp discontinuity in ground level relative humidity with extremely low humidities existing to the north and higher values to the south.

Generally, the discontinuity is at its farthest south position in January, a few degrees north of the Guinea Coast at about 7° N latitude. Progressively the front moves northward until August when it reaches approximately 23° N latitude. A more rapid southward retreat restores the January position.

The weather associated with this system has been subdivided into five types, as follows:

Zone A. North of the relative humidity discontinuity: (a) very low atmospheric humidity; (b) few clouds; (c) possible dusty haze; and northeast trade winds.

Zone B. Humid, No-Rain Zone: (a) much higher relative humidities; (b) continued strong easterly components in winds; (c) little (limited diurnal) cloud formation and (d) no rain.

Zone C. Thunderstorm-Shower Zone: (a) more frequent cloud development; (b) occasional showers and thunderstorms; (c) in the southern part of the zone, large scale organized thunderstorms moving with strong squalls from east to west; (d) the result is a scattered rainfall pattern with bright sunlight days between showers (often torrential rains) of short duration.

Zone D. Overcast-Steady Rain Zone: (a) clouds stratiform rather than cumulus type; (b) frequent, prolonged steady rains.

Zone E. Overcast-Drizzle Zone: (a) overcast skies; (b) light

rains and drizzle but extended, heavy rainfall rare.

A number of other factors interact with the moist air wedge to influence both (a) the extent of its northward movement during a given year and (b) the amount of moisture actually precipitated. At least in Zone C, which provides most of the rainfall to the Sahel-Sudan region, high level easterly air flows stimulate the disturbance line phenomena. Any reduction of these high level easterly winds decreases the rainfall of the zone. At times the northern parts of the subdesert and Sahel are influenced by westerly winds, resulting in unseasonal extensive cloudiness and occasional dry season precipitation. Such "heugs" as they are called, appear to be extreme southerly extensions of winter rainfall of the Mediterranean region. For practical purposes, such aberrant dry season rainfall is of no use for crop production.

3.1.1.3 —Variability: Significant variation of the weather often occurs. Such variations are generally most extreme in the arid and semiarid zones, and include geographic and temporal (daily, seasonal and annual) components.

Especially in the desert and to a lesser extent throughout the thunderstorm shower zone (Zone C) a given storm may deposit a significant amount of rainfall in one area, while only a few hundred meters away, no rainfall occurs! In the subdesert and Sahel, these widely spread storms (which often result in excellent forage conditions, especially of ephemeral plants) provide the basis for nomadic grazing.

Some areas simply may not receive adequate rainfall for one or more years, while others may have enough to produce relatively favorable grazing conditions.

The rainfall at Niamey, Niger, and its airport only a few kilometers away were compared for the year 1953 (Cocheme and Franquin 1967). The results showed that the average difference amounted to 62 percent of their combined daily means, yet the annual totals differed by only 11 percent.

In the wet season, especially in the zones of low average annual rainfall, rains do not occur every day but as "wet spells." Cocheme and Franquin (1967) examined the distribution of wet spells at Zinder, Niger, a station with a mean annual precipitation of 540 mm. They found that most rainy days occur singly (63-70 percent), or in groups of two days (17-18 percent), with single wet days being most numerous both at the beginning and at the end of the wet season. The monthly mean occurrence of three-day wet spells is less than one and has been recorded only in July, August, and September. As a general rule, in the area here considered, there is one day in the growing period (wet season) for each 5 mm of annual precipitation (Figure 3.1).

3.1.2 Climatic zones: The weather patterns permit the designation of five east-west oriented climatic zones based primarily upon average rainfall and associated vegetation characteristics (Figure 3.2). From north to south, these zones are:

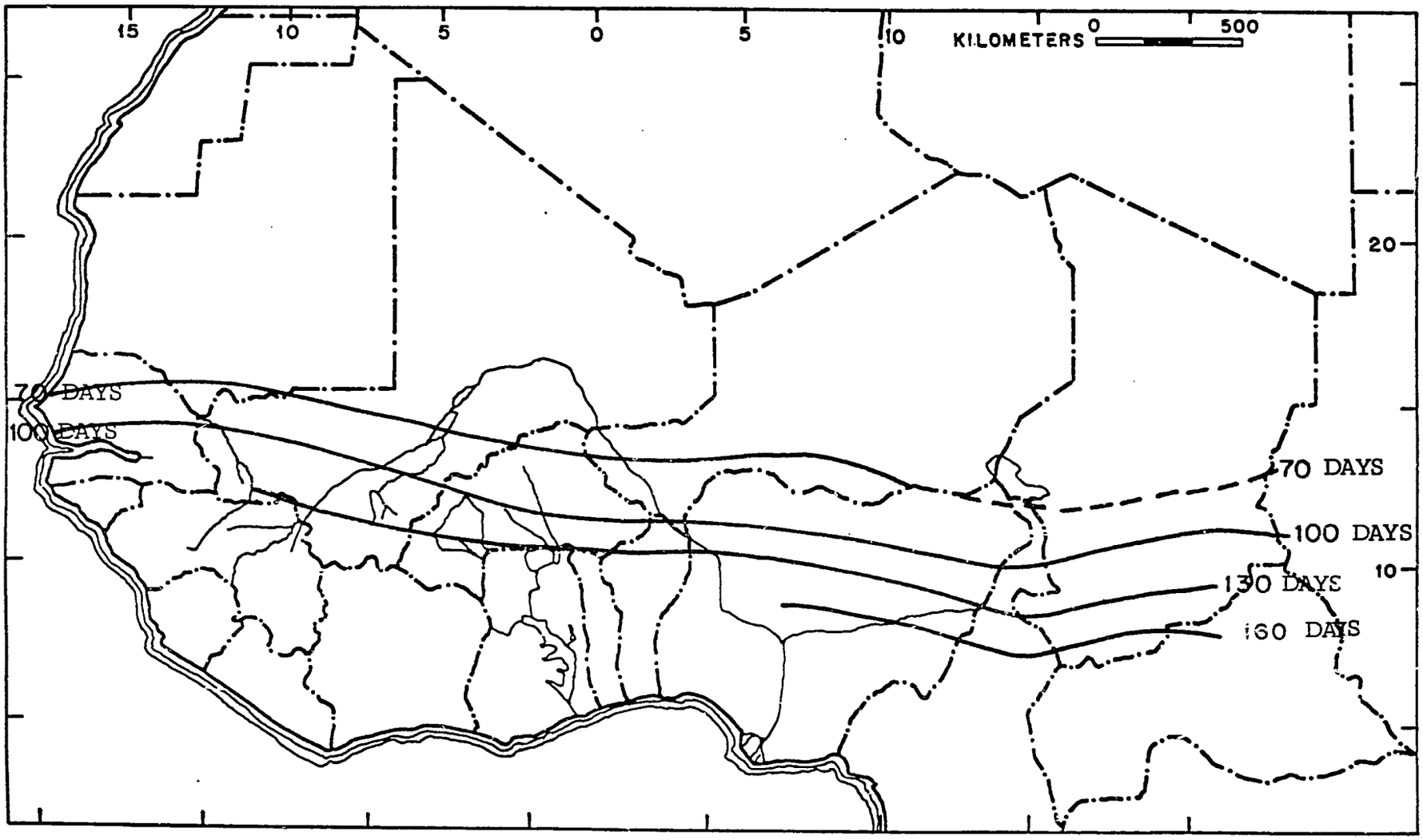

FIGURE 3.1 Average Number of Days in the Wet Season

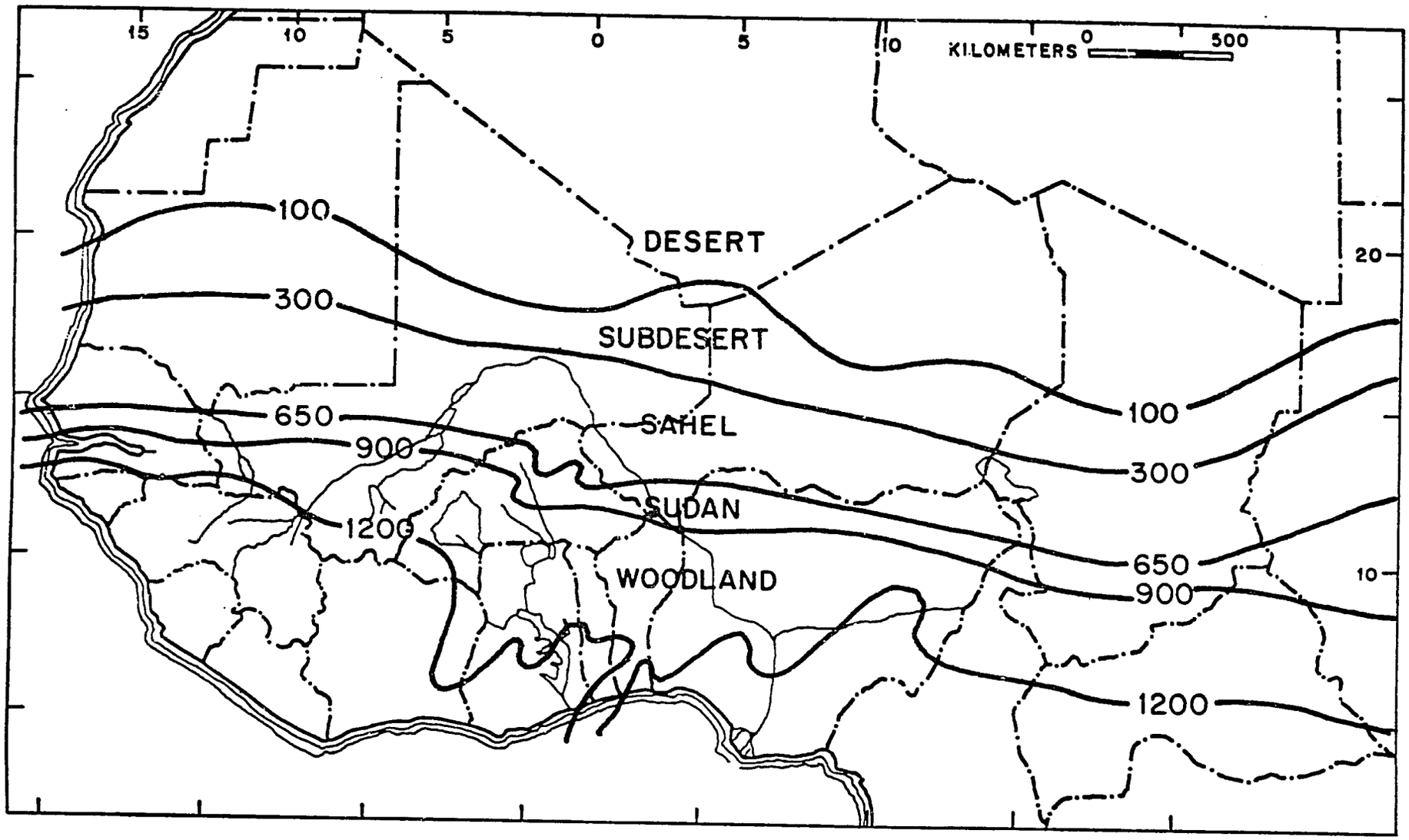

FIGURE 3.2 Climatic Zones of the Sahel-Sudan Region

Desert. The desert has an average rainfall below 100 mm/yr; annual deviations from the mean are ± 60 percent. Generally fewer than 10 rainy days/yr. occur. Evapotranspiration rates are generally more than 2100 mm; no marked rainy season exists, and winds are generally light, averaging 3-5 km per hour. Parts of the desert may not have rainfall for several successive years.

Much of the area is a barren, sandy subtrate that quickly absorbs any rainfall. In local situations, groundwater is trapped near the surface, supporting isolated oases. In others, surface conditions are such that long dormant seeds of quick maturing ephemerals sprout, grow and mature rapidly, producing another crop of seeds that await the next rain, one, two, or ten years in the future.

Under average conditions, 36 percent of the region is desert.

Subdesert. Average rainfall is between 100 and 300 mm/yr; annual deviations from the mean are ± 40-75 percent; 28 percent of the region is subdesert. Generally there are 10 to 25 rainy days per year, more or less concentrated in the months of July and August. Evapotranspiration rates generally range from 1800 to 2300 mm/yr. Winds are stronger, averaging 6-13 km/hour.

Sahel. Average rainfall is between 300 and 650 mm/yr; annual deviations from the mean are ± 30-45 percent. This zone makes up 17 percent of the region. Generally there are 26 to 46 rainy days per year, concentrated in a rainy season during the months of June, July, August, and September. Evapotranspiration ranges from 1700 to 1950 mm/yr. Winds are often strong, averaging 5-16 km/hour.

Sudan. Average rainfall is between 650 and 900 mm/yr; annual deviations from the mean are ± 25-30 percent. Generally there are 50 to 65 rainy days per year, concentrated in a rainy season during the months of May through October. Ten percent of the region is in this zone. Evapotranspiration rates range from 1600 to 1800 mm/yr. Winds are less strong, averaging 6-7 km/hour.

Woodland. Average rainfall is over 900 mm/yr; annual deviations from the mean are low, ranging ± 20-25 percent. Generally there are 65 to 80 rainy days per year, concentrated in a rainy season between May and October in the nine percent of the region which is in the woodland zone. Evapotranspiration ranges from 1600 to 1750 mm/yr. Winds are low, averaging 3-8 km/hour.

The statements made here were derived from detailed ranifall data and climatic parameters from weather stations in the Sahel-Sudan region as provided by a variety of sources.*

3.1.3 Climatic trends: Some knowledge of past climatic conditions of a region is necessary to evaluate possible future climatic trends. Three types of evidence of past climatic conditions exist: weather station records, historical writings and paleoclimatological studies.

3.1.3.1 —Weather station records: Instrumental measurements of climatic variables have been taken only during the past 300 years. Enough stations to determine global or hemispherical averages have been available only since about 1880. Few weather stations with continuous records covering more than 30 years exist in sub-Saharan west Africa. One of the longest records is from Dakar, Senegal for the period from 1887 to date.

The records for west Africa, like weather station data throughout the world, exhibit typical patterns of alternating ups and downs, especially in rainfall. As pointed out by Landsberg (1974) this "has always been an incentive to the periodicity hunters. Yet in data universes so beset by irregularities, where it may take five decades to obtain a reasonably stable mean value, this has--by and large--been a disappointing enterprise."

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*

U.S. Dept. Commerce, Monthly Climatic Data for the World;
U.S. National Climatic Center, World Climatic Data—Africa, 1952-1973;
Senegal A.S.E.C.N.A. Service Meteorologique, Normales Climatologiques du Senegal (1963);
U.N., F.A.)., Nouakchott, Mauritania, Pluviometric (1974); and
Chad Service Hydrologique, Precipitations Journalieres (1965).

Becker (1974) correlated rainfall with cereal production in Niger and Upper Volta in forecasting future yields in the region. He tested two hypotheses: "Rainfall over the Sahelian region during the past several years has not decreased in a significant manner with time," and "Relative changes in rainfall trends have not been significantly different between the north and south extremes of the sahel." Becker, for various reasons, included only rainfall data for the years between 1955 and 1972. He assumed that the average rainfall for this period was normal for the regions and made projections therefrom. However, as shown later, the base used by Becker was apparently too high.

When Landsberg (1973a, 1973b) and associates analyzed rainfall records from three stations in Senegal, they found the annual variations to be great. Their analysis of wet and dry years led "to the simple statistical conclusion that one would at least once in a century expect a sequential series of six or seven years with rainfall deficiencies, but there is an equal chance for that many years wetter than the median."

Various reports indicate that the years immediately preceding the current drought were much wetter than normal (a "little pluvial" period) throughout sub-Saharan west Africa. One indicator was the high level of Lake Chad. Lake Chad receives most of its recharge from river systems that arise in the more moist zones to the south. Because of the seasonal nature of rainfall in the area, the lake has an annual variation

of about one meter in level, reaching its lowest point at the end of the dry season.

Variations in Lake Chad levels for the period 1907-1972 were indicated on a graph published by the UNDP (1972). Their graph was based in part on actual records of lake levels and in part on reconstructed points derived from other information. Figure 3.3 is redrawn from their data.

An examination of the graph reveals that the level of Lake Chad was higher in 1955-1965 than at any period since 1907. In order to determine whether these levels were indicative of widespread conditions, a set of isohyets (lines of equal rainfall) for all of the region was constructed, based on data for 1962, 1963, and 1964, the years in which Lake Chad reached its highest levels. Lack of data points in northern areas, especially in northern Mali, Niger and Chad, made the drawing of isohyets very tentative. In spite of the limitations of the basic data on which the "little pluvial" isohyets are based, it is clearly evident that increased precipitation occurred throughout the area and not just in the Lake Chad basin.

An examination of the Lake Chad data (Figure 3.3) also reveals that the levels during the current drought are no lower than they were during 1913-1915 and 1941-1943. This is true even though the current upstream use of water is probably greater than earlier. To determine the extent of the drought, isohyets were constructed for the years

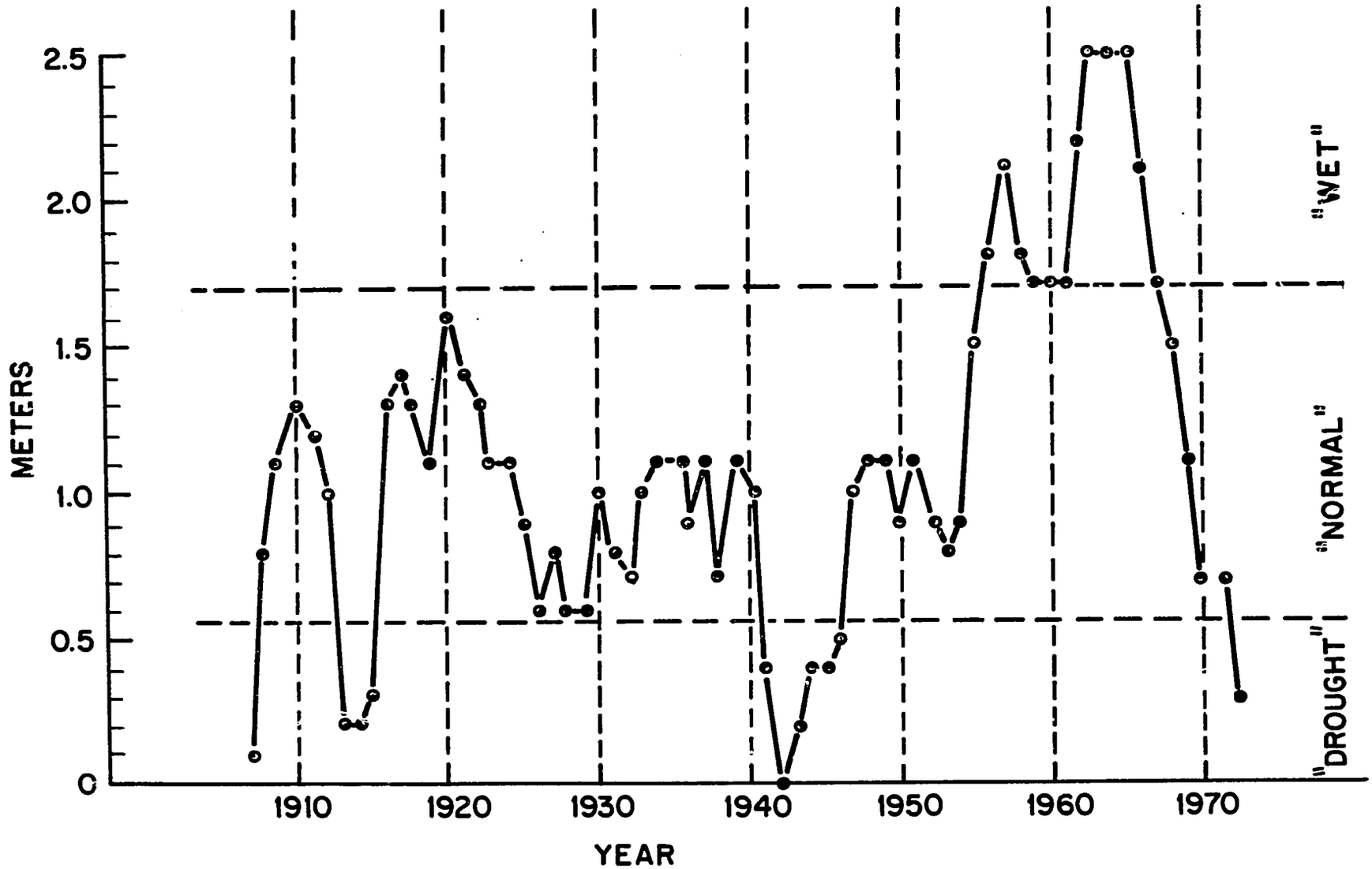

FIGURE 3.3 Variations in Maximum Levels of Lake Chad

1970-1972. Again the absence of weather stations in northern areas made the drawing of the 100 mm isohyet very tentative, but the widespread nature of the drought became apparent.

To help quantify the magnitude of the effects of the contrasting wet and dry periods, the areas of each of the six countries lying between various isohyets were calculated and compared with the areas under average conditions. Several significant observations can be made. Refinement of the isohyets probably would not change significantly the conclusions but would certainly add more precision to them. The conclusions are:

> Isohyet shifts. The north-south shifting of isohyets during wet and dry periods is more pronounced in the northern, drier zones than in the southern Sahel and Woodland zones.
>
> Geographic variations. At least during 1970-72, the drought was markedly more severe in the western (Mauritania, Senegal) part of the region. The effects of the wet period appear to have been relatively uniform throughout the region.
>
> "Little pluvial" results. The wet period resulted in relative changes of area from average conditions in rainfall zones as follows: below 100 mm zone, 9 percent decrease; 100-300 mm zone, 9 percent decrease; 300-650 mm zone, 13 percent increase; 650-900 mm zone, 1 percent increase; over 900 mm zone, 25 percent increase.
>
> Drought results. The drought periods resulted in relative changes in area from the wet period as follows: below 100 mm zone, 28 percent increase; 100-300 mm zone, 16 percent decrease; 300-650 mm zone, 20 percent decrease; 650-900 mm zone, 51 percent decrease; over 900 mm zone, 73 percent decrease.

3.1.3.2 —Historical writings: Prior to the development of instrumentation and the establishment of weather stations, some

indications of short term variations and longer trends in climate can be inferred from various historical records. In some parts of the world written records are available for periods as early as 2000 years ago. However, the earliest written records for the Sahel-Sudan region apparently date from the Sixteenth Century.

An analysis of part of these records reveals that 21 droughts of varying lengths have been reported, with reports based on epidemics which resulted from drought caused famines. It is probably unwise to make any generalizations concerning the lengths of past drought periods, especially the earlier ones where only a year or two is listed as a famine or epidemic. Most of these were probably preceded by two or more years of little or no productivity. Of the 21 droughts/epidemics listed, 6 lasted 1 year; 7 lasted 2 years; 1 lasted 3 years; 1 lasted 4 years; 1 lasted 5 years; three lasted 6 years and 1 lasted 18 years. The records demonstrate that droughts are a part of the normal climate of the region.

3.1.3.3 —Paleoclimatology studies: A number of techniques have been developed to evaluate, at varying levels of temporal precision, past climatic conditions. Especially in the past two decades considerable knowledge concerning prehistoric climatic conditions has been accumulated. Paleoclimatology bases its conclusions on data from many sources including physical geography, paleontology, chemistry, ice cores, deep sea cores, pollen studies, tree ring

analysis and others (Butzer 1971).

Paleoclimatology studies in the Sahel-Sudan region have barely begun. However, some general conclusions concerning past climates are indicated in the following summary.

The mean temperature of the middle latitudes decreased gradually throughout the Cenozoic era, with virtually no change in the tropics. During the Pleistocene a series of glacial and interglacial periods occurred. Current geochronological techniques place the last of these glacial periods as having reached its maximum about 20,000 years B.P. (before present). Although the Sahara and its southern semiarid belts have not been studied as intensively as some other parts of the world, considerable is known about major climatic variations there. Figures 3.4 and 3.5 compiled from several different sources, summarize major happenings.

It is evident that during the past 20,000 years the Sahel-Sudan has varied from much wetter than present to drier than present conditions. Some researchers consider past wetter periods as being more the result of decreased evaporation associated with lower temperatures than the result of actual increases in rainfall.

3.1.3.4 —Interpretations: Various people have postulated that mankind's modifications of the world environment can result in major climatic shifts. That such impacts are evident in micro-geographic areas (such as cities) cannot be argued. That such

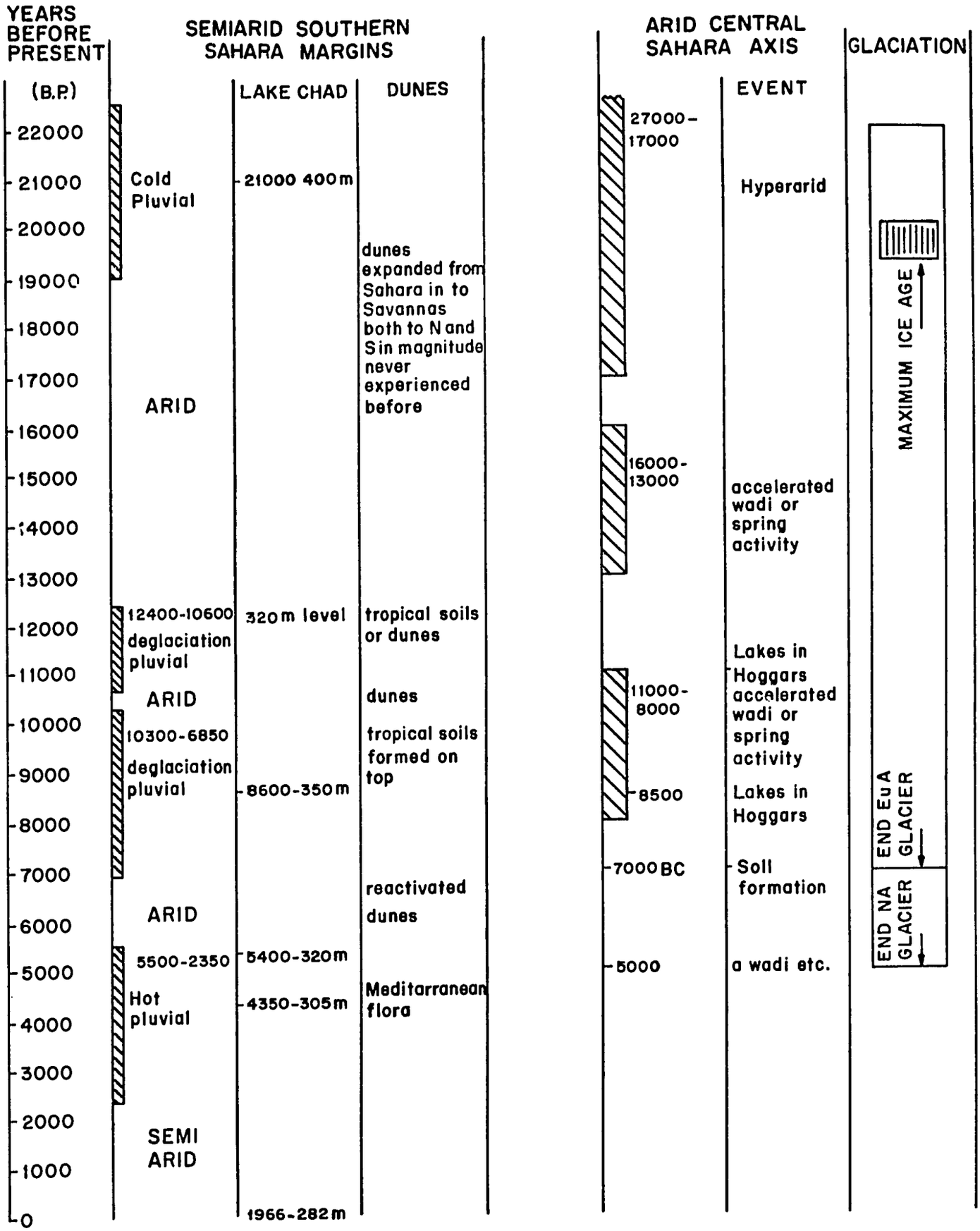

Figure 3.4 Summary of Past Bioclimatic Conditions

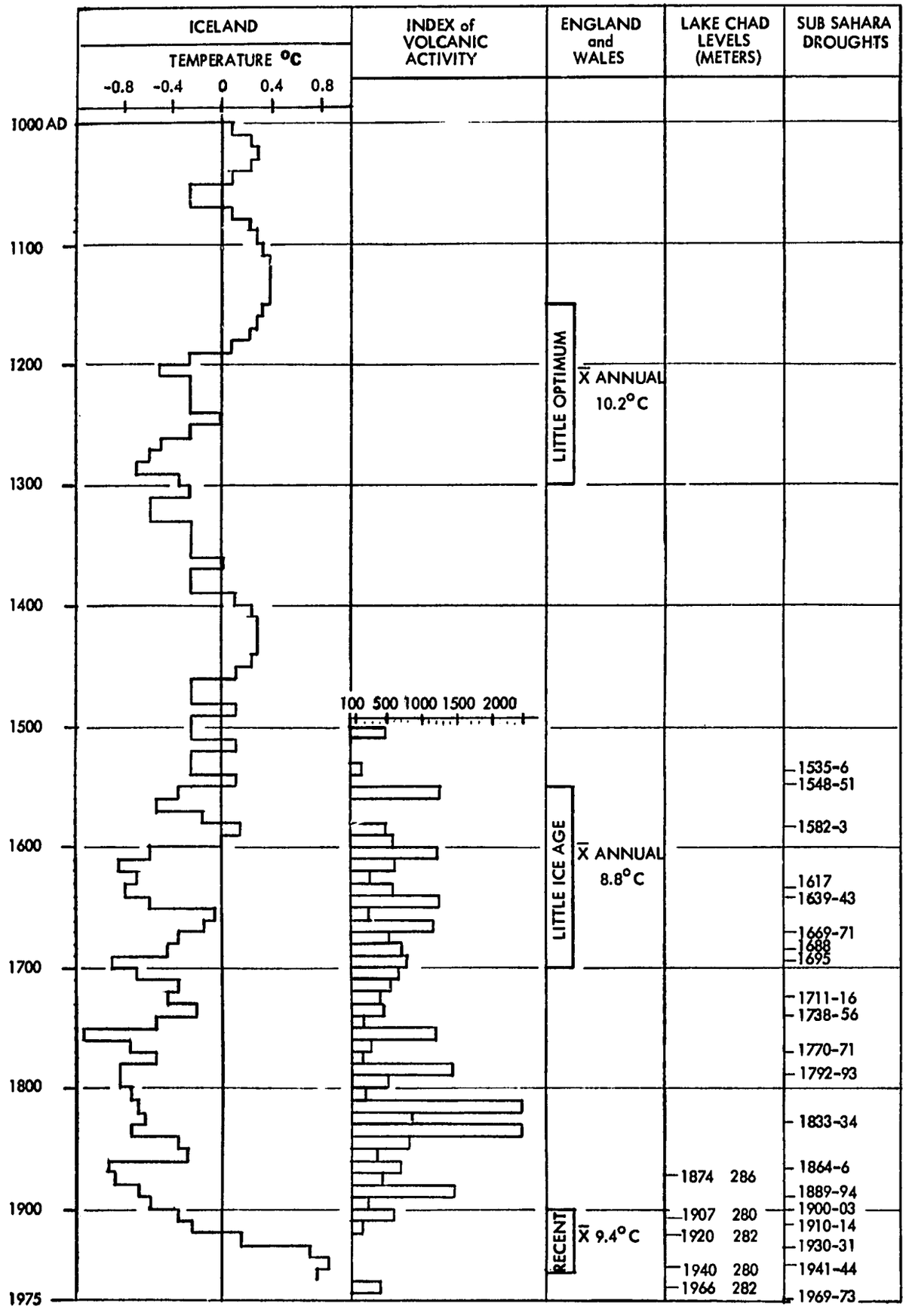

Figure 3.5 Climatic Indications of the Past 1,000 Years

modifications as slight increases in CO_2 and particulate pollution in the atmosphere can cause any major climatic shift in an area as large as the Sahel in 10 or even 50 to 100 years is not at all evident.

