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9. ABSTRACT

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Part III presents out interpretation of the basic problems facing the Sahel-Sudan region, while Part IV examines alternative actions that might be taken to cope with the basic problems. Part V summarizes the findings of the various sectors into which the overall study was subdivided. These include: (1) Agricultural Development, (2) Economic Considerations, (3) Health, Nutrition, and Population, (4) Industrial and Urban Development, (4) Socio-Political Factors, (5) Technology, Education and Institutional Development, (6) Transportation,(7) Water Resources, (8) Energy and Mineral Resources.

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

Volume 1

SUMMARY REPORT: PROJECT OBJECTIVES, METHODOLOGIES, AND MAJOR FINDINGS

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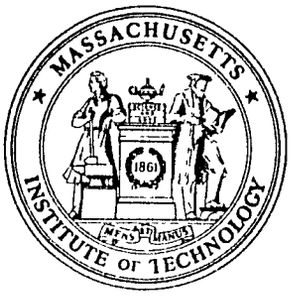

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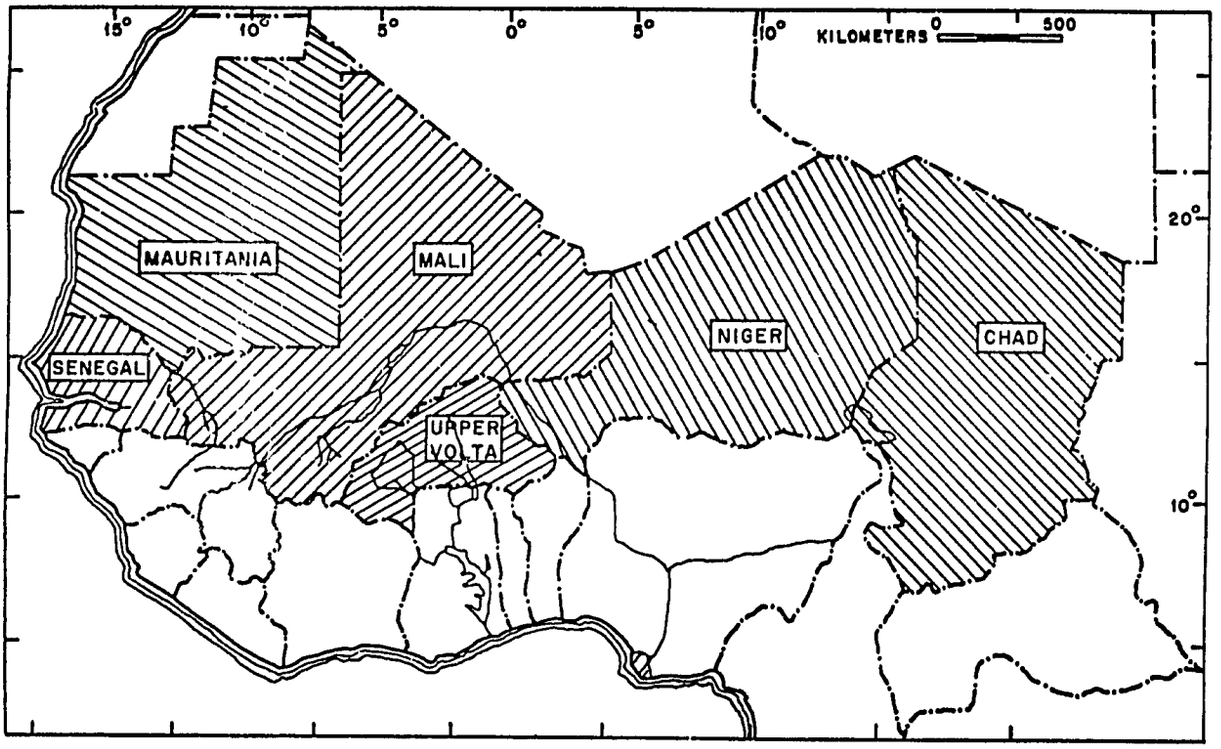

Volume 1. Summary Report: Project Objectives, Methodologies and Major Findings

Volume 2. 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.

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.

William W. Seifert
Principal Investigator

Nake M. Kamrany
Project Manager

SUMMARY REPORT

PROJECT OBJECTIVES, METHODOLOGIES, AND MAJOR FINDINGS

CONTENTS

PART I. INTRODUCTION

During 1972 and early 1973, it became increasingly clear that the Sahel-Sudan region of West Africa was suffering from one of the worst droughts it had experienced in the last half century. Crop failure was widespread, and millions of cattle died. In response, numerous organizations -- private and governmental, national and international -- came forward with humanitarian assistance that effectively reduced the number of deaths due to starvation, malnutrition, and disease.

Although such aid in coping with the immediate problem of famine was vital, general recognition was growing that the region needed other forms of assistance in order to achieve long-term self-sufficiency* and improvement in the well-being of its people. As a consequence, the problems of the region were discussed at a meeting of donors and U.N. agencies held in Geneva in June 1973.

In turn the U.S. Agency for International Development (A.I.D.) approached representatives of M.I.T. in August 1973 to determine whether M.I.T. would consider preparing a proposal for an initial study aimed at developing a framework which could be used in appraising long-range assistance strategies for the Sahel-Sudan region.

Accepting this challenge, M.I.T. prepared a proposal which was accepted. Our study was formally initiated upon signing a contract for the period from September 1 through August 31, 1974.

The Sahel-Sudan region, as the term is used in this report, includes the countries of Chad, Mali, Mauritania, Niger, Senegal, and Upper Volta, which form an east-west belt across western Africa. The region is characterized by desert in the north with gradually increasing rainfall toward the south. The region's southern boundary adjoins the woodlands of the coastal countries.

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*By self-sufficiency we mean that by the year 2000 the region will have developed sufficient agricultural output to adequately feed its population and to provide a net surplus for export.

Although the geographic boundaries of the Sahel-Sudan region extend to the east and south somewhat beyond the political boundaries of the countries named, several considerations led to the limitation of our study area to these six: (1) similarity of ecological and climatic zones within the six-country area, (2) similarity of the countries' political and developmental histories, and (3) project manageability. Relationships among the six countries and between them and their neighbors are, however, explicitly taken into account when appropriate. Furthermore, our research principles, evaluation processes and conceptual framework could be readily adapted to encompass neighboring countries.

The analysis of the region's problems required the cooperation of individuals trained in a broad spectrum of disciplines. Information generated by each project sector was monitored by other sectors in order to take into account relationships between strategic opportunities, constraints, and sensitive variables.

The ultimate utility of this work rests in its potential for assisting decision-makers to decide upon and implement programs promoting long-term viability for the region and increased social and economic well-being for its people. Recommending specific courses of action is not within M.I.T.'s role.

As indicated previously, this study is directed at the Sahel-Sudan region's long-term (defined as 20 to 25 years) development. In many ways, that time frame is too short. A significantly improved quality of life for any sizable fraction of the region's people will require substantial social and political changes as well as economic and technical assistance. Realization of major changes in these areas requires a number of decades. On the other hand, social and political bodies, as well as individuals, place a high value on short-term development and are reluctant to think in terms as long as even five years. Thus, the

choice of a 20-25 year time horizon for this study is a compromise.

Because of the region's vast size, climatic variability, and socio-cultural-political diversity, a large number of varied opportunities for long-range development exists. This large number of potential development opportunities (and the large capital commitments many of them would require) makes necessary a careful examination of these options and their potential impacts on the region. Such an examination can help decision-makers in Africa and in donor organizations establish their choices and priorities.

To provide tools for this examination of options and potential impacts, A.I.D. asked M.I.T. to construct an evaluative framework appropriate to the complex tasks of problem-definition and problem-solving. We were asked to define the region's problems, as specifically as possible, identify possible alternatives to alleviate them, and tentatively outline methods of evaluating in depth these alternative approaches to long-term development. M.I.T.'s research was restricted to the description of observed relationships between phenomena, generalizations about these relationships, and (so far as observed relationships and possible generalizations permit) predictions of alternative courses of events. In the process of identifying practical options we have been led to recommend that some further studies be undertaken to close information gaps revealed in this analysis.

To recapitulate, the ultimate objective of this project is to construct a framework -- a comprehensive system of theories and concepts--that will help the Sahel-Sudan countries and international donor ogranizations to reach informed judgments about various alternatives for the region's long-term social and economic development.

Numerous cases have shown that unless complex situations are addressed broadly, well-intentioned steps to correct a problem in one area frequently prove counterproductive in the long run for the system

as a whole. Therefore the M.I.T. group adopted a multidisciplinary approach to its task so that no single problem of the study region would be looked at in isolation. As will be detailed later in this volume, a small group of analysts, representing the fields of anthropology, ecology, and systems analysis, made a preliminary assessment of the regions's problems and potential. They then began collecting data and recruiting an appropriately diverse multidisciplinary team. On the basis of its work in Cambridge, its interaction with consultants drawn from a variety of disciplines, and several additional site visits, this team evolved the various methods utilized during this study. The total study group included individuals trained in areas ranging from ecology to economics, transport systems planning to agriculture, and sociology to energy systems. The group utilized a variety of techniques, some highly analytical (such as statistical analysis and computer modeling), others primarily descriptive. The particular mix of techniques utilized by the subgroups focusing on the individual sectors varied with the characteristics of the sector and the background of the investigators. Continuing interaction among various members of the whole group served to develop in each member an appreciation of how the others were approaching their tasks and of their principal findings. In this way, areas of conflict and inconsistency were minimized.

In the context of the task of constructing a framework for analyzing alternative strategies for the development of the Sahel-Sudan zones, this approach of engaging the diverse talents of a multidisciplinary team is termed <u>systems analysis</u>. This approach does not utilize any specific set of rules or steps and does not guarantee easy solutions to difficult problems. It certainly includes no magic, and many might term it merely the application of common sense. Nonetheless, the systems' approach probably offers the best technique available for insuring that all aspects of complex situations are examined and dealt with. We hope

that through our use of this approach we have been able to offer important new insights which will be useful to those concerned with the long-term development of the Sahel-Sudan area.