Some have suggested that massive, long-term climatic changes have already resulted from such factors as air pollution (Bryson 1973). Others take the view that variability is one of the characteristics of climate in most parts of the world and that no clear indications of long-term climatic shifts are yet evident.

Several interdisciplinary seminars have been conducted in recent years concerning various aspects of mankind's effect on the environment. One was "Inadvertent climatic modifications--Report of the study of man's impact on climate," sponsored by the Massachusetts Institute of Technology in 1970 (Anon. 1971). The following statement was included in their conclusions.

> In relation to the earth's history our recent climatic fluctuations, covering less than 300 years, are only small-scale noise, are seemingly random, and are certainly not well understood. . . In fact, as has been frequently pointed out, it will be difficult to identify any man-made effect because, first, with our present state of knowledge, we do not know how to relate cause and effect in such a complex system, and, second, man-made effects will be obscured by the natural changes that we know must be occurring.

This same symposium attempted to put into perspective any effect of industrial activities of the past one or two centuries by pointing out

that long before the Industrial Revolution, agriculture and animal grazing had denuded about 20 percent of the continental landmasses. This drastically changed the heat and water budget of the earth and may well have had effects on climate.

Little direct evidence relating to the Sahel-Sudan region exists. At the Symposium on Drought in Africa, held in July 1973 by the Center for African Studies at the University of London, various views about the future of the region were expressed (Dalby and Harrison Church 1973). Some predicted continued, long-term drought; others saw the current drought as only another in a continuing series of drought-moist periods characteristic of the region.

El-Sayed and Landsberg (1973) analyzed rainfall records from Dakar, Senegal (1887-1972) and found that rainfall decreased by one-third mm/yr during the period of record. Similar analyses performed by Landsberg (1972) on rainfall data from two other stations in Senegal (Bambey, 1923-1972 and Ziguinchor, 1920-1972) revealed no significant persistent departure from median values.

Dr. James McQuigg, Professor, Department of Atmospheric Physics, University of Missouri, Columbia, recently (1974) stated in part:

> While it is true that there are important differences in topography, soil and in societal and governmental structure from one part of the Sahel-Sudano region to another, there is a climatic feature that is common to the entire area. This feature is the <u>variability</u> in precipitation from year to year. The periods when precipitation is below some threshold value of

> economic importance may not always be coincident over the entire region, but the fact that there will be periods when there is not enough rain is one aspect of the climate that is dependable.
>
> Whether one views the current prolonged drought as just the sort of event one expects from time to time through random chance, or a manifestation of a shift to some different climate, the implications for modelling climatic impact on economic/ecological/societal events are almost the same.

3.1.4 Weather control: Studies of attempted weather control in other areas, especially cloud seeding to increase precipitation, were examined. Some attempts appear to have been locally successful, under special conditions, in increasing rainfall. However, the technology for inducing increased rainfall over such wide expanses as the Sahel-Sudan region apparently does not exist; even if it did it would probably be economically unfeasible. When the moisture bearing monsoon air masses do not move far enough northward, early enough in the season, current cloud seeding techniques could not possibly produce rainfall, especially on the timetable needed for crop production.

3.1.5 Climatic projections:

> Throughout his history, and in spite of his technology, man has remained impotent before the task of predicting with certainty--let alone controlling--the fluctuations of the climate on which he depends.

This quote, from Dalby and Harrison Church (1973), represents the view of many, if not most, modern climatologists. From the previously referred to Symposium on Drought in Africa, J. A. Allan (1973) concluded,

concerning the question of climatic change in west Africa:

> Those competent to appraise the evidence had to conclude that the causes of such changes are numerous and still not well understood. Climate is always changing and there is no such thing, for example, as 'normal rainfall,' only an average rainfall over a specific period.

3.2 Plant Ecology

West Africa has a series of vegetation zones that more or less correspond with the previously defined climatic zones. The exact north-south extent of these, and even their average rainfalls, are not clearly defined (Whyte 1967, Holdridge et al. 1971, McGinnies et al. 1968, Rosevear 1965, and others). Generally, three belts are recognized: the northern desert belt with annual rainfall less than 300 mm, the savanna belt with rainfall less than 900 mm, and the southern woodland belt with rainfall more than 900 mm. Each of these belts is further subdivided into vegetation zones (Figure 3.6).

Desert belt. Desert zone (below 100 mm rainfall per year). In a few places today, and formerly more extensively, the vegetation consists of scattered areas of small perennial trees, shrubs, and grasses. These occur wherever physical conditions combine to concentrate and retain runoff water from the scattered rainfall. Under certain conditions these plants survive, even though no rain falls locally for several years. In areas where scattered violent desert rainstorms saturate the surface, seeds of ephemeral plants (grasses and herbs) that have been dormant

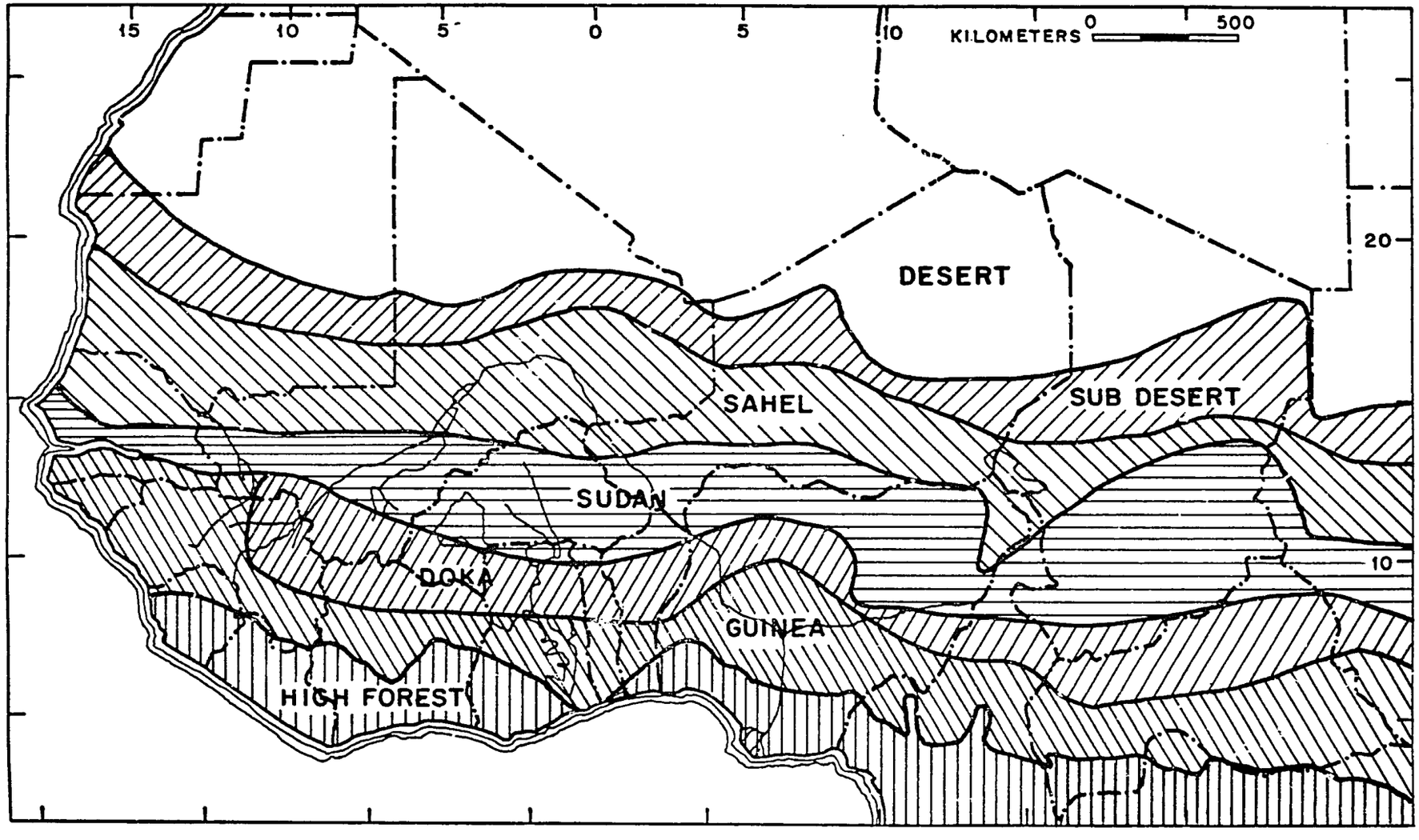

FIGURE 3.6 Vegetation Zones of West Africa

for years, sprout, grow, and result in large expanses of green vegetation. Even after such an area dries out and the plants die, their roots and stems remain for years to help prevent wind and water erosion.

In the Sahara area, wide areas on and around the higher elevations of the Tibesti (northern Chad) and Ahaggar (southern Algeria between northern Mali and northern Niger) have more rainfall and formerly had more vegetation. The Ahaggar had extensive tree cover even within historic times. Total precipitation minus potential evapotranspiration generally exceeds -2200 mm/yr and may reach -2400 mm/yr.

Subdesert zone (100 to 300 mm rainfall per year). This is a more moist version of the desert, with wider expanses of scattered perennial woody vegetation. Grasses and herbs are more widespread and little dune activity exists. Total precipitation minus potential evapotranspiration generally ranges between -1300 and -1650 mm/yr.

Savanna belt. Sahel zone (300 to 650 mm rainfall per year). This part of the savanna belt has vegetation consisting of scattered acacias and other thorny, narrow-leaved trees and bushes. Between the bushes and trees is an almost uniform cover of short grasses that are generally below 40 cm in height. Because of the low height of these grasses, fires are rarely widespread and have little impact on the ecosystem. The total precipitation minus potential evapotranspiration generally ranges between -1300 and -1650 mm/yr.

Sudan zone (650 to 900 mm per year). This zone has scattered,

taller trees, often broad-leaved and deciduous. Between the trees are tall (to 80 cm) perennial grasses. Fires, especially in the southern part, are partially responsible for the maintenance of the savanna. Locally, where conditions combine to contain fires, the trees become quite dense and forests develop. The total precipitation minus potential evapotranspiration generally ranges between -800 and -1300 mm/yr.

Woodland belt. Doka woodland zone (950 to 1400 mm rainfall). This zone is part of the woodland that formerly extended south to the coast. The Doka woodland is characterized by large numbers of *Isoberlinia* trees (*I. doka* and *I. Dazielli*) that are deciduous, losing their leaves during the dry season. During this four to six month period, widespread fires occur in the woodland and associated grasslands. Total precipitation minus potential evapotranspiration generally ranges from -400 to -800 mm/yr.

Guinea woodland zone (1400 to 1800 mm rainfall). This zone is characterized by several kinds of trees that tend to include fewer seasonally deciduous species and are classified as "relatively moist" types. The dry season in this zone lasts only three to four months. Total precipitation minus potential evapotranspiration generally ranges between 0 and -400 mm/yr.

High forest zone (over 1800 mm rainfall). This is a closed rain forest, with a great diversity of kinds of trees including many broad-leaved evergreens. The dry season is quite short, often only a few

weeks in length. Even during this period, the relative humidity remains high. Total precipitation generally exceeds the potential evapotranspiration.

3.3 Wildlife

Wildlife is often used in a narrow sense as being the big game animals of an area, usually including only the largest of the herbivorous mammals. More commonly, the word includes all of the vertebrates except fish (that is, all amphibians, reptiles, birds, and mammals) and is subdivided into game species (those hunted for meat, hides or other valuable parts, or sport) and non-game species. Game species may be variously classified as big game, small game, water fowl, fur bearers, upland game birds, frogs, and so on. Non-game may be divided into: protected species, predators, pests and so on.

3.3.1 Wildlife as a protein source: Historically hunting and gathering has provided food for many Africans. A few primitive ethnic groups south of the Sahel-Sudan region still utilize this as their only source of food. Sedentary farmers and nomads continue to utilize varying amounts of wildlife as food. The list of animal life used as food by at least some people is extensive, ranging from invertebrates (locusts, termites, crabs), fish, amphibians (frogs, toads), reptiles (many lizards), birds (a large list), and mammals (including rodents and wild herbivores). A number are actually sold in public markets.

Big game species, especially various wild bovid mammals (antelopes, goats, gazelles, and relatives) because of their large size, are often assumed to offer great potential as meat sources. Dorst and Dandelot (1970) provide data on the characteristics of the important game species of the Sahel-Sudan region and Asibey (1974) has collected data on the bushmeat sold at the Accra, Ghana, market.

Recent newspaper articles (see for example Cushing 1974), based on reports of biologists (e.g., Dasman 1964, 1973; Riney 1967; Talbot et al. 1961a, 1961b, 1963, 1965, 1966) and agriculturalists (e.g., Brown 1971, Kyle 1972) have presented fairly convincing arguments that much of Africa, including the Sahel-Sudan region, should eliminate domestic herbivores (cattle, sheep, goats, etc.) and depend upon various native herbivores.

The gist of the argument is that native species, having evolved in the region, are much more efficient in meat production. This results from a number of factors: (a) the environment, especially of the arid and semiarid grasslands, is fragile and rapidly deteriorates when grazed by domestic animals; (b) the various native ungulates are more flexible in water requirements, and reputedly more disease resistant; (c) the differing food preferences of the species in a given region result in a more complete utilization of the plant productivity and larger standing crop biomass than is possible with cattle (Table 3.1); (d) the rate of weight gain of native ungulates is more rapid and the age of attaining adult

TABLE 3.1

Standing Crop Biomass of Native and Domestic Herbivores

Animals	Location	Habitat	Biomass (kg/h)
wild ungulates	East Africa	savanna	122-175
wild ungulates	East Africa	bush	140
cattle	East Africa	managed savanna	37-56
domestic livestock	East Africa	savanna (tribal grazing)	19-28
bison and wild ungulates	W. United States	prairie	25-35
mule deer	California	chaparral	18
mule deer	Pacific Coast, U.S.	chapparal	12
white-tailed deer	Michigan	best local habitat	10
mule deer	California	average all ranges	2.4
mule deer	Arizona	average all ranges	2.3
red deer	Scotland	deer forest	6.2
domestic livestock	W. United States	grasslands	34-47

Source: Talbot and Talbot (1963).

size is less than in cattle.

Riney (1967) listed presumed advantages of wildlife species: (a) most contain a higher percentage of protein than cattle or sheep; (b) they are more productive, thus higher offtake rates are possible; (c) wild ungulates can thrive in areas where domestic animals cannot exist; (d) total production of protein per unit area in many arid and semi-arid regions is higher; (e) large numbers can exist on a permanent basis without the degradation of the ecosystem that results from domestic animals; and (f) quick returns are possible from little capital investment.

3.3.2 Utilization of wildlife: Three general and not necessarily mutually exclusive approaches have been proposed for utilizing native ungulates as a meat source. In fact, each has been and is currently being utilized: (a) game ranches devoted to raising native ungulates, (b) domestication and selective breeding of native species, (c) natural areas devoted to native ungulates that are harvested selectively.

Some game harvesting activities have removed surplus production in National Parks, especially in the east African region.

Talbot (1961) speculated that since

> The standing crop of wild animals. . . on savanna land may be two to eight times that of domestic stock, and . . . on bushland may be from four to fifteen times that of goats and sheep . . . it can be assumed that other things being equal, the potential harvest of protein

> and other animal products from wild animals should be several times that possible from domestic livestock alone . . .

However, many problems are encountered in attempting to utilize wildlife on a sustained yield basis over large areas.

a. Harvesting difficulties. Unlike domestic animals that can be driven, often long distances, to slaughter houses, free-ranging wild animals must be killed and bled, and then transported somewhere for processing. Mobile processing plants have been developed but transport of meat is still a problem, especially during the wet season.

b. Offtake rates. Kyle (1972) estimated that a 10 to 18 percent offtake rate is possible for wild ungulates. However, in actual practice, some offtake rates have had to be reduced to as little as 6 percent to maintain herd size (Gogan undated). Further, the comparison does not include the large amount of cattle productivity in the form of milk that makes up much of the food of the herders.

c. Range requirements. Most native ungulates have evolved for survival in a specific set of ecological conditions. Migratory herbivores maintain diet preferences by constantly moving where local conditions of rainfall, fire or other factors have provided the proper conditions (Talbot and Talbot 1963). In the case of the hartebeest the migration route may involve airline distances of up to 1000 miles. When the routes are cut (by fences or land use adverse to the animal) and animals are forced to remain throughout the year in only part of their former range,

malnutrition and low reproductive rates often result.

Any major shift in the ecosystem as a result of human activities (such as extensive burning, field crops, forest clearing, cattle grazing) often creates conditions adverse to the survival of wild species.

d. Competition for graze. In a given region a given amount of browse and graze is produced each year. If this is heavily utilized by domestic grazers and browsers, little is left for wild ungulates. The groups are in direct competition for the same feed resource and any increase in one group results in a lowered population of the other.

e. Animal diseases. Some animal diseases indirectly cause further interaction problems. For example, most wild ungulates are highly susceptible to rinderpest while at the same time being little affected by the sleeping sickness transmitted by the tsetse fly. In contrast, domestic animals are highly susceptible to sleeping sickness and less so to rinderpest.

f. Social customs. Various authors have referred to the problems inherent in getting herdsmen to give up domestic animals (and their milk) and to rely upon wild ungulates for protein. Further, wild animals are generally assumed to belong to the person who kills them. The problem of maintaining a sustained yield offtake, especially in migratory species, is great.

3.3.3 Future of Sahel-Sudan big game: Historically, as human population in an area increases, more and more changes in the

ecosystem are brought about by man. Burning, forest clearing, field crops, fences, domestic animals, roads, buildings--all result in changes adverse to most (but not all) wild species. Add to this the direct impact of humans killing for meat, hides, ivory or sport, and wild species generally fare badly and often are exterminated in all but the most protected ranges. Migratory species tend to disappear more quickly than sedentary ones, large species before small ones. In times of food shortages, such as the current drought, man-made impacts are even greater.

Assuming that the present population trend continues, many, if not most of the large African game mammals are doomed to be eliminated throughout most of their ranges. Some, especially those with narrow environmental tolerances, will soon become extinct. For example, Dorst and Dandelot (1970) estimated that in all of Africa there were only some 11,000 to 13,500 Black Rhinoceros. The recent importing of lions from temperate zone zoological gardens to restock some South African regions "made the news" throughout the world.

3.3.4 Effects of changing ecosystems: Changes in ecosystems may result in the reduction or extinction of wildlife species, but human modifications are not always detrimental to wild animals. Apparently bushpigs (*Potamochoerus porcus*) and the topi (*Damaliscus korrigum*, a kind of antelope) are even more numerous than they were 50 years ago. The bushpigs often feed on field crops.

With the planting of cereal crops, the food available for certain birds, especially the Quelea weaver-birds, greatly increased. Breeding colonies ranging from a few hundred to several million nests exist throughout the southern Sahel, the Sudan and northern woodland zones. Night roosts of birds vary in size from a few hundred to tens of millions of birds (Magor and Ward 1972). Essentially seed-eaters, a flock of birds can destroy a cereal crop in a few hours. Extensive research and control activity is devoted to preventing crop destruction, and sedentary farm villages in infested areas assign residents to guard fields of cereals.

3.4 Agricultural Production in the Sahel-Sudan Region

Agricultural production in the region is directly related to climatic and land characteristics. The methods of the traditional agriculture system also have a major influence on production.

3.4.1 Land use: Much of the Sahel-Sudan region is arid, even in periods of normal rainfall. The result is that only 7.9 percent of the region is considered arable, 25.8 percent consists of permanent grazing (meadow) and pastures, 11.5 percent forests, and 54.6 percent "other areas" (FAO 1972). Presumably, much of the latter is in the desert and subdesert zones that are the realm of nomadic herdsmen.

Significant areas of cultivation exist, generally concentrated along the major streams and in the wetter southern parts of the countries

Table 3.2). The availability of high quality (deep, fertile) agricultural soil is extremely low. Soils data of a reconnaissance nature have been compiled for much of the region, but detailed soil survey information is fragmentary. Time constraints prevented an extensive review of the soils data. An extremely small portion of the region is irrigated.

3.4.2 The traditional system: The region is inhabited by ethnic groups which differ markedly in social and cultural traits. Because of this and the climatic variability there is no one "traditional way" of agriculture.

The type of agricultural activity varies markedly from north to south. In general, the inhabitants of the desert and subdesert engage almost solely in animal husbandry where grazing is utilized to harvest the limited ecosystem productivity. Nomads inhabit the area with their herds made up primarily of camels and goats. Oasis agriculture, especially date production, is carried on wherever possible.

In the southern part of the subdesert, Sahel and northern Sudan zones are the transhumant herdsmen who, in general, have fewer camels and goats but more cattle and sheep. The animals are kept on the subdesert and northern Sahel during and immediately after the short northern rainy season to take advantage of the forage produced and then are driven southward to graze on fallow lands and the stalks and other crop residue available during the dry season. The cycle begins anew

TABLE 3.2

Areas and Land Use in the Sahel-Sudan Region

(10^3 hectares)

	Total Area	Arable		Area cultivated (1970)	Irrigated (1970)	Grazing & permanent pastures	Forests	Other Areas
			Percent of Area*	Percent of Arable*	Percent of Arable*			
Chad	128,400	7,000	5.5	1,380	19.7	-	45,000	16,500	59,900
Mali	124,000	11,600	9.3	1,541	13.3	61	0.52	30,000	4,451	77,943
Mauritania	103,000	308	0.3	258	83.8	3	0.01	39,250	15,134	48,423
Niger	126,700	12,177	9.6	3,315	27.2	5	0.2	2,900	15,600	96,023
Senegal	19,700	5,564	28.2	2,119	38.1	92	1.7	5,700	5,318	3,037
Upper Volta	27,420	5,315	19.4	2,291	41.7	2	-	13,755	4,101	4,187
Total	529,220	41,964		10,904		163		136,605	61,110	289,513
Percent of Total	100	7.9		26.0		0.4		25.8	11.5	54.6

Source: F.A.O. (1971-1972), except those marked * which were calculated by the authors.

with the next wet season when the animals again follow the rains northward.

In the southern woodlands few cattle are raised because of the need to limit the animals' exposure to parasites, arthropods, and arthropod borne diseases (especially the tsetse fly and the associated sleeping sickness that is generally fatal to most breeds of cattle) during the longer humid season of the south. Horses, donkeys, pigs, and chickens are also raised, especially in the southern part of the region.

In Niger, the northern (and more nomadic) Tuaregs have herds that average 20 cows, 27 sheep, 24 goats, 0.3 horses and donkeys, and 11 camels. In contrast, Peuls, living to the south and practicing transhumance have herds averaging 64 cows, 11 sheep, 9 goats, 1.2 horses and donkeys, and 0.4 camel. Such differences in herd composition appear to be typical.

Animals sold in the north are driven along traditional trails to the markets in the south. This trek may involve several weeks, hundreds of kilometers, and weight losses of more than 25 percent. The resulting meat is generally tough and lean. However, its cost, in terms of external inputs such as feed, supplements, and transportation, is minimal. Essentially, the meat was produced by the natural productivity of the ecosystem and poorly compensated human labor.

From the Sahel zone on southward, wherever arable land exists, sedentary farming is practiced. Isolated areas of irrigation are found.

Most such farmers have some domestic animals. Figure 3.7 indicates the relative importance of animal and crop production in the various climatic zones.

Three major types of crop cultivation are practiced: dry-land, flood retreat and wadi farming. Most prevalent is dry-land farming, planting seeds at the beginning of the wet season and depending upon rainfall for the moisture needs. Flood retreat agriculture is practiced on the flood plains of some of the major rivers, especially the Senegal, Niger, and Chari. Annual flooding causes varying areas of flood plains to be inundated. As the floodwaters retreat and the soil dries out, seeds are planted. Growth depends upon the water remaining in the soil. Wadi farming is essentially a modified flood retreat technique practiced in certain places in the Sahel and subdesert. Either by some natural topographic barrier, or by the construction of retention dams across drainage wadis (channels), the runoff water from relatively large areas is trapped and permitted to seep downward in small areas of good soil. The resulting soil moisture is often adequate to produce a low yield of short season millet.

Millet, sorghum, wheat, and corn are grown by the above methods. Rice is generally grown in irrigated fields.

Peanuts and cotton occupy about 25 percent of the cultivated area in the six countries. Most of their production is sold and exported from the region.

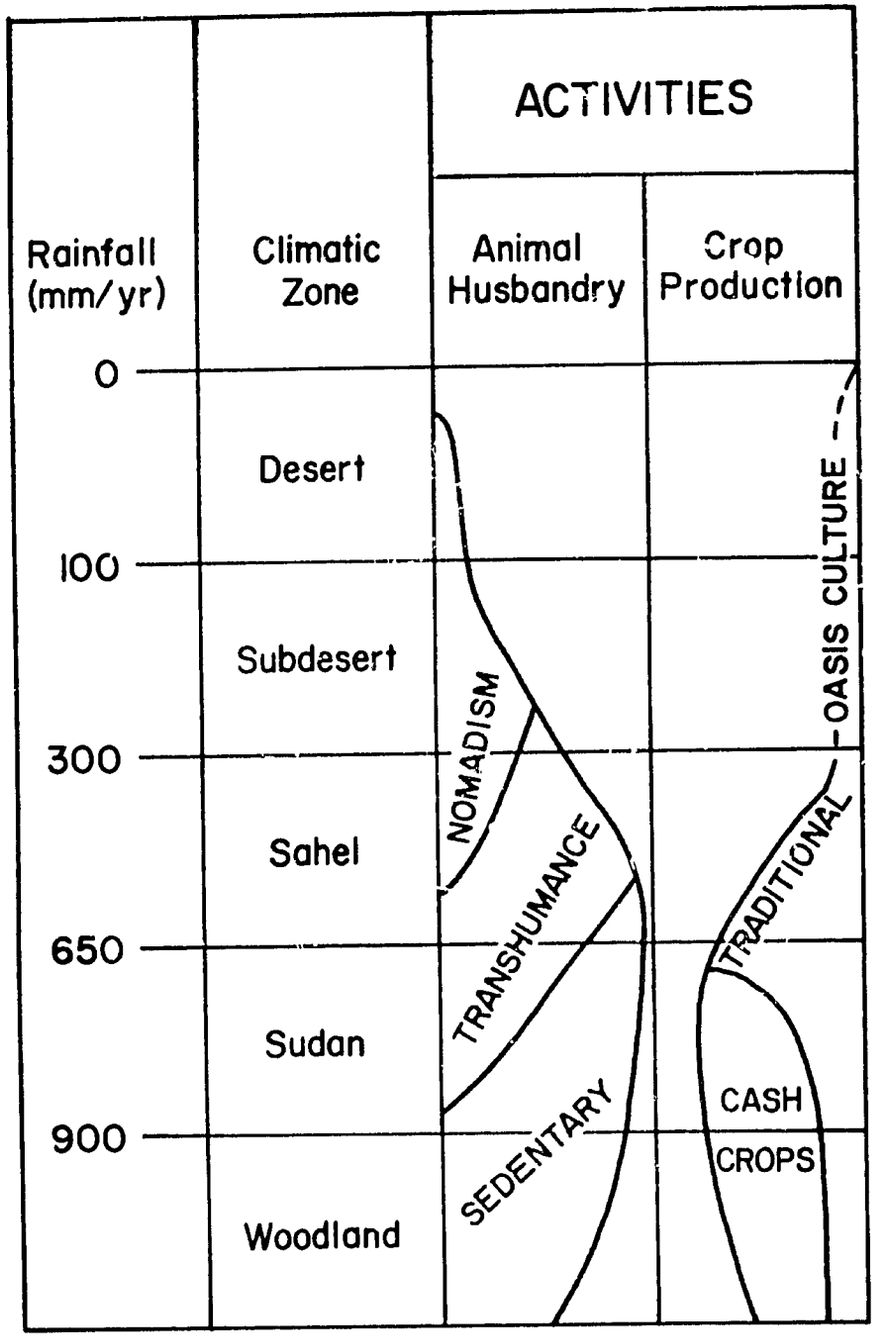

FIGURE 3.7 Distribution of Agricultural Practices in Climatic Zones

Traditionally, the soils are not tilled. (If used, tillage is rudimentary, to depths of 5 to 10 cm.) Rather, holes are made in the ground with a stick and the seeds inserted.

Hill seeding is unorganized and the seed rate low (5,000 to 7,000 hills/ha for millet, 10,000 to 15,000 hills for sorghum and maize). The crops are only partly thinned or not at all.

Limited cultivation with short-handled hoes is usually done during the growing season to control weed growth. Hoeing-weeding operations are poorly done: they are begun too late and not done often enough. The lack of labor for weeding sometimes limits the cultivated area.

The plant varieties used are generally tall and in response to fertilizers, straw production is increased more than grain production; although the increase in grain production is substantial. Mixed cropping is customary and all types are found. Millet and sorghum are commonly grown with legumes.

The traditional systems depend upon the natural productivity of the ecosystem. Nomads, especially in the north, depend almost entirely upon natural forage for their animals.

Rangeland animals are of two types, the grazers that primarily feed upon low grasses and herbs, and the browsers that feed primarily on leaves and stems of more woody, often perennial vegetation. While grazers will take some browse and browsers will eat some graze, especially when feed is short, the differences between the two result in

markedly different impacts on rangelands. An area overgrazed by cattle can still be utilized by sheep. Goats can thrive on areas overgrazed by sheep because they utilize browse and camels can survive on areas overgrazed by goats because they can utilize even woodier or more spiny browse than that used by goats.

The cattle in the north are generally Zebus. On occasion they may go two or three days without water on the long drives (Westebee 1971).

The nomads depend directly upon milk and meat for a large part of their food. The amount of food derived from the herds, as well as its form, varies not only seasonally but also geographically and with ethnic customs. In one study, this off-take was reported, as a yearly average, to be 3/4 milk and 1/4 meat (Brown 1971).

Such offtake has many deleterious effects on productivity. Cows, as a result of their poor lactation characteristics and the low availability of feed, generally produce barely enough milk to support their calves. Hence, taking milk for human consumption results in malnourished, slow growing calves.

During the dry season, because forage is scarce and often at great distances from watering points, animals undergo a period of no growth, and, often, of actual weight loss. Much of the weight gain is thus lost each year in sustaining the animal until the next wet season (Figure 3.8).

The combination of genetic traits and the poor environmental

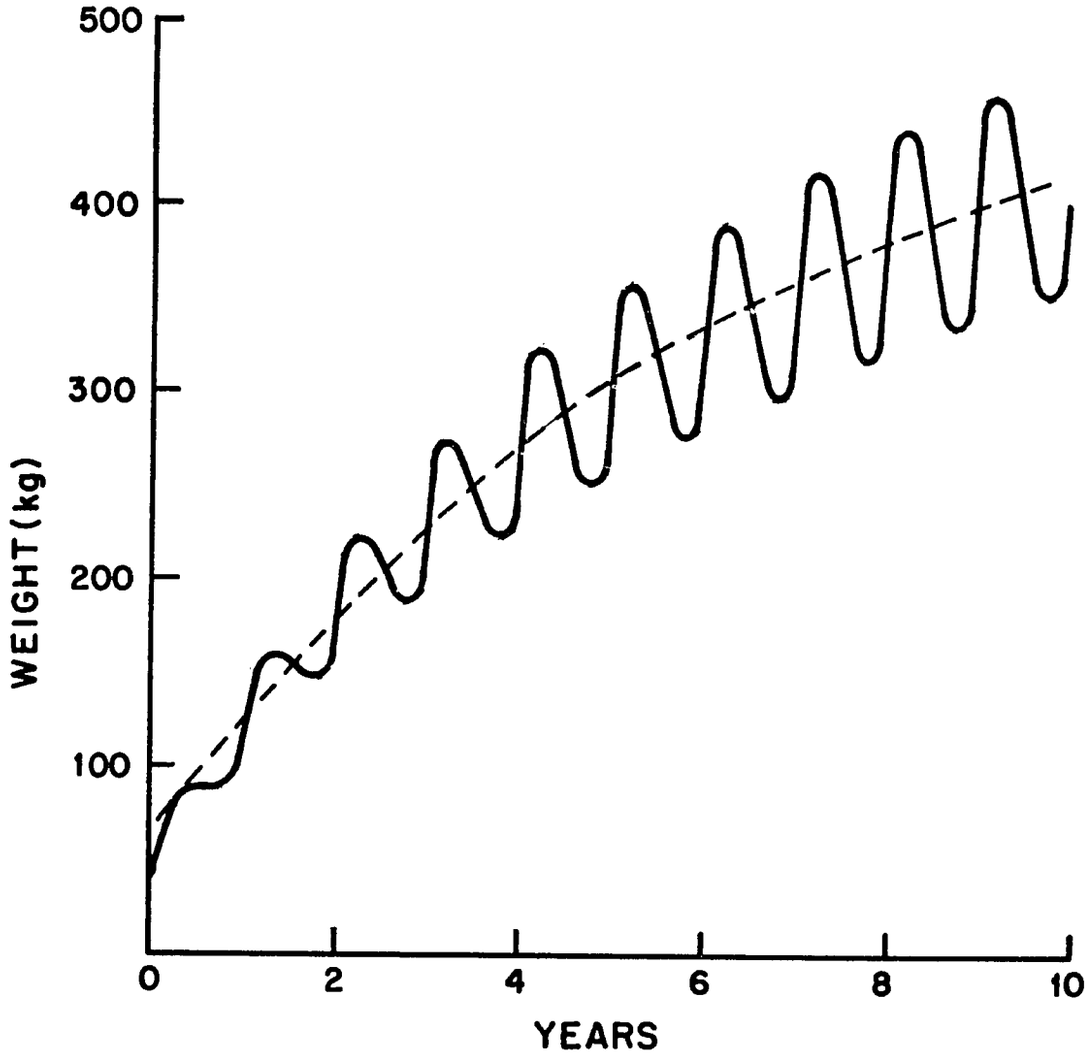

FIGURE 3.8 Seasonal Variability in Weight of Cattle Raised under Traditional System

conditions results in slow maturation, requiring four or more years to reach adult size and sexual maturity; extended nursing time for calves, often lasting eighteen months to two years; low fecundity with mature cows generally having a calf only every other year; and high mortality rates because of decreased resistance to diseases and parasites especially during the first year (Westebee 1971).

A significantly less efficient system of converting ecosystem productivity into meat is the outcome. Modern cattle raising systems require only about 8 kg of feed to produce 1 kg of meat. The ratio in the Sahel may run 20 to 1 or higher.

Other domestic animals raised in the region have varying feeding habits. Penned chickens depend primarily upon grain, but in semi-wild conditions under which many are raised, significant amounts of wild seeds, berries, animal material (especially insects) and garbage are eaten. Pigs feed by rooting on the roots, tubers, and animal material exposed as well as feeding on significant amounts of garbage and grain.

Traditional crop farming depends primarily on human labor and a fallow period (up to 20 years) for restoration of fertility and moisture and for pest reduction. Chemical fertilizers generally are not applied directly but the cereals may benefit from the residual effects of fertilizers used on the cash crops. Manure is often used around the dwellings, but only infrequently in the open field. Virtually nothing is applied to protect the seed, plant or stored grain, even though all stages are

attacked by many pests.

Various relationships exist between the settled farmers and nomads, especially in areas with both transhumant animal husbandry and crop production. The grazing of animals on fallow lands and crop residue adds manure to the ecosystem and utilizes some of the by-products as feed. In some areas the stalks and vines of harvested crops are gathered by the farmers, either for use by their own animals or for exchange or sale to the nomads.

Most of the inhabitants exist in a subsistence status that is essentially outside of the monetary economy. They utilize all food sources available, not only animal products from domestic stocks and crops but also significant amounts of "wild game" including rodents, insect grubs, and termites as well as wild vegetation (May 1968, Jardin 1967). According to the country, millet, sorghum and maize (corn) are consumed in the form of gruel, dumplings, or couscous. Part of the cereal production is used for making beer and other alcoholic drinks (Sene 1970).

3.4.3 Ecological effects of traditional agriculture: Most recent changes in the vegetation of the region appear to have resulted from human use, and misuse, of the area (Dregne 1970, Bakker 1972) and not from climatic shifts.

Various evidence exists that much of north Africa, north of the tsetse fly zone, formerly supported grazing cattle (Davidson 1973).

Various indicators suggest that herds existed as early as 6000 to 7000 B.P. (before present), not only in the Tibesti region but also in areas now essentially bare rock and drifting sand (Hufnagl 1972). Obviously, more surface water and grasses for grazing were available then than now.

Ecologists and range managers are generally agreed that the disappearance of perennial vegetation in the Sahara, the development of the sand seas and large expanses of bare rock, as well as the expansion of desertification through the adjacent subdesert into the savannas, both north and south of the Sahara proper, are the result primarily of misuse of the ecosystems by man (Kassas 1970).

The desertification process in subdesert and savanna regions is generally envisioned as involving (a) reduction of perennial plant cover, (b) impoverishment (reduction in diversity of species) of flora; (c) soil erosion (by wind and water action), and finally (d) the formation of mobile sand dunes and areas of desert pavement (pebble and rock covered areas) or bare rock (Kassas 1970).

The initiation of this process results from one or more human activities including (a) the cutting of woody species for firewood and other uses at a faster rate than natural regrowth occurs; (b) over-grazing by livestock that results in the eradication of palatable species, or, when further overgrazed by browsing animals, the elimination of all plant species; and (c) the clearing of land for cereal cultivation,

especially in regions of marginal rainfall where fields soon may be abandoned.

South of the Sahara, the long-term misuse of the land has caused large scale shifts to the southward of all vegetation zones. Bare rock and sand dunes of the desert have invaded former subdesert and Sahel zones, the Sahel vegetation has invaded the Sudan, the Sudan invaded the Doka woodland, and so on to the south with the Guinea woodlands invading the High Forest. At least in the Sahel and Doka woodland zones the widespread occurrence of uncontrolled fire is another man-instigated practice that contributes to the general southward shifting of vegetation zones.

In the Sahel and Doka woodland zones, small streams, within the memory of living men, have changed from permanent to intermittent flow as a result of human activities. The following (from Kassas 1970) is typical:

> In his account of the Dongotona Hills (Sudan), which are far from the Sahara, Jackson (1950) reported on several streams that have become intermittent. The native story to explain the drying up of the Ikotos stream since 1927, except for floods in the rainy season, tells that in 1924 one of the Sudan Defense Force men killed a sacred snake, 'the guardian spirit of the stream.' Jackson's story (1950, p. 141) is different: 'The actual cause of the drying-up of the stream is destruction of the vegetation on the slopes and its valley by over-grazing and cultivation.'

The increasing rate of desertification in recent decades, and

shifting of vegetation zones appear to be associated with the ever increasing human population in the area. No estimates are available as to the population of sub-Saharan west Africa during Stone Age times, however, Davidson (1973) indicated that the total Late Stone Age population of all of Africa south of the Sahara may have been three to four million. By the 19th century it had grown to 150 million, with people inhabiting every suitable area. The human population in the region has increased markedly during the past few decades and is having an increased impact on the ecosystems (Godiksen 1974).

Much of the problem of desertification has been associated not only with increased herds of grazing animals but also with the introduction and establishment of herds of browsing animals. Cattle generally require drinking water (about 30-40 liters per day but more in hot, dry periods) at least once every three days. Resultantly, cattle cannot effectively graze more than about 8 kilometers from a source of water. Thus, as overgrazing by large herds of cattle destroyed ever increasing concentric areas around water sources, much unexploited graze remained in the desert and subdesert areas beyond the sources of drinking water. Primitive herdsmen developed wells that effectively increased the potential grazing for cattle, but still did not saturate the area.

In contrast, sheep, goats, and camels can live for various lengths of time by "jezzin" (Hufnagl 1972). (Jezzin is Arabic for being able to

live on pasture without water.) The extreme adaptation to jezzin is seen in the camel which can survive for weeks, perhaps even indefinitely, on green browse and forage and for several days on dry pasture (Cloudsley-Thompson 1970). Reports of camels being driven, without water, for up to nine days across barren deserts are not at all uncommon. From this it is evident that sheep, goats and camels can all utilize graze and browse in areas not suitable to cattle.

Little is known concerning the history of the degradation of the west African sub-Saharan region. More is known about the pre-Saharan and coastal regions of north Africa (Hufnagl 1972). At the time of the Greek historian, Herodotus (484-424 B.C.), north Africa still had large populations of elephants along the coast and in the forest covered Atlas Mountains. Areas to the south were reported as being the "land of the herdsman and nomads." Hartebeest, wild donkeys, addax, antelope, ostrich and other such animals were widespread. The Sahara was a desert at the time but it appears to have been smaller and the oases were surrounded by large areas of thornbush and coarse grass. In the subdesert, streams ran longer in the dry season and provided some grazing in their beds, even when they dried up.

Under Greek and Roman exploitation, the coastal and desert edge regions were cultivated, with dams, cisterns, and aqueducts to increase the production from the limited rainfall.

Goats were introduced into north Africa about 194 B.C. At about

the time of the birth of Christ, a Roman, Polybius, reported that "the number of horses, sheep, and goats in the country (north Africa) is so large that I doubt if so many could be found in the rest of the world."

Camels were introduced into the region from Syria between 193 and 211 A.D. In 429 A.D., the Vandals invaded and Roman control of the region was lost. Most of the intensive water control devices of the Romans were allowed to fall into disrepair. The continued exploitation of available vegetation by grazing and browsing animals resulted in extensive desertification. As a result, many of the old Roman farms are now bare rock and moving sand dunes.

Probably a similar history of long-term overgrazing and resulting desertification will someday be documented for sub-Saharan west Africa. Archeozoological studies are just getting underway that eventually may reconstruct a chronology of man's activities there.

That continued overgrazing, especially by goats and camels, is a major factor in vegetation destruction and resulting desertification has been demonstrated many times in recent decades by exclosure studies (Kassas 1970). Basically, such studies involve putting fences around sites, thus protecting them from grazing. Most have been in the subdesert and savanna zones where significant changes have been observed in periods of five to twelve years. A fenced ranch in Niger that was so visible in ERTS satellite photographs (Ottaway 1973) is but another example as to how limited grazing permits the restoration of native

vegetation and, if properly managed, can result in a long-term sustained yield of forage.

3.4.4 Effects of recent climatic conditions: The "little pluvial" period appears to have resulted in increased productivity in the region in both the natural vegetation and in the field crops. This caused several marked changes, as far as human activities and expectations were concerned.

The carrying capacity of the grazing lands was increased, especially as the result of the large increase of the ephemeral herbs. Simultaneously, animal health programs were increased and new wells were drilled that opened up even additional areas to cattle. Furthermore, because cattle are the only way of saving available to the nomads, they increased herd sizes. The interaction of these factors resulted in a marked increase in animal populations to levels that, even with the improved production of forage from the wet conditions, exceeded the sustainable carrying capacity of the ranges.

The areas being cultivated and the productivity both increased during the wet period. Sedentary farming activities expanded to the north.

The human population continued to rise during this period. Export cash crops (cotton, peanuts) became an important percentage of the agricultural output, replacing part of traditional cereal production. The result of pressure for increased production was a decrease in average

fallow time (to five or even one year) and consequently a lowered fertility, poorer soil structure, and less erosion resistance. However, the increased rainfall masked at least part of the effects of the decreased fertility as enough marginal land was brought under cultivation so that the total production of cereals actually increased. The growth in cultivated lands could only decrease that available for the nomads and their livestock. Heavy cutting of trees for firewood occurred near the urban areas.

By the end of the "little pluvial," beginning about 1966, the expectations of the people in the area had risen to the point that a return to average rainfall conditions was considered by many to be a drought. Widespread reductions in forage production (especially the ephemeral herbs) coupled with the all-time high animal population resulted in extensive overgrazing and even further reduction of the perennial grasses and shrubs. Desertification of rangelands began, particularly around the well sites, and northern grain fields were abandoned. Soil erosion and gully formation became more common in central and southern zones. Animal and crop productivity decreased markedly.

With the beginning of the drought (actually just less than average rainfall) in 1969-1970, the stage was set for a major crisis. Even though the current drought is no worse than many that occurred in the past, its effect was a human and livestock catastrophe far exceeding any recorded previously. Major crop failures were widespread as was

human and animal starvation. Desertification and soil erosion occurred throughout the area, degrading the ecosystems to the point that total abandonment for generations may be necessary for their natural restoration.

3.4.5 Crop production: Millet, fonio, and sorghum make up the majority of the cultivated crops, averaging about 70 percent of the area planted and 63 percent of the total production. Productivity from traditional millet and sorghum crops is low, especially in northern areas where productivity of 250 kg/h or less is not uncommon even with normal rainfall. Productivity is lowest in Chad and Mauritania. Some of the millet varieties mature in about 55 days. They have generally low productivity, but are the only cereals that can be grown in the short rainy season areas. Even in the more moist southern regions, millet or fonio are often grown, apparently as a result of taste preferences. However, productivity from the currently grown millets averages only about 60 to 70 percent of that from sorghum.

The area cultivated, total production and productivity of the major crops in each of the six countries for the last 25 years are tabulated in the F.A.O. Production Yearbooks.

In 1969, rainfall was near average values throughout the Sahel-Sudan region. That year was therefore selected to be used for comparison purposes in the example of the use of the ISYALAPS planning framework later in this report. Major crop production data in the region in 1969 are

summarized in Tables 3.3, 3.4, and 3.5. In 1969, more than 25 percent of the arable area was under cultivation.

Small amounts of a number of minor crops are produced, generally for local consumption, including dates, pulses (various beans and peas), cassava (manioc) yams (including sweet potatoes), sesame seed, sugar cane, tobacco, and many others. They occupy about 10 percent of the total cultivated area. Table 3.6 summarizes information for this production during 1969. Date production is generally around oases in the northern subdesert regions of Chad, Mali, Mauritania, and Niger. With few exceptions, date palms grow wild, without special pruning or care. Gum arabic, a product from a native species of acacia, is routinely harvested for export in many of the countries.

Limited market gardening, both for local consumption and export, has been conducted in recent years. In terms of the whole region, this activity currently is insignificant.

3.4.6 Livestock production: Data for regional livestock production in 1969 show a total of 26 million animal units (Tables 3.7 and 3.8). As noted previously, 1969 is considered an average rainfall year and used as an example for comparison in a later section of this report. Meat production data (Table 3.8) are scanty. Productivity was reported as only 10 to 13 kg of meat per carcass for cattle and 4 kg for sheep and goats (UN 1973). Livestock production data for the last two decades in each country in the region are summarized in the F.A.O.

TABLE 3.3

Major Crop Production in the Sahel-Sudan Region, 1969
(10^3 metric tons)

Crop	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
Millet	651	913	110	590	609	382	3,255
Sorghum	*	*	*	289	*	547	836
Corn	12	126	4	2	49	60	253
Rice	37	119	1	39	163	34	393
Wheat	8	4	-	-	-	-	12
Peanuts	115	122	-	252	796	71	1,356
Cotton-seed	71	23	-	4	8	18	124
lint	40	18	-	2	4	12	76

*Sorghum combined with millet. Source: F.A.O.

TABLE 3.4

Major Crop Productivity in the Sahel-Sudan Region, 1969
(kg/hectare)

Crop	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta
Millet	707	646	393	407	609	440
Sorghum	*	*	*	485	*	500
Corn	1,923	867	597	542	881	600
Rice	1,007	688	812	2,521	1,538	836
Wheat	2,105	1,333		982		-
Peanuts	710	580		650	830	520
Cotton-seed	240	320		400	810	230
lint	130	250		210	420	150

*Sorghum combined with millet. Source: F.A.O.

TABLE 3.5

Area of Major Crops in the Sahel-Sudan Region, 1969

(10^3 hectares)

Crop	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total	Percent
Millet	921	1,413	280	1,450	1,049	867	5,980	56
Sorghum	*	*	*	596	*	1,094	1,690	16
Corn	6	146	7	3	55	99	316	2.9
Rice	36	172	1	15	106	40	370	3.5
Wheat	4	3	-	-	-	-	7	-
Peanuts	162	212	-	320	960	137	1,791	17
Cotton	294	71	-	20	10	82	477	4.8

*Sorghum combined with millet.

Source: F.A.O.

TABLE 3.6

Minor Crops in the Sahel-Sudan Region, 1969

A. Area in 10^3 hectares; B. Production in 10^3 metric tons; C. Productivity in kilograms per hectare.

Crop		Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
Cassava	A	17	10	-	28	40	2	97
	B	55	150	-	199	177	41	622
	C	3,200	15,000	-	7,200	4,400	20,000	6,400
Dates	B	22	-	13	5	-	-	40
Pulses (peas and beans)	A	185	14	40	968	56	450	1,713
	B	90	9	10	160	15	174	468
	C	490	610	250	170	270	380	273
Sesame	A	40	-	-	-	-	22	62
	B	120	-	-	-	-	38	158
	C	3,000	-	-	-	-	1,700	2,548
Yams (and sweet potatoes)	A	12	7	3	1	4	16	43
	B	52	67	3	9	16	50	197
	C	4,300	9,600	1,000	7,000	4,500	3,100	4,500
Sugar	A	-	1	-	1	-	-	2
	B	-	50	-	25	-	-	75
	C	-	58,400*	-	20,400	-	-	37,500
Onions	A	-	-	-	2	-	-	2
	B	-	-	-	27	-	-	27
	C	-	-	-	13,000	-	-	13,000
Tobacco	A	-	-	-	1	-	2	3
	B	-	-	-	0.2	-	0.8	1
	C	-	-	-	280	-	500	333

*Experimental production.

Source: F.A.O.

TABLE 3.7

Numbers of Animals in Sahel-Sudan Region, 1969

(10^3 animal units)*

Animal	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
Cattle	3,150	3,745	1,785	2,940	1,769	1,715	15,104
Sheep	360	1,150	740	486	270	295	3,301
Horses	135	153	19	153	171	81	712
Donkeys	114	190	90	144	68	76	682
Total Grazers	3,759	5,238	2,634	3,723	2,278	2,167	19,799
Goats	440	110	600	1,228	290	470	4,128
Camels	426	262	816	432	37	6	1,979
Total Browsers	866	362	1,416	1,660	327	476	6,107
TOTAL	4,625	6,600	4,050	5,383	2,605	2,643	25,906

*Incomplete, one animal unit (A.U.) is equivalent to one 450 kg cow and calf.

Source: F.A.O.

TABLE 3.8

Meat Production, Sahel-Sudan Region, 1969

(10^3 metric tons)

	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
Beef and veal	32	48	15.5	25.3	40.5	29	190.3
Mutton and lamb		32				14	46*
Other	9					13	22*
Total							258*

*Incomplete.

Source: F.A.O.

Production Yearbooks.

Cattle account for about 58 percent of the total livestock in terms of animal units. Sheep, horses, and donkeys make up 13 percent, 3 percent and 3 percent, respectively. Goats and camels account for 16 percent and 8 percent, respectively.

In Chad, livestock production provides 15 to 20 percent of the Gross Domestic Product and 30 percent of export earnings. Approximately 500,000 cattle were consumed or exported in 1971 from a total herd of 4,500,000. The birth rate was reported as 60 percent, calf survival 30 to 40 percent and herd reproduction 11 percent. Females first gave birth at about four years of age (AID 1974).

3.4.7 Other animal production: In addition to the production from the crop and major livestock segments, there is a significant contribution to the total food supply from fish, poultry, milk, and pigs. These agricultural commodities generally are produced near the population centers.

3.4.7.1 —Fish: Fish production in the region results from operations in the Atlantic coastal waters and from inland waters. Fishing in the Atlantic is controlled largely by foreign interests with little direct benefit to the countries of the region. The bulk of the ocean catch is exported directly to Europe. In 1968, 16,400 tons were landed in Port-Etienne, Mauritania. A small local fleet of about 300 Mauritanians earns on the order of CFAF 25 million.

Approximately 500 full time and 10,000 part time fishermen provide fresh and dried fish for people along the Senegal River. Significant investments have been made in fish handling facilities, although the volume of fish processed has never reached their capacity.

Detailed information regarding fish production in the other countries was unavailable. A summary of fish produced in the region shows a total of about 440,000 metric tons annually (Table 3.9).

3.4.7.2 —Poultry and eggs: Poultry operations are not extensively distributed throughout the region. The industry is commercialized only near the urban areas. In the rural areas many families have a few chickens which largely are left to forage for themselves. Production of poultry (meat) is given in Table 3.10 and production of eggs is given in Table 3.11.

3.4.7.3 —Milk: Milk production in all countries of the region increased steadily but at a low rate in the 1967 to 1971 period (see Table 3.12). Per capita consumption for the region averaged less than one-seventh liter per day. Since some nomads are known to subsist largely on a diet of milk, there are some groups whose diet probably almost excludes milk. For example, in Mauritania, which is inhabited primarily by nomads, Westebee (1972) estimated the 1968 utilization of milk in millions of liters as follows: production, 580; consumed by nomads, 360; consumed by sedentary households, 65; consumed by urban dwellers, 35; converted into butter, 30; and fed to animals, 150.

TABLE 3.9

Fish Production in the Sahel-Sudan Region

(10^3 metric tons)

Country	Pre 1966 Average	1966	1967	1968	1969	1970	1971
Chad	83	100	110	110	110	120	n.a.
Mali	90*	90*	90*	90*	90*	90*	90*
Mauritania	21	27	30.7	30	30	30	32
Niger	6.3	5	3.7	4.3	5	8	12.5
Senegal	112.2	141.5	155	174.7	182.1	189.2	239.8
Upper Volta	2.8	4.0	4.5	4.5	5.0	5.0	5.0
Total	315.4	367.5	393.9	413.5	422.1	442.2	

*Estimate.

Source: F.A.O.

TABLE 3.10

Poultry Production in the Sahel-Sudan Region

(number of birds x 10^3)

Country	1967	1968	1969	1970	1971	1972
Chad	2,600	2,700	2,800	2,900	2,950	3,000
Mali	13,000	13,000	13,400	13,500	13,000	12,500
Mauritania	2,200	2,300	2,400	2,500	2,600	2,700
Niger	6,000	6,250	6,500	6,750	7,000	7,100
Senegal	6,000	6,500	6,800	6,800	6,000	6,000
Upper Volta	10,000	10,000	10,000	10,420	10,640	10,640
Total	39,800	40,750	41,900	42,870	42,190	41,940

Source: F.A.O.

TABLE 3.11

Egg Production in the Sahel-Sudan Region

(metric tons x 10^3)

Country	1967	1968	1969	1970	1971
Chad	2.3	2.4	2.5	2.5	2.7
Mali	6.8	6.9	7.0	7.0	7.1
Mauritania	1.9	2.0	2.1	2.2	2.3
Niger	4.2	4.4	4.4	4.5	4.5
Senegal	4.2	4.4	4.5	4.5	4.6
Upper Volta	2.8	2.9	3.1	3.2	3.3
Total	22.2	23.0	23.6	23.9	24.5

Source: F.A.O.

TABLE 3.12

Milk Production in the Sahel-Sudan Region*

(10^3 metric tons)

Country	1967	1968	1969	1970	1971
Chad	205	207	209	212	215
Mali	195	200	197	197	198
Mauritania	197	203	206	209	213
Nige	227	233	237	241	245
Senegal	148	147	147	144	149
Upper Volta	85	88	92	95	98
Total	1,059	1,078	1,088	1,098	1,118

*Includes milk from cows, sheep and goats.

Source: F.A.O.

3.4.7.4 —Pigs: Pigs make up a very minor component of the domestic animal population of west Africa. FAO estimated that the 1969 population (in thousands) was Mali, 32; Niger, 22; Senegal, 90; Upper Volta, 137; a total of 281,000 animals for the four countries.

3.4.8 Agricultural byproducts: Industries using agricultural byproducts are not highly developed in the region. There is some use of peanut hulls for fuel. Cotton seeds are largely exported. There is some local use of hides and skins for water bags, clothing, tents, etc., and a sizeable quantity of hides and skins is exported. Local artisans use animal horns in making souvenirs and decorative artifacts, but this is not really commercialized.

The only data on byproducts concern that fraction which is exported and which is discussed in a later part of this section.

3.4.9 Wood production: Wood is one of the principal renewable resources of the region, at least in the wetter zones. It is the major fuel source for home consumption. Industry requires less than 10 percent of the total wood use.

Three to five hundred kilograms of wood per capita are used annually in the Sahelian countries, most of it for cooking. Table 3.13 shows the forested area of the region and production of wood for fuel. Note that the total consumption of fuel wood is almost 9 million metric tons.

Wood supplies 54 percent of the total energy used in Senegal and

95 percent of the total energy used in Upper Volta. Fuelwood is the cheapest form of energy available but at 7-10F CFA per kilo, the annual per capita expenditure amounts to about 4000F CFA.

Deforestation of the region is a severe problem. In heavily populated urban areas wood cutters must go out as much as 60 to 80 kilometers from the city to find trees.

3.4.10 Population in agriculture: Exact numbers of people engaged in agriculture in the region are unknown. Some indications are given in Table 3.14 and various sources report that 80 to 90 percent of the total population is in agricultural pursuits. Nomads make up 15 percent of the population in Upper Volta and Senegal (UN 1973). Salaried positions in agriculture are available for only about 0.1 percent of the total population.

3.4.11 Education and research in agriculture: Little attention has been given to education or research in the agricultural sector. Formal educational programs have placed little emphasis on agriculture's needs from the colonial era to the present. Few educated Africans have returned to the villages or rural development programs (Kadlec 1974).

Research institutions in the past directed their efforts primarily at export crops, with some significant results. Present programs are more concerned with applied and adaptive research on a number of food crops (IRAT 1971).

TABLE 3.13

Forested Area and Annual Production and Use of Roundwood[a]

Country	Forested Area (km)^2	Production 10^3 M.T.[b] 1967	1968	1969	1970	Per Capita Use* (kg)	Percent of Total Energy Use*
Chad	165,000	-	2,072	2,079	2,100	500	93
Mali	44,570	1,761	1,792	1,813	1,820	340	89
Mauritania	151,340	358	365	372	-	320	73
Niger	140,000*	-	1,430*	-	-	360	93
Senegal	53,000*	-	1,360*			340	54
Upper Volta	41,010	2,514	2,574	2,637	-	430	95
Total	594,920		8,950				

[a]Primarily for fuel.

[b]one m^3 - 700 kg.

Source: Europa 1973, *Yearbook of Forest Products, F.A.O.

TABLE 3.14

Population in Agriculture, Sahel-Sudan Region

(x 10^3)

	Economically active	Herders (nomads)	Salaried	Total Population
Chad	470-1,086	45-278		3,791
Mali	2,511	30-200		5,143
Mauritania	360	150-980	1.1	1,180
Niger		150-840		4,239
Senegal	1,288	570	4.1	3,822
Upper Volta	1,900-2,457	350-810		5,426
Total		1,295-3,488		23,601

Source: Various.

3.4.12 Government agencies: A request was made through AID for information on the organization and manpower of the Ministry of Agriculture and other government agencies in agriculture in the six-country region. Unfortunately, no information was received in time to include it in this report.

The livestock service in Chad was reported to provide one staff office (animal health related) for each 40,000 to 50,000 animals (UN 1973). Approximately 2.29 percent of the general budget was expended on the Livestock Service in 1961, but only 0.93 percent of the budget in 1972.

3.4.13 Technical assistance: Technical assistance in agriculture ranged from 4 to 40 percent of total assistance to the six countries during recent years (Table 3.15). Of the bilateral portion of this aid, U.S. funds accounted for 40 percent in 1969 and 1970.

3.4.14 Economic analysis: In a large part, the agricultural sector does not operate as part of a "market economy;" therefore actual economic statistics are scarce. Data are relatively available for those agricultural products that move through the import-export facilities.

The primary sector (agriculture, livestock, forestry, fishery) contributes from 31 to 53 percent of the total gross domestic product (GDP) in the six countries. Livestock production makes a substantial contribution to the economy. In Upper Volta from 1967 to 1972, livestock provided 10.3 percent of the GDP. In Chad, 16 to 20 percent of the GDP results from livestock. The value of meat, milk, and skins was reported

TABLE 3.15

Technical Assistance in Agriculture to the Sahel-Sudan Region

(10^6 $U.S.)

Country	Years of Record	Total Assistance	Agricultural Assistance	Percent o total
Chad	1957-1971	169.88	19.34	11
Mali	1969-1973	221.34	88.42	40
Mauritania	1960-1968	447.96	47.981	11
Niger	1964-1969	54.22	6.78	12
Senegal	1964-1969	1,616.2	69.49	4
Upper Volta	1964-1969	78.9	20.56	26
Total		2,588.5	252.57	9.8

TABLE 3.16

Representative Budgets of Nomads

(by household per year, CFA Francs)

	Peul budget	Targui budget
Cash income	15,640 (97% from sale of cattle)	19,320 (89% cattle)
Barter income	2,392	4,473
Household consumption	17,213	29,988
Per household income per year	35,000	54,000
Cash outlay	15,640 (32% on food)	19,320 (25.7% on clothing)
Taxes	25%	23.9%
Size of household	4.63	4.15

Source: AID

as $35.4 million in 1971 (AID 1974).

Credit is not readily available for agricultural enterprises. Only from about 2 to 10 percent of total country credit is used for agriculture.

High losses (up to 40 percent) of agricultural production between the field and the consumer are mentioned in various reports but no specific data were found. Such losses, when they occur, markedly reduce income to farmers and herders as well as decrease the contribution of agriculture to the GDP.

3.4.14.1 —Farm Income: Herdsmen have extremely low incomes, according to the only available budget study of nomads which was published in 1960 by the National Institute of Statistics and Economic Studies (INSEE) and concerns the Tahoua of the Niger. The survey provided the data in Table 3.16.

Income distribution data for Senegal indicate that the rural population (75 percent of total) receives 27 percent of the national income while the urban population (24 percent of total) receives 60 percent and the foreigners (1 percent of total) receive 13 percent of the national income. In Upper Volta the rural population (87 percent of total) receives 42 percent of national income.

Income of sedentary farmers is largely undetermined on a wide scale but has been reported for isolated groups as from $25 to $40 per capita per year.

3.4.14.2 —Exports-imports: Agricultural exports account for 37 to 95 percent of total exports from countries in the region

(Table 3.17). Crop exports are primarily cotton and peanuts (Table 3.18). fish exports for Mali and Mauritania for the 1967 to 1971 period are shown in Table 3.19. The values of livestock products exported in 1970 are given in Table 3.20.

In Chad in 1971, 48 percent of the animals removed from the rangeland were exported. Most of them were sent "on the hoof" to Nigeria, Cameroon, and the Central African Republic, but a sizeable quantity was shipped by air to Congo, Gabon, Ghana, Libya, Lebanon, and Zaire.

Imports of agricultural products represent from 4 to 20 percent of total imports in the six nations (Table 3.21). In addition to products tabulated, a sizeable quantity of food supplies was imported as emergency food relief.

Senegal was reported to be importing one-fourth of its meat supply in the early 1970's with projections of an increase to one-third by 1980. The balance of trade data, where available, indicate that agriculture is contributing to a favorable balance (Table 3.22).

3.4.14.3 —Investments: Investments of public funds in agriculture vary from 15 to 40 percent in the six countries. Much of the investment is applied to export crops. Some commercialization of large scale agriculture operations is taking place. Most of it, however, is being done with foreign capital.