This summary of the work consists of five parts. Part I provides an introductory statement of the project's background and objectives. Part II outlines approaches which were examined as potentially useful in constructing a framework for identifying and assessing long-term development strategies for the Sahel-Sudan region and describes the approach followed.

Part III presents our interpretation of the basic problems facing the Sahel-Sudan region, while Part IV examines alternative actions that might be taken to cope with the basic problems. Application of the framework in evaluation of development alternatives in the agriculture sector serves as an example of the general methodology, while examination of a specific agricultural strategy illustrates how the framework can be applied to a particular situation. Part V summarizes the findings of the various sectors into which the overall study was subdivided.

Part II. METHODOLOGICAL APPROACH

2.1 General Method Utilized

In the beginning of this project, we believed that the central features of an evaluative framework would include (1) ways of identifying alternative development strategies consistent with the region's characteristics and (2) means for analytical examination of these strategies and their probable consequences. Such a framework, we believe, could provide decision-makers with a basis for establishing their own priorities and implementation plans and could also be used in monitoring or reviewing implemented projects.

The integrated multidisciplinary approach we have followed was designed to safeguard against what has been called the "illegitimate isolation" of variables. All variables were to be viewed as inseparably related to other variables. This approach was designed to help policy-makers avoid costly mistakes resulting from oversights which stem from a single-sector or from a single-project approach.

The term integrated multidisciplinary approach connotes considerably more than merely collecting individuals from various disciplines and asking each of them to describe the steps he or she believes should be taken to tackle regional development problems. We believe, rather, that in-depth interaction among the members of a multidisciplinary team must be conducted over a period of time if realistic solutions are to emerge.

The methods employed by our project's various disciplines range from common sense deduction based upon available information to evaluation of data using such known analytical tools as trend analysis, linear programming, and systems dynamics. They involve examining the total subject, identifying sensitive variables, and analyzing the impacts both of changing variables or policies within the system and of constraints on the variables.

Analytic techniques should help solve problems. We defined our problem as an all-encompassing one -- to identify for study everything potentially significant for the region's development, and to take into account the possibility of important interrelations among the problem's various features. Obviously, no single large-scale model could provide one complete package of coefficients and equations relating to all social, economic, and resource factors for the region. Moreover, the climate variability of the region posses critical problems of uncertainty, especially since we are concerned with the long term (20-25 years). Many other risks (probability function of foreseen events) and uncertainties (probability function of unforeseen events) also exist.

A commitment to one particular analytic method would have forced us to define our problem to suit the method. Instead, we sought and used a variety of methods to construct a framework that would encompass most aspects of the problem. Our overall approach, therefore, contains many "packages of methods," including qualitative and normative statements, cross- and time-series comparisons, and formal mathematical computer models.

As stated earlier, this collection of methods may be called the systems approach. This approach, by combining "hard" and "soft" methods, offers a useful way to loosely structure and summarize an enormous amount of information and to apply collective judgment to large-scale problems. It includes both rigorous and intuitive processes, identification of causal relationships, and explanatory analysis utilizing experience, projective assessment, and insight concerning risk and uncertainty. We attempted no hypothesis-testing in a formal sense. A project such as this cannot verify its results or conduct controlled experimentation.

Several other points may be made about the proposed framework and the methods followed in constructing it.

1. Insofar as possible, methods were selected that would avoid introducing value judgments (or, at least, would identify such judgments).
2. Both the large scale and the heterogeneity of the Sahel-Sudan region demanded a framework that could take into account a large number of complexly related variables. At the same time, simplicity was sought, so that the framework will be of the greatest possible use.
3. Because of the anticipated importance of nonquantifiable variables, methods were utilized that permitted their incorporation in the analysis.
4. The framework was designed to be a dynamic one, allowing for incorporation of changing functional relationships among variables (as well as variations in data type) over time.

2.2 Possible Approaches

This section describes some of the approaches we considered in developing a framework for appraising development strategies for the Sahel-Sudan region, and outlines the approach we finally followed.

2.2.1 Large-scale simulation models: Over a decade ago, in response to a need for better planning techniques, computer-oriented analysis began to be developed, refined and applied to an expanding range of problems. A region as large as the Sahel-Sudan is a very complex system, entailing a multitude of interacting relationships in which effects, which are not always simply proportional to causes, are related in complex, nonlinear ways. Few analysts or policymakers can predict on the basis of experience, judgment, or intuition alone the long-range effects of implementing proposed policy changes in such complex systems. Regional decision-makers of the Sahel-Sudan

therefore could benefit greatly from the development of quantitative analytic techniques.

Recently economists have devoted considerable attention to econometric techniques which attempt to develop quantitative mathematical relationships that describe an economy's various sectors. Both econometric models and input-output relationships (which chart an economy's flow of goods, money, etc.) can increase our understanding of a nation's economic behavior, particularly over a short term. But they are not designed to illuminate underlying and interacting long-term cause-effect relationships, which the interplay of economic, political, social, and environmental concerns make so important today.

Beginning at M.I.T. with the work of Professor J.W. Forrester (1961)* and E.P. Holland (1961), considerable progress has been made in developing techniques for formulating truly dynamic models of various socio-economic systems. By studying the dynamics of industrial corporations and of cities, Professor Forrester (1961, 1969) showed that steps which produce positive short-term results frequently prove basically counterproductive in the longer run.

Holland (1961) simulated the economies of India and Venezuela (1966) and the Battelle Memorial Institute applied systems dynamics to a regional growth analysis of the Susquehanna River Basin (Hamilton 1969). Although such studies significantly helped to develop methodologies for analyzing national economies, their specific utility was somewhat limited by the computer capabilities then available and by their own pioneering nature.

More recent dynamic modeling studies of national economic sectors include works on alternative plans for electric power generation and transmission in West Pakistan (Lieftinck et al. 1969) and on Nigeria's agricultural economy (Manetsch et al. 1971).

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*Cited references are listed in Appendix C.

From 1970 to 1972, a small group of M.I.T. graduate students working with Professor Seifert developed extensive models to simulate portions of Bolivia's economy. One of these models, concentrating on the demographic sector, examined effects on population growth, unemployment, and per capita income (Picardi 1972), which would result from various strategies for developing the industrial sector and upgrading agriculture, health, and family-planning programs. A concurrent study examined the dynamics of the Bolivian economy's tin-processing sector (Kaminski 1972).

The Systems Dynamics Group under Professor Forrester has continued work in the area of urban and world dynamics (Forrester 1971; Meadows, et al. 1972), examining in detail subsystems ranging from waste recycling to village economies.

(1) Dynamic modeling: Dynamic modeling differs from the many other techniques which make projections of the economic performance. The usual projections are based upon an extrapolation of past data, while dynamic modeling recognizes that biological, economic, and social systems include feedback loops. For example, cities which offer good jobs, adequate housing, pleasant surroundings, and low taxes grow rapidly. If the job base does not continue to expand, however, unemployment and taxes increase, housing deteriorates, and general attractiveness declines. Ultimately, feedback effects produce a balance between internal growth and out-migration to more attractive areas.

Dynamic modeling can be used to analyze very complex systems. Experience has shown that understanding increases very substantially in the process of identifying basic relationships within the system being modeled.

The computer plays a very important role in the analysis process. Unlike human analysts, it can accommodate nonlinearities. Using this

capability, the analyst can examine both long- and short-term consequences of implementing various policy decisions and can thereby select that set of actions which comes closest to producing the desired results. Even so, unforeseen exogenous events may have unexpected consequences in the long run. Once recognized, however, they can be incorporated readily in the analysis.

One possible approach to constructing a framework for appraising alternative development strategies would be to design a large-scale dynamic simulation model for the region. We considered this possibility but rejected it for several reasons.

Constructing a computer model sufficiently disaggregated to yield information which would be useful in appraising any but the grossest strategies would be a very difficult task. Because the region under consideration comprises six independent political entities, policies for improving conditions must be identified and implemented on a country-by-country basis. Furthermore, each country has several distinct ecological zones, each with its own unique problems. In addition, the problems of the rural population are very different from those of urban dwellers. If account were taken of these and many other considerations which would have to be included if a simulation model were to be useful to policymakers, the development of the model would represent a task much more difficult than any heretofore attempted by workers in the dynamic computer modeling field.

Because we believe that dynamic modeling is a very useful technique, we did elect to construct models representing two subproblems. The first was a study of the interaction between cattle-raising activities and ecology in Niger's Tahoua district. This fairly simple model is discussed in more detail in Part V. A second dynamic computer model assessed the potential impact on agricultural productivity, and in turn on village life, of various policies that might be elected by sedentary

farmers. This effort turned out to be difficult, both because of lack of pertinent data and because of an incomplete understanding of the social dynamics of village life. As a result, rather than providing any concrete appraisal of the effects of alternative policies the completed work is useful only in illustrating a possible approach to modeling the village agricultural sector and in raising questions for further research.

(2) Input-output modeling: Input-output analysis (Leontief et al. 1953; and Chenery and Clark 1959) shows the impact of alternative policy parameters upon the national income account. The approach recognizes interactions and dependencies of numerous variables. For instance, an input-output model could trace the impact of increased demand for automobiles upon employment in steel, rubber, glass, and other industries feeding into the auto industry. It could also measure secondary effects upon coal production (needed to increase steel production), petrochemicals (required to produce plastic), etc., and could calculate the environmental effects of these productions in terms of pollution and environmental degradation (Kamrany 1973).

By using input-output modeling to evaluate the interactions and trade-offs between regions, as in the Niger-Nigeria relationship, for example, the policymaker could examine the impact of one region's development upon another's. In a further extension, this methodology could be made dynamic -- i.e., could trace out the consequences over time.

We gave careful consideration to the possibility of developing a regional input-output model. The key issue was not the availability of appropriate analytic and computer techniques but the magnitude of the effort required to identify appropriate functional relationships and to develop the equations and coefficients necessary to make the technique operationally useful. The data requirements for the size of input-output model deemed useful would have been very large and would therefore have

called for the commitment of a greater effort to this particular task than was considered possible within the resources of this study. For the same reasons, we did not use econometric system dynamics analysis (sophisticated programming models developed by Professor Richard S. Eckaus and others), although they have been applied with success in some areas. However, we did employ the Chenery-Strout model for making long-term projects under alternative sets of assumptions concerning economic parameters (Chenery and Strout 1966).