3.4.15 Trends: Several significant variations have taken place in the agricultural production system in the last 25 years. The

TABLE 3.17

Exports of Agricultural Products and Percent of Total Exports

(million CFA Francs)

Country	1967	1968	1969	1970	1971
Chad	n.a. (6,635)	6,505 95.3	7,598 94.7	6,200*	n.a. (7,787)
Mali**	n.a.	4,853 91.6	8,288 92.7	n.a. (18,240)	n.a. (19,630)
Mauritania	3,513 17.7	1,412* (17,714)	1,843* (20,015)	2,030* (24,680)	2,140* (25,129)
Niger***	n.a. (8,226)	n.a. (7,125)	5,269 84.3	7,408* (8,795)	5,177* (10,670)
Senegal	n.a. (33,890)	n.a. (37,358)	18,042 56.5	21,335 50.6	12,767 36.8
Upper Volta	n.a. (4,429)	n.a. (5,290)	4,952 92.9	4,651 92.0	3,023* (4,408)

n.a. - not available.

*Incomplete.
( ) total exports.

**Million Mali francs.

***Does not include much smuggling between Niger and Nigeria.

Source: Europa 1973.

TABLE 3.18

Cotton Exports

(10^6 CFA Francs)

Country	1968	1969	1970	1971
Chad	5,778	6,586	5,910	n.a.
Mali	2,099*	895*		
Upper Volta		1,593	1,492	834**

*Excluding linters.

**Excluding seed.

Source: Europa.

TABLE 3.19

Fish Exports in the Sahel-Sudan Region

(10^6 CFA Francs)

	1967	1968	1969	1970	1971
Mali		691 (6,354)	1,259 (5,297)	(5,138)	(3,887)
Mauritania	1,536	1,545	1,843	2,030 (31,500)	2,140 (23,600)

( ) Total fish production, metric tons.

Source: Europa.

TABLE 3.20

Selected Exports in 1970

(thousands of dollars)

	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta
Meat fresh, chilled, or frozen	4,903.3(a)	197.5		556.6		726.8
Live animals	574.8(a)	12,164.8		5,004.3	179.8	5,684.3
Crude hides and skins	300.6	109.1		783.4	683.0	268.8
Zoo animals	244.2				50.7	
Fresh or frozen fish	92.0	2,737.7	6,179.9		1,777.8	
Meat dried, salted, or smoked	166.0					
Livestock feed		760.9	693.0	694.7	28,845.5	
Canned fish			436.5		6,247.2	

(a) Trade Yearbook by F.A.O., volume 25, gives 580 for cattle, 440 for sheep and goats and 5,150 for fresh, chilled, or frozen meat.

Source: UN, 1973.

TABLE 3.21

Imports of Agricultural Products and Percent of Total Imports

(million CFA Francs)

Country	1967	1968	1969	1970	1971
Chad	n.a. (9,248)	1,033 12.5	2,436 20.4	n.a. (17,059)	n.a. (17,117)
Mali**	n.a.	3,604 21.3	2,887 14.4	n.a. (26,200)	n.a. (30,500)
Mauritania	1,457 16.0	2,137 24.5	1,488* (11,764)	n.a.	n.a.
Niger***	n.a. (11,352)	n.a. (10,237)	671 5.3	690 4.3	260* (14,975)
Senegal	n.a. (40,401)	n.a. (44,680)	8,106 25.8	7,438 13.9	9,676 16.0
Upper Volta	n.a. (8,970)	n.a. (10,119)	2,417 19.4	2,526 19.5	2,402 17.3

*Incomplete.

**Million Mali francs.

( ) Total imports.

***Does not include much smuggling between Niger and Nigeria.

Source: Europa 1973.

TABLE 3.22

Balance of Trade in Agriculture

(million CFA Francs)

Country	1967	1968	1969	1970	1971
Chad	n.a.	+5,472	+5,162	n.a.	n.a.
Mali	n.a.	+1,249	+5,401	n.a.	n.a.
Mauritania	+2,056	n.a.	n.a.	n.a.	n.a.
Niger	n.a.	n.a.	+4,598	n.a.	n.a.
Senegal	n.a.	n.a.	+9,936	+13,897	+3,091
Upper Volta	n.a.	n.a.	+2,535	+ 2,125	n.a.

area of cultivated crops increased from about 8 million hectares in 1948 to more than 10 million hectares in the last 10 years. The area devoted to cash crops (cotton and peanuts) increased by about 60 percent while that devoted to cereal production increased by only 33 percent (Figure 3.9).

The total cultivated area for the region reached a maximum in 1969; that for the individual countries reached maxima in the late 60's except for Chad (1962) and Mali (1971).

The six-country crop production increased from a little less than 4 million metric tons in 1948 to a maximum of 6.5 million metric tons in 1967. Since that time production has varied up and down with a generally downward trend (Figure 3.10). The production of cereal crops alone also reached a maximum in 1967 and shows the same downward trend since, but at a slightly lower rate.

Average productivity of all crops also peaked in 1967 at 620 kg/hectare although it attained the same value in 1971. Partial data for 1972 showed a decline of several percent in productivity.

The total number of animals on the range and pasture lands of the region reached a maximum of 26 million animal units in 1970. Data for the years prior to 1960 are incomplete but at that time the total was about 18 million animal units (Figure 3.11). Cattle alone had increased from 4.3 million animal units in 1950 to more than 15 million in 1969 to 1971.

The total number of animal units decreased since 1970 but most of

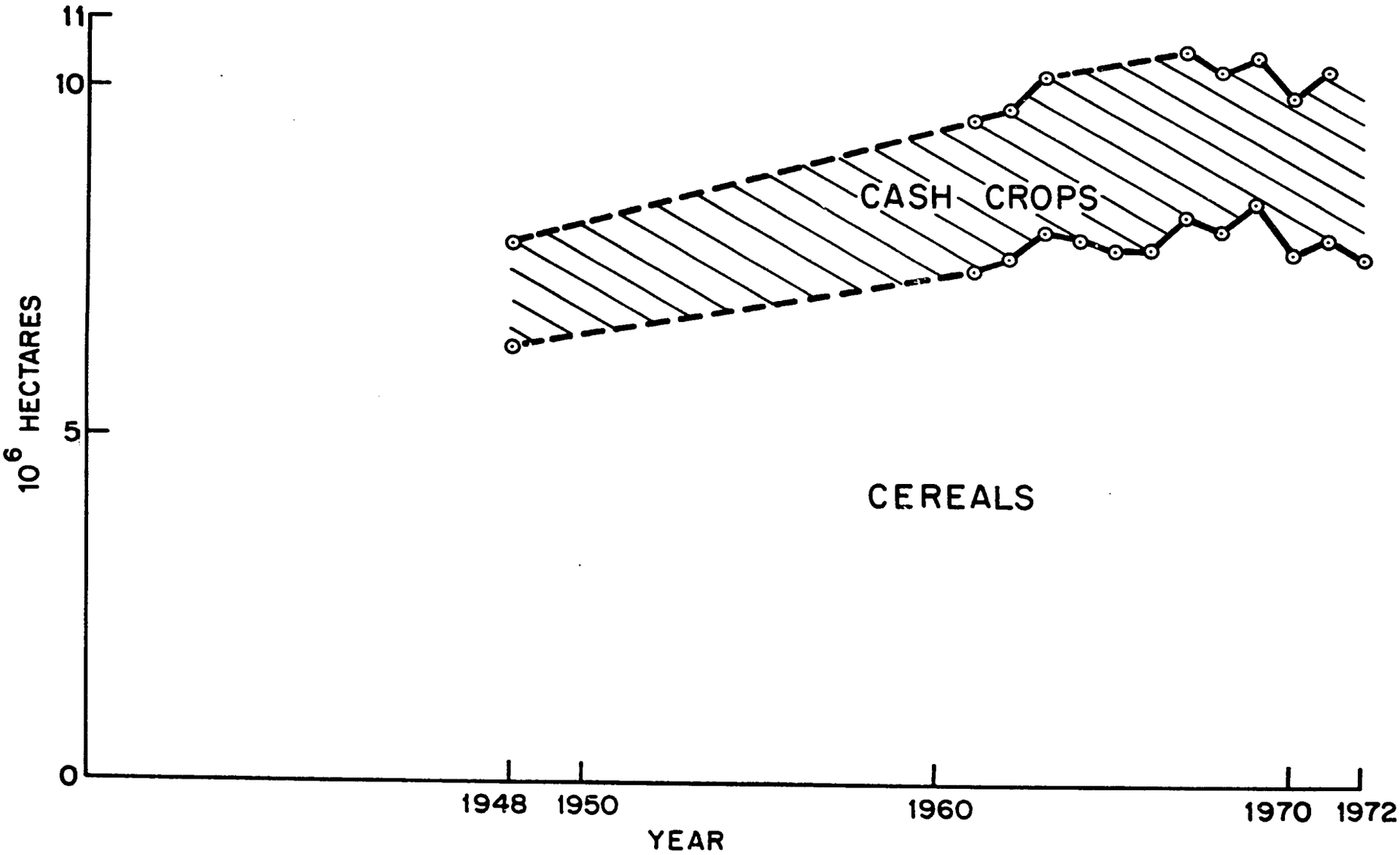

FIGURE 3.9 Comparison of Cultivated Area, Cereal and Cash Crops, Sahel-Sudán Region

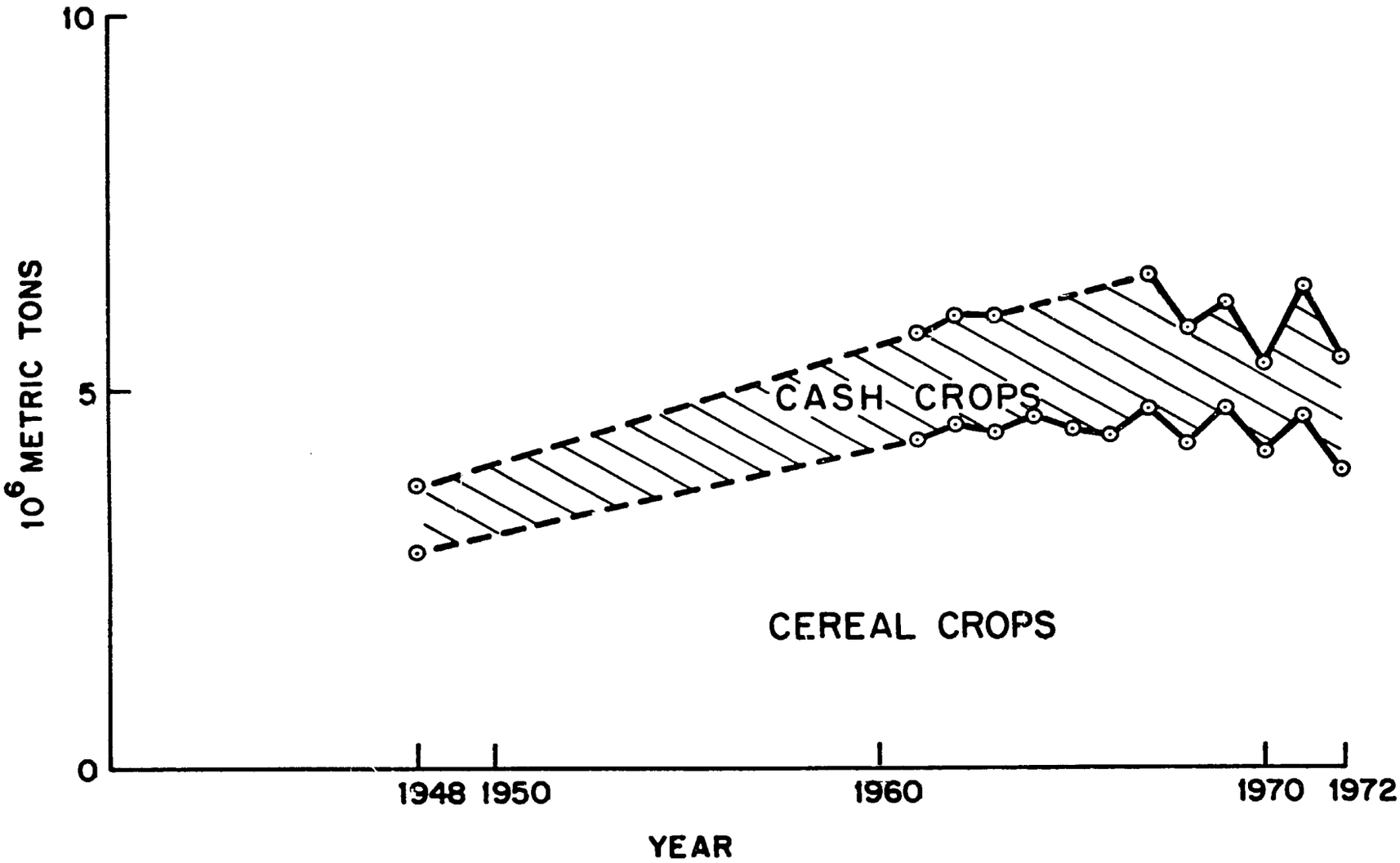

FIGURE 3.10 Comparison of Production, Cereal and Cash Crops, Sahel-Sudan Region

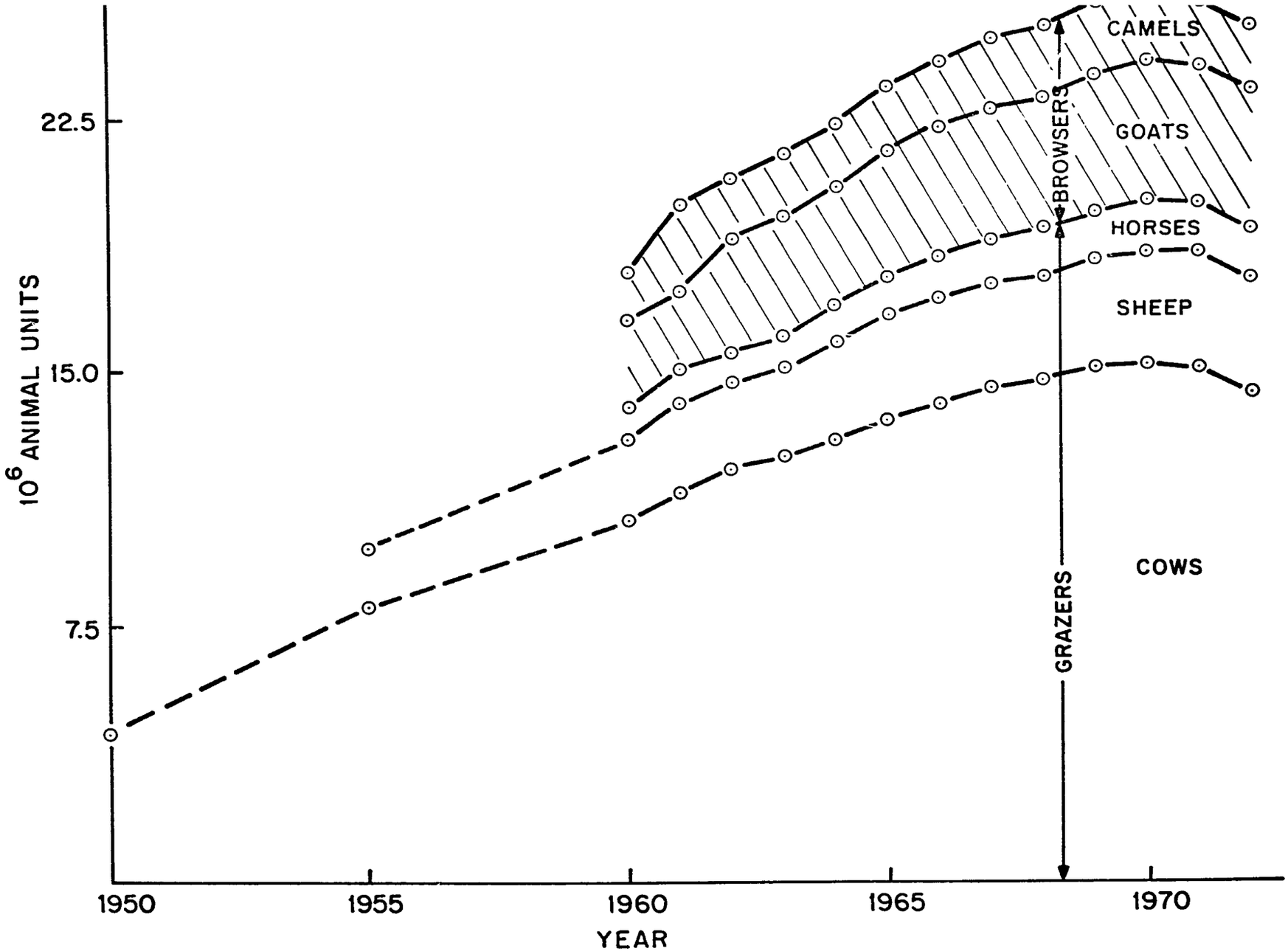

Figure 3.11 Livestock in the Sahel-Sudan Region

the decrease took place in cattle numbers. The significant fact here is that the numbers of animals that browse or use low quality range land remained essentially constant or even increased until 1972.

Data for actual meat production are scanty but show an increasing trend for the past few years, probably as a result of drought induced pressures to sell off the herd and relatively favorable beef prices. Productivity in terms of kilos of meat per unit area was no doubt decreasing during this period.

At the present time most cattle herds are already greatly reduced or are being reduced drastically. Young, immature bulls are reportedly being sold in large numbers in Chad.

Other animal production showed modest to substantial increases from 1966 to 1972 in most cases. Poultry production decreased slightly in 1971 and 1972.

Based on incomplete data, wood production (harvest) appears to have increased by several percent in the 1967 to 1970 period. Most of the increase reflects the increasing demand of the growing population for fuelwood during the period.

The population in agriculture has grown during the last decades as a result of both increasing health care (increased life expectancy) and the favorable climatic conditions up to 1969. The population has been affected by out-migration as a result of the drought but also by the lure of employment in the adjoining coastal countries. The latter has had particular effect on the young men of the region.

Although some new institutions (research, education, government agency) have been established in the region, their impact on the total agricultural production system has been slight. The exception is in the area of cash crops where emphasis has had significant results in increased productivity.

Educational institutions with agricultural emphasis have been started but as yet their impact has not been great. Government agencies to serve agriculture have not been effective. In recent years their share of the national budget has, in some cases, actually declined.

No real data exist on changes in farm income on a regional basis but income probably increased slightly until the full effect of declining rainfall was felt in 1970. Declines were inevitable since that time. The gross domestic product resulting from the primary sector was rising about 3.5 percent per year in Mali from 1967 to 1972.

Exports of agricultural products were compared for two time periods (Table 3.23). Generally significant increases occurred. Exceptions are in exports of hides and skins and zoo animals. Since 1969 exports have declined, largely because of declining production. Imports of agricultural products do not show any consistent pattern of change. Declines in exports have resulted in a less favorable balance of trade ratio in agricultural products.

3.4.16 Data limitations: Determination of the characteristics of the existing agricultural production system was hampered

TABLE 3.23

Percentage Change of selected Exports Between 1965-1968 and 1968-1970

	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta
Meat fresh, chilled, or frozen	48.9	0.4		210.5		26.8
Live animals	-23.6	15.9		2.9	38.8	3.6
Crude hides and skins	- 7.0	- 1.8		5.3	7.1	-11.7
Zoo animals	2.0				-18.1	
Fresh or frozen fish	4.5	0.9	24.1		16.0	
Meat dried, salted, or smoked	-15.2					
Livestock feed		14.4	++	- 0.8	17.3	
Canned fish			514.1		4.2	

Source: UNCTAD-1973.

considerably by the lack or poor quality of agricultural statistics. In many cases there were significant gaps in the yearly data, and where data were available from several sources (FAO, UN, IBRD, etc.) there was generally disagreement in the values given. Other data inconsistencies exist throughout the records, especially when comparing pre-and post-independence periods.

Another major difficulty is that data are not readily available by climatic zone. Productivity of field crops is directly related to rainfall, but an attempt to demonstrate this for west African locations revealed that variations in productivity in one rainfall zone are almost as great as variations resulting from differences in rainfall. The source of the variability is not evident from the material available. Part may be due to local variability in rainfall, part may be the result of variations in farm practices (cultivation, fertilizers, etc.) and part may be the result of poor data.

Reporting categories often do not separate some of the production. For example, fonio, millet, and sorghum are generally combined into a single category, even though yields of sorghum are generally twice those of millet or fonio. Sheep and goats are generally taken together, even though they have entirely different effects on range lands, one being a grazer, the other a browser. Horses and donkeys also are combined even though they differ in size and have different grazing impacts. Since intercropping (two or more crops grown at the same time in the same field)

is common, data regarding such associations are necessary but rarely available to make estimates of productivity. Production data often are given only for commercial enterprises and do not include subsistence amounts, and no information was found on the magnitude of losses which are known to occur between harvest and consumption.

3.5 Major Issues and Problems

From the preceding discussion a set of major issues and problems confronting the Sahel-Sudan region was identified. They directly or indirectly influence the agricultural production system.

3.5.1 Ecosystem fragility: The fragile ecosystem of this semiarid to arid region is being harmed by man's actions and inactions. Desertification is occurring because the carrying capacity of the land for man and animals is being exceeded. Damaging soil erosion is occurring extensively.

3.5.2 Low productivity and production: Productivity and total production of both crops and livestock are lower than their potential under existing resources, yet at times there are insufficient food and protein for the population of the area. Even in normal times part of the food supplies must be imported, because priority by governments has been given to export cash crops. Livestock, cotton, and peanuts account for 70 percent of the regional exports. Many diseases affecting humans and animals are endemic and limit production from some of the most

fertile areas.

3.5.3 Cyclical drought: As is typical of semiarid regions in general, more or less cyclical drought periods occur. The recent severe and prolonged drought interacted with the animal and human populations already exceeding the carrying capacity of the system in its present technological state. The result was local losses of up to 100 percent in cattle herds and a generally southward movement of distressed people and animals.

3.5.4 Problems of governments: Some of the governments in the region are characterized by lack of personnel, especially qualified administrators. They give low priority to the needs of agriculture. Ninety percent of the activity and 88 percent of the rural population are in agriculture, yet agriculture produces less than 50 percent of the total GDP. Moreover, only 6 to 8 percent of recent investment in rural development has been in agriculture.

3.5.5 Economic policies: Economic policies are strongly influenced by forces outside the region. For example, agricultural commodity prices are depressed by market and tax policies in the neighboring countries. Savings opportunities are limited, resulting in investment in more animals. The findings of the M.I.T. groups which examined the economic considerations which influence long-term development of the Sahel-Sudan region are summarized in Volume 1.

3.5.6 Coastal zone influence: Adjacent coastal zones under pressures of urbanization have created a demand for both labor and agricultural products, particularly meat, further jeopardizing the resources of the area.

3.5.7 Agricultural goals and policy: There are no practically defined and clearly understood goals for agriculture. Farmers have been given few incentives to produce more. Drought recovery programs to insure human survival are needed.

3.5.8 Agricultural technology: A modern agricultural technology is lacking. There is no coordinated research effort nor any real "delivery system" to provide assistance to farmers.

3.5.9 Infrastructure: There is little infrastructure in support of agriculture (enabling legislation, credit, transportation, storage, communication, markets, price and tax policy, chemicals, seeds, etc.). There are insufficient middle level technicians and necessary tools.

3.5.10 Land tenure: Insecure land tenure and ownership patterns restrain rapid agricultural development.

3.5.11 Educational institutions: There are no high-level institutions for educating French-speaking Africans in the technology of arid land agriculture within the region or in sub-Saharan Africa.

3.5.12 Natural resources: Natural resources are severely limited and the harsh climate includes frequent droughts and local

flooding. Increasing numbers of both men and animals are competing for the meager resources available. Wood, which provides most of the utilized energy, is in short supply and must be transported long distances. Available water resources are largely undeveloped.

3.5.13 Traditions and culture: Traditional agricultural practices and ethnic group specialization hinder an integrated agricultural effort.

3.5.14 Data limitations: Statistical information is meager and unreliable.

3.5.15 Agricultural projects: Many research and development projects have been conducted and others are currently underway. The second Sahelian Newsletter (Nov. 1973, U.N. Special Sahelian Office) in a partial listing showed 2145 projects involving 17 different agencies. However:

a. Few previous research studies have been followed by action. Existing studies have not been assessed in terms of applicability to agricultural needs and environmental constraints of the region.

b. Previous projects largely have been unsuccessful because they failed to recognize environmental constraints, did not receive adequate support, and often because they lacked complementarity with the existing system (including social aspects) and with other projects.

4. APPLICATION OF THE FRAMEWORK TO THE SAHEL-SUDAN

The ISYALAPS planning framework described in Section 2 can be used to analyze agricultural development problems in areas of varying size--a region, such as the Sahel-Sudan, a nation, or some smaller geographical unit or project. A watershed (drainage basin) because of its well-defined physical boundaries makes a good planning area. To illustrate its use, two planning areas are studied separately to determine potential agricultural production within environmental constraints. Succeeding steps in the process are considered jointly.

First, the Sahel-Sudan region is considered as a whole with an integrated strategy (mix of activity levels). Then Mali, a country within the region, is analyzed under two strategies, the integrated system and an across-the-board application of Activity Level B. (Details of the analysis for Mali are not included but the conclusions are presented in Section 7.)

4.1 Basic Premises

During this preliminary application of the ISYALAPS planning framework for the Sahel-Sudan region, the following set of basic premises provided a foundation. Additional assumptions may have to be made for subsequent planning as more detail is added.

4.1.1 Lifestyle: Crop and animal production will continue to be the primary occupation of most people in the region. Nomadism will gradually decrease in importance as a way of life and eventually

will be eliminated.

4.1.2 Land capability: Most land in the region is capable of some agricultural production. Its suitability for intensive cultivation, animal grazing, or timber production is a function of such factors as slope, rockiness, and soil depth as well as rainfall.

4.1.3 Exploiting productivity: Agricultural production can be realized from suitable lands in the region without degradation of the natural resource base. Effective management will prevent desertification and foster recovery of afflicted lands.

4.1.4 Technology: Use of technology and crop varieties and animal breeds available in other areas of the world could increase the productivity of the region to the point that it could continue to export agricultural products and become more nearly self-sufficient in food supply.

4.1.5 Energy use: Although little energy is used in the food production system at the present time, animal and wind power inputs will increase, and fossil fuels will be made available for critical operations such as land preparation in increasing amounts.

4.1.6 Government stability: Government stability will increase during the next few decades, and there will be continued improvement in the human resources of the region.

4.1.7 Migration: Agricultural development, however effective, will slow but not reverse the trend of migration to the urban centers.

4.1.8 Agricultural projects: Financial support is available for agricultural development projects in the region and money will continue to be spent for them regardless of the presence or absence of effective overall planning.

4.2 Application of ISYALAPS Planning Framework

A basic planning philosophy was adopted to guide decisions made in using the ISYALAPS framework. An attempt was made to emphasize the social element.

Climatic zones for the Sahel-Sudan region are described. (A more complete analysis was given in Section 3 of this report.)

4.2.1 Planning philosophy: Agriculture has lagged behind other developments in the Sahel-Sudan region and, without improved agricultural practices, sometime in the future would have become incapable of supplying needed food and fiber regardless of the present situation. The current drought apparently is not significantly more serious in hydrologic terms than those of 1913-14 and 1942. Perhaps the principal contributing factor to today's problem is the period of above average precipitation which immediately preceded the drought. This allowed both animal and human populations to increase far beyond the normal carrying capacity of the land. For example, animal numbers doubled during this period. To recover and move forward agriculture must be brought into accord with hydrologic and environmental reality.

A major thrust of the approach is to identify things which need to be done to permit the agriculture sector to keep pace with country or regional needs and to create a dynamic, flexible, and increasingly productive system. This is neither a project-oriented nor a "look for a miracle" approach. It demands the acceptance of the philosophy of long term sustained yield from agriculture in a realistic economic setting, based on the concept of living within the carrying capacity of the region's resources. Moreover, the resources are evaluated in terms of their ability to improve the quality of life for the people in the region by providing more food, increasing stability, minimizing risk and expanding opportunities, rather than in terms of their cash value on the world market. The process is tempered throughout by recognition of the importance of defining accurately a set of realistic expectations for the people of the Sahel-Sudan region, particularly the rural poor.

4.2.2 Climatic zones: The climate of the Sahel-Sudan region ranges from that of a true desert in the north to areas with more than 1250 mm of rainfall per year in the south. Potential evapotranspiration is in excess of 2100 mm in the north and below 1600 mm in the south. The interacting factors of rainfall, potential evapotranspiration, and native vegetation result in five major east-west oriented climatic zones extending across most of the region. The irrigable land makes up a sixth zone, and an urban zone is considered for specialized production (Table 4.1).

TABLE 4.1

Climatic Zones, Sahel-Sudan Region

Climatic Zone	Annual Rainfall	Potential Evapotranspiration	Native Vegetation
Desert	Below 100mm	over 2100mm	rare; low, thorny, narrow leaved; rapid growing ephemeral annuals after rains
Sub desert	100-300mm	1800-2300mm	sparse, low, thorny, narrow leaved; ephemerals after rains
Sahel	300-600mm	1700-1950mm	scattered acacias and other thorny, narrow leaved trees, grasses below 40 cm.
Sudan	650-900mm	1600-1800mm	scattered broad-leaved deciduous trees; perennial grasses to 80 cm.
Woodland	Over 900mm	1600-1750mm	large expanses of deciduous forests
Irrigated	n.a.	n.a.	n.a.
Urban	n.a.	n.a.	n.a.

The size of the various climatic zones was determined by plotting average rainfall isohyets and planimetering the enclosed areas (Table 4.2). The potential irrigated area was determined by taking the total water resource available (allocated) for irrigation and dividing by an average consumptive use of one meter (1 m^3/m^2). Details of the allocation procedure and quantity available are given in the Water Resources section of the report of the M.I.T. Sahel-Sudan project. Double cropping was not considered for the irrigated zone because water is, in most parts of the region, the limiting factor, and the argument can be made that single cropping extends the benefit of water resources development to the greatest number of people. Isolated areas of groundwater are known to exist in the region, but insufficient data are available at this time to permit their inclusion in the analysis. Preliminary indications are that their potential impact is small.

4.2.3 Agricultural strategy: A number of possible agricultural strategies exist for the Sahel-Sudan region, some of which are shown in Table 4.3. Each has merit, but based on preliminary evaluation no one of the first five by itself will have a significant impact on agricultural production. For this reason the integrated approach was chosen for the example. It emphasizes effective natural resources management, takes advantage of all possible productive capacity, and can be implemented by realistic means. Other alternatives, not listed here, also can be evaluated within the ISYALAPS planning framework.

TABLE 4.2

Area in Climatic Zones

Climatic Zone	Sahel-Sudan Region (km^2)	Mali (km^2)
Desert	1,919,250	421,600
Sub desert	1,516,360	347,200
Sahel	887,270	221,200
Sudan	502,568	109,200
Woodland	453,122	136,400
Irrigated	12,550	4,400
Total	5,292,200	1,240,000

TABLE 4.3

Possible Agricultural Strategies for the Sahel-Sudan Region

Strategy	Comments
1. Emphasize livestock	few people affected, low productivity, limited by disease
2. Emphasize dryland agriculture	cultivable land is limited, energy is limited
3. Emphasize irrigation	limited water availability (demands are increasing), capital intensive
4. Emphasize groundwater irrigation	capital intensive, questionable availability (especially in long term)
5. Emphasize export crops	a social disaster
6. Integrated approach	systems based, comprehensive, uses all productive capacity

The only real advantages the Sahel-Sudan region has over some parts of the world are a potential 12-month growing season, abundant sunshine, and a vast land area. However, a lot of other arid and semi-arid regions are similarly endowed. Limited water supplies place severe constraints on utilization of the advantages.

Livestock production, because of the ability of animals to forage over large areas and make use of plant materials unsuitable for direct human consumption, and because of the generally favorable climate, is one segment of agriculture in which the Sahel-Sudan region might have an advantage over other areas.

In the irrigated zone, crops can be produced which are seasonally unavailable in developed country markets such as in Europe. To date, operations of this type have been exploitive and have not contributed much to the quality of life of the producers. Such schemes, although they might have been included, are not a part of this analysis.

The integrated strategy within the ISYALAPS framework involves specialization in activities as follows:

a. The more arid zones of the north and other nonarable areas throughout the region are utilized for cow-calf livestock operations (Figure 4.1).

b. The young and nonproductive old animals are periodically removed from breeding-ground ranges and raised to marketable size on more productive range land.

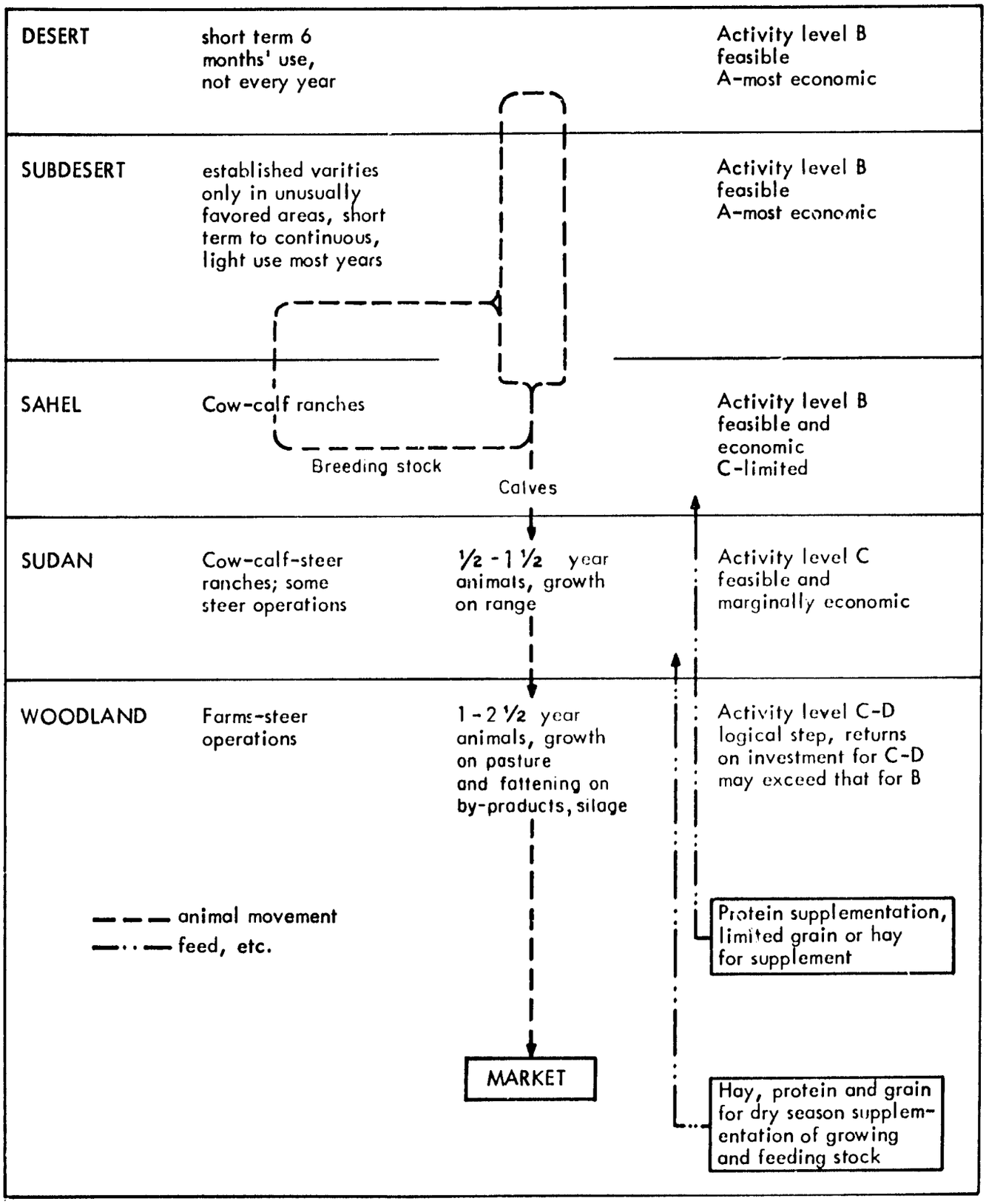

Figure 4.1 Schematic of Possible Livestock Production System

c. Dairy and poultry operations are located near urban centers.

d. Perennial inland waterways and lakes are utilized for fish production.

e. Dryland crop production is concentrated in the zones where rainfall, even during drought periods, tends to be adequate for some productivity.

f. Irrigation projects are initiated in areas where adequate supplies of water and suitable soils are present.

g. Designated parts of all climatic zones are devoted to wood production.

h. Technology is utilized to increase productivity of livestock, food crops and exportable cash crops, and wood.

i. New agricultural areas are exploited wherever possible.

j. Farmers are encouraged to move into more productive areas, and larger scale productive units are encouraged. These policies do not aim at wholesale resettlement and migration, but rather at localized adaptation to production possibilities.

The integrated strategy is not an attempt to maximize any production factor or factors but is a mix of activity levels for the segments of agriculture appropriate in the various climatic zones. The selected activity levels for the agricultural sector are given in Table 4.4. Substantial changes in the socio-economic system will be required for implementation of the strategy in addition to the changes necessary in

TABLE 4.4

Selected Strategy (Mix of Activity Levels) for the Sahel-Sudan Region

Agricultural Segment	Climatic Zone					
	Desert	Sub desert	Sahel	Sudan	Woodland	Irrigated
	Activity Levels					
Crops			A	B	C	D
Livestock	A	B	B	C	C	-
Milk (Dairy)	-	-	-	B	C	D
Poultry	-	-	-	B	C	D
Fish	-	-	A	B	C	D
Wood	-	-	-	A	B	-

the agriculture production system. Details will be provided in a later part of this section.

4.2.3.1 —Human resource development: People are a crucial resource in the Sahel-Sudan region, and they can be trained to work more effectively. Low productivity of labor in agriculture is a primary factor in the "vicious circle" of poverty. Education and training that will raise labor productivity are of paramount importance. Raising rural labor productivity through education and training implies that new knowledge and trainers (teachers, extension agents, etc.) are available or will become available as part of an integrated rural development program. In the Sahel-Sudan region the development of new knowledge as well as the training of teachers and extension personnel will be necessary.

4.2.3.2 —Effect of activity level: Productivity will be different in each climatic zone for each activity level. Remember that Level A is the minimum activity with impact, Level B is extensive management activity, Level C is intensive management activity, and Level D is the maximum activity level. Specific kinds of improvements which can be made in various segments of the agricultural sector were listed in Section 2. Their effects on productivity are estimated later in this section.

4.2.4 Land allocation: Each unit of land area within a given climatic zone has a particular use for which it is more suitable.

Some parts of the zone may be completely barren or are occupied by roads, villages, stream channels, etc. In the Sahel-Sudan region, the land areas of the zones were allocated as shown in Table 4.5. The allocations are conservative, based on similar zones in the United States and other countries rather than on specific knowledge of land use and capabilities in the Sahel-Sudan region. The allocation to crops is slightly less than the quantity of land reported as arable for the region; thus the allocations are probably realistic.

4.2.5 Crop and wood production factors: In the subsistence agriculture of the Sahel-Sudan region a fallow period is used to maintain crop productivity. This means that only a fraction of the land area allocated to crops is actually farmed in any one year. The fraction varies with both climatic zone and activity level. Estimated values are given in Table 4.6. (The practice is assumed to be replaced in the irrigated zone by fertilization, crop rotation, and green manure crops.)

Possible dryland crops are listed in Table 4.7. All are presently being grown in the region. (Any crop might be grown in the irrigated zone.) Effective precipitation is that which provides moisture for crop production.

A possible assortment of crops for each climatic zone of the Sahel-Sudan region is given in Table 4.8. This selection is not entirely arbitrary, but reflects to a certain extent crops actually grown in each zone. Cotton, the only non-food crop, is included because of the area

TABLE 4.5

Land Allocation, Sahel-Sudan Region

(percent of total)

Climatic Zone	Crop	Livestock	Wood	Barren or Other Uses
Desert	0	30	0	70
Sub Desert	0	40	0	60
Sahel	10*	50	0	40
Sudan	30	30	20	20
Woodland	30	20	20	30
Irrigated**	90	0	0	10

*Area reduced to 6 percent for Activity Level A because of lack of domestic water.

**Percent of possible irrigated area actually used reduced by activity levels as follows:
A - 25%, B - 50%, C - 75%.

TABLE 4.6

Land Actually Cultivated

(fraction of cultivable)

Climatic Zone	Activity Level			
	A	B	C	D
Sahel	.07	.08	.09	.11
Sudan	.09	.11	.14	.20
Woodland	.14	.20	.33	.50

TABLE 4.7

Possible Dryland Crops in the Sahel-Sudan Region

Climatic Zone	Effective Precipitation	Crops	
		Primary	Secondary
Sahel	250-475	Millet Sorghum	Cowpeas
Sudan	600mm	Millet Sorghum Peanuts	Cowpeas Corn Cotton
Woodland	750mm	Sorghum Corn Peanuts Cotton	Millet Cowpeas

TABLE 4.8

Assumed Crop Assortment in Sahel-Sudan Region

(percent of land actually cultivated)

Crop	Climatic Zone			
	Sahel	Sudan	Woodland	Irrigated
Millet	45	20	10	-
Sorghum	35	20	20	-
Corn	-	20	20	10
Cowpeas	20	20	20	10
Peanuts	-	15	20	10
Wheat	-	-	-	20
Rice	-	-	-	40
Cotton	-	5	10	10

already devoted to its production in the region.

Productivity of crops is affected by both the climatic zone (largely by effective precipitation) and by the activity level at which a strategy is implemented. The estimated productivities of crops and wood for the Sahel-Sudan region are given in Table 4.9. Maximum productivity is attained with Activity Level D in the irrigated zones; other productivities in the matrix are fractions of that maximum. Values are based on productivity in similar zones around the world.

Then productivity of the crops in the chosen assortment and of wood was calculated for Activity Levels A through D in the climatic zones (Tables 4.10 to 4.13). Note that the values obtained are extremely conservative, but they represent long term sustained yield averages and thus account for both rainfall fluctuations and differences in farmers' capability. In the Sahel zone, for example, the potential productivity under Activity Level D is less than one-third of that reported for the current exploitative system.

Potential production of each food crop in the selected assortment was computed and an example for millet is shown in Table 4.14. Total production was converted to calories and grams protein.

Potential food crop production for the Sahel-Sudan region in calories and grams protein is summarized in Table 4.15. Corrections are made to the total production: (a) because of the use of animal power in the woodland zone under Activity Level C and consequent animal

TABLE 4.9

Crop and Wood Productivity Matrix for Sahel-Sudan Region

(percent of maximum)

Climatic Zone	Activity Level			
	A	B	C	D
Sahel	3	5	8	10
Sudan	9	15	24	30
Woodland	18	30	48	60
Irrigated	30	50	80	100

TABLE 4.10

Possible Crop and Wood Productivity, Activity Level A

(kg/hectare)

Crop	Sahel	Sudan	Woodland	Irrigated
Millet	75	225	450	750
Sorghum	125	375	750	1,260
Corn	120	360	720	1,200
Cowpeas	45	135	270	450
Peanuts	70	210	420	675
Wheat	120	360	720	1,200
Rice	-	-	720	1,200
Cotton	90	270	540	900
Wood	-	540	1,080	-

TABLE 4.11

Possible Crop and Wood Productivity, Activity Level B

(kg/hectare)

Crop	Sahel	Sudan	Woodland	Irrigated
Millet	125	375	750	1,250
Sorghum	210	630	1,260	2,100
Corn	200	600	1,200	2,000
Cowpeas	75	225	450	750
Peanuts	115	345	690	1,130
Wheat	200	600	1,200	2,000
Rice	-	-	1,200	2,000
Cotton	150	450	900	1,500
Wood	-	900	1,800	-

TABLE 4.12

Possible Crop and Wood Productivity, Activity Level C

(kg/hectare)

Crop	Sahel	Sudan	Woodland	Irrigated
Millet	200	600	1,200	2,000
Sorghum	335	1,000	2,000	3,360
Corn	320	960	1,920	3,200
Cowpeas	120	360	720	1,200
Peanuts	180	540	1,080	1,800
Wheat	320	960	1,920	3,200
Rice	-	-	1,920	3,200
Cotton	240	720	1,440	2,400
Wood	-	1,440	2,880	-

TABLE 4.13

Possible Crop and Wood Productivity, Activity Level D

(kg/hectare)

Crop	Sahel	Sudan	Woodland	Irrigated
Millet	250	750	1,500	2,500
Sorghum	420	1,260	2,520	4,200
Corn	400	1,200	2,400	4,000
Cowpeas	150	450	900	1,500
Peanuts	225	675	1,350	2,250
Wheat	400	1,200	2,400	4,000
Rice	-	-	2,400	4,000
Cotton	300	900	1,800	3,000
Wood	-	1,800	3,600	-

TABLE 4.14

Potential Production of Millet, Sahel-Sudan Region

Climatic Zone	Sahel	Sudan	Woodland	Irrigated	Total
Area in zone (km^2)	887,270	502,568	493,122	12,550	1,855,510
Allocation to crops	.06	.30	.30	.90	-
Cultivable area (km^2)	53,236	150,769	135,937	11,295	351,237
Cultivated fraction	.07	.11	.33	1.0	-
Allocation to this crop	.45	.20	.10	-	-
Area in crop (km^2)	1,677	3,317	4,486		9,480
Activity level	A	B	C	D	-
Productivity (kg/h)	75	375	1,200		-
Production (kg x 10^6)	13	124	538		675
Cal/kg	3,410	3,410	3,410		-
gm protein/kg	95	95	95		-
Calories x 10^9	43	424	1,836		2,303
grams protein x 10^6	1,195	11,817	51,140		64,152

TABLE 4.15

Potential Food Crop Production, Sahel-Sudan Region

Crop	Climatic Zone				
	Sahel	Sudan	Woodland	Irrigated	Total
	Calories x 10^9				
Millet	43	424	1,836	-	2,303
Sorghum	56	715	6,137	-	6,908
Corn		695	6,013	1,577	8,285
Cowpeas	10	255	2,196	575	3,036
Peanuts		261	2,800	770	3,831
Wheat				2,973	2,973
Rice				6,163	6,163
TOTAL	109	2,350	18,982	12,058	33,499
Draft Animal Consumption 25%	-	-	4,746	-	4,746
Poultry Consumption	-	308	1,147	2,276	3,731
NET PRODUCTION	109	2,042	13,089	9,782	25,022
	Grams protein x 10^6				
Millet	1,195	11,817	51,140	-	64,152
Sorghum	1,630	20,897	179,440	-	201,967
Corn	-	18,109	156,793	41,132	216,034
Cowpeas	681	17,025	146,642	38,363	202,711
Peanuts	-	12,900	138,600	38,100	189,600
Wheat	-	-	-	80,456	80,456
Rice	-	-	-	104,818	104,818
TOTAL	3,506	80,748	672,615	302,869	1,059,738
Draft Animal Consumption 25%	-	-	168,154	-	168,154
Poultry Consumption	-	9,860	38,990	79,660	128,510
NET PRODUCTION	3,506	70,888	465,471	223,209	763,074

consumption and (b) because of use of crops for poultry feed.

Cotton is the only non-food crop considered for the region. Potential production of cotton was calculated and is shown in Table 4.16. Its value to the economy was calculated as $239 million. Peanuts, considered in this example as a food crop for the region, may also contribute as an export crop if surplus food production is available.

Potential wood production in the Sahel-Sudan region (arbitrarily limited to the sudan and woodland zones) is summarized in Table 4.17.

4.2.6 Livestock production factors: Potential animal carrying capacities for the different activity levels and climatic zones of the Sahel-Sudan region are shown in Figure 4.2 and summarized in Table 4.18. Carrying capacity estimates are based on those in similar climatic zones around the world. The limited value of the higher activity levels in the drier zones is apparent as well as the high potential for improvement in the wetter zones.

Estimated livestock production system parameters given in Table 4.19 are also based on those attained under similar conditions in other locations. These parameters are used in calculating potential meat production from each climatic zone.

Potential livestock production is calculated and summarized in Table 4.20. Dairy animals and non-producers (horses and donkeys) are subtracted from the total animal units. The number of dairy animals was assumed to be 10 percent of total animal units (approximately 20

TABLE 4.16

Potential Production of Cotton, Sahel-Sudan Region

Climatic Zone		Sudan	Woodland	Irrigated	Total
Area in zone km^2	887,270	502,568	453,122	12,550	1,885,510
Allocation to crops	.06	.30	.30	.90	
Cultivable area km^2	53,236	150,770	135,937	11,295	351,238
Cultivated fraction	.07	.11	.33	1.0	
Allocation to this crop	-	.05	.10	.10	
Area in crop km^2		829	4,486	1,129	6,444
Activity level	A	B	C	D	
Productivity kg/h	-	450	1,440	3,000	
Production 10^6kg		37	646	339	1,022

TABLE 4.17

Potential Wood Production, Sahel-Sudan Region

Climatic Zone	Sudan	Woodland	Total
Area in zone (km^2)	502,562	453,122	955,684
Activity level	A	B	
Allocation to wood	.20	.20	
Area in wood (km^2)	100,512	190,624	191,136
Productivity (kg/h)	540	1,800	
Production (10^3kg)	5,428,000	16,312,000	21,740,000

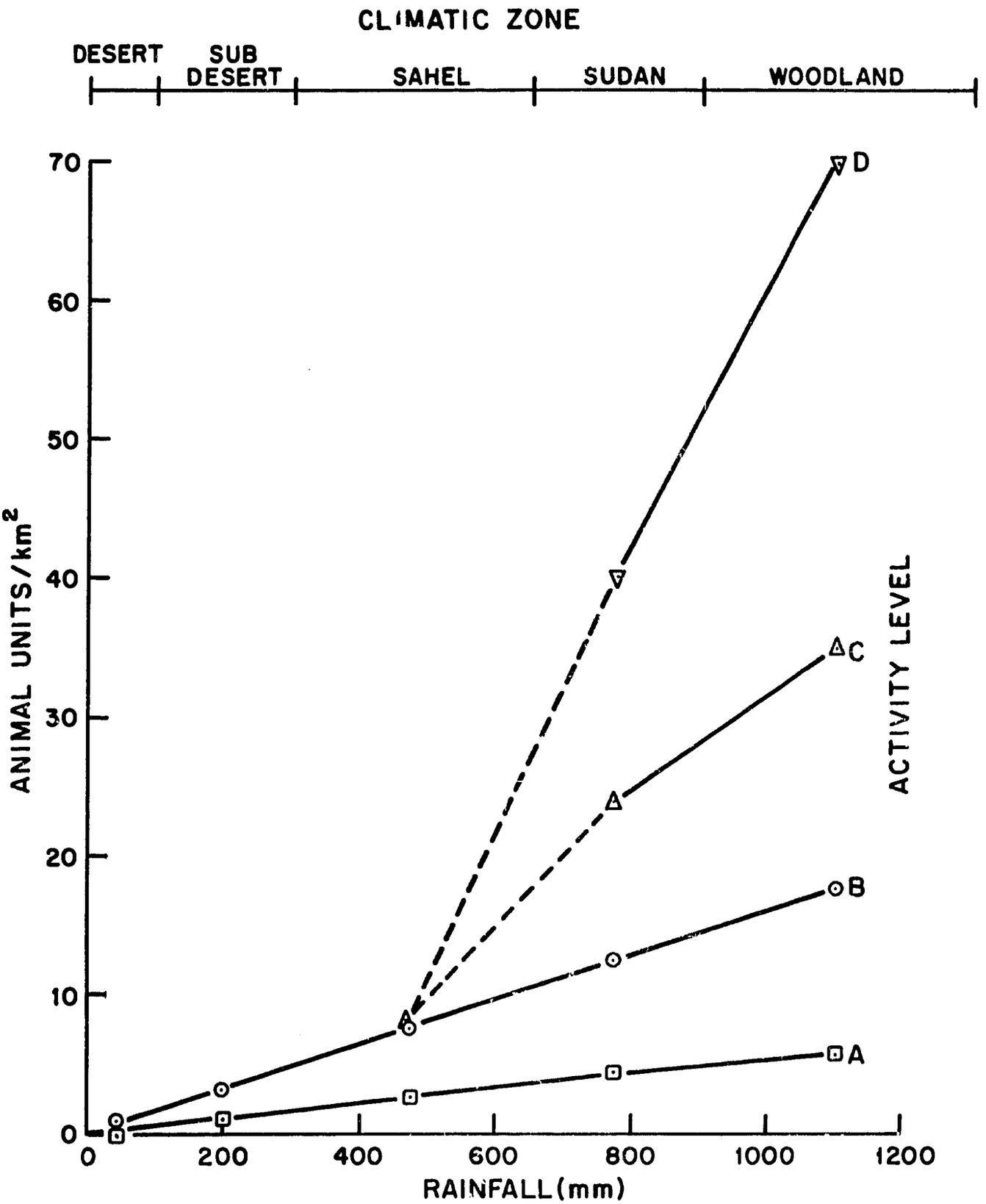

Figure 4.2 Estimated Livestock Carrying Capacity for Different Activity Levels

TABLE 4.18

Potential Animal Carrying Capacities, Sahel-Sudan Region

(animal units/km^2)**

Climatic Zone	Activity level			
	A	B	C	D
Desert	0	0.8	0.8*	0.8*
Sub desert	1.0	3.0	3.0*	3.0*
Sahel	2.5	7.6	8.0	8.0*
Sudan	4.1	12.4	24.0	40.0
Woodland	5.8	17.6	35.0	70.0

*This activity level not technologically or economically feasible in this zone.

**1 animal unit = 1 cow and calf (450 kg) = $\frac{1}{2}$ camel = 5 sheep = 5 goats = 1 horse = 2 donkeys.

TABLE 4.19

Estimated Livestock System Parameters

Parameter	Activity level			
	A	B	C	D
Calving percent[a]	35	50	65	80
Mortality, 0-3 mos. %	20	50	65	80
Mortality, 3 mos-sale percent	20	12	5	2
Cow replacements/yr, percent	12[b]	12[b]	20[c]	20[c]
Age at sale, mos.	55	55	43	19
Offtake, percent of A.U. for sale	9	14	22	31
Offtake, percent of A.U. for consumption	14[d]	18[d]	22	31
Dressing, percent	48	50	55	60

a. Calves born as a function of number of cows.

b. Assumes salvage value of 50 percent of culled cows.

c. Assumes salvage value of 95 percent of culled cows.

d. 80 percent of dead or dying animals (3-55 mos.) are consumed.

TABLE 4.20

Potential Livestock Production, Sahel-Sudan Region

Climatic Zone	Desert	Sub desert	Sahel	Sudan	Woodland	Total
Area in zone	1,919,250	1,516,360	887,270	502,562	453,122	5,278,564
Allocation [illegible] ock	.30	.40	.50	.30	.20	-
Livestock are	575,775	606,544	443,635	150,768	20,624	1,867,346
Activity level	A	B	B	C	C	-
Carrying capacity	0	3.0	7.6	24.0	35.0	-
Animal units 10^3	-	1,820	3,372	3,618	3,172	11,982
Non producers* A.U. x 10^3	-	91	169	181	159	600
Dairy A.U. x 10^3	-	-	-	360	720	1,080
Net A.U. x 10^3	-	1,729	3,203	3,077	2,293	10,302
Offtake**	-	18	18	22	22	-
Returned dairy animals x 10^3	-	-	-	43	130	173
A.U. offtake 10^3	-	311	577	677	504	2,069
Dressing percent	-	50	50	55	55	-
Meat production 10^6 kg	-	70	130	178	157	535
Cal/kg	-	1,500	1,500	1,500	1,500	-
gm.protein/kg	-	200	200	200	200	-
Calories x 10^9	-	105	195	267	236	836
Grams protein x 10^6	-	14,000	26,000	35,600	31,400	107,000

*Horses and donkeys.

**Percent of animal units for consumption.

percent of cattle) in the sudan and twice that number for the woodland and urban zones. Note that total animal units recommended are reduced to a little more than 10 million. According to the World Bank, the optimum number for the region is 15 million (Wade 1974). Meat production was calculated and then converted to equivalent calories and grams of protein. Fifteen percent of dairy animals are assumed to be slaughtered each year.

4.2.7 Other animal production: Potential productivity of other animal products (milk, poultry, eggs, and fish) is estimated in Table 4.21. Total potential production of these commodities is recorded in Tables 4.22 to 4.24. The number of animal units of livestock for meat production was reduced to compensate for forage consumed by dairy animals, and feed for poultry was previously subtracted from total potential crop production.

4.2.8 Summary of agricultural production and human carrying capacity: The total potential agricultural production of the Sahel-Sudan region under the integrated strategy is summarized in calories and grams protein of food and kilograms of wood in Table 4.25. Totals are corrected for storage and transit losses ranging from 7 to 40 percent. (No estimate was made of the value of agricultural by-products because of insufficient data.)

Carrying capacity parameters for the Sahel-Sudan region were estimated and are given in Table 4.26. Calorie requirements were

TABLE 4.21

Other Animal Productivity Factors

Product	Activity level			
	A	B	C	D
Milk (kg/yr/animal)	500	1,000	2,000	5,000
Lactating percent	30	40	50	60
Poultry kg/yr/1,000	250	400	570	880
Eggs (kg/yr/1,000)	1,370	2,740	4,100	6,840
Mortality (poultry)	25	20	15	10
Fish kg/yr/1,000	150	200	300	450

75% layers, 25% broilers
60% yield for layers
70% yield for broilers

TABLE 4.22

Potential Milk Production, Sahel-Sudan Region

Climatic zone	Sudan	Woodland	Urban	Total
Number of animals* x 10^3	288	432	144	864
Lactating percent	40	50	60	-
Activity level	B	C	D	-
Productivity kg/yr	1,000	2,000	5,000	-
Milk production 10^6 kg	115	432	432	979
Cal/kg	680	680	680	-
gm. protein/kg	35	35	35	-
Calories x 10^9	78	294	294	666
gm. protein x 10^6	4,025	15,120	15,120	34,265

*Animal numbers subtracted from carrying capacity for livestock production.

1 dairy cow = 1.25 animal units.

15% animal return as meat each year.

TABLE 4.23

Potential Poultry and Egg Production, Sahel-Sudan Region

Climatic Zone				
Number of birds x 10^6	10	25	30	65
Activity level	B	C	D	-
Productivity kg/yr/1,000	2,740	4,100	6,840	-
Production (eggs) kg x 10^6	27.4	102.5	205.2	335.1
Productivity kg/yr/1,000	400	570	880	-
Production (meat) kg x 10^6	4	14.3	26.4	44.7
Cal/kg (eggs)	1,600	1,600	1,600	-
Cal/kg (meat)	1,000	1,000	1,000	-
gm/protein/kg (eggs)	125	125	125	-
gm/protein/kg (meat)	200	200	200	-
Calories x 10^9	47.8	178.3	354.7	580.8
gms. protein x 10^6	4,225	15,673	30,930	50,828
Feed consumption* calories x 10^9	308	1,147	2,276	3,758
gm/protein x 10^6	9,860	38,990	79,660	128,510

*Feed consumption subtracted from crop calories.
20 eggs/kg.
8,500 cal. feed/kg meat.
10,000 cal. feed/kg eggs.

TABLE 4.24

Potential Fish Production, Sahel-Sudan Region

Climatic Zone	Sahel	Sudan	Woodland	Irrigated	Total
Number of fish x 10^6	250	500	1,000	500	2,250
Activity level	A	B	C	D	-
Productivity kg/yr/ 1,000	150	200	300	450	-
Production kg x 10^6	37.5	100	300	225	663
Cal/kg	1,000	1,000	1,000	1,000	-
gm protein/kg	150	150	150	150	-
Calories x 10^9	38	100	300	225	663
grams protein x 10^6	5,625	15,000	45,000	33,750	99,375

TABLE 4.25

Summation of Potential Agricultural Production, Sahel-Sudan Region*

Climatic Zone	Desert	Sub desert	Sahel	Sudan	Woodland	Irrigated	Total
Crop calories x 10^9	-	-	65	1,490	11,260	9,100	21,915
Livestock calories	-	80	140	230	205	-	655
Milk calories	-	-	-	60	255	275	590
Egg calories) Poultry calories)	-	-	-	35	155	330	520
Fish calories	-	-	25	75	260	210	570
TOTAL CALORIES x 10^9	-	80	230	1,890	12,135	9,915	24,250
Crop protein (gms) x 10^6	-	-	2,105	51,750	400,305	207,585	661,745
Livestock protein	-	10,220	18,980	30,615	27,005	-	86,820
Milk protein	-	-	-	2,940	13,005	14,060	30,005
Egg protein) Poultry protein)	-	-	-	3,085	13,480	28,765	45,330
Fish protein	-	-	3,375	10,950	38,700	31,390	84,415
TOTAL GMS PROTEIN x 10^6		10.220	24,460	99,340	492,495	281,800	908,315
Wood production (kg) x 10^6	-	-	-	5,428	16,312	-	21,740

*Corrected for losses, see Table 4.32.

TABLE 4.26

Carrying Capacity Parameters, Sahel-Sudan Region

Parameter	Activity level			
	A	B	C	D
Storage loss percent	30	20	10	5
Transit loss percent	10	7	4	2
Dryland hectares/farmer	5	5	10	20
Irrigated hectares/farmer	2.5	2.5	5	10
Animal units/herder*	25	40	80	100
Wood producing hectares/collector	50	100	200	500
Birds/poultry producer	500	1,000	2,000	5,000
Fish kg/fisherman	1,000	2,000	4,000	10,000
Calories/yr/capita x 10^5	7.3	7.3	7.3	7.3
gms protein/yr/capita x 10^4	2.2	2.2	2.2	2.2
Wood kg/yr/capita	500	500	500	500

*Same value for dairy operators.

Note: Each farm family is assumed to have 5 persons.

assumed to be 2000 calories/capita/day and protein requirements 60 grams/capita/day. (These values are above World Health Organization minimums.) Wood needs were estimated as 500 kg/capita/year. Each farmer, herder and wood collector is assumed to be part of a five-person family. In establishing the carrying capacity parameters each farm worker (and family) is given what is considered to be an economically viable unit to prevent his being condemned to a subsistence operation.

Potential human carrying capacity was then examined by determining the number of people supportable by the production of the region. The number of people employable in direct agricultural production activities was also considered. Data are presented in Table 4.27. Population in other supporting services is not included.

4.3 Comparison of Potential and Existing Production

The analyses of potential production in the examples of the use of the ISYALAPS planning framework for both the Sahel-Sudan region and for Mali showed that calorie availability would be the limiting factor, that is, the potential protein produced would support a greater population than the calories produced. Comparisons of calories available from the existing production and those potentially available from implementation of the alternative agricultural strategies were made along with comparisons of human carrying capacities.

4.3.1 Calorie production: Data for existing production in

TABLE 4.27

Potential Human Carrying Capacity, Sahel-Sudan Region

Climatic Zone	Desert	Sub desert	Sahel	Sudan	Woodland	Irrigated	Total
Net calories produced x 10^9	-	80	230	1,890	12,135	9,915	24,250
Population supportable x 10^6	-	0.110	.315	2.589	16.623	13.58[illegible]	33.219
Net protein produced gm x 10^6	-	10,220	24,460	99,340	492,495	281,800	908,315
Population supportable x 10^6	-	.465	1.112	4.515	22.386	12.809	41.287
Wood produced kg x 10^6	-	-	-	5,428	16,312	-	21,740
Population supportable x 10^6	-	-	-	10.856	32.624	-	43.48
Animal units x 10^3	-	1,729	3,203	3,077	2,293	-	10,302
Population employable x 10^6	-	.215	.40	.19	.150	-	.955
Area in dryland ha. x 10^6	-	-	.373	1.658	4.486	-	6.517
Population employable x 10^6	-	-	.373	1.658	2.243		4.274
Area irrigated ha. x 10^6	-	-	-	-	-	1.130	1.130
Population employable x 10^6	-	-	-	-	-	.509	.509
Area in wood ha. x 10^6	-	-	-	10.051	9.062		19.113
Population employable x 10^6	-	-	-	1.005	.906		1.911
Population in other* agricultural activities x 10^6	-	-	.188	.336	.465	.15	1.139
Total population employable x 10^6	-	.215	.961	3.189	3.764	.659	8.788

*Milk, poultry and eggs, fish production.

the Sahel-Sudan region are meager and no estimate can be made of production in each of the individual climatic zones. In Table 4.28 a comparison is made of potential crop, livestock, and other food production in calories for the Sahel-Sudan region under existing conditions (using 1969 data) and the integrated strategy.