(3) Interactive simulation modeling: Interactive simulation models incorporate subtle decision-making issues, elements of uncertainty, and some intangibles difficult to account for in an analytical approach. Among their functions are (1) focusing on issues and tracing their implications; (2) providing mechanisms for generating as well as evaluating new ideas and policies; and (3) accounting for changes in the system or in people's perception of the system. They can be used when lack of data makes the task of systematic analysis and planning difficult (Kaminski 1974).

Interactive simulation models are considered more specifically in the part of the project dealing with technological choices. Since such choices are inextricably linked to social, economic, and political issues, the proposed framework for evaluating them could also be, broadly considered, a framework for evaluating socio-economic development alternatives.

Such an approach would enable us to evaluate several sets of policies: buying technologies at high costs versus developing a country's own specialties at high risks; cooperation among West African countries on technological policies; governmental support and intervention, and so on. This framework would also provide a medium for discussing and generating ideas. Thus, a series of simulation runs involving advocates of contrasting theories could trace theoretical implications and show

their strengths and weaknesses, evaluating, for example, group pressures to influence world market prices. Finally, the impact of stochastic (or pseudo-stochastic) variables such as climate could be traced. It would then be possible to evaluate decisions such as whether to risk emphasizing economic development at the expense of drought preparation (relying on relief aid in the event of drought) or vice versa.

Time constraints prevented us for developing the model indicated. However, we believe that with further development the technique could prove to be a valuable additional tool for the evaluation of alternative development strategies for the area.

(4) Other methods: A host of other techniques such as the Delphi approach (Dalky and Helmer 1963), cross-impact analysis (Gordon 1970), weighted-worth procedures (Miller 1967), and the like, have been developed and experimented with in a wide range of applications. These methods have broken away from formal modeling techniques and have made substantial progress in incorporating both quantifiable and qualitative factors in their analysis.

The essence of the Delphi approach lies in quantification of opinion through repeated presentation of a carefully designed questionnaire to a group of "experts." It attempts to avoid a "bandwagon effect" among the experts by employing sequential interrogation and keeping the identity of other experts anonymous. We believe this approach would have application to some issues relative to the Sahel-Sudan region. However, the task of designing suitable questionnaires, enlisting appropriate experts, carrying out the surveys, and analyzing the results would have required a commitment of time and effort greater than we considered justified by the the potential value of results that could be obtained.

The weighted-worth procedure attempts to provide a rating system for various groups or mixes of activities and to determine if each alternative satisfies specific predetermined objectives.

The next step would involve worth estimation of the alternatives. A variety of techniques, such as multivariate regression, psychometric and sociometric techniques, factor analysis, the Delphi approach, opinion polls, simulation, etc., are available to quantify the attributes of a program.

Application of the method assumes a clear statement of the objectives of the various national, regional, cultural, ethnic, and other groups involved; developing this statement of objectives would require very close interaction with decision-makers and close understanding of the wishes of the various power groups.

While we did not employ these methods in constructing our framework, we strongly recommend they be considered when the Africans themselves apply it. Likewise, a planning-programming-budgeting system (PPBS) (Millword 1968), established in collaboration with Africans and donors, would be useful in the analysis of trade-offs among various programs and projects.

2.3 Approach Followed

The M.I.T. group decided that it should not attempt to focus its study of the Sahel-Sudan region on any one of the techniques outlined in the previous section but should employ a mix of analytic and qualitative approaches. The framework we developed for analyzing the highly complex issues of development of the Sahel-Sudan area thus consists of a structure within which the total problem is subdivided into sectors such as agriculture, transportation, and economic considerations. The methods utilized for studying the individual sectors were selected as those best suited for analyzing the specific problems of each sector. Coordination among those working on the various sectors was maintained through individual and group interactions. Each subgroup examined the entire six-country area and, where appropriate, included the influence

of both neighboring and overseas countries. For illustrative purposes, several studies also focused on single countries or on regions within a single country. The study thus provides a framework for use in planning but does not attempt to present a master plan for development of the region.

The principal methods utilized by the subgroups in their studies are outlined in Table 2.3-1 while the relationship between components influencing the development of the Sahel-Sudan region is illustrated schematically in Figure 2.3-1. A continuing dialogue was maintained among the individuals working on the various subsectors in order to insure that major inconsistencies did not develop.

2.3.1 Processes and organization: The process we envisioned at the outset and subsequently pursued may be described as follows:

(1) A small team briefly assessed the region's problems and potentials to identify key problem areas and the disciplines required in a team assembled to address them. This phase was accomplished through preliminary review of documents available in the Cambridge area or supplied by A.I.D. and a few others knowledgeable about the area.

(2) Recruitment of an appropriately diverse multidisciplinary team was initiated, and a broader data-collecting phase was begun.

(3) As team members began to understand the data bases of their respective areas and to identify constraints impeding development, they engaged in a continuing dialogue with one another. As the principal constraints to development emerged, additional data that should be collected and specific analytic methods that should be employed to appraise suggested development alternatives were identified.

TABLE 2.3 – 1

Summary of Methods Used

Sections	Methodologies Used
Entire Project	The systems approach -- diagnostic, prognostic, heuristic methodology, including qualitative and quantitative analysis.
Economics	Harrod-Domar model, Chenery-Strout model, regression analysis, conventional macro-economic analysis.
Socio-Political	Cross-sectional descriptive analysis, trend analysis, and quasi-experimental analysis.
Agriculture/Livestock	Diagnostic, prognostic systems approach and systems dynamic modeling.
Health, Nutrition, Population	Descriptive, diagnostic, content analysis.
Technology	Survey of the state of the art, analysis of specific large-scale projects; computer modeling.
Energy and Mineral Resources	Demand and supply models, projections, and cost analysis.
Transportation	Computerized models, costs/effectiveness models for alternative transport modes.
Water Resource Planning	Computerized mathematical programing of water demand and supply including cost-projection model.
Industry	Regional functional analysis using cross-comparison and time-series analysis.

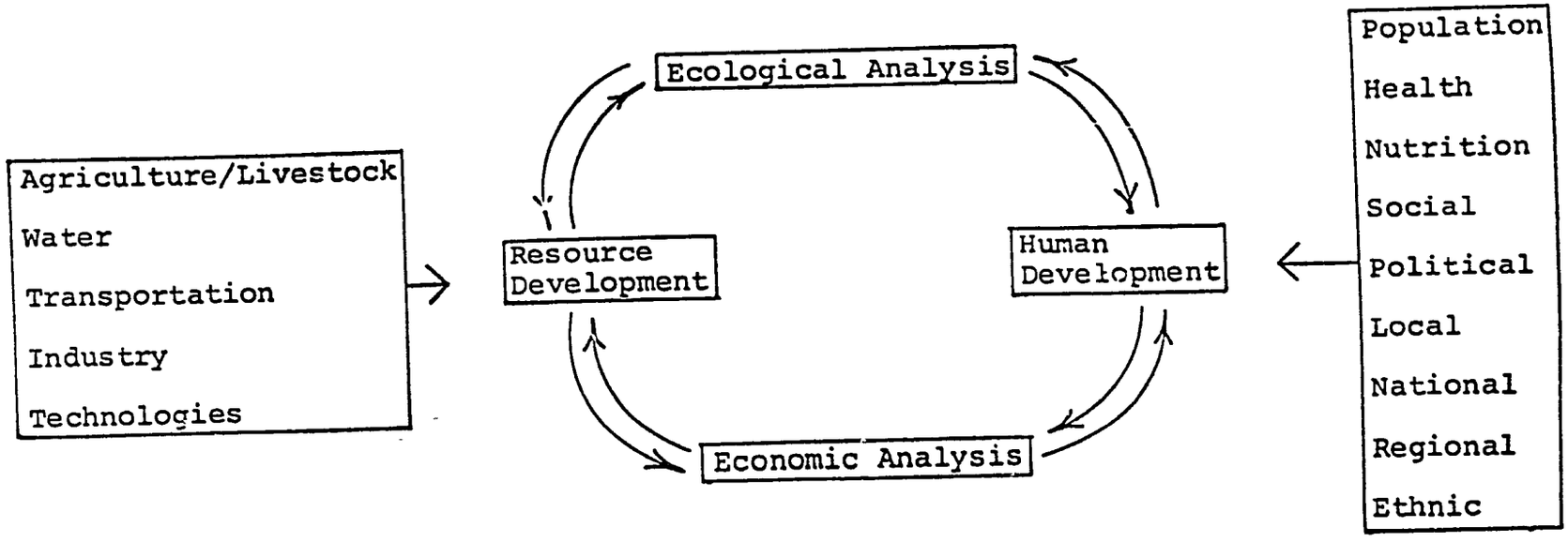

Figure 2.3 - 1: Schematic Relationships of Components Influencing the Long-Term Development Strategies of the Sahel-Sudan Region

As our understanding of the problem developed further and we identified additional facets, we recruited more members for the team and obtained the services of consultants to provide needed inputs and guidance.

(4) To acquaint at least some of the participants with the actual conditions in the region, several teams made short field trips to the study area. This effort was purposely limited because its objective was to make contacts which would facilitate collection of available data rather than to conduct original research and data-collection. In all, three teams spent a total of 230 man days in Africa. Other contacts were made in Europe.

(5) To safeguard against overlooking important considerations and to solicit ideas that might not have occurred to us, we periodically outlined the state of our thinking to groups and individuals with experience in Africa or in large-scale problem solving and to A.I.D. representatives. We also called upon consultants (from the U.S., Canada, Europe, and Africa) to provide assistance in areas not adequately represented by team members.

In addition to numerous internal presentations by the project staff, presentations were made to the special National Academy of Science panel on Sahel-Sudan problems, the United Nations Special Sahelian Office, an M.I.T. internal review committee, the advisory committee established for this project, and others.