A significant potential production increase occurs with the integrated strategy for all segments of the agricultural sector except milk production. A different allocation of animal units would result in a positive change here, also. Total production is increased more than 30 percent.

Similar comparisons for Mali are given in Table 4.29 for the integrated strategy and in Table 4.30 for a strategy of implementing Activity Level B in all segments of the agricultural sector. Data for 1970-71 are used in making the comparisons for Mali.

The integrated strategy in Mali results in a potential overall production increase of greater than 100 percent. Fish production would apparently decrease; however, fish potential was arbitrarily assigned and a different assumption would obviously change the results. In this case, the results would seem to indicate that the assumptions were too low, because they yield less than existing production (1970-71) which has not decreased over the last few years.

The total potential production under the constant Level B strategy in Mali, however, is 12 percent less than the existing production. All

TABLE 4.28
Comparison of Potential Calorie Production in the Sahel-Sudan Region
(calories x 10^9)

Agricultural Segment	Existing*	Integrated Strategy	Change (%)
Crops	16,785	21,915	+ 31
Livestock	409	655	+ 60
Milk	664	590	- 11
Poultry and eggs	63	520	+725
Pigs	3	-	- 00
Fish	422	570	+ 35
Total	18,346	24,250	+ 32

*Estimated from 1969 data corrected for losses of 27%.

TABLE 4.29
Comparison of Potential Calorie Production, Mali, Integrated Strategy
(calories x 10^9)

Agricultural Segment	Existing*	Integrated Strategy	Change (%)
Crops	3,221	6,924	+115
Livestock	117	162	+ 38
Milk	88	130	+ 48
Poultry and eggs	15	72	+380
Fish	64	44	- 31
Total	3,505	7,332	+109

*1970/71 data, corrected for losses of 27%.

TABLE 4.30
Comparison of Potential Calorie Production, Mali, Level B Strategy
(calories x 10^9)

Agricultural Segment	Existing*	Level B Strategy	Change (%)
Crops	3,221	2,862	- 11
Livestock	117	93	- 21
Milk	88	19	- 78
Poultry and eggs	15	62	+313
Fish	64	36	- 44
Total	3,505	3,072	- 12

*1970/71 data corrected for losses of 27%.

segments of agriculture show net decreases except poultry. Here again, different allocations would change the magnitude, but probably not the sense, of the results.

4.3.2 Cash and export production: Since a major portion of the exports from the Sahel-Sudan region is agricultural products, a comparison was also made in this category (Table 4.31). Exportable surplus of peanuts and livestock was assumed to be that in excess of calorie requirements of the existing (1969) population in the first case (integrated strategy) and 20 percent of production in the latter (constant Level B strategy).

Cotton is an important cash crop and also is included. Figures given are for total production without regard to whether the cotton was locally processed or exported.

The comparison of similar data for Mali with 1970-71 production shows that potential peanut production for export (integrated strategy) in the region is 7 percent less than existing production. Tobacco was not included in the crop assortment but for all other products substantial increases are possible. For cotton the increase is more than 400 percent.

For Mali the comparison under the integrated strategy shows a 10 percent decrease in peanut production for export or cash sales, and a 60 percent decrease in fish output. Substantial increases are noted as possible for meat, cotton, and wood.

With the alternative strategy of constant Level B in Mali there

TABLE 4.31

Comparison of Potential Cash Crop and Export Production, Sahel-Sudan Region

(10^6 kg)

Product	Existing	Integrated Strategy	Change (%)
Peanuts	1,356	1,264	- 7
Meat	66*	107*	+ 62
Cotton	200	1,022	+411
Tobacco	1	(not included)	- 00
Fish	20**	30**	+ 50
By-products			
Wood	8,950	21,740	+143

*20% of production.

** 5% of production.

would be no surplus of peanuts or meat for export. Fish production for export is reduced by 60 percent, but cotton and wood show sizeable increases.

4.3.3 Human carrying capacity: The ability of the Sahel-Sudan region or Mali to support or employ people in agriculture is of great concern. Comparisons of human carrying capacity for the Sahel-Sudan region under the integrated strategy are given in Table 4.32.

The potential agricultural production under the integrated strategy in an average year would support a population in the Sahel-Sudan region 30 percent greater than does the existing production. Of interest, however, is the fact that the current production, as reported, would support a population of about 25 million in the region, some 2 million more than live there now. One is thus led to the absurd conclusion that all is well in the Sahel-Sudan. More likely the production figures reported are not valid or losses have been underestimated. Distribution problems also may contribute to this discrepancy.

The population which can be gainfully employed with the integrated strategy is a little less than 9 million or almost 60 percent less than the estimated employment in agriculture at present. Insufficient data are available to compare the various parts of the agriculture sector.

In Mali, the integrated strategy has the potential to support an increased population, in this case more than double the existing human carrying capacity. However, the same situation as described above for

TABLE 4.32

Comparison of Human Carrying Capacity in Sahel-Sudan Region

($x\ 10^6$)

	Existing	ISYALAPS	Change (%)
Population supported or supportable by			
Crops	23	30.0	+ 30
Livestock	.56	.90	+ 61
Other Products	1.58	2.30	+ 46
Wood	17.9	43.48	+143
Total*	25.1	33.2	+ 32
Population employed			
Crops	10.1**	4.783	- 53
Livestock (nomads)	1.3 - 3.5	.955	-27 to -73
Other agricultural activities	?	1.139	-
Wood	?	1.911	-
Total	21.2***	8.788	- 59

*Excluding wood.

**Assumed 1 hectare/person.

***90% of total population.

the region occurs regarding employment in agriculture. A decrease of more than 50 percent is inferred.

The existing production in Mali will apparently support a population of 4.79 million. This is about 95 percent of the current population (5.02 million).

The constant Level B strategy for Mali does not have the potential to support the existing population. A decreased capacity of 13 percent is noted. The lower activity level does provide opportunity for more employment in agriculture than the integrated strategy but still indicates a decrease of 44 percent when compared with existing employment figures.

4.4 Steps for Implementation

Certain steps would be required to implement the integrated agricultural strategy (or any other) in the Sahel-Sudan region at each activity level. (The steps required for implementation can be assumed at this time to be the same in Mali.) One part of the process of determining the steps for implementation is the preparation of more detailed plans which fit the ISYALAPS planning framework.

In this report the strategy is not disaggregated below the national level. Obviously, a modular approach can be applied to other, smaller land units such as a complete watershed or an area of high (political or other) priority. Such areas could be selected on the basis of climatic conditions, seriousness of existing problems, and potential for improvement.

The material following indicates some of the apparent steps necessary for implementing an agricultural strategy in the Sahel-Sudan region. It is illustrative at this point in time rather than detailed. Possible actions by the government, private economic sector, individual farmers, and the donor agencies are suggested.

The needs for inputs, infrastructure, and trained personnel are identified. Where possible, information is presented on an activity level basis. Complete detail is beyond the scope of this work.

4.4.1 Government: Governments in the Sahel-Sudan region can implement actions in the areas of policy, legislation and program. The current level of government activity in agriculture is low and all of the possible actions suggested in Section 2 are in need of consideration. As an example of need for policy establishment, one might consider the concept of risk sharing. In the traditional Sahel-Sudan system, the farmer or herder bears almost all the risk of production, which is high because of the extreme climatic variability. Risk can be reduced by storage of harvested crops and by avoiding stress on the fragile ecology of the region. (Climate modification is not a realistic alternative.) Government policy can address both of these methods and be translated into legislation and action programs. Production variations can't be eliminated, but the magnitude of the "ups and downs" can be reduced. Direct emergency relief programs (e.g., easy credit) can be included. Examination of any other of the policy needs suggested in Section 2 will

lead in a similar manner to action programs for the region.

4.4.2 Private economic sector: The private sector in the region is not deeply involved in country development. However, part of the action of development can be shifted to the private sector. The illustrative examples of Section 2 can all be considered as possible actions for the private sector. The supply of inputs and infrastructure can be profitable operations in the region.

4.4.3 Individuals: Individual farmers or herders in the region can be actively involved in the implementation process. The individual operator usually does and can learn more to make wise management decisions, to use available technology, and to respond to incentives. Training programs at the local level and the provision of incentives are necessary.

4.4.4 Donor agencies: Multilateral organizations can assist the six country governments in formulation of agricultural policy and model legislation as well as in action programs. Significant assistance can be given to countries in the Sahel-Sudan region in planning and setting priorities as well as in financing those development projects which fit the planning framework.

Donor agencies interacting with the private economic sector may undertake such activities as consulting services and financing infrastructure under the higher activity levels in the Sahel-Sudan region.

Religious groups and bilateral aid programs such as the Peace Corps can provide effective assistance in transferring low level

technology improvements (Activity Levels A and B) in the region. Training programs in range management for ethnic (nomad) groups might be particularly effective for these donors.

4.4.5 Inputs: Specific inputs needed in the region can be identified as projects are proposed but are difficult to quantify on a broad-scale basis. By examining the possible improvements of the activity levels in the various aspects of agriculture, some of the needs of the Sahel-Sudan region can be specified. A compilation of some examples of the needed inputs for the region based on activity levels is given in Table 4.33. The expendable inputs, such as chemicals, fuels, lubricants, and fertilizers for the higher levels will have to be supplied on a routine basis.

Reasonably priced consumer goods and services are essential as incentives to farmers and herders in the region.

4.4.6 Infrastructure: Agricultural development in the Sahel-Sudan region can occur only if accompanied by growth of supporting infrastructure. Existing systems must be strengthened and new systems developed. At low activity levels any new infrastructure will have to be provided by the country governments. In those climatic (or irrigated) zones where higher activity levels are indicated, the private economic sector will need to be involved. To a certain extent this is already happening where large-scale commercial farming has been organized.

In a drought prone region such as the Sahel-Sudan, storage of

TABLE 4.33

Examples of Input Requirements

Activity Level			
A	B	C	D
Construction materials for storage facilities. Veterinary supplies.	Certified crop seeds. Hand tools - hoes, knives, threshing devices. Fence materials. Wells and pumps (domestic or livestock). Salt 3-10 kg/A.U./yr. Corrals 1:1,000 A.U. Dripping vats 1:50,000 A.U.	Seeds of new varieties. Fertilizer (N) 1M kg/50,000 ha. Sudan 25 M for woodland 50M for irrigated Phosphate as needed. Animal drawn plows, cultivators, threshers. Grass seeds Vaccines Chemical dips	Insecticides Herbicides Machinery and tractors, fuel and lubricants, irrigation pumps

surplus production is an essential aspect of being able to cope with the resultant problems. Requirements for storage will vary with activity level from local (on-farm) storage at Level A to central storage for up to 40 percent or more of the annual crop at Level D.

Transportation facilities to move agricultural products from producing to consuming areas are needed. As activity levels increase, the requirements for transportation also increase.

Similar requirements exist for improved marketing systems, water resources development and other institutions which support agriculture.

4.4.7 Trained personnel: In the Sahel-Sudan region, the lack of trained personnel in agriculture is notable. Requirements thus are very high and deserving of attention. At Activity Level A, substantial numbers of trained personnel are required but the level of their training is relatively low. Many range managers and livestock and agricultural extension agents, working with local groups, are needed. Highly trained personnel are required in planning for agricultural development and supervision of resultant programs. Personnel needs are different with each activity level (Table 4.34). Requirements are given in terms of various agricultural production units.

4.4.8 Timeframe: The time required for implementation of the integrated agricultural strategy (or any complex alternative strategy) cannot be precisely determined now. Among the factors contributing to the problem of setting a timeframe are the size of the area for

TABLE 4.34
Numbers of Trained Personnel Required

Specialty	Units of Measure	Activity Level A	B	C	D
Animal Scientists	A.U.	1:50,000	1:50,000	1:40,000	1:30,000
Veterinarians	A.U.	1:20,000	1:15,000	1:10,000	1:7,000
Extension (livestock)	A.U.		1:50,000	1:30,000	1:15,000
Extension (dairy)	milk units			1:3 or 4	
Range Managers and Agronomists	hectare	1:500,000	1:250,000	1:250,000	1:250,000 desert
	hectare	1:250,000	1:100,000	1:100,000	1:100,000 sub desert
	hectare	1:150,000	1:75,000	1:50,000	1:40,000 Sahel
	hectare	1:75,000	1:50,000	1:25,000	1:20,000 Sudan
	hectare	1:50,000	1:35,000	1:15,000	1:10,000 Woodland
Extension (agents)	hectare	1:5,000	1:2,500		
Extension (agronomy)	hectares	1:25,000			
Plant Pathologists	hectares	1:50,000			
Entomologist	hectares	1:50,000			
Animal Technicians	herder families		1:10	1:10	
Economy Aides	hectare	1:2,500	1:500		
Information specialists	hectares	1:50,000			
Agric. Eonomists	hectares	1:50,000			
Agric. Engineers	hectares	1:50,000		1:17,000	1:25,000-irrigation
Subsidy Officer	hectares	1:250,000			
Research Agronomist	hectares	1:250,000			
Research Economist	hectares	1:250,000			
Seed Control Super.	hectares		1:250,000		
Weed Specialist	hectares		1:250,000		
Seed Control Officer	hectares		1:25,000		
Agronomy Demo Leader	hectares		1:50,000		
Extension (program planning)	hectares		1:50,000		
Credit Supervisors	farm families	1:150	1:150	1:100	1:100

implementation, the resources (fiscal and human) available, and the characteristics of the strategy.

Implementation of the integrated strategy on a regional basis will take longer than would its implementation in a single country or smaller area. Monetary resources probably will not constrain implementation in the Sahel-Sudan region as much as the lack of human resources will. Each activity level also implies a different time scale. In most cases, implementation of Activity Level A can be more rapid than implementation of Activity Level D.

Furthermore, there will be a delay between implementation of the integrated agricultural strategy in the region and any significant impact. Nevertheless, some action can be taken immediately to prevent further deterioration of the fragile ecosystem and to prepare for implementation of activities at a later date. As examples, time will be required for range recovery regardless of what else may be done, and training of personnel will have to precede implementation of certain activities.

Based on these factors, implementation of the integrated strategy in the entire Sahel-Sudan region probably would take from 15 to 50 years. Smaller scale activities can be implemented and have substantial impacts in 3 to 10 years.

4.5 Determination of Impacts

Implementation of a selected agricultural strategy in the Sahel-

Sudan region will result in certain benefits and associated costs. Changes in the agricultural sector will have an effect on other sectors of the economy.

4.5.1 Benefits of implementation: The benefits of implementing an agricultural strategy obviously differ with the strategy selected. For the Sahel-Sudan region only a single integrated strategy was herein analyzed. The same strategy was applied to Mali separately, and benefits in Mali are assumed to be the same as those for the entire region. (The strategy of applying a constant Activity Level B in Mali is not discussed here because of its failure to meet present needs.)

Application of the integrated strategy showed a potential increase in food production for both the region as a whole and Mali taken separately. Self-sufficiency in food production appears to be a possibility, and if attained, eliminates the chronic need for food imports.

The quality of life for rural families can be improved by the increased productivity of the strategy. For example, a herder with 25 animal units and a potential offtake of 18 percent can produce approximately 1000 kilograms of beef annually with a value of about $700. A sedentary farmer in the sudan zone can produce more than 3000 kilograms of grain annually with a value of about $300. Combined with other animal production, total income might be increased by 50 percent. In more favorable areas income would be even higher, particularly in the irrigated zone.

The ecosystem of the region would be stabilized. Degradation would be halted and recovery initiated. The long-term sustained yield principle insures a balance between natural resources and man's use of them.

Exports of agricultural products could be increased. The specific items of export will depend on the crop assortment selected, but the capability of surplus production will permit exports. Livestock and by-products can also continue to be exported, possibly in increasing quantities.

Increased agricultural production means increased opportunity for development of related industries. Processing for local or export markets and manufacture from by-products are distinct possibilities. New employment opportunities thereby will be generated.

Supporting services (infrastructure) for the production system will need to be strengthened. This will provide opportunities for employment and entrepreneurship.

A further benefit comes with the capability of the production to keep up, at least for a while, with population growth in the region.

What is the value of the above benefits? Exact dollar values cannot be assigned for the entire region or even for a single country, Mali. When planning reaches the project proposal state exact values will have

to be determined.

4.5.2 Costs of implementation: Problems of determining the actual costs for implementing a strategy involving the four activity levels in the Sahel-Sudan region are innumerable. Many alternative decisions are involved including source of funds, labor vs. mechanization policy, training in Africa vs. elsewhere, and so on. It is therefore probably inadvisable to attempt to estimate costs at the present time. Due to the shortage of information and vastness of the Sahel-Sudan region, the potential for error is great and probably no estimate is better than a wild guess. Any estimate of the total costs for implementation of the integrated strategy in all six countries of the region probably is not of value since it unquestionably exceeds the funds available from the donor agencies.

When estimating the costs of implementing alternative strategies at the project level, the existing facilities, equipment, and infrastructure which will provide support for the project should be subtracted from total estimated costs.

Some of the items for which costs must be determined in project evaluation for the Sahel-Sudan region include fencing materials and installation, wells, pumps and water tanks, mineral supplements and medical supplies for livestock, improved seeds, fertilizers and other chemicals, hand tools, tractors, machines and implements, and construction of facilities for storage, livestock handling, and water

management. In Table 4.35 requirements for fencing and wells are estimated on the basis of activity levels as an example. This is a first step in cost determination and a similar procedure can be followed for other identifiable project needs.

4.5.3 Impacts on other sectors: Implementation of any agricultural strategy has obvious impacts on the government, economic, transportation, and other sectors. Not so obvious are its impacts on the social-political system.

Some of the indicators of the system which can be expected to change in response to implementation of the integrated agricultural strategy in the Sahel-Sudan region are discussed below.

4.5.3.1 —Social-political: A substantial impact on the social-political system will result from implementation of the natural resource based agricultural strategy. Unrestrained nomadic use of range lands can no longer be permitted. This involves a change in the authority of local ethnic group or village leaders.

Active employment in agriculture will decrease under the strategy. Population in the urban areas will increase more rapidly as a result. (Some of the increase can be absorbed by growth in infrastructure activities and agriculturally related industries.)

Incentives will be required for the farmers and herders to promote increased production. Reasonably priced consumer goods and services will be needed in the rural areas.

TABLE 4.35

Need for Fencing and Wells

Item	Activity Level			
	A	B	C	D
Fencing (km/km^2)				
Desert		.14	.14	.14
Sub desert		.2	.2	.2
Sahel	none	.45	.6	1.1
Sudan		.6	1.1	2.0
Woodland		1.0	2.0	2.8
Wells (km between)				
Desert	16	10	8	8
Sub desert	13	8	6	6
Sahel	10	5	3	3
Sudan	8	3	2	2
Woodland	5	2	1	0.5

4.5.3.2 —Economic: Per capita income can be increased and income distribution made more equitable. Agricultural output for export can be increased, consequently increasing earnings of foreign exchange and improving the balance of trade. (Import requirements will be reduced.)

Prices of agricultural products will increase if producers are to receive a fair return for their effort. This may be socially unacceptable in urban areas.

Government and private sector investment in agriculture will have to be increased.

4.5.3.3 —Water resources: Implementation of the integrated strategy requires the development of the potential for irrigation in the region. A seven-fold increase in irrigated area is required. A strategy using lower activity levels still requires a significant increase in water resources development for irrigation. Because of the international character of the rivers in the region, basin-wide planning and cooperation are required.

4.5.3.4 --Transportation: Handling a 30 to 50 percent increase in agricultural production will require an improved transportation system. New collection/distribution centers will be needed in addition to all-weather roads, ox carts and trucks.

More intensive production methods will require more inputs to be delivered to the farming areas. Transport requirements will increase

in this direction also.

4.5.4 Non-implementation impact: To make a valid evaluation of an agricultural strategy, whatever it may be, the potential consequences of a "do nothing different" strategy must be examined. Although predictive in nature, the examination of current trends in the Sahel-Sudan region is an essential part of the process. Premises used in the analysis are as follows:

- Population growth will continue at about its current rate (2 percent).
- Insignificant changes will occur in the lifestyle of the people in the region.
- Existing land use practices will endure.
- Government support of the agricultural sector will remain constant.
- Economic disparity between the rural and urban sectors will increase.
- Donor assistance in agriculture will continue at current levels.

The above premises are not really separate; they are all interrelated in a population-agricultural production-natural resources vicious circle (Figure 4.3). Increasing population in the rural area creates greater pressure on the natural resource base (land, water, and vegetation). Demand for agricultural products is increasing concurrently,

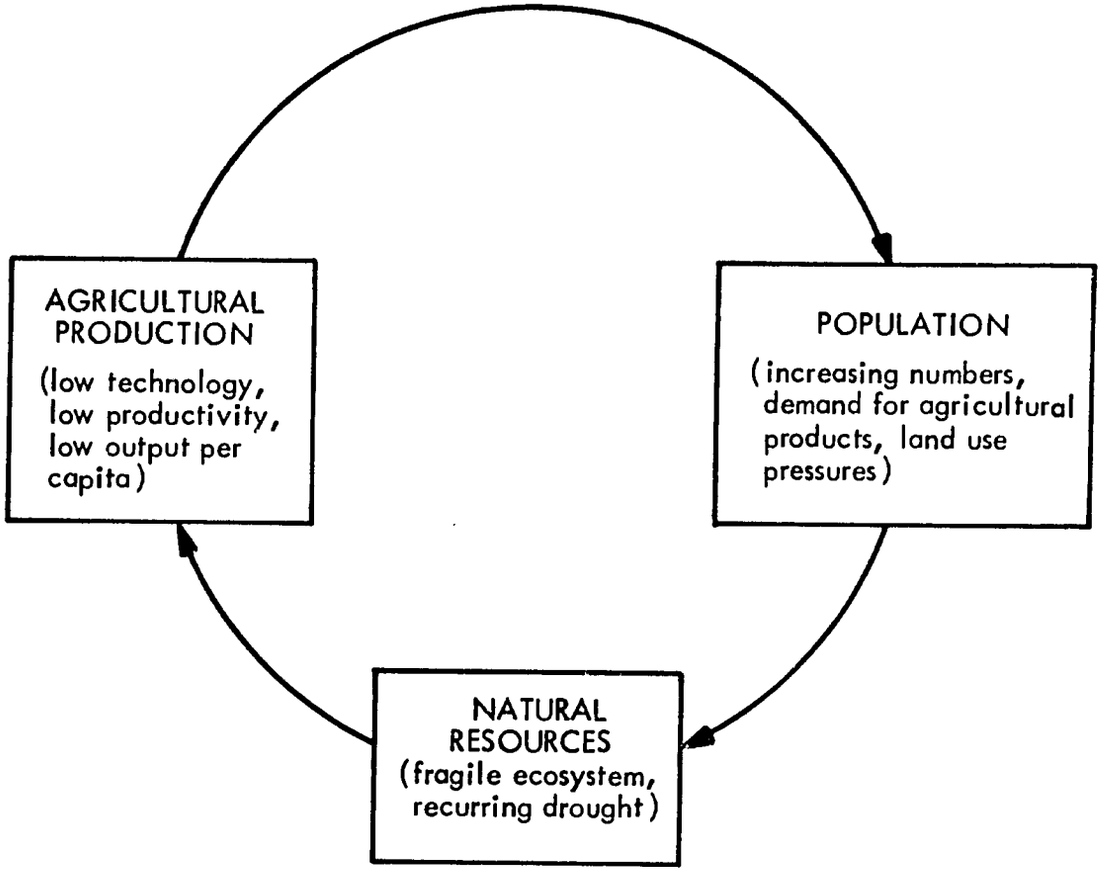

FIGURE 4.3 Population-Agricultural Production-Natural Resources Viscious Circle

presumably at about the same rate. Land use becomes more intensive. Productivity of individual land areas thereby will decrease as fallow time is reduced. Consequently income per capita also will decrease and the migration rate to the urban areas will become larger.

Continuation of existing land use practices under pressures of an even larger population portends greater destruction of the fragile ecosystem. Cyclical drought will occur and when it does devastation will be more widespread. Losses of arable soil by erosion of wind and water will be magnified. Without massive food aid, malnutrition and starvation will result. Some will occur regardless of aid. Each recurrence will be more serious than the preceding one.

There will be increasing conflict between the nomads and the sedentary farmers during drought periods. Increasing competition for scarce resources is inevitable.

The present support level of the agricultural sector by national governments and donor agencies will not break the vicious circle. The economy of the urban sector, because it is in contact with the world market, will continue to grow if only because of inflation, but the gap between the rural and urban sectors will widen.

4.6 Representative Projects Within the ISYALAPS Planning Framework

The principal objective of this study is to prepare a planning framework, not to propose projects. Ultimately, however, planning

must be translated into action or the effort will have been wasted. In agricultural development such action usually takes the form of individual projects. It is of critical importance in this case that the projects fit the ISYALAPS framework because the Sahel-Sudan is such an ecologically fragile region. In addition, they must be compatible with a selected strategy.

In Section 2, a matrix for project evaluation was proposed to enable the decision makers to consider a wide scope of possible project activities for a planning area and to insure completeness in their analysis. For the Sahel-Sudan region the four dimensional matrix provides for the vast size and consequent geographic variability of the region, its diverse social arrangements and the fragmented political structure and recognizes that financial and other resources are limited. Sub-sectors of the matrix are defined as follows:

I. Geographic

- A. Desert zone
- B. Subdesert
- C. Sahel zone
- D. Sudan zone
- E. Woodland zone
- F. Irrigated zone

II. Mode of Social Arrangements and/or Land Use

- G. Current nomad/village systems

H. Private ownership

I. Cooperatives (of groups either in G and H or both)

J. Contract and/or corporate ranching and farming

K. Complete government control

L. Other

III. Level of Implementation

M. Do nothing different

N. Minor (Activity Level A)

O. Extensive (Activity Level B)

P. Intensive (Activity Level C)

Q. Major (Activity Level D)

R. Other

IV. Political Unit

S. Local (village, ethnic group)

T. National

U. Regional

V. Other

From the above choices it is evident that there is a set of cubes each of which is made up of sub-cubes as shown in Figure 4.4. Various intermixes and intermediate combinations are possible but this matrix gives a total of 6 (geographic zones) x 6 (social arrangements) x 6 (levels of implementation) x 4 (political units) = 864 subcubes. Interpolation between appropriate subsets will suggest other possible situations.

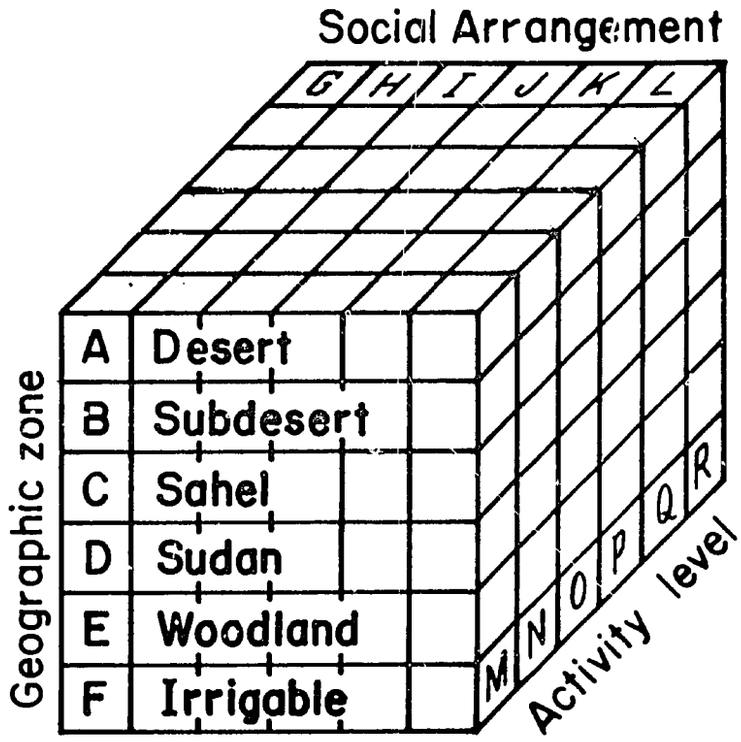

FIGURE 4.4 Matrix for Project Evaluation for Sahel-Sudan Region

Further, it is evident that some of these subsets (e.g., AGQS--Total resource development of the desert under current nomadic arrangements with a local political unit) approach null situations.

Each subset must then be analyzed for applicability of development activities and evaluated considering the parameters described in Section 2.

Four illustrative examples of possible projects which fit the natural resource based ISYALAPS planning framework for the Sahel-Sudan region are outlined below. A project description is given along with a listing of possible benefits, methods of approach and some preliminary questions to be answered before project approval.

4.6.1 Green belt establishment:

Project Code: AKQU (refers to matrix: a regional project, of major level, in the desert zone, requiring complete government control)

Abstract: This regional project aims at the establishment of a "green belt" to restore the natural vegetation of the northern Sahel. Appropriate grasses, shrubs, and trees will be selected and planted within fenced boundaries of a strip X kilometers wide along the northern edge of the region. Access of both people and animals will be strictly controlled. (Note: The establishment of a "green belt" can in no way be

construed as a protection or rehabilitation of the areas south of the "belt.")

Benefits: 1. Recover desert and make more grazing land available for the future.

2. Demonstrate range management techniques for an arid area.

3. Educate Africans in range management practices.

4. Promote regional cooperation.

Methods: 1. Fence both sides of a strip X kilometers wide, control access, permit no grazing initially, controlled grazing later.

2. Develop water resources as necessary to establish vegetation.

3. Plant grasses, shrubs, trees.

4. Use various management practices.

Questions: 1. How wide should the strip be?

2. What are costs per kilometer? (Fencing, seeds and plants, water resources development)

3. What is a reasonable time scale?

4. How many people (nomads) will be displaced? How will they be compensated?

5. How many professionals are needed? (Range managers, foresters, agronomists, etc.)

4.6.2 Extended family livestock production:

Project Code: CGNS&T

Abstract: This project will increase income from livestock production for a nomadic ethnic group on a defined area by applying range management techniques, controlling numbers of grazing and browsing animals, and introducing livestock management and veterinary medicine. National government provisions of guaranteed land use and market meat price are required.

Benefits: 1. Increase meat production and thereby income and quality of life for an ethnic group.

2. Restore productivity of range land.

3. Develop land use and market policies.

Methods: 1. Permanently assign to an "extended family" group a fenced or otherwise isolated area.

2. Provide technological assistance and supplies in livestock production, water development, and range management (medicine, vaccines, salt, and other mineral supplements, seed, brush control, herbicides, pesticides, fences, etc.)

3. Provide weight-based marketing facilities for livestock and make available foodstuffs and consumer goods for exchange.

4. Provide incentives to make it work, e.g., a "guaranteed" income.

Questions: 1. How large an area is involved?

2. How much would it cost?

3. What is the value of increased production?

4. What social restraints, benefits are involved?

5. What governmental policy changes are required?

6. What funding agencies will support it?

4.6.3 Government food production centers:

Project Code: FKQT

Abstract: This national project will produce food for X people on a Y hectare government owned and operated irrigated farm. All modern agricultural technology will be applied to obtain maximum productivity from each cultivated hectare. Jobs will be provided for Z workers.

Benefits: 1. Food will be provided for X people.

2. Modern agricultural technology will be introduced to the area.

3. Training will be provided for managers and others.

4. Jobs will be provided for Z workers.

Methods: 1. A sizeable farm (minimum 200 hectares) will be obtained in an irrigated area.

2. The land will be leveled and irrigation and

drainage facilities will be installed.

3. Buildings will be erected.

4. Machinery and supplies will be purchased.

5. A resident (expatriate) farm superintendent and local superintendent trainee will be hired.

6. Farming will begin.

7. Training programs of various levels will be organized.

Questions: 1. How much food can be produced?

2. How much will it cost?

3. How many jobs will be provided?

4. How many people will be trained?

5. What is the probable time scale?

4.6.4 Computer oriented natural resource inventory:

Project Code: A to ELOU

Abstract: This regional project will provide basic natural resource data for the six-country region. New methods of gathering, storing, and using extensive resource data will be investigated.

Benefits: 1. Needed basic data for agricultural development planning will be provided.

2. New methods for natural resource evaluation will be developed and perfected.

3. Africans will be trained in techniques of natural resource investigation.

4. Regional cooperation will be promoted.

Methods: 1. Modern sensing techniques will be used (satellite and aerial photos, etc.)

2. Field parties will establish ground truth and collate available information.

3. A computer-based, geo-referenced data collection, storage, and retrieval system will be developed.

4. Results will be supplied to regional and national planning agencies.

Questions: 1. How many professionals are required? (Soil scientists, hydrologists, ecologists, etc.)

2. How much will it cost?

3. What is the projected time scale?

4. How will the results be utilized?

The above are representative projects; many others are conceptually possible. Practical limits on the number of projects which can be implemented are set by financial and human resources among other factors.

5. USE BY THE DECISION MAKERS

Evolution of the ISYALAPS planning framework for the Sahel-Sudan region is a wasted effort if the methodology is not put to use. In this section the analysis procedure is summarized, and some of the possible users, actions to be taken, and procedures for use are discussed.

5.1 Summary of Analysis Procedure

Details of the procedure to be followed in applying the ISYALAPS framework were given in section 2. The procedure can be summarized in the following steps:

- Divide the planning area(s) into climatic zones.
- Decide what a possible alternative strategy will be. (Select activity levels for the various climatic zones and segments of the agricultural sector.)
- Make the land allocation for crops, livestock, etc. in each climatic zone. (Anticipate problems if allocations are substantially different than existing uses.)
- Determine percent of land cultivated (based on assumed fallow/cultivated land ratios) for climatic zones and activity levels.
- List possible crops for each climatic zone.
- Assume an assortment of crops for each climatic zone. (Existing crop assortments should be considered.)
- Prepare a productivity matrix for climatic zones and activity

levels. (Use information available in area and from similar zones in other areas.)

- Prepare tables of projected crop and wood productivity in each climatic zone for each activity level.
- Calculate production of each crop in each climatic zone.
- Convert food crops to calories and grams protein (or other indicator).
- Summarize food crop calories and grams protein.
- Summarize non-food crop production.
- Calculate wood production in each climatic zone.
- Estimate animal carrying capacities of rangeland for climatic zones and activity levels. (Use information available in area and from similar zones in other areas.)
- Estimate livestock system parameters.
- Calculate livestock (meat) production in each climatic zone.
- Convert to calories and grams protein.
- Calculate milk production in each climatic zone. Convert to calories and grams protein.
- Calculate poultry and egg production in each climatic zone. Convert to calories and grams protein.
- Calculate fish production in each climatic zone. Convert to calories and grams protein.
- Summarize agricultural production in calories and grams of

protein and kilograms of wood.

- Estimate human carrying capacity parameters.
- Calculate human carrying capacity of the planning area.
- Compare potential production and carrying capacity with existing situation.
- Determine impacts (benefits, effects on society, costs, etc.) of implementation.
- Iterate the process, if necessary.

5.2 Types of Users

The ISYALAPS planning framework can be used by planners and decision makers within and outside of the Sahel-Sudan region. National governments and donor agencies can benefit from its application to planning problems.

5.2.1 Country planners: At the present time central planning groups in all of the six countries of the region are struggling with the problems of agricultural development. Use of the ISYALAPS planning framework will simplify their task by permitting them to apply the principles of effective resource management and enabling them to answer more readily the questions they are asked about the potential for agriculture.

If country planners are able to balance the capability of the available natural resources and any proposed agricultural production from the planning area, their plans will be more realistic and have a much greater

chance of long-term success. The broadly conceived system analysis approach will assist them in identifying pertinent factors in planning and project preparation and in setting goals, selecting strategies and establishing priorities for action programs in the various climatic zones. Counterproductive activities can be identified and then modified or eliminated.

5.2.2 Donor agencies: The donor agencies can use the ISYALAPS planning framework in the ways outlined above as they seek to assist the Sahel-Sudan countries. Perhaps even more important for them is the use of the planning framework to coordinate the donor assistance. The Sahel-Sudan region is so large and the problems of agricultural development so serious that any wasted effort (or funds) is intolerable. (A brief respite from uncoordinated project activities is probably in order.)

5.3 Actions to be Taken

The ISYALAPS planning framework can lead to the preparation of general development plans for the region, a single country or other planning area as for example, the Niger river basin. It can also be utilized for small-scale project activities.

5.3.1 Plan preparation: A general policy for the agricultural development of a particular planning area is used to set goals for land utilization, agricultural employment, total production, etc. The

ISYALAPS framework can be used to prepare plans which test the compatibility of such goals. A critical test is the relationship of proposed goals and the carrying capacity, both human and animal, of the area.

The existing agricultural production system in the planning area can be compared with the plan developed by using the ISYALAPS framework. Some specific questions can be asked: What activity level is predominant in the various segments of agriculture in the different climatic zones of the planning area? Are all the required support systems for this particular level of activity operating effectively? If the answer is no, why not? What action can be taken to make them operative? If the answer is yes, then new goals can be set, perhaps at the next higher activity level or some appropriate intermediate point.

Planning is a dynamic process and the best test of a plan is its use. After a plan is implemented, modifications are then made as necessary. The ISYALAPS framework permits the planner to manipulate relationships as desired particularly natural resource relationships.

5.3.2 Project evaluation: Individual project activities can be tested for their ability to fit within the planning framework. Any project which stresses the natural resource base of the Sahel-Sudan region beyond its sustained ability to produce is doomed to failure within a short time.

The matrix for project evaluation (Figure 4.4) provides the basis for project classification. Projects which are similar can be identified

to avoid duplication, and comparative evaluations can be made with previous or existing projects.

5.4 Procedures for Use

A guide to the use of the ISYALAPS planning framework (a systems analysis approach to natural resources utilization) is given below. Project evaluation procedures are also discussed.

5.4.1 Planning: The ISYALAPS planning framework was described in section 2. (A concise summary of the individual steps in the analysis procedure was given earlier in this section.) Then in section 4 the framework was applied to the Sahel-Sudan region and to Mali as examples of its use.

The procedure used in those examples is valid for use of the methodology in actual planning for the Sahel-Sudan region. However, many of the estimated or assumed parameters used in the examples will need revision. The values used in this study were determined from the best information available, but as was previously indicated, in many cases the data were woefully inadequate. The framework can be made more operational by getting additional cost information.

Planning cannot be done in a vacuum. The existing agricultural production system may not be compatible with any plan, but identification, and where possible, quantification of the differences are essential so conflicts can be eliminated or at least minimized.

5.4.2 Evaluation: Projects or packages of projects may be proposed. The ISYALAPS framework will lead planners to direct their attention to the most productive actions.

Evaluation procedures can be applied to a plan or a project. Some of the criteria for evaluation were identified in section 2. Planners are particularly concerned with the question of where to spend limited funds. A step by step procedure which might be used for project evaluation in the Sahel-Sudan region is outlined below.

- Classify the project according to the matrix for project evaluation.
- Ascertain that the project fits the natural resources framework (ISYALAPS) and other goals of the planning area.
- Determine whether similar or duplicating projects have been implemented or proposed in the area.
- Determine success or failure of such projects and reasons therefore.
- Identify in project design those features designed to avoid known causes of failure.
- Determine the availability of, or provisions to supply required inputs and infrastructure.
- Measure the adequacy of financial and other resource commitments of donor and recipient.
- Determine the time frame for implementation and completion of

the project.

- Identify the factors which can be used to measure project success.
- Rate the project for priority against other proposals.

A proposal will then either be approved or rejected by the decision maker(s) on the results of the evaluation procedure.

6. CONCLUSIONS AND RECOMMENDATIONS

This effort provides a framework for planning, not a plan, and although the study is incomplete in the sense that much remains to be done to solve the problems of the Sahel-Sudan region, certain conclusions can be drawn from the results of the analysis to date. Recommendations also can be made, not of a prescriptive nature, concerning what should be done to guide activities of the six countries and the donor agencies in the immediate future and to make this study more complete.

6.1 Conclusions

The following conclusions were made on the basis of information collected and analyzed during the course of the project. Additional, more exact data would strengthen but not materially change them.

6.1.1 Climate: The current drought is not permanent and no major climatic change has occurred in the recent past nor is there any indication that such a change will occur in the near future (50 to 100 years). What there will be is a continuation of major multiannual variations from the mean resulting in drought periods as well as pluvial periods, perhaps four or five times each century, lasting up to 6, 7, or even 18 years.

6.1.2 Environment: The fragile environment of the Sahel-Sudan region has been greatly harmed by unconstrained land use practices and at the present time is badly out of balance. Effective natural

resource management is required to correct this condition. Regional and/ or country plans which recognize environmental and natural resource limits to agricultural development are needed to halt further degradation and desertification and to initiate range and farmland recovery. The problem of maintaining balance will necessitate continued, careful monitoring of the ecosystems throughout any development projects.

6.1.3 Wildlife: Wild animals will continue to provide some protein in the diet of the inhabitants of the Sahel-Sudan region. However, with increasing human population and widespread ecosystem modification, most large game species will disappear from much of the region. A strong game reserve system is necessary immediately if certain species are to be saved. By promoting tourism, revenue to operate the system (and some profit) might be obtained.

Developing game harvesting at the expense of limiting domestic animals does not appear to be viable. Game ranching with selected species shows some promise of economic feasibility in certain areas.

With further ecological change some wild animals may become major competitors with man for the agricultural production.

6.1.4 Agricultural production: Agricultural production was examined from two viewpoints. First the existing system was evaluated; then the potential productivity of the region within the limits of available natural resources was studied using the proposed ISYALAPS planning framework. Conclusions reached are completely different in the two cases.

6.1.4.1 —Existing situation: The existing agricultural production system is part of a vicious circle including the growing population and limited natural resources of the Sahel-Sudan region. Operation of this system over the past decade and particularly during the recent drought has contributed directly to the problems of desertification, reduced productivity, soil erosion, and deforestation. Combined pressures of population and the export-oriented economy resulted in increasing use of marginal lands for food production. Animal numbers increased for the same reasons but also for lack of other savings opportunities. With the ecosystem badly out of balance, the consequences of the drought were inevitable.

The social costs of continuing this agricultural production system are staggering, with recurring and increasingly severe famine, starvation and need for relocation of distressed people and animals. Actual monetary costs are also high in terms of continuing requirements for technical assistance and massive food relief and the lost productivity from the region.

6.1.4.2 —Potential: The Sahel-Sudan region can be made significantly more productive than it is or has been. Application of an integrated strategy, which is only one of many possible strategies, clearly demonstrates this potential. Control of land use and changes in the social system will be required, but substantial progress can be made with relatively low level (and low capital) technology. Most of the

region is best suited for livestock grazing. More intensive agriculture has greater potential in the wetter and irrigated zones where a considerable increase in irrigation would be needed. Self-sufficiency in food can be realized for the present and near future. Production for export can also be increased. Quality of life for the rural population can be improved, but to do so the number of people gainfully employed in agriculture will be reduced.

A strategy which calls for constant Activity Level B for the agricultural sector will not produce enough to support the existing population, let alone any increase in population which might occur. However, many segments of agriculture already are operating above this level, and, more important, must continue to do so unless human population in the region is reduced.

Intuitively, it can be seen that Activity Level A alone would support even fewer people. Nonetheless, the entire agricultural sector ultimately must attain at least Level A if a sustained yield status is to be achieved.

6.1.5 Requirements for implementation: Broadly conceived and adequately implemented programs will be required to break the population-agricultural production-natural resources vicious circle. Governmental emphasis on agriculture will need to be increased and administrative organization and capacity improved. Incentives will help to make the necessary changes in the agricultural system and increase

production. Project activities, particularly in the irrigated zone, appear to be profitable enough to attract private capital.

Regional cooperation is essential for several reasons. Livestock control in one country alone will not halt overgrazing problems because of the movements of animals across unpatrolled borders. The major river systems of the region lie in several countries; water resources development thus requires international agreements. The coastal nations to the south of the Sahel-Sudan region provide an outlet for surplus production which is an important factor in regional planning.

Not to be overlooked in establishing action programs for the region are the social-political-economic constraints. Their removal or reduction is required for project success.

6.1.6 The ISYALAPS planning framework: The ISYALAPS planning framework was evolved because it is an essential step for future planning, it is unsophisticated and more easily understood than complex models, and furthermore, it does not require large amounts of input data. A regional viewpoint was taken because of the geographic vastness of the problem, the climatic similarities and already shared water resources, and general parallelism of existing agricultural production systems. The activity level concept allows planners in the six countries to set their own priorities and to integrate according to their desires the arid north with the more humid south, while recognizing the environmental constraints.

The systems analysis approach to natural resources utilization as a basis for agricultural development planning in the Sahel-Sudan region is a way of organizing the agricultural sector. It is a micro approach to global planning with emphasis on physical relationships. Natural resources and their limitations are now being recognized for their importance to development. Lester R. Brown (1974) recently stated:

> Those of us who are economists forget that the economic structure man has erected rests entirely on the earth's natural resources and processes. Economic activity depends on the earth's capacity to produce food, to absorb waste, to supply fresh water and energy fuels, to produce forest products and fish, and to supply minerals and other raw materials.

One may question the accuracy of the results of applying the methodology, and rightfully so, when it depends so heavily on assumptions and estimates. By selecting conservative values for productivity factors based on areas of similar climate and soils (as was done in the examples of Section 4), the planner can avoid the common pitfall of over-optimistic production estimates. Any error should be on the conservative side, however, extreme conservatism may mal-allocate resources. In any event, the flexibility of the method and its inherent completeness facilitates changes or additions as more data and more exact data become available.

The assumed human carrying capacity factors are founded on a strong conviction of the need to provide agricultural workers and their

families with a viable production unit in terms of numbers of animals or farmed area. Division of agricultural resources based solely on population loses sight of the fact that not everyone can be a good farmer, and some definitely can be encouraged and aided to seek other employment. If income per capita is to be increased in the agricultural sector, a decline in numbers of agricultural workers is inevitable. This argument does not ignore the possibilities for labor intensive practices in the more humid and irrigated zones, and increased employment in infrastructure occupations.

Many simplifications had to be made in dealing with the vast size and complexity of the Sahel-Sudan region. No externalities were included, and a major weakness of the study is found in the economic analysis of existing and potential agricultural production.

6.1.7 Limits of data: Shortcomings of the available agricultural production data were pointed out in Section 3. Comparisons of existing and potential production would be more meaningful with: (1) reporting by climatic sub-areas, (2) separation of all crops, (3) separation of animal types, and (4) generally increased accuracy.

The activity level concept is not fully developed and considerable research is needed to make it complete. Estimates of potential productivity in the Sahel-Sudan region under the lower activity levels (A and B)

seem low in comparison with reported figures. The estimates are based on available moisture in the particular climatic zone during the growing season and are backed up by some experimental results (not necessarily with the same crops). Unfortunately, little attention has been given in the U.S. or other developed countries to determination of crop production functions with less than optimum water available. The same lack exists for less than optimum levels of technology, management, and other inputs. More data would have been useful.

There is some evidence that the area reported as being farmed in any one year is not really well known. The fallow system for restoring productivity depends on an undetermined but not indeterminant time for the land to rest before being cultivated again, and more exact land use information would permit accurate determination of fallow/cultivated land ratios being used in the region.

The information regarding the population engaged in various agricultural pursuits was extremely uncertain. No data were found concerning the number of fishermen in most countries nor the number of woodcutters. In some cases, estimates of particular populations varied by an order of magnitude.

A significant improvement in the data base will be required for more detailed agricultural development planning in and for the Sahel-Sudan region. Both the quality (accuracy) and quantity of information need to be improved.

6.1.8 Unsupported media statements: Much sensationalism has accompanied the reporting of the plight of the Sahel-Sudan region. Someone's unsubstantiated opinion is overheard and picked up by a journalist. The statement then appears in print and thereby automatically gains authenticity. The following items are in this "no-evidence" category.

6.1.8.1 —Groundwater reservoirs: "Vast reservoirs of easily available groundwater underlie the region just waiting to be tapped for irrigation." Isolated areas with some potential for groundwater development occur in parts of the region. Deep consolidated rock aquifers occupy much of the subsurface. Their exact potential is unknown, but they probably will supply stock and limited domestic water. (Stock water for 10,000 animals is only enough to irrigate about 10 hectares.) There is no evidence of aquifers having the potential for extensive irrigated agriculture development on a long term basis.

6.1.8.2 —Breadbasket of Africa: "Properly managed, the Sahel-Sudan region can be a breadbasket supplying food (beef) for half of Africa." Agricultural production from the region can be increased but it is extremely unlikely that production for export, even under the best management, will increase significantly in the next few decades.

6.1.8.3 —Desert encroachment: "The Sahara Desert is encroaching on the Sahel-Sudan region at a rate of 20 to 30 miles a year." Desertification is a process which occurs in place, not as an

advance of an existing desert. Sand dunes may move as a result of wind and water forces, but not at rates in excess of a few meters per year.

6.1.8.4 —Intransigence of nomads: "There is no way short of a major social upheaval, that the nomads will consent to reduce their herds." Nomads are wise in the ways of the desert and have evolved a system which permits them to survive in the face of adversity. However, the intervention of Western civilization and then granting independence to resource-poor nations have imposed constraints on the system. Nomadic people respond to incentives just as others do, and, as a result of changes in the social or economic or physical environment have indicated their willingness to adapt their way of life.

6.2 Issues Arising From Implementation

Implementation of an improved agricultural strategy would result in impacts on the various sectors of the society of the Sahel-Sudan region. Some of the impacts are pleasant, for example, the prospect of increased availability of food. In other cases, an issue is raised for which this study can provide no answer. The issues identified below are not the only unresolved issues but include those which are most readily apparent. In most cases, a new or strengthened governmental policy will be required to deal with them.

6.2.1 Grazing limitations: The principal problem of the Sahel-Sudan region is the unrestricted grazing on low productivity

rangelands. In the recent past no control of range use has been exercised; formerly tribal chieftains apparently controlled land use to some extent. Solution of this problem requires some form of controlled livestock use.

6.2.2 Insecurity of tenure: Farmers or herders are reluctant to invest time (labor) or money in land improvement practices when there is no assurance that they will receive any benefits from such practices. The land tenure (or ownership) system in the Sahel-Sudan region is a confused one at present and will have to be stabilized in some way before long term productivity increases can be obtained.

6.2.3 Equitable income distribution: The income gap between the rural and urban sectors is widening. There are many reasons why this is happening. Among them are price and tax policy, emphasis on export crops, unstable markets, shortage of credit, etc. The major incentive for farmers and herders to produce more is a larger share of the profits. Governments can promote more equitable distribution.

6.2.4 Weak infrastructure: The Sahel-Sudan region is a classic example of the lack of infrastructure in support of agriculture. No attempt is made herewith to provide specific details of the needs of the other sectors, for example, transportation and water resources. The infrastructure needs to be measurably strengthened before significant production increases can be obtained.

6.2.5 Population in agriculture: The integrated strategy within the ISYALAPS framework, if implemented, would provide sufficient food for the existing population of the Sahel-Sudan region on a long term basis, and perhaps, even provide a cushion for future population growth. However, the number of people (and families) who can be directly employed in agriculture and have a reasonable income in this example of an agricultural strategy is less than half of the total at present and will decrease as higher activity levels are introduced into the agricultural production system. Labor intensive production systems may absorb some of the imbalance. Welfare camps can be established but ultimately some meaningful employment will be required for millions of people.

6.3 Recommendations

A study of this type, in which a planning framework for the Sahel-Sudan region is proposed and tested, cannot be expected to produce solutions for all the ills of the region. Nevertheless, the study by taking a broad and hopefully somewhat detached view of the overall problem, does point out some areas for possible action of a general nature. The study, itself, can be improved and made more complete. However, a balance must be achieved between the need for more study and the need for action.

6.3.1 Recommendations for the region: A number of steps can be taken immediately which will facilitate agricultural projects in

the future. The inherent time lag between study and implementation emphasizes the need for action now.

6.3.1.1 —Priority establishment: No additional agricultural development projects should be initiated until priorities have been established. This will prevent dilution of both human and monetary resources. Projects must fit within an overall planning framework (such as ISYALAPS) and recognize environmental constraints. Because the rural areas will, for the foreseeable future, remain the backbone of the economy, emphasis should be placed on programs to improve productivity in rural areas, but agricultural development projects should not be thought of primarily as a means of controlling people movements.

Furthermore, commitments for large-scale projects, such as river valley development programs, should be delayed until an understanding of the full ecological, social, and economic implications is achieved.

6.3.1.2 —Evaluation group: A team with substantial experience in arid lands agriculture and with African representation should be organized by the donor countries and agencies to evaluate and approve all agricultural project proposals for the Sahel-Sudan region before funding is authorized.

6.3.1.3 —Project evaluation: Methodologies for evaluating the success or failure of past, present, and proposed agriculturally oriented projects in the region should be utilized. Mistakes

of the past should be avoided; successes should be copied.

6.3.1.4 —Data bank: A central data bank (library) should be established in the region as a repository for pertinent agricultural (and other) information. Adequately trained staff and copy facilities should be provided to serve the needs of resident and foreign users.

Steps should be taken to upgrade the existing agricultural data collecting system in each country. For example, efforts should be directed towards the establishment of additional weather stations to supply farmers with forecasts to help determine when to plant crops.

6.3.1.5 —Drought relief: No known strategy can provide drought-proofing, but funds and technical assistance should be provided for the establishment of an effective regional program for the storage of food and water reserves (for both people and animals) to meet the demands of probable future drought years. The program should include a system of equitable distribution.

6.3.1.6 —Agricultural program support: Support is required specifically for the ministries of agriculture and rural development in the Sahel-Sudan countries, to upgrade their capabilities for instituting agricultural and rural improvements in their respective countries. Some of the areas requiring immediate attention are listed below:

— Strengthening of the national civil service organizations and bureaucracies in agriculture including study of legislation

and national plans for development.

- New patterns of extension services to get basic information to farmers and herders.
- Establishment of rural credit and banking systems for agriculture.
- Linkages with international agricultural research centers in Nigeria and other English and French speaking African countries.
- Training for planners and other personnel in agricultural disciplines.

The productivity of the Sahel-Sudan region has suffered from serious overgrazing. Restoration of productivity will occur only if the grazing intensity is reduced. Consequently, advantage should be taken of the fact that the drought has reduced the size of the herds. Although selective reconstitution of some herds may be desirable, requests for support to restore the herds to their pre-drought size should be resisted strenuously.

6.3.1.7 —Use of new technology: New technology should be used wherever possible in solving the agricultural development problems of the Sahel-Sudan region. Some of the items below were taken from a preliminary M.I.T. Sahel-Sudan Project report (Rao and Soussou 1974).

- Technologies for delivery of agricultural information to dispersed populations including TV and radio.

- Curriculum and textbook development and alternatives for packaging and dissemination of agricultural educational programs in local languages.
- Popular science films to illustrate the fragility of the ecology of the region and agricultural problems of the region for use among adults and school children.
- Unconventional protein sources including oil seeds, legumes, grass, and wood.
- Processes for conversion of agricultural wastes into food and feed.
- Water conserving techniques:

  Drip irrigation

  Hydroponics

  Impervious layer to reduce deep seepage

  Water harvesting for food production
- Fertilizers:

  Nitrogen fixation by enzymes

  Agricultural wastes for fertilizers
- Refrigeration devices using solar energy
- Enriched bread based on cassava or millet flour
- Space technology for communications, weather monitoring, and surveying (satellites, ERTS, magnetic field distortion)
- Rice husks, bamboo and local materials in the construction

industry

- Computers and data banks
- Low maintenance and solar powered pumps
- Conversion of cellulose and wood to alcohol, methane

6.3.2 Recommendations for agricultural research: Priority should be given to applied research related to crop and livestock production in the Sahel-Sudan region. Basic scientific research is also needed, and some research is required before implementation of an agricultural strategy.

6.3.2.1 —Basic research: An understanding of the climatology and plant, animal, and human ecology of the region is an essential prerequisite to planning for development. Among the arid regions of the world, the Sahel-Sudan is one of the least understood. Statements regarding problems and potentials of the region are often based on hearsay or generalizations from experience elsewhere. A list of appropriate projects would include the following:

- Monitoring climatological variations, rainfall, evaporation, long range forecasting
- Location and evaluation of groundwater aquifers, position and changes in water tables
- Soil maps, soil chemistry and salinity, fertility (responses), erosion, and structural changes
- Measurement of rates of desertification

- Studies of species of plants and their distribution
- Population studies of animal species
- Relations between degradation of grazing lands and reduction of wildlife
- Insect pests, effect on reestablishment of desert vegetation

6.3.2.2 —Range management: Research needs in range management include the following activities:

- Identification of grass types for optimum production with single season rainfall and extreme climatic variability
- Determination of best grazing intensities and management strategies (carrying capacities) for cattle, sheep, goats, camels in various climatic zones
- Identification of methods for range rehabilitation
- Definition of range sites and productive potential
- Preparation of standards for evaluating range condition and trends

6.3.2.3 —Dryland farming: Substantial improvements can be made in dryland agricultural practices. Adaptive research of the following types is needed:

- Identification of soil and water conservation and fertilizer practices for maximum long term production on small, non-mechanized farms
- Improved varieties (higher yield, faster maturing) of millet,

sorghum, corn, cowpeas, etc.

- Utilization of natural nitrogen sources on small, non-mechanized farms to reduce fallow time
- Introduction of new garden crops for improved nutrition
- Low cost grain storage facilities for small non-mechanized farms
- Integrated crop and livestock production on small non-mechanized farms

6.3.2.4 —Livestock production: Animal offtake rates can be greatly increased. Research of the following types is needed to bring about such improvements:

- Selecting and breeding for improved production from small herds
- Increasing reproductive efficiency in high temperature environments
- Determination of nutrition requirements

6.3.2.5 —Economic studies: Economic research, including the following, is necessary as a basis for development planning:

- Analysis of the microeconomic aspects of land, labor, and capital use
- Evaluation of current management practices of farmers and herders emphasizing attitudes and actions with respect to risk and uncertainty also focusing on the joint consumer and

producer decisions

— Evaluate the current marketing system for crop and livestock products and factors of production

6.3.3 Recommendations for refinement of the ISYALAPS planning framework: The following activities are important for the agricultural sector analysis of the Sahel-Sudan region (or other area) under a continuation of this or similar projects.

6.3.3.1 —Systems analysis: The analysis already made should be refined, filling in data gaps and revising coefficients, etc. Particularly needed are more exact information on activity levels and their costs and benefits. Simple computer programs to use the methodology developed should be written and tested. This will permit rapid evaluation of alternative strategies.

6.3.3.2 —Planning units: The ISYALAPS planning framework has particular data needs. Geographic detail for planning purposes should be increased by disaggregation of the Sahel-Sudan region; isolated areas with potential for immediate, high priority actions should be located. Existing data on current agricultural production should be collected and assessed.

7. SUMMARY

7.1 Introduction

7.1.1 Project description: The major objective of the agriculture study was to construct a planning framework to assist decision makers in selecting alternative strategies for long-term agricultural development in the Sahel-Sudan region, an area with limited natural resources and no extensive mineral wealth or energy resources.

The approach to this task began with identification of the problem through collection and analysis of data concerning climate, ecology, and the agricultural production system. A systems analysis approach to natural resources utilization was evolved as the ISYALAPS* planning framework which was then applied as an example to predict potential agricultural production in the region under alternative strategies. A matrix was created to evaluate project activities for various segments (s bsectors) of agriculture. Conclusions and recommendations which result from the analysis were made.

This effort does not encompass the whole gamut of agricultural development planning. It provides a first step for the decision makers--a method to assist them in making rational decisions.

7.1.2 Geographic setting: The six-country Sahel-Sudan

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*Integrated Sustained Yield Arid Lands Agricultural Production Systems

region (Chad, Mali, Mauritania, Niger, Senegal, Upper Volta) encompasses part of the southern Saharan Desert and adjacent semi-arid savannas. It extends 1950 km from north to south and 4400 km from east to west, and has a total area about 1.7 times that of Western Europe and equal to 67 percent of the area of the United States. The region is sparsely populated, particularly in the drier parts.

The elevation ranges from sea level to 3417 m in the mountains of northern Chad. Four major rivers flow through the region: the Senegal, Niger, Volta, and the Logone-Chari, which flows into Lake Chad.

7.2 The ISYALAPS Planning Framework

A planning framework was created to assist decision makers in evaluating alternative strategies for integrated sustained yield arid lands agricultural production systems (ISYALAPS). Its basis is quantification of the natural resources for agricultural production in a planning area using a systems analysis approach according to the following:

a. Productivity is different in different ecosystems

b. Productivity can be exploited without ecosystem degradation

c. Productivity can be increased by technology, management, and other inputs

Planning constraints are identified, and the potential for sustained production in different climatic zones is established with four optional activity levels for implementation. Impacts of an arbitrarily selected

alternative strategy (mix of activity levels) then are evaluated and human carrying capacity is determined. A comparison with the existing situation is made and finally a matrix for project evaluation is used.

7.2.1 Nature and purpose of planning: Planning is the essence of management and a vital part of modern life. It aims to transform a subsistence economy into a modern one. Planning must account for constraints, set priorities and resolve conflicts. It must adjust to the human and economic situation and available resources.

7.2.2 Constraints to development: Climate constraints limit agricultural productivity; weather variability can be a critical factor. Drought and pluvial periods will occur with more frequency and severity in arid and semiarid areas.

Ecologic constraints also are paramount in arid or semiarid areas. Ecosystem destruction is quick and easy but reconstruction is slow and difficult. Many arid and semiarid areas suffer widespread overutilization by grazing and browsing. Moist periods may lead to excessive human and animal populations and cultivation of marginal lands. Rapid ecosystem degradation then occurs with a return to average or drought conditions.

Most changes in agricultural development occur slowly. The U.S. example shows that a series of laws passed over a 60 year period providing funds for education and research, regulating land use and conservation, and establishing credit and other assistance for farmers was

necessary to establish the present high intensity agricultural system.

Primitive food production systems provide from 5 to 50 food calories for each calorie of energy invested. Industrialized systems provide only about 0.1 to 0.2 calories for each calorie of fuel. Current energy supply problems focus concern on energy use, but use of wind and animal power, animal manure and green manure crops, and limiting chemical inputs can reduce energy needs significantly without sacrificing output.

There are many institutional and attitudinal obstacles to development. Agricultural planning must take account of human needs, but many factors are exogenous to agriculture.

Development requires financing and resources are usually limited. Technical assistance and food aid may be required. Farmers want to receive a fair share of the profit from export crops as well as other economic incentives. Demand for agricultural products is a critical factor.

7.2.3 Systems analysis approach: Systems analysis is a process of examining the total agricultural production system, which includes determination of relevant factors, quantification of relationships, and calculation of effects of following various strategies. It provides insight into what ought to be or can be done and helps determine priorities.

7.2.4 Natural resources utilization: Natural resources are the base for agricultural production and also its upper limit. Evaluation of natural resources provides guidelines regarding development.

7.2.5 Description of the ISYALAPS planning framework: The analysis procedure which constitutes the ISYALAPS planning framework involves a sequence of about 25 steps depending on the complexity of the planning area. They can be summarized as follows:

(1) Division of the planning area into climatic zones. Where sufficient water resources are available, irrigable land is considered as a separate zone. Some form of agricultural production ordinarily is possible in each zone.

(2) Definition of four activity levels for implementation to provide alternatives for decision makers.

Level A - Minimum activity with impact, seeks ecological balance.