Work in the various disciplines was not all begun simultaneously. Staffing-up was a response both to felt demand and to availability of suitable personnel.

The essential first step toward understanding the problems of the Sahel-Sudan countries was to discover how the countries actually func-

tion and what mechanisms regulate their performance. We felt that failure to root our analysis firmly in these realities would invite both distortion in research and faults in planning. Hence, we began our work with basic descriptions, generalizations, and diagnoses.

We identified basic development opportunities for the region and analyzed and evaluated them in a preliminary way. For the most part our work has not entailed basic research, and we have not attempted to carry on programs to collect original new data. However, we have identified some areas in which we believe data collection programs should be initiated.

M.I.T.'s efforts must be understood as only an initial step necessary for examining potential broad-scale development opportunities for the region. The ideas presented in the following pages represent our current understanding of the problems of the Sahel-Sudan region and a set of ideas illustrating a range of actions that might be taken to foster logical development of the area. Both the framework presented herein and the ideas and data on which it is based require continuing updating, monitoring, and review. The framework should thus be viewed in a dynamic sense. It provides a way of approaching the problems of the area, rather than a prescription for their solution. Much of its potential value lies in the fact that the broad view taken helps to identify interactions which might be overlooked in a study focused on specific projects or programs. This potential will be realized, however, only if the Africans and the donors find that it provides them with valuable new ways of looking at the problems of the region.

2.3.2 Problems encountered: A brief discussion of some of the problems we encountered in carrying out this work may be of value to future researchers, and will suggest underlying reasons for some of our omissions and errors.

(1) Tight time schedule: The M.I.T. staff involved in the initial

discussions with A.I.D. were aware that they were being asked to undertake a very difficult task. Various individuals and groups at M.I.T. had expertise in analyzing a variety of complex problems but few had had experience in francophone Africa. The difficulty of the task was further compounded by the requirement that the work be completed in one year.

As the study progressed and the true complexity of the task began to unfold, it became increasingly apparent that the group could have done a substantially better job had the same total effort been extended over a two-year period. This extended schedule would have permitted a more orderly recruitment of staff and identification of consultants. It would also have permitted the team members to spend more time in Africa. Likewise, with additional time it should have been possible to bring some Africans to Cambridge to work with the team. The time, constraint, coupled with the problem of attempting from several thousand miles away to identify suitable individuals and persuade them to come to M.I.T., prevented our obtaining any African participation.

(2) Project cohesion: The systems approach assumes a cohesive group of researchers from various fields working together on a project with well-defined objectives accepted by all participants. The alternative, a hierarchical approach, is usually not very effective in interdisciplinary research. Managing an interdisciplinary research project is a formidable task under the best of circumstances. Researchers usually tend to define project objectives in terms of their own special interests and, more important, define research specifications in terms of their own disciplines rather than the projects requirements. The one-year time frame increased the problem of achieving as high a degree of integration among the efforts of the various subgroups as would have been desired. A reasonable degree of interaction was developed, but the time and effort required to achieve integration in a project of this complexity was at the outset underestimated.

(3) Competing project objectives: A research project of this kind -- emanating from an immediate problem (the drought), but aiming to assess long-term options and focusing on an approach methodology rather than specific programs -- comes under pressures for immediate results and action. Such pressures are created by the researchers themselves, the sponsoring agencies, and concerned parties such as (in this case) international agencies, the Africans themselves, the academic community, and the news media.

Research of this kind also creates an "expectation gap." The problem at hand (the drought) creates both actual and psychological need for finding quick dramatic and technological solutions -- a temptation which, though understandable, tends to detract from the effort to focus on actions whose effect will be evident only after decades. Sharply defining the objectives at the outset is, thus, a prerequisite for such undertakings. However, too specific an initial definition of objectives can also be dangerous, since the directions of inquiry may then be established before sufficient understanding of the basic aspects of the problem is achieved.

Those at M.I.T. responsible for accepting the task of developing a framework for evaluating long-term strategies for the Sahel-Sudan area had had considerable experience with other large-scale problems and were aware of the problems involved in carrying out such studies. We realized we had undertaken a very difficult task, but even so we underestimated the complexity of this particular problem. Nonetheless, in spite of the difficulties encountered we believe that we have achieved essentially what we set out to do.

Part III. THE BASIC PROBLEMS OF THE SAHEL

3.1 Introduction

Although the total area of the Sahel-Sudan region is approximately two-thirds that of the United States, its 23 million inhabitants represent a population only approximately 11 percent of the U.S. The majority of the people live at a subsistence level, depending primarily on agriculture and animal husbandry for their existence. The drought of the past few years has exacerbated the chronic problem of moderate malnutrition and has drastically reduced herds. Only extensive assistance from the international community has prevented widespread loss of human life.

Disaster relief has helped to minimize the effects of the present drought and very significant amounts of foreign assistance have financed a variety of projects and programs in the area for many years. However, these funds were either inadequate or not always directed to the most effective ends. New approaches are clearly necessary if the region is to become self-sustaining and begin an era of positive economic development and widespread improvement in the quality of life of its people.

3.2 Basic Questions

Employing the systems approach to examining the whole problem led us first to identify and assess several critical questions.

3.2.1 Climate changes: In view of the region's five consecutive years of drought, a fundamental question raised was: is the climate changing? Although others disagree (Bryson 1973, Bryson 1974, Bryson and Giordano 1974) we maintain that the present drought should not be considered indicative of a climatic change. Analysis indicates that long droughts are not statistically unlikely; six or more consecutive years of drought could take place in the region once in a century. Furthermore, the region must expect to cope with recurrent droughts of

random frequencies and varying intensities, at different locations.*

3.2.2 Long-term self-sufficiency: The second critical question that emerged was related to the region's long-term self-sufficiency. Given its climatological characteristics, would the area be capable in the long run of supporting its population on a sustained basis? This question was addressed first from a technological viewpoint. Our deliberations ranged from assumptions of utopian conditions to computations of the region's carrying capacity, given the known resource potentials and conditions (including both average rainfall and drought).

The answer to the second critical question was yes: with the known resources and under varying rainfall conditions, it is possible, technologically speaking, for the region to support the population projected from the year 2000 on a sustained basis. If the answer to this question had been negative, the factor of migration would have to have been given greater weight in terms of the options realistically open to the people in the area.

3.2.3 Plausible diagnosis: These conclusions, then, led us to a third question: what are the underlying reasons for the region's present inability to provide sustained support for its population? What are the plausible diagnoses and remedies?

We maintain that the current loss of human lives and livestock and the region's increasing desertification result primarily from an overstressed, frail ecology; the drought simply accelerated the occurrence and intensity of these conditions. Even without the drought, had the pressures from livestock and population continued, the region would

*This matter was addressed by Professor E. L. Cockrum, an ecologist from the University of Arizona who worked on the team throughout the year, and three of our consultant climatologists, Professors Hermann Flohn, Helmut Landsberg, and James McQuigg.

have encountered the same problems within a decade or slightly longer. Thus the essence of the problem is ecological imbalance, emanating from socio-cultural and institutional variables and intensified by natural and climatic conditions. To remedy this situation, new social technologies are as necessary as new engineering technologies.

Since we are examining the entire region and attempting to conceptualize its problems in a unified, comprehensive framework, we are necessarily leveling major differences that exist among the individual countries (see Appendix A). However, these countries do share a number of structural problems. These common characteristics are examined in order to discern their implications.

The bottlenecks to development of the region can be conceptualized as a set of interacting problems incorporating resources, socio-cultural variables, and institutional factors. The present state of each of these has roots deep in the past and will have important bearing on the region's future.

3.3 The Interacting Problems

3.3.1 Interaction between agriculture and the ecology:

Climate in the Sahel-Sudan region is the predominant factor in determining agricultural production. Yet the development economists, by and large, have neglected to treat this variable rigorously and adequately. Progressive deterioration of the region's ecology is due both to recurrent droughts (22 recorded over the last 400 years, at varying degrees of frequency and intensity) and to human factors -- the socio-cultural behavior of 24 ethnic groups whose instincts for survival, sustenance, and improvement have paved the way to a "tragedy of the commons."*

*This phrase was used by Garrett Hardin (1968) to describe the fact that individuals acting rationally in their own best interests can create conditions which are detrimental to the society in which they operate.

The northern cattle-raising and southern sedentary farming areas are both caught in a vicious circle. The region's climate has been and will remain subject to extreme variations in annual precipitation, which have in turn caused variations in the agricultural output achieved by the farmers and led to a system of cattle-raising that leads to seasonal weight fluctuations in the animals. A relatively long period of cattle-grazing (8-10 years as compared to 3-4 years under European or American conditions) is therefore required before animals reach maturity. Significant increases in cattle population (50 percent increase in 1970 over 1960) have caused range depletion, which, in turn, has lowered the carrying capacity of the grazing land; repetition of the process has reduced the land's grazing capacity even further. According to preliminary calculations, the region's 1970 cattle population exceeded the carrying capacity under the most favorable set of conditions and policies we tested.

In the area of sedentary agriculture, a similar phenomenon is observable. Frequent periods of adverse climatic conditions and pressures of increasing population have, over time, reduced soil fertility. In the absence of modern agricultural technologies and fertilizers, the traditional farming system depends on fallow periods to restore soil fertility. Since little new arable land is available, the rate of soil fertility decline (with use time) has been higher than the rate of soil recovery with fallow time. For example, from 1961 to 1970, the fallow time in Niger declined by 50 percent, while farming technology and application of fertilizers did not change substantially.

The foregoing problems are exacerbated by the patterns of energy consumption, in which nearly 90 percent of the energy is drawn from wood resources. The rate of wood consumption in Upper Volta, for example, is now estimated to equal the rate of net reproduction of trees. If this trend continues and alternatives sources of energy are not developed, the problems of deforestation and desertification will be magnified.

Finally, overgrazing of the fragile range has led to an increase in the amount of the sun's energy reflected by the ground. This increase could in turn have an adverse effect on cloud formation and on the frequency and quality of precipitation.

3.3.2 Interaction between the productive capacity of the area and its institutions: Failure to develop adequate social institutions has influenced both the modern and traditional sector's production functions since colonial times. The interaction between agriculture and the ecology has led to low production, low output, and subsistence living conditions in the traditional sector. This low productive capacity in the rural areas has led to a failure to develop institutions which would in turn foster development of the rural sector. A lack of institutions for saving, credit, and investment means that the rural sector relies on traditional forms of savings (e.g., more cattle), which are counterproductive to maintenance of the ecological balance and thus the productive capacity of the area. Lack of availability of credit, together with low investment in agricultural technology exacerbates the problem of low productivity. Failure to develop productive capacity has led to a lack of employment opportunities which has in turn resulted in out-migration and loss to these areas of many of the most able people.

The rural areas also suffer from inadequacies in health care facilities and infrastructure, an education system unresponsive to social needs, and lack of other social amenities. As a result of these restricted opportunities, the well-being of the region's inhabitants -- especially when measured in terms of the potential that might be realized if adequate services were available -- has deteriorated over time.

3.3.3 Relations between the traditional and modern sectors: Pricing policies for agricultural production, taxes, and other fiscal

policies have favored the modern sector at the expense of the traditional sector. These policies have siphoned resources from the traditional sector and increased the migration of rural labor to the cities.

However, the rapid rate of migration from the traditional sector into the modern sector has created problems within the modern sector. The rate of migration into the modern sector has been much higher than the rate of increase of employment opportunities, thus creating a very high unemployment in the cities. Moreover, minimum wage laws, overvalued currencies, and a very low level of worker skills have created conditions adverse for competition in the international markets. The rapid migration to the cities has also led to inadequate housing, sanitation, water systems, health care, and nutrition, and thus to a generally poor quality of life among the urban masses.

These policies and conditions have fostered certain internal inconsistencies. Since the prices of both imports and the modern sector's products have been held quite high, the growth of a market for industrial goods has been inhibited in the traditional sector. That sector's elasticity of income demand has been disregarded in pricing, income, and tax policies. Industrial policies have been geared to foreign markets, neglecting rural demands and the need for a synergistic system linking industry and agriculture.

3.3.4 Additional Problems: A number of additional problems over which these countries now have little control have limited their development. These include:

(1) Restrictive economic policies -- The monetary union to which these countries belong results in restrictive monetary and fiscal policies in which there is limited flexibility.

(2) Poor foreign trade situation -- The region's exports are subject to short-term fluctuation on both the demand side (world market) and the supply side (because of climatic conditions), while prices of

imports have been steadily rising.

(3) Dependence on other countries -- The growth of the Sahel-Sudan countries is heavily dependent on foreign aid, on European markets, and on outlets for the region's products in the countries to the south.

(4) High population growth rate -- The population growth rate has been and will probably remain for some time high. The resultant high dependency ratio is a detriment to economic development.

(5) Underdevelopment of human resources -- Lack of trained indigenous personnel will continue to impose a major constraint upon the region's absorptive capacity and keep the region dependent upon foreign technical assistance.

For the economies of the Sahel-Sudan region to support their populations at a self-sustaining level, these interacting problems would have to be addressed and their effects minimized.

The determination of the answers to the basic question of the ecology and long-term self-sufficiency, together with the identification of persisting and interacting problems, provides the basis for the framework within which development alternatives can be identified and evaluated.

Part IV. IDENTIFICATION AND EVALUATION OF ALTERNATIVES

Many development alternatives are, theoretically at least, available to a particular region at any given time. However, most are not viable or are otherwise not realistic. A number of such alternatives were explored by the project staff.

4.1 Major Infusion of Technologies and Capital

U.S. experiences with the atom bomb and the space program have tended to create an impression that, given sufficient funding and effort, a technical solution can be found for nearly any problem. Consequently, there are those who might hope for an economically, socially, and politically feasible technological approach which could have a major impact on the region. The project identifies several alternatives that could precipitate massive changes in the region.

For example, the region's sparse and extremely variable rainfall, particularly in the north, seriously limits its agricultural productivity. Consequently, a weather modification approach could be very attractive. It might increase the region's average output and minimize variations in output. However, while moderate success in increasing rainfall through cloud seeding has been achieved in some parts of the world, the results are unpredictable even under the best of conditions and cannot guarantee more than a few percentage points of improvement. More fundamentally for this region, there must be moisture in the air if seeding is to produce rain. The characteristically dry air over deserts and subdeserts during most of the year cannot produce precipitation. Only during the summer months does warmer, moisture-laden air push northward from the equator, bringing rain to the Sahel-Sudan region. The brief but hard showers, resulting in much runoff, cause soil erosion instead of infiltrating usefully into the ground. Although some cloud seeding experiments have recently been tried in the region, the results were inconclusive, and it is doubtful that cloud-seeding could significantly affect

either the total quantity of precipitation or the type of showers. Much further research is required if the effectiveness of weather modification is even to be appraised.

The ratio of the amount of the sun's energy incident on an area to the amount of energy reflected is called its albedo. Recently a relationship has been postulated between an area's albedo and the amount of precipitation received. Specifically it has been hypothesized that if the albedo of the Sahel-Sudan region could be decreased by increasing the amount of ground vegetation, the moisture-bearing clouds would progress further north, carrying additional rain to the region. Although this hypothesis is as yet unverified, it is believed by some investigators that the albedo must be changed significantly over an area approximately 400 kilometers on a side in order to modify rainfall significantly. The cost of successfully replanting an area that large would be very high -- larger than justified given the slim evidence now available to support the hypothesis.

Alternatively, use of such an area could conceivably be carefully controlled so as to permit the ground cover to regenerate itself. The social difficulties this would create, coupled with the long pay-off time for such a project, would probably make it politically infeasible.

If the region's rainfall cannot be increased, what are the possibilities for expanding agricultural productivity through large-scale irrigation? One of the grandest schemes of this type has been discussed for a number of years. It proposes construction of a large dam on the Congo River, a relatively short distance downstream from its junction with the Ubangui. The water thus impounded would gradually flood a large part of Zaire -- forming one lake -- and portions of Chad, Niger, Cameroun, Nigeria, and the Central African Republic -- forming a second immense lake. Ultimately, after construction of some canals, the water would discharge into the Mediterranean. Such an undertaking would have enormous impact

on the region. Vast amounts of water would be available for irrigation, and the extent of the lakes formed would be so large as to cause a probable increase in rainfall to the west (in view of the region's prevailing west wind).

This scheme is probably possible technically and might not be impossible economically, but its enormous social and political implications render serious consideration doubtful.

A less ambitous modification of this grand plan calls for diverting a portion of the Ubangui's flow into the Logone or Chari rivers in order to control the level of Lake Chad. Evaluation of the plan's technical feasibility would require a site visit and preparation of detailed topological maps. Only then could even approximate cost estimates be prepared. However, it is clear that because of the region's high evaporation rates and the large surface of Lake Chad, a very substantial amount of water must be added to the lake to maintain its level in the dry season. Even if this proved technically and economically feasible, would the Central African Republic, Zaire, and the other countries involved agree to divert this water?

On a more modest scale are the still very extensive plans to build dams along the Senegal and Niger rivers, thereby regularizing the flow and permitting extensive irrigation, improved navigation, and power generation. These studies indicate that approximately 400,000 hectares could be irrigated along the Senegal River and 600,000 hectares along the Niger. Although some believe that the implementation of this plan would support up to 10 million people, others set the figure substantially lower. While these projects offer considerable advantages, they cannot, alone, make the region self-sufficient because, by the year 2000, if current trends continue, the region must support a second 23 million people.

Without doubt some of these water-control schemes are feasible

both technically and economically and further appraisal of the more attractive possibilities is desirable. However, such endeavors in themselves, even if they prove to be as successful as indicated by optimistic analyses, will not guarantee that the entire region moves forward in development.

The framework for evaluation which we have developed therefore has been designed to direct attention primarily to possibilities for accelerating the widespread infusion of simpler technologies throughout the population. This can be achieved only if an institutional structure is developed to bring the desired technology to the people and prepare them to accept it. Such an approach will not yield large short-term gains, but we believe that it offers the surest means of securing sustained long-term development of the region. Some possibilities under this approach are outlined in the following section.

4.2 Widespread Development of Human and Natural Resources

Creation of an institutional structure and training of the people required to bring about a widespread infusion of improved technology in the society represents a major long-term task. Successful results require the consideration of many complexly interrelated social, economic, and political factors and the patience of both countries and donors, who must recognize that significant changes take time and require commitment to a long-term effort.

In the past, a major fraction of development assistance has been directed toward specific projects which offer the promise of short-term results. Consequently, although this project-by-project approach to development has been acceptable to both donors and recipients, too often the attention in project design has been so narrowly directed that serious detrimental side effects have occurred that have outweighed the positive aspects of the projects. The framework which we have developed is

designed to provide a more holistic view of projects and a means for appraising how they coordinate with long-term goals.

In our study we place a larger than usual emphasis on development of human capabilities and construction of the socio-political-economic infrastructure needed to support the economy's production sectors. Progress along these lines is not achieved quickly. Such developments would require expansion of the educational system, which should aim to diffuse knowledge about improved agricultural practices throughout the traditional sector and to develop managerial and entrepreneurial skills among the urban workers. At least among the former group, much of the education might be nonformal, and might be carried out in vernacular languages.

Agricultural practices which will result in improved and sustained yield of both food and cash crops have been demonstrated in other areas of the world. However, development of social and economic policies conducive to utilization of these practices would require close cooperation between representatives of the central government and of the agricultural sector.

The synergistic development of industry and agriculture could create employment opportunities to absorb the workers who would be released by more efficient agricultural productivity. Here again, new social and economic policies would be required to expedite the desired development.

The developed countries of the world did not attain their present state of development quickly. Widespread education of their citizens and creation of institutions enabling them to exploit technology advanced slowly, hand-in-hand with technological development. Today, ample evidence exists that introduction of a few advanced technological activities into a developing country does little to improve the quality of life for the people in general. Certainly it should be possible to accel-

erate the pace of development and by-pass many of the adverse side-effects associated with the industrial revolutions through which the developed countries have passed. However, we should not lose sight of the fact that development is, in the final analysis, based upon people and the pace of development is to a large extent tied to the rate at which human capability can be developed.

We therefore conclude that development of the Sahel-Sudan region should focus on identification of realistic long-term goals and development of the human resources which will stimulate the social, political, and economic changes necessary for the region's nations to take advantage of the technology now available.

4.3 Long-Term Options Considered by the Project Group

As the group developed its understanding of the area and began to formulate its framework for evaluation, a number of development alternatives were postulated and examined. Some of the specific possibilities examined are listed here and the major findings of the associated studies are presented in Part V.

(1) Continuation of current development practices. The objective of this examination was to determine whether forces now operating in the region would, with a continuation of foreign assistance at present levels and following present allocation practices, lead to elimination within the next 20-25 years of the pervasive problems now facing the region. The basic conclusion of our analysis was that past trends will continue if no new forms of intervention take place and reliance is placed upon some assumed, inherent self-corrective mechanism assisted only by current development practices. In fact, future catastrophes most probably would be larger and more intense than those experienced in the past. Human and animal populations would continue to increase, and the productive base of the region would be further eroded, thus diminishing all hope for

improvement in the quality of life of the region's masses. The further erosion of the region's economic productive base would also necessitate an ever-increasing amount of foreign aid, even during periods of average rainfall. And during periods of drought, ever-increasing peak levels of emergency relief would be required to prevent human and environmental catastrophe.

(2) Widespread introduction of improved agricultural practices. Because agriculture is currently of central importance in the region and because major opportunities exist for introducing improved techniques and thereby improving yields, we decided to evaluate an integrated agricultural strategy by our iterative process. This choice was influenced by the problem at hand, they region's existing resource base, and the possibility that self-sufficiency of the region as a whole could be achieved if a short-term, 10-15 percent increase in average annual production could be achieved and if production could then keep pace with the growth of population. Furthermore, it is our view that improvement of the region's productive capacity will enable the Africans to reduce their dependency on foreign aid and to improve their quality of life in consonance with their own cultural, ethical, and value systems.

(3) Development of the industrial sector. The industrial sector has not been developed to any significant extent, but the need exists to increase the job opportunities in the region if introduction of improved agricultural techniques leads to reduced requirements for labor in the agricultural sector. Particular attention was directed to development of industries which would relate closely to the agricultural sector, both by processing agricultural products and by supplying the needs of that sector.

(4) Development of mineral extraction. Mineral extraction is currently an important activity in Mauritania and Senegal. Less important mining activities are underway in other parts of the region. Current

knowledge of the resources of the area indicates that possibilities exist for modest expansion of the activities, but there is no present indication of significant new deposits which would lead to a major change in the economy of the area.

(5) Improvement in health, education and nutrition. The high incidence of disease, marginal diets, and the low level of educational achievement of a very large fraction of the people in the region act as serious r traints on development.

(6) Improvement in economic policies. Study of economic considerations points to the possibility that changes in the monetary, pricing, and fiscal policies in the region could create an environment more favorable to development.

(7) Changes in socio-political policies. Study of the role of social political factors in the development of the region indicated that changes in social and political policies offer a way to foster general development of the area.

Obviously, development efforts should not be concentrated wholly in one or two of these sectors. The problems in the various areas are closely interrelated and changes made in one will have major repercussions in others. Consequently, the M.I.T. group considered that some of its own effort should be directed to each of the major sectors identified. However, because of the present importance of agriculture to the region and the probable continuation of agriculture as the region's principal activity, we focused particular attention on explication of a framework for evaluating agricultural development possibilities in the region. This example of the application of our general framework to a particular sector is described in detail in Volume 2.

4.4 Development of a Planning Framework for the Agriculture Sector

The framework for agricultural development planning which we have

proposed illustrates the application of our broad approach to the area of agriculture. The specific objective has been to devise a framework which would permit evaluation of the agricultural potential of the six-country region under a range of conditions. Under the general methodology employed, the area was divided into a number of zones based on rainfall, and the potential of each area was determined. First, a theoretical yield was calculated. Then successively more stringent constraints were imposed and the production evaluated under various assumptions as to the level of agricultural technology employed. Finally a strategy was chosen to illustrate the way in which the framework could be utilized for appraising the productivity when different levels of agricultural technology are applied in different areas. The acronym ISYALAPS has been applied to the strategy because it represents an Integrated Sustained Yield Arid Land Agricultural Production System.

The framework for evaluating development alternatives for the agricultural sector includes four levels of activity based on the use of successively higher levels of technology. The aim of the lowest level of intervention is to halt further degradation of the ecology of the region, thereby avoiding further deterioration in its productive capacity. Higher levels provide for successively higher levels of sustained output. Briefly, the activity levels have the following characteristics.

Level A -- This is the minimum level of intervention capable of having significant impact. The population, number of animals and area farmed are controlled so as to seek ecological balance in the planning area. Essentially the current technology is retained.

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

Level C -- This activity level seeks further increase in production

through the introduction and utilization of advanced agricultural technology in crop, wood, and livestock production. Intensive management practices are required.

Level D -- This activity level calls for widespread utilization of intensive agricultural systems, similar to those employed in developed countries. All available agricultural technology and practices (including irrigation and drainage, mechanization, and chemical fertilizers, herbicides, and pesticides) are used to maximize production of crops, wood, and livestock.

The framework provides a systematic way for evaluating the consequences of utilizing land in the different geographic (location and climate) zones of the region under different levels of intervention. In its fully developed form the framework takes account not only of geographic variability but also of social diversity and political structure, and it recognizes financial and other limitations.

Final appraisal of any specific strategy under the agricultural framework should be carried out within the broader framework which includes the other sectors of the economy. As goals are established, possible conflicts between goals must be appraised, costs and benefits evaluated, human and infrastructural needs evaluated, a time framework established, and factors which might lead to failure of the strategy identified.

4.4.1 The ISYALAPS Strategy: The discussion of this strategy illustrates how the agricultural framework can be employed to evaluate a specific set of agricultural activities. The guiding principles envisioned in developing the ISYALAPS strategy are:

(1) The more arid zones of the north and other low-productivity areas throughout the region would be utilized as a breeding ground for animals at sustained-yield carrying capacities.

(2) Both young and nonproductive old animals would be system-

atically removed from breeding-ground ranges and raised to marketable sizes on more productive range land.

(3) The sustained-yield carrying capacities of cow-calf range lands would be increased through supplemental feeding.

(4) Technology would be utilized to increase the per-hectare yield of both food crops and exportable cash crops.

(5) Monetary and fiscal policies would be modified, and expansion of monetary institutions in the rural areas would be encouraged.

(6) Crop production would be concentrated more in the southern zones (where rainfall, even during drought periods, tends to be adequate for some productivity) and in small-scale irrigated projects in areas where adequate water supplies and suitable soils are present.

(7) New agricultural areas would be exploited wherever possible.

(8) Farmers would be encouraged to move into more productive areas, and larger-scale productive units would be encouraged. These policies aim at localized adaptation to production possibilities rather than wholesale resettlement and migration.

(9) Local capacity for implementing technical/organizational solutions would be increased.

Development of the agricultural sector should be coordinated with development of associated industrial activity, transport and marketing structures, and educational programs designed to acquaint the rural population with techniques for improving the yields of their operations.

4.4.2 A strategy for coordinated agriculture-industry development: The strategy of an agriculture-based industrial system assumes development of a natural interaction between the agricultural and industrial sectors. Fostering the development of industry to process the rural area's agricultural products would benefit the region since higher value products would be exported and jobs would be developed. Some of this industry would be located in the rural towns so as to be close to the

source of the agricultural products. These towns would also serve as points from which fertilizers and other needs of the agriculturists could be supplied. Some towns which are located on principal transportation axes could develop into new urban nuclei and, along with existing cities expanding through conversion of the agricultural sector from a subsistence level to a market economy level, could become an important source of jobs. These developments would create a natural interchange between the traditional and modern sectors and afford the possibility of eliminating some of the factors which now impede development of the agricultural sector.

-- The major criteria which evolved during the early phases of our study and caused us to focus on agricultural development as offering the best course for the region included the following potential outcomes we deemed desirable:

(1) creating and satisfying demand of the urban sector for food and of the rural sector for fertilizers, manufactured goods, etc.;

(2) taking advantage of the demand for meat in the neighboring southern states (thus increasing north-south trade relations);

(3) improving the relationship between the rate of migration from the traditional sector and the rate of increase of industrial employment in the modern sector;

(4) utilizing indigenous factor inputs according to comparative cost advantages and economies of scale; and

(5) integrating industrial and agricultural development strategies with population, migration, and manpower-training factors. All these factors are, in turn, affected by both prospective domestic demand and north-south trade relations.

The time required for a major level of implementation to generate significant impact is at least 10 to 15 years. Certain activity levels require significant periods of lead-time in order to construct the neces-

sary and appropriate social and technological infrastructures. For example, time is required to introduce various agricultural technologies and to develop the social organizations, skills, etc. conducive to the acceptance of new products or methods.

4.5 Elaboration of the Framework

M.I.T.'s effort has been directed toward the initial construction of a framework -- a way of assessing options -- that is capable of capturing the total long-term impact upon a region of a variety of development strategies. It was not intended that the framework developed during this initial phase be sufficiently detailed to provide a direct evaluation of specific projects or programs. The next step that should be taken is elaboration of this initial work to provide more specific and detailed information on the human, physical, and economic resources which will be required to achieve prescribed levels and rates of development.

This type of expansion of the framework would benefit very significantly from -- and, in fact, would require -- considerable interaction with and involvement of the Africans and representatives of the donor organizations.

Part V. FINDINGS OF THE SECTOR STUDIES

In this section, we have summarized the principal substantive findings and the conclusions of our analysis of the various sectors.

5.1 Agriculture

(1) The loss of lives and livestock and the accelerated desertification now being experienced throughout the Sahel-Sudan region result from attempting to support too many people and animals in an ecologically fragile zone.

(2) While rainfall in the Sahel-Sudan region varies significantly from year to year, accounts of droughts over the last several hundred years and rainfall data which have been collected over the past 30 to 50 years show no solid evidence of an actual climatic shift in the region. Therefore, the present drought should be viewed as merely one in a series of such events. Similar droughts can be expected in the future, and the region must learn to cope with them

(3) On the basis of climate, five zones which extend from east to west across the region can be identified. Increasing levels of rainfall and agricultural development are seen as one moves from north to south in the area. Except for developments around riparian areas, and in isolated areas where groundwater can be effectively utilized, there is little likelihood that this general pattern will change.

(4) Bringing the carrying capacity of the land into balance with the number of livestock and people it supports is the first step that must be carried out if the area is to achieve long-term self-sufficiency in food. This balance can be achieved either by reducing agricultural population and herd size or by increasing the productivity of the land. Our analysis suggests that both approaches should be developed.

(5) Currently, approximately 90 percent of the people of the Sahel-Sudan are engaged in agriculture or animal husbandry, and these activities account for about 45 percent of the GNP and two-thirds of the exports of

the area. We believe that agriculture will continue to constitute the major activity of the region.

(6) The general level of technology employed in agriculture is very low; therefore the productivity of crops and herds is low.

(7) On the basis of comparison with areas which have comparable rainfall, we believe that this area should, on the average, be able to produce several times the current output if improved technologies and practices are instituted. These changes must however, be coordinated with industrial development and expanded trading arrangements, because with improved agricultural practices less farm labor will be required.

(8) New technologies and practices can be applied effectively at considerably higher activity levels in the higher rainfall areas of the south than in the desert, subdesert, and sahel zones.

(9) The greatest potential of the more arid parts of the region lies in their controlled use as a breeding and calving area. However, realization of this potential will require a significantly higher level of north-south cooperation than currently exists. Excess male yearlings and selected older cattle would have to be moved southward for additional growth and finally to markets -- largely in the coastal zones. Provision would have to be made to supply some supplementary feed to the animals during the dry season and during drought years.

(10) Through better preparation of the fields and use of improved seeds, fertilizers, and pesticides, agricultural productivity can be increased. However, adoption of the improved techniques by farmers will require concomitant social, political, and economic reforms. Such reforms must foster diffusion of knowledge about agricultural practices among the rural population, facilitate farmers' ability to obtain loans in order to finance the required improvements, and insure the farmers a satisfactory return for their labors.

(11) The amount of land now devoted to irrigated agriculture is about one percent of the total area cultivated. Projects to construct major dams which will regularize the flow of the Senegal and Niger rivers and dikes to permit irrigation around Lake Chad could potentially bring considerable amounts of land under intensive cultivation. While such developments will be important to the region, in themselves they can support probably not more than one quarter of the population projected for the region for the year 2000.

5.2 Economic Considerations

(1) The major distinguishing macro-economic characteristics of the region are the low per capita income and the high dependence of the region's countries on foreign aid. Contributing to these characteristics is the large extent to which the region is influenced by factors over which it has little if any control. These include the climate (a fluctuating factor to which the economies are highly sensitive); a prolonged colonial experience and post-colonial ties which have resulted in attitudes and institutions which have not in all cases been responsive to development (such as the monetary system and the mass/elite gap); a high dependency ratio in the population; and an acute shortage of indigenous entrepreneurial skills and skilled labor. These conditions suggest a two-pronged approach to development. Over-all planning strategy, by necessity, would require development to proceed from the top down, while realizing that major development plans would be heavily dependent on the creation of incentives and implementation capabilities from the bottom up.

(2) The relatively small and sparse population of the area means that domestic markets are small and scattered and that transport costs and the costs of rendering government services are high.

(3) The West African monetary union and membership in the franc zone have significantly influenced monetary policy in this region and

may have a major bearing upon the rate of economic growth of the area. The entire monetary system in the region is geared to fulfilling one main economic objective: maintaining a fully convertible and stable African currency within the franc zone, with emphasis on unimpeded capital and trade credit flow.

(4) The banking system in the region has not fostered domestic capital accumulation, since its rules of operation are basically aimed at financing trade flows and capital repatriations rather than at stimulating monetization, savings, and local investment.

(5) Comparison of the low trade proportions* of Niger and Upper Volta with those of developed countries of comparable population reflect to a considerable extent the low income levels and poor natural resource base characterizing these two countries. By contrast, Mauritania and Senegal have relatively high trade proportions, reflecting their better natural resource endowment and higher level of development, respectively. However, even in these cases the performance of the economies as a whole bears little relation to that of the external sector. This fact indicates a lack of full integration of the external sector into the growth process.

The commodity composition of exports and imports and the geographic concentration of trade increases the vulnerability of the region to supply and demand fluctuations. Iron ore accounted for more than 90 percent of the exports of Mauritania, while in Niger and Upper Volta agricultural and livestock products account for two-thirds or more of the total exports.

Moreover, the dependence on one or two commodities has apparently increased over time as has the concentration on a few markets. France and the franc area countries constitute well over half of the export markets. The import side depicts the same pattern of high commodity

*Trade proportion is the ratio of the combined value of imports and exports to the GDP.

and geographic concentration as prevails for exports. Foodstuffs and tobacco constitute a large portion of the total import bill, whereas industrial raw materials and capital goods play a less important role. Once again, France and franc-zone countries are the major suppliers. Moreover, the trade patterns, for both imports and exports, has not radically shifted since independence. In the future the importance of fuel imports can be expected to increase appreciably.

(8) In analyzing and evaluating development options, foreign aid requirements for emergency relief should be separated from those for long-term development purposes. We have not made estimates of emergency relief requirements and do not have adequate information on the extent of the damage incurred by the drought or the progress being made in rehabilitation. Our attempt to estimate total foreign assistance requirements for development purposes has also been hampered because of the uncertainties created by weather fluctuations of the region. Thus, considerable difficulty is posed in estimating such parameters as saving rates, capital-output ratios, and rate of growth of exports.

Nonetheless, we used the Chenery-Strout model to arrive at some preliminary economic projections and foreign aid requirements. The principal advantages of this model are (1) its non-stringent data requirements, and (2) its explicit recognition of the three most important economic development constraints that seem to be relevant for the Sahel-Sudan countries -- the domestic savings constraint, the balance of payments constraint, and the absorptive capacity constraint.

We believe that estimates of foreign aid requirements based on the assumption that the low historical parameter values will continue to operate for the entire projection period could be seriously misleading. Instead of using constant values of the various parameters, we assumed that some of them, e.g., the marginal propensity to save, the rate of growth of exports, and the maximum feasible growth rate of investment,

will change in a favorable direction over time. These trends are feasible in the sense that several underdeveloped countries have been able to achieve them through determined efforts.

The projections were made on the assumption that the target growth rate in each country is 5 percent (a U.N. target for the development decade). The important conclusions were:

(a) The absorptive capacity constraint will prove to be a very significant bottleneck, particularly in Chad and Upper Volta. In both of these countries annual gross capital formation has actually declined over the period 1964-1971, the only period for which data are available. Taken literally, this would imply a negative value of investment growth rate. However, even if investment increases at a rate of 8 percent during 1975-1979, and 10 percent thereafter, it will take more than 15 years merely to achieve the target growth rate due to the low initial values.

(b) For Mauritania, values of parameters based on historical data are such that the model indicates that enough savings and foreign exchange will be available to sustain a 5 percent growth rate of GDP. In fact, even for an 8 percent growth target, the model predicted no bottlenecks. These results must be treated with caution, however, since most of the investment in the past decade was carried out by foreign investors who brought with them not only financial resources but also the required skilled personnel. Even though the earnings from existing mines will be sufficient to finance investment and import requirements implied by an 8 percent growth rate, the absorptive capacity constraint may prevent the economy from achieving such a growth rate.

(d) Two estimates of total foreign aid requirements were derived, one on the assumption of a sustained growth of exports at an annual rate of 6 percent, the other on the assumption that they will grow at 3 percent during 1975-79, at 4 percent during 1980-1984, and at 5 percent thereafter. Other assumptions remained the same for the two sets of projections. Our conclusion is that in the former case about $5 billion in foreign aid will be required during 1975-2000, and in the latter case about $9 billion. Clearly, these estimates also depend upon the accuracy of our assumptions regarding saving factor, etc.

(e) The Sahel-Sudan region has experienced two kinds of droughts -- minor droughts, when there is below-normal rainfall for only one or two years, and major droughts such as the one recently experienced, when rainfall stays at subnormal levels for three years or more. Our procedure for estimating the capital-output ratio attempts to take account of minor droughts. But we cannot "average out" the influence of major droughts, which can create severe dislocation throughout the economy in addition to causing a decline in output. Thus, if a major drought occurs within our projection period, the projections will be in error.

5.3 Health, Nutrition, and Population

(1) Because of the low average population density in the countries of the Sahel-Sudan, few of the leaders of this area are concerned with the question of population. In fact, arguments are made that development of the area is hampered by its low population. However, the present average growth rate of 2.2 percent per year and the fact that nearly half of the total population is below 15 years of age mean that the population

will probably double in 30 years or less. This prediction must be taken into account for long-range planning.

(2) The Sahel-Sudan countries have a medical infrastructure which is, to varying degrees, both weak and unbalanced and which is too seriously undermanned to meet the people's medical needs. As a result, a broad spectrum of diseases that have been largely eliminated from developed countries is highly prevalent in this region.

(3) Significant improvements in health will require improved nutrition, water supply, waste disposal, education, and transportation as well as improved health-care systems themselves.

(4) Vaccination against measles and improvements in infant and child feeding could significantly reduce the infant mortality rate.

(5) In the past, critical nutritional deficiency has not seemed to be a particularly important problem in the region. However, a chronic, moderate protein-caloric deficit has probably existed for a long time in some parts of the region, at least in the younger age groups. This condition contributes to the mortality from common communicable diseases, especially measles.

(6) The drought has caused substantial short-falls in the availability of food and has resulted in significant and severe malnutrition among the nomads, especially those who have moved to the outskirts of cities as a result of the drought. Deficiencies in the region's transport system have exacerbated the problems of supplying relief food to outlying regions.

(7) Significant improvement in the health care available in the area will require integration of all components of the system, improvements in the monitoring of disease, reorientation of the system toward preventive medicine with emphasis on prenatal, maternal, and infant care, utilization of communications media in health education, and strengthening of the health education system to enable it to provide the personnel necessary for improved health care delivery.

Strong interrelationships exist among improvements in health and nutrition, population growth rate, and the added stress which further expansion of the dependency ratio would place on available food resources and on schools and other services geared to young age groups. These considerations must be taken into account in long-range planning for the region.

5.4 Industrial and Urban Development

(1) Industry accounts for only about 6 percent of the GNP in the six-country region (if Mauritania's iron-mining operation is disregarded). Non-agricultural exports come principally from the extractive industries (iron ore in Mauritania, phosphates in Senegal). Manufacturing industries play a minor role, but significant expansions in textile production, construction, and food processing have occurred in the past decade.

(2) Although urban areas still account for only 11.3 percent of the region's total population, urbanization has recently been proceeding at a rate substantially higher than growth of the general population (7.0 percent versus 2.2 percent). The drought has contributed somewhat to the recent high rate of urbanization, but a continued high urban rate of growth can be expected.

(3) Except for Nouakchott, which was established only at the end of the French colonial rule to serve as the capital of Mauritania, the region's cities have developed from a few old trading centers. As a result, each country has only one or two cities of significant size. Since government operations, wage-paying jobs, health services, etc. tend to be concentrated in these few urban areas, the rural population (the majority of people) has poor access to such advances.

(4) Although the Sahel-Sudan region exports raw materials to Europe and the United States, it cannot compete successfully against the industralized countries. Wage rates in West Africa are relatively high and skilled labor is scarce with the result that modern industry has

not been attracted to the area. Also, the migrant or "uncommited" nature of the majority of the labor force creates a serious problem for industry. Since land provides security against unemployment, sickness, and old age, an individual must preserve his claim to it by inhabiting and working it. Thus, although large numbers of workers are attracted to the cities there is a constant incentive for them to quit their jobs periodically and return to their families and land. Basic social and economic changes must be made if a supply of labor adequate to permit an effective exapnsion of industry is to be achieved. Introducing capital-intensive methods will, in most cases, increase the unemployment problem.

(5) In the region, managers have tended to choose more advanced technologies for application in export-oriented production, leaving small-scale industries and production for local consumption to operate with less efficient techniques.

A lack of development of the manufacturing-trade-distribution process has hindered industrial production. Exported goods are shipped unfinished; most imported goods arrive finished. If industry is to grow, materials produced in the country should be processed further before being exported, and the finishing operations on imported commodities should be performed within the region.

(6) Export-import duties, the limited and fragmented nature of industrial activities, similarities between the products of the individual Sahel-Sudan countries, and lack of an adequate transport system all tend to retard industrial development. Regional federations to establish customs unions, common market areas, etc. and industrial preference agreements would encourage development of local industry, thus reducing the need for imports.

These findings have led us to outline for evaluation within the analytic framework an industrial strategy designed to complement the

ISYALAPS agricultural strategy. Under this strategy industries would be located in the rural sector so as to help develop the rural areas, thereby reducing the problems associated with high growth rates in the urban centers. In the pattern envisioned for the development of rural towns, industries and the service sector (education, medical, and welfare) would evolve together and serve to reduce the economic and social gap between the rural and urban areas, thus converting the present specialized agricultural communities into balanced agro-industrial communities capable of greater utilization of local resources and able to move freely to supply local needs.

Under this strategy the agriculture-based industrial development would strive to:

a. be labor intensive;

b. create ancillary local employment opportunities, particularly in services;

c. reflect balanced growth in response to the traditional sector's demands; and

d. respond to the possibilities present in north-south as well as east-west relations.

Development of the industrial sector will require concurrent development of the infrastructure and institutions required to permit effective industrial operations. Examples of the types of development required are:

a. Improvement of the transport system so as to facilitate the collection of unprocessed agricultural products and the transport of processed products to urban consumption centers and export points. An improved transport system will also be required to bring fertilizer, machinery, and consumer goods from outside the area to the rural community.

b. Development of the infrastructure necessary to support the industry. The types of facilities required will include water and sewer

systems, housing, electric power systems, etc.

c. Development of the financial institutions necessary to support an agricultural community moving from subsistence operations into the monetary economy and of the institutions necessary to support the development and operation of industry. Institutions to provide credit and encourage savings will be very important.

d. Development of the social infrastructure required to support this new agriculture-industry development. This infrastructure will include schools, health care delivery facilities, and local government capability.

Planning for the type of agriculture-based industry envisioned thus required consideration of the interaction of essentially all of the sectors which have been considered during this study. In this initial step toward constructing a framework for evaluating alternative strategies for development, we have been able to outline only the principal features of this complex problem. Formulation of energy policies to support industrial growth and relieve the projected balance of trade problems is discussed in Section 5.10. We believe further examination of the potential for industrial development should receive considerable attention in any follow-on efforts.

5.5 Social-Political Considerations

(1) The relationships which have developed between the urban and rural areas in the Sahel-Sudan work to the disadvantage of the rural areas and the advantage of the urban areas. Understandably, medical and educational services are more available in the cities than in the rural areas. Prices of agricultural products are controlled to the disadvantage of the rural sector. In spite of the importance of agricultural exports, evey little input has been made available to the rural sector to enable it to increase its output. The transportation infrastructure tends

to be poor, thus further retarding transformation of the agricultural sector into a true market economy.

As a result of the lack of attention being given to rural development, the cities offer a great attraction to those in the rural sectors. Thus, migration to the cities is proceeding at a very high rate and is placing a severe burden on the urban areas where infrastructure and employment opportunities are not expanding with sufficient rapidity to accommodate the immigrants.

(2) As shown in Table 13 in Appendix A, 24 distinct cutlural groups have been identified in the area. Any plans or strategies which do not take adequate account of the cultural patterns of these groups (e.g., authority patterns, forms of social organization, modes of livelihood, and inheritance patterns) and the differences among them not only will fail to capitalize on existing cultural resources, but will run the risk of meeting serious opposition or of failing if implemented. On the other hand, we do not mean to suggest that these patterns either must or should be maintained. Cultural patterns are subject to change, and there is a history of adaptability in the Sahelian region.

(3) Political, economic and technical considerations now severely restrict the options open to the herders (the group most vulnerable to the impact of the drought) to protect themselves and their herds. Many families were forced to settle in refugee camps merely to survive. Detailed analysis is needed to determine the options available and the receptivity of the various herder groups to alternative life styles and means of livelihood.

The problems of the pastoralists who engage in a transhumance* deserve somewhat special attention since their movements may bring them across national boundaries. The solution to the problems must,

*"Transhumance" refers to the regular north-south migration of pastoralists and their herds for the purpose of following available pastures.

therefore be handled within a regional framework.

(4) Existing rules regulating land tenure are an integral part of cultural patterns of kinship, authority, and social control. The social and political costs of undermining these cultural systems may be prohibitive, and attention should be directed toward options which work within the traditional structures. Volume 2 on agricultural development indicates that effective utilization of modern agricultural technology would be facilitated by increase in the scale of operations. This might be done through increases in scale which function within the traditional cultural system.

(5) The social and political consequences of any attempts to modify land ownership concepts as they relate to the question of transfer of rights must also be carefully considered. The possibility of buying and selling land can be attractive to both buyer and seller but wide-scale moves to consolidate land holdings in order to improve agricultural production could result in a large class of "rural dispossessed" and a semi-feudal stratification of the society.

(6) The governments of these Sahel-Sudan states are centralized, either through a single party system or through a military regime. In all six states, the decision-making elites are primarily from the modern sector. This results in a lack of direct representation of important interest groups.

(7) Analysis of decision-making structures indicates that local structures are largely controlled from the national level and have little autonomous decision-making power. Large segments of the rural population lack a voice in central decision-making and the administrative structure often does not relate effectively to the rural sector. The lack of linkage between the rural population and the national goverment presents a formidable obstacle to rural development programs. There is a need for opening up communications and interaction with the local

level and for establishing mechanisms for local initiation and participation in problem-definition and policy-formation. The nomads are probably less represented in central decision-making structures than any other group in the area, including the farmers, who are usually underrepresented.

(8) The average level of government budgets in the six countries is low (Chad, Mali, Niger, and Upper Volta are in the lowest ten percent of all African states in per capita government spending), suggesting that governments have limited resources with which to deal with routine processes and are poorly equipped to deal with the task of implementing long-range plans for effective development of the area. The distribution of scarce budget resources seems to favor general administrative structures (including civil service) over development structures (including infrastructure and agriculture). Improving communications facilities and fostering rural development have not been budget priorities, though transport is receiving increased attention.

(9) Educational institutions at present tend to be "elite producing" mechanisms. The current experimentson non-formal education designed to train individuals to play a more effective role in rural development are encouraging. Crucial questions include whether African languages will be used in rural education, and whether career and reward structures can be devised to attract good teachers and reduce the rate of rural "brain drain."

(10) In this region all official communications have been in French, even though rural literacy in French is about one percent and there are several major indigenous languages in the area. Changes in language policy and the strengthening of mass communications facilities, notably radio communiciations, could facilitate the development of the rural as well as the urban areas. Likewise, transport system development would increase rural-urban interaction and increase the access of the rural

population to educational opportunities and health care facilities.

(11) The administrative and economic pattern of the colonial period was one of regional interaction and decision-making. The pattern of economic and administrative interaction since independence, however, has been one of limited interstate interaction within the Sahel-Sudan region and a rapid increase in relations (both economic and administrative) with the coastal countries (including English-speaking states such as Nigeria and Ghana). The move to increase institutional linkage between French-speaking and English-speaking states is a matter which is currently attracting increasing political attention. Such a move would involve decisions in any or all of the following areas: trade policy, monetary policy, and policy concerning the movement of people across borders. The existing regional organizations have directed primary attention to data collection and planning of large-scale projects such as regularization of rivers and elimination of river blindness. A whole pattern of inland-coastal relations is developing, with major coastal centers in Senegal, Ivory Coast, and Nigeria