Level B - Extensive management activity, enlarges the production area.

Level C - Intensive management activity, applies technology, management, and some inputs.

Level D - Maximum activity, uses all available technology to maximize production.

(3) Selection of an arbitrary agricultural strategy (or strategies), which is a mix of activity levels for the different segments of the agricultural sector in the various climatic zones. Many strategies are possible but tradeoffs are involved in production

factors, impacts, etc. There is a benefit-cost relationship associated with each activity level and climatic zone.

(4) Allocation of land in each climatic zone to specific agricultural purposes. Lands are allocated according to their most appropriate agricultural use, keeping in mind the constraints of existing uses in the zone.

(5) Determination of potential crop and wood production. Total production under the arbitrary strategy is calculated. The process includes selection of a fallow/cultivated land ratio, choice of crops, and determination of effect of activity level on productivity. Production is measured in calories and protein for food crops and kilograms for non-food and wood crops. Total calculated crop output is reduced to account for animal consumption.

(6) Determination of potential livestock production. Livestock production under the arbitrary strategy is calculated by estimating carrying capacity and assuming production parameters such as fertility, mortality, and offtake (percent of herd removed for consumption or sale). Total production is converted to calories and protein content.

(7) Determination of potential production of milk, poultry, eggs, and fish. Similar procedures are used to calculate calories and protein from these sources. Quantities of agricultural

by-products (hides and skins, cottonseed, etc.) are also estimated.

(8) Summation of potential production. Production from all segments of agriculture is combined in terms of calories and grams of protein for food products and kilograms for non-food products for the entire planning area under the selected strategy.

(9) Estimation of carrying capacity, surpluses, and shortages. Human carrying capacity is calculated after correcting total production for losses in transport and storage. The number of people who can be productively employed in agriculture is estimated.

(10) Comparison with existing situation. Potential production and human carrying capacity are compared with those obtained under the existing agricultural production system. (Data limitations may make such comparisons difficult.)

(11) Determination of steps necessary for implementation. Implementation of an agricultural development strategy requires action by local and national governments, the private business sector, individual farmers, and the donor agencies. Changes are needed in policy, legislation, programs, and the indirectly related social-cultural area. Certain inputs, infrastructure and trained personnel are needed. Required steps are tabulated. Time required for implementation is estimated.

(12) Determination of impacts. Implementing the strategy will have obvious impacts on the agricultural sector but also on other aspects of the society. Cost-benefit analysis is used to evaluate quantifiable impacts but social impacts are approached subjectively.

(13) Iteration with alternative strategies. The first trial of the use of the ISYALAPS planning framework will not answer all the questions of development, and changes over time necessitate frequent revisions. Other alternatives are prepared and tested.

7.2.6 Matrix for project evaluation: A matrix for project evaluation was designed as part of the ISYALAPS framework to provide for completeness of analysis of action programs arising out of any selected strategy which will have a long-term impact on agricultural development. Dimensions included are: (a) geographic (location and climate), (b) social and/or land use arrangements, (c) activity level (an economic dimension), and (d) political. The matrix thus takes account of geographic variability, social diversity, and political structure, and recognizes financial and other resource limitations. Proposals which fit the framework can be further evaluated and priorities can be set.

7.2.7 Evaluation criteria: Project proposals can be evaluated only after goals for the agricultural (and other) sectors of the economy have been set by the government(s) concerned. Guidelines for measuring the acceptability of projects can be set up. Questions should be asked

concerning possible conflicts with goals, success of similar projects, financial and other demands, costs, benefits, need for inputs and infrastructure, methodology to measure project accomplishments, time framework, and restraints to project success.

7.3 The Agricultural Problem of the Sahel-Sudan Region

7.3.1 Climate: Climate in the Sahel-Sudan region varies from that of a hot desert to that of a dry subtropical woodland. Rainfall ranges from less than 100 mm/yr. in the north to more than 1250 mm/yr. in the south.

Most of the region receives its rainfall from a monsoom system. Significant geographic and temporal variations of weather often occur, generally most extreme in the more arid zones. As a general rule, there is one day in the growing period (wet season) for each 5 mm of annual precipitation.

Temperatures range from warm to hot, with only stations in the mountains of northern Chad ever recording temperatures below 0 C. Stations in the northern areas have recorded maximum temperatures over 50 C. Temperatures are low in December-January and again during the wet season.

During the dry season, the region is under the influence of dry northeasterly trade winds. At the beginning of the wet season violent winds associated with thunderstorms are common. Later in the wet season, southerly monsoon winds dominate.

The level of solar radiation is high, with few cloudy days recorded other than during the rainy season. Relative humidity is generally low. Evaporation rates are high.

The weather patterns permit the definition of five climatic zones of varying width lying across the area from east to west whose boundaries are based upon rainfall and vegetation. From north to south these zones are:

desert: less than 100 mm annual rainfall, fewer than 10 rainy days per year, 36 percent of the region.

subdesert: 100-300 mm annual rainfall, 10-25 rainy days per year (July-August), 28 percent of the region.

Sahel: 300-650 mm annual rainfall, 26-46 rainy days per year (June-September), 17 percent of the region.

sudan: 650-900 mm annual rainfall, 50-65 rainy days per year (May-October), 10 percent of the region.

woodland: over 900 mm annual rainfall, 65-80 rainy days per year (May-October), 9 percent of the region.

Few weather stations with continuous records covering more than 30 years exist in subSaharan west Africa. One of the longest records from Dakar, Senegal, for the period from 1887 to date exhibits typical patterns of alternating ups and downs, especially in rainfall.

Reports indicate that the years preceding the current drought were wetter than normal (a "little pluvial" period) throughout the region. One

indicator was that the levels of Lake Chad were higher from 1955 to 1965 than at any period since 1907. Records show that increased precipitation occurred throughout the region and not just in the Lake Chad basin. The Lake Chad data also reveals that the levels during the current drought are no lower than they were during the 1913-1915 and the 1941-1943 periods.

The north-south shifting of isohyets (lines of equal rainfall) during wet and dry periods is more pronounced in the northern, drier zones than in the southern Sahel and woodland zones. At least during 1970-72, the drought was more severe in the western part of the region. The effects of the wet period appear to have been relatively uniform throughout the region.

Recurring droughts of varying lengths have been reported in historical records since the 16th century. Of the 22 droughts listed, 6 lasted 1 year; 8 lasted 2 years; 2 lasted 3 years; 1 lasted 4 years; 4 lasted 5 years; and 1 lasted 18 years (1738-1756). During the past 20,000 years, the Sahel-Sudan has varied from much wetter than present to drier. Some researchers consider the pluvial periods as being more the result of decreased evaporation from lower temperatures than the result of increases in rainfall.

Many people have been concerned with the possibility that mankind's modifications of environment have had significant impacts on climate. That increases in carbon dioxide and particulate pollution in the atmosphere have caused any major climatic shift in the Sahel-Sudan

region is not at all evident.

7.3.2 Plant and animal ecology: West Africa has three major vegetation belts that more or less correspond with the previously defined climatic zones: the northern desert, the savanna, and the southern woodlands. Each is further subdivided into vegetation zones.

Desert belt. Desert zone (below 100 mm annual rainfall). In a few places, but formerly more extensively, the vegetation consists of scattered areas of small perennial trees, shrubs, and grasses.

Subdesert zone (100 to 300 mm annual rainfall). This is a moist version of the desert, with more scattered, perennial, woody vegetation. Grasses and herbs are more widespread.

Savanna belt. Sahel zone (300 to 650 mm annual rainfall). The vegetation consists of scattered acacias and other thorny, narrow-leaved trees and bushes interspersed with short grasses below 40 cm in height.

Sudan zone (650 to 900 mm annual rainfall). This zone has scattered taller trees, often broad-leaved and deciduous. Between the trees are tall perennial grasses. Where conditions restrict fires, forests develop.

Woodland belt. Doka woodland zone (950 to 1400 mm annual rainfall). The Doka woodland is characterized by large numbers of trees that are deciduous during the four to six month dry season when widespread fires also occur.

Guinea woodland zone (1400 to 1800 mm annual rainfall). This zone is characterized by trees that include fewer deciduous species. The dry

season lasts only 3 to 4 months.

High forest zone (over 1800 mm annual rainfall). This is a rain forest, with a diversity of trees including broad-leaved evergreens. The dry season is short, often only a few weeks during which relative humidity remains high.

Hunting and trapping has provided food for many Africans. Sedentary farmers and nomads continue to utilize varying amounts of wildlife as food. Big game species are often assumed to offer potential as meat sources, and recent newspaper articles have presented arguments that the region should eliminate domestic herbivores and depend upon various native herbivores.

Many problems are encountered in attempting to utilize wildlife on any sustained yield basis over large areas including: harvesting difficulties, low offtake rates, unique range requirements, competition for graze, animal diseases, and social customs. Killing by humans often causes wild species to be exterminated in all but protected areas. Migratory species disappear more quickly than sedentary ones, large species before small ones. In times of food shortages, man-made impacts are greater. Only the establishment of wildlife refuges with protection and management can save some species from extinction.

However, human modifications of ecosystems are not detrimental to all native species. Apparently bushpigs and topi (a kind of antelope) are even more numerous than they were 50 years ago.

With increased cereal cultivation, the food for birds, such as weaver-birds, increased. Breeding colonies exist throughout the southern Sahel, sudan, and northern woodland zones. A flock can destroy a cereal crop in a few hours and villages in infested areas assign residents to guard fields. Other major pests (rodents, other birds) consume as much as 25 percent of production.

7.3.3 Agricultural production in the Sahel-Sudan region: Much of the region is arid even in periods of normal rainfall. Only 7.9 percent of the land (42 million hectares) is considered arable, 25.8 percent (136 million hectares) is grazing land, 11.5 percent (61 million hectares) is forest, and 54.6 percent is classified as "other lands." Twenty-six percent of the arable lands were being cultivated in the mid-1960's. A small portion (163,000 hectares) is irrigated. High quality soil is scarce.

The region is inhabited by ethnic groups which differ markedly in social and cultural traits, hence there is no one "traditional way" of agriculture. The inhabitants of the desert and subdesert zones engage almost solely in animal husbandry. In the southern part of the subdesert, Sahel, and northern Sudan zones are the transhumant herdsmen. Their animals are kept on the subdesert and northern Sahel during and immediately after the northern wet season to use the forage produced and then are driven southward to graze on fallow lands and crop residue during the dry season.

Animals raised in the north are driven to market in the south. This trek may involve several weeks, hundreds of kilometers, and significant weight losses, however, meat cost, in terms of external inputs is minimal. Essentially, it is the result of natural productivity and poorly compensated labor.

From the Sahel zone southward, sedentary farming is practiced. Most farmers have some domestic animals. In the southern woodlands few cattle are raised because of the prevalence of sleeping sickness. Horses, donkeys, pigs and chickens are raised, especially in the southern part of the region.

Three major types of cultivation are practiced: dry-land farming, flood-retreat farming, and wadi farming. Most prevalent is dry-land farming, which depends upon rainfall. Flood-retreat agriculture involves planting seeds on plains of rivers as the annual floodwaters recede. Growth depends upon the moisture remaining. Wadi farming is a modified flood retreat technique practiced in smaller drainage channels.

Traditionally, the soils are not tilled. Rather, holes are made in the ground and the seeds inserted. The seeding rate is low, and the crops are only partly thinned. Limited cultivation is usually done to control weed growth. Mixed cropping is customary.

Traditional crop farming depends on human labor and a fallow period for restoration of fertility and moisture and for pest reduction. No treatment is applied to protect the seed, plants or stored grain, even though

the crops are attacked by many pests.

The rangeland animals include grazers and browsers. The nomads depend upon milk and meat for most of their food. Such offtake has deleterious effects on herd productivity. Cows produce barely enough milk to support their calves and taking milk for human consumption results in malnourished, slow growing calves.

During the dry season, animals undergo a period of little growth and, often, of weight loss. The combination of genetic traits and poor environmental conditions results in slow maturation, low birth rates, extended nursing time for calves and high mortality rates. A significantly less efficient conversion of ecosystem productivity into meat results. Animal grazing on fallow and harvested fields adds manure to the ecosystem and utilizes crop residue.

Evidence exists that much of north Africa formerly supported grazing cattle. The disappearance of perennial vegetation in the Sahara, the development of sand seas and expanses of bare rock, as well as desertification in adjacent subdeserts and savannas, are primarily the result of misuse of the ecosystems by human activities including wood cutting, overgrazing, and land clearing.

Long-term misuse of the land has caused shifts to the southward of vegetation zones. In the Sahel and Doka woodland zones, small streams have changed from permanent to intermittent flow. The increasing rate of desertification and shifting of zones appears to be associated with

increasing human population in the region.

Much of the problem of desertification is associated with the introduction of browsing animals. Sheep, goats, and camels, because they have less need for water, can graze and browse in areas not usable by cattle.

The "little pluvial" period resulted in increased productivity in both natural vegetation and in field crops. Sedentary farming activities expanded to the north. The carrying capacity of the range was increased. Simultaneously, animal-health programs were increased and new wells were drilled. The interaction of these factors resulted in a marked increase in animal populations to levels that exceeded the sustainable carrying capacity of the range.

The human population continued to rise. Export crops became an important part of the output, replacing traditional cereal production. The pressure for increased production decreased fallow time and consequently productivity. The expansion of cultivated lands decreased the land available for the nomads and their livestock. Heavy cutting of trees for firewood occurred near the urban areas.

By the end of the "little pluvial," about 1966, the expectations of the inhabitants had risen to the point that a return to average conditions was considered to be a drought. Reductions in forage and the high animal population caused extensive overgrazing and even further reduction of forage. Desertification of rangelands began, particularly around wells,

and northern grain fields were abandoned. Soil erosion became more common. Animal and crop productivity decreased.

With the beginning of the genuine drought in 1969-1970, the stage was set for a crisis. The present drought is no worse than many of the past, but its effect was a catastrophy far exceeding any previously recorded. Major crop failures were widespread as was human and animal starvation. In some locations, the ecosystem was degraded to the point that abandonment for generations may be necessary for natural restoration.

Cereals are the major crop; many varieties are grown. Productivity is low, 1969 production was about 5 million metric tons. Peanuts and cotton occupy about 25 percent of the cultivated area, and production (1969) was about 1.5 million metric tons. Small amounts of dates, cowpeas, manioc, yams, sugarcane, and tobacco are produced on about 10 percent of the cultivated area.

In 1969, there were 26 million animal units (equivalent of one 450 kg cow and calf) in the region including cattle (58 percent), sheep (13 percent), horses (3 percent), donkeys (3 percent), goats (16 percent), and camels (8 percent). Productivity is low; death and disease losses are high, but livestock accounts for 15-20 percent of gross domestic product (GDP).

Fish production (inland) is about 440,000 metric tons annually. There are about 42 million chickens in the region and egg production is about 24,000 metric tons annually. Milk production is more than 1

million metric tons annually. Pigs make up a minor component (281,000) of the domestic animal population. Agricultural by-product (hides, skins, cottonseed, etc.) use is not highly developed.

Wood is the principal source of fuel energy in the region, and per capita use is 300-500 kg/year. Total consumption is almost 9 million metric tons.

About 80 to 90 percent of the population is in agriculture, and nomads make up 6 to 15 percent of the total. Less than 0.1 percent are in salaried agricultural positions.

A generally poor relationship exists between education and agriculture. Research has largely been confined to cash crops; some significant results have been obtained.

Technical assistance in agriculture ranged from 4 to 40 percent of total assistance during recent years. U.S. funds accounted for about 40 percent of the bilateral aid.

Agriculture does not operate as part of a market economy, but this primary sector contributes from 31 to 53 percent of the GDP in the various countries. Farm income is low, and the rural population receives a small share of national income. On a national basis agricultural products (cotton, peanuts, livestock, and meat, fish, etc.) account for 37 to 95 percent of total exports, and imports of agricultural products represent 4 to 20 percent of total imports (emergency food supplies have been imported in recent years). Agriculture is contributing to a favorable balance of

trade. Investment of public funds in agriculture varies from 15 to 40 percent. Much of it is applied to export crops.

Recent trends in the region show increasing land use, with a greater increase for cash crops, decreased total production and productivity. Livestock numbers increased until 1970 and have decreased since then (sheep and goats remained relatively constant). Meat production has increased in recent years, probably because of pressures to sell more animals than normally. Other animal production shows modest to substantial increases in recent years. Wood production increased largely because of increased demand. Population has grown although outmigration has had some effect. New agricultural education and research institutions and agencies have been established; their impact to date is slight. Exports of agricultural products generally increased until 1969 and have declined since then. Imports do not show a consistent pattern of change.

Characterization of the agricultural production system was hampered by lack or poor quality of statistics. Many gaps exist in the yearly data, and different sources present conflicting information.

7.3.4 Major issues and problems: Analysis of the preceding discussion of climate, ecology, and agriculture identified some major issues and problems directly influencing agricultural production systems. They include: cyclical drought, ecosystem fragility and limited natural resources, low productivity and production, lack of agricultural goals

and policy, lack of modern agricultural technology, little infrastructure, inadequate land tenure, insufficient educational institutions, strong traditions, limited agricultural statistics, poorly planned and implemented projects, outside influence on economic policies, and strong coastal zone influence.

7.4 The Sahel-Sudan Example

The ISYALAPS planning framework was applied as an example to the entire Sahel-Sudan region and to Mali separately. Potential agricultural production is compared with the existing situation, implementation steps and impacts are discussed, and four representative projects are described.

7.4.1 Basic premises: The following basic premises provided a foundation for use of the planning framework:

(1) The region will remain predominantly agricultural.

(2) The land is capable of some agricultural production.

(3) Production can be realized without ecosystem degradation.

(4) Technology, management, and inputs can increase productivity.

(5) Energy will be available for critical operations such as land preparation.

(6) Government stability will increase.

(7) Migration to urban centers will continue.

(8) Money will be spent for agricultural projects, whether adequate planning occurs or not.

7.4.2 Application of the ISYALAPS planning framework: Agriculture has lagged behind other developments in the region and would have become incapable of supplying needs in the near future without the current drought. Human and animal numbers increased far beyond carrying capacity in the years immediately preceding the drought, and now agriculture must be brought into accord with hydrologic and environmental reality. The use of the ISYALAPS planning framework demands the acceptance of the philosophy of long term sustained yield from agriculture in a realistic economic setting, based on the concept of living within the limits of the available natural resources. Moreover, the resources are evaluated in terms of improving the quality of life of the rural poor.

The region was divided into five east-west oriented climatic zones: desert, subdesert, Sahel, sudan, and woodland, as previously described. The irrigated area makes up a sixth zone.

An integrated strategy (mix of activity levels) was determined to be one feasible alternative for the region. It emphasizes effective natural resources management, takes advantage of all possible productivity and can be implemented by realistic means. (Time will be required for implementing any strategy in the region, but action is needed immediately to prevent further deterioration. Time is required for range and land recovery, and some preliminary steps are necessary now to permit later implementation of action programs.)

Land was allocated on a trial basis to crop, livestock, and wood

production in the various climatic zones of the region. Crop and wood production factors were determined and potential production was calculated. Livestock and other animal production factors were determined and potential production was calculated.

The total potential agricultural production of the Sahel-Sudan region under the integrated strategy was summarized in calories and grams protein of food and kilograms of non-food crops and wood. Totals were corrected for storage and transit losses. Potential human carrying capacity was then computed.

The ISYALAPS planning framework also was used as an example for Mali under two alternative strategies--the same integrated strategy used for the entire region and a constant application of Activity Level B in all climatic zones, and for all segments of the agricultural sector. Procedures used were as described above.

7.4.3 Results of the application examples: The potential production was compared with existing production in terms of calories, the limiting factor. The integrated strategy has the potential to increase calorie production in an average year by 30 percent in the region and by 100 percent in Mali alone. However, the strategy of constant Activity Level B in Mali shows a decrease in calorie production of about 12 percent.

Cash and export crop (largely peanuts and cotton) production was also compared. The integrated strategy has the potential to increase

total exports by more than 400 percent in the region and by 900 percent in Mali although existing exports of peanuts are 7 percent higher. The strategy of constant Activity Level B for Mali provides no surplus of food crops for export. Cotton production shows an increase of about 180 percent

Potential wood production under the integrated strategy is 140 percent greater than existing production in the region and 240 percent greater in Mali. With the strategy of constant Level B in Mali potential wood production is 280 percent greater.

Comparison of human carrying capacity shows that the potential production of the integrated strategy in the region would support a population of 33 million, 30 percent larger than the existing production. However, population effectively employable in the improved agricultural activities is about 60 percent less than the estimated employment in agriculture at present. In Mali, the integrated strategy has the potential to support a population of more than 10 million, double the existing population. However, population employable is again reduced, this time by 50 percent. The strategy of constant Level B does not have the potential to support the existing population in Mali, falling short by 13 percent. However, employment in agriculture would be reduced by only 44 percent.

Steps for implementation of an agricultural strategy in the region are like those discussed in Section 7.2 above for governments, the private economic sector, individual farmers and herders, and the various

donor agencies. The activity level of each alternative strategy determines the explicit action required in the different climatic zones.

Inputs and infrastructure needs for the Sahel-Sudan region can be identified on a project basis but are impossible to quantify at this time on a broadscale, regional basis. The single most important requirement for implementation of an agricultural strategy is trained personnel. At Activity Level A, requirements are lower in general educational level but significant in numbers. Personnel require a higher educational level with higher activity levels.

The benefits of the integrated strategy include self-sufficiency in food production and elimination of the need for imports. The quality of life in rural areas can be improved by increased productivity of farmers and herders. The ecosystem would be stabilized and recovery initiated. Exports of agricultural products could be increased resulting in possibility for capital accumulation. There would be increased opportunities for agriculturally related industries. Opportunities for industrial employment and entrepreneurship will be provided in supporting services. For a time, the above benefits will keep up with anticipated population growth.

The strategy of constant Activity Level B in Mali provides lesser benefits. The ecosystem will be brought into balance. The quality of life of rural families would be improved by stabilization and increased income. Supporting services and industries will have some potential for increased activities.

Problems of determining costs of a complex agricultural strategy are immense. It is unwise to attempt to measure exact activity level costs at this time because of the tremendous potential for error.

Impacts of implementing the strategy also will be felt in the social-political, economic, water resources, and transportation sectors. (Details are given in those sections of the M.I.T. Sahel-Sudan Project report.) For example, the substantial decrease in direct employment in agriculture presents a tremendous problem. Furthermore, there is an impact resulting from the selection of a "do nothing different" strategy. The population-agricultural production-natural resources vicious circle shows that increasing population creates greater pressure on the natural resource base while demand for production is increasing. But decreasing fallow time then decreases productivity, further increasing pressure on land resources. Greater destruction of the ecosystem results along with malnutrition and starvation. There will be increasing conflict between nomads and sedentary farmers. The existing support level of agriculture in the region by governments and donor agencies will not break the vicious circle.

7.4.4 Representative projects: A matrix for project evaluation for action programs provides for the vast size, ecologic variability, social diversity, and political fragmentation of the Sahel-Sudan region. Financial limitations are also included.

Illustrative examples of development projects which fit the natural

resource based ISYALAPS planning framework include: green belt establishment, extended family livestock production, government food production centers, and computer oriented natural resources inventory.

7.5 Conclusions and Recommendations

This effort provides a framework for planning, not a plan, and although the study is incomplete in that much remains to be done in the Sahel-Sudan region, conclusions can be drawn from the results of the analysis. Recommendations also can be made concerning what should be done to guide activities of the six countries and the donors in the future and to make this study more nearly complete.

7.5.1 Conclusions: The current drought is not permanent and no major climatic change has occurred in the recent past nor is there any indication that such a change will occur in the near future (50 to 100 years). What will occur is a continuation of major multiannual variations from the mean resulting in drought periods as well as pluvial periods.

The fragile environment of the Sahel-Sudan region has been harmed by unconstrained land uses and is badly out of balance. Effective natural resource management is required in planning and development projects.

Wild animals will provide some protein for the inhabitants of the region. However, with increasing human population and widespread ecosystem modification, most large game species will disappear. Developing game harvesting does not appear to be viable, but game ranching

with selected species shows some promise of economic feasibility. With further ecological change some wild animals may become major competitors with man for agricultural production.

The existing agricultural production system is part of a vicious circle, including the growing population and limited natural resources. Operation of this system over the past decade and particularly during the recent drought has contributed directly to the problems of desertification, reduced productivity, soil erosion, and deforestation. Pressures of population and the export-oriented economy resulted in increasing use of marginal lands for food production. Animal numbers increased for the same reasons but also for lack of other savings opportunity. With the ecosystem out of balance, the consequences of drought were inevitable.

The social costs of such a system are staggering, with recurring and increasingly severe famine, starvation and need for relocation of distressed people and animals. Monetary costs are also high in terms of requirements for assistance, massive food relief and lost productivity.

The region can be made more productive than it is or has been. Application of an integrated strategy within the ISYALAPS planning framework demonstrates this potential. Control of land use and change in the social system will be required, but progress can be made with low level (and low capital) technology. Most of the region is suited for livestock grazing, but more intensive systems have potential in the wetter zones.

A constant Level B strategy will not support the existing population,

however, much of agriculture is operating above this level and must continue to do so unless population is reduced. Activity Level A supports even fewer people, but the entire agricultural sector must attain it if long term sustained yield is to be achieved.

Broadly conceived and adequately implemented action programs will be required to break the population-agricultural production-natural resources vicious circle. Governmental emphasis on agriculture must be increased. Incentives must be provided to make the necessary changes in the agricultural system.

Regional cooperation is essential. Livestock control in one country will not halt overgrazing because of movements of animals across unpatrolled borders. The major river systems of the region lie in several countries; water resources development thus requires international agreements. The coastal nations to the south provide an outlet for surplus production which must be included in regional planning.

The ISYALAPS planning framework was evolved as an essential step for future planning. A regional view was taken because of the size, climatic and other similarities and parallelism of existing production systems. The activity level concept provides flexibility in developing alternative strategies while recognizing ecologic constraints.

The systems analysis approach to natural resources utilization as a basis for agricultural development planning in the region is a way of organizing the agricultural sector. Natural resources and their

limitations are now being recognized for their importance to development.

One may question the accuracy of applying the methodology when it depends so heavily on assumptions and estimates. By selecting conservative values for productivity factors the planner can avoid over-optimistic production estimates. In any event, the flexibility of the method and its inherent completeness facilitate changes or additions as more data become available.

The human carrying capacities are based on a conviction of the need to provide agricultural workers with a viable production unit. Division of natural resources based solely on population ignores the fact that not everyone can be a good farmer. If income per capita is to be increased, a decline in numbers of workers is inevitable. Labor intensive practices in the wetter zones may have some modifying effect.

Many simplifications were made in dealing with the size and complexity of the region. No externalities were included, and a major weakness of the study is found in the economic analysis of agricultural production.

Shortcomings of the available agricultural production data make comparisons of existing and potential production questionable. The activity level concept needs additional research to be complete. Estimates of potential productivity in the Sahel-Sudan region under the lower

activity levels are low in comparison with reported figures. The estimates are based on available moisture in the zone during the growing season and are backed up by some experimental results.

There is evidence that the area reported as being farmed is not really well known. More exact data would permit accurate determination of fallow/cultivated land ratios being used.

The information regarding the population engaged in various agricultural pursuits was extremely uncertain. No data were found concerning the number of fishermen in most countries nor the number of woodcutters. A significant improvement in the data base must accompany agricultural development planning.

Much sensationalism has accompanied the reporting of the plight of the Sahel-Sudan region. Someone's unsubstantiated opinion is overheard and picked up by a journalist. The statement then appears in print and thereby automatically gains authenticity. The following items are in this "no evidence" category.

"Vast reservoirs of easily available groundwater underlie the region just waiting to be tapped for irrigation." Although isolated areas with some groundwater potential occur in the region, and consolidated rock aquifers occupy much of the subsurface, there is no evidence of aquifers with potential for extensive irrigated agriculture development.

"Properly managed, the Sahel-Sudan region can be a breadbasket supplying food for half of Africa." Agricultural production from the region

can be increased but it is extremely unlikely that production for export, even under the best management, will increase significantly in the next few decades.

"The Sahara Desert is encroaching on the Sahel-Sudan region at a rate of 20 to 30 miles a year." Desertification is a process which occurs in place as a result of misuse of land, not as the advance of an existing desert.

"There is no way, short of a major social upheaval, that the nomads will consent to reduce their herds." Nomads are wise in the ways of the desert and have evolved a system which permits them to survive in the face of adversity, but they respond to incentives, and as a result of the drought, have indicated their willingness to change.

7.5.2 Issues arising from implementation: Implementation of an integrated agricultural strategy based on the ISYALAPS planning framework would result in impacts on the society of the Sahel-Sudan region. Some of the impacts are pleasant, for example, the prospect of increased food. In other cases, an issue is raised for which this study can provide no answer.

The principal agricultural problem of the Sahel-Sudan region is the unrestricted grazing of low productivity rangelands. Solution of this problem requires some form of controlled livestock use.

Farmers or herders are reluctant to invest in land improvement when there is no assurance that they will receive any benefits. The land tenure

system in the region is a confused one and must be stabilized in some way before long-term productivity increases can be obtained.

The income gap between the rural and urban sectors is widening. Among the reasons why this is happening are price and tax policy, emphasis on export crops, unstable markets, shortage of credit, etc. The major incentive for farmers and herders to produce more is a larger share of the profits.

The Sahel-Sudan region is a classic example of the lack of infrastructure in support of agriculture.

An integrated strategy would provide sufficient food, but the number of people who can be directly employed in agriculture and have a reasonable income is less than half of the total at present and will decrease as higher activity levels are introduced into the system.

7.5.3 Recommendations: No additional agricultural development projects should be initiated until priorities have been established by the governments concerned. This will prevent dilution of human and monetary resources. Projects must fit within an overall planning framework and recognize ecological constraints.

A team with substantial experience in arid lands agriculture and with African representation should be organized by the donors to evaluate and approve all agricultural project proposals before funding is authorized.

Existing methodologies should be utilized to evaluate the success

or failure of past present, and proposed agricultural projects in the region.

A central data bank should be established in the region as a repository for pertinent agricultural information.

Steps should be taken to upgrade the existing agricultural data collecting systems. Regional efforts also should be directed towards the establishment of additional weather stations.

Action should be initiated to establish a regional program for storage of food and water reserves to meet the demands of drought years.

Support is required specifically for the ministries of agriculture and rural development in the Sahel-Sudan countries, to upgrade their capabilities for instituting agricultural and rural improvements in their respective countries.

New technology should be used wherever feasible in solving the agricultural development problems of the Sahel-Sudan region.

A basic understanding of the climatology and ecology of the region is an essential prerequisite to planning for development. A list of appropriate research topics includes the following: climatological changes, long term forecasting, location and evaluation of groundwater aquifers, soil characteristics and classification, rates of desertification, plants and their distribution, population of animal species, relations between

degradation of grazing lands and reduction of wildlife, and insect pests.

Range management research should include selection of grass types, grazing intensities, management strategies, range rehabilitation, and evaluating range condition and trends.

Dryland farming research should include soil and water conservation and fertilizer practices, improved varieties, natural nitrogen sources, new garden crops, storage facilities, and integrated crop and livestock production.

Livestock production research should include selecting and breeding for improved production, increasing reproductive efficiency with high temperatures, and nutrition requirements.

Economic studies should include microeconomic aspects of land, labor and capital, evaluation of management practices, and evaluation of the marketing system.

The following activities are important for improvement of the ISYALAPS planning framework: refine the analysis already made, filling in data gaps and revising coefficients, etc. Particularly needed are more exact information on activity levels and their costs and benefits. Write and test computer programs to use the methodology developed for rapid evaluation of alternative strategies.

Increase geographic detail for planning purposes by disaggregation of the Sahel-Sudan region; locate isolated areas with potential for

immediate, high priority actions. Collect and assess existing data on current agricultural production.

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This is not an exhaustive bibliography of either agricultural development or west Africa. Both are beyond the scope of this report. Listed are quoted sources or those considered to be of major importance.

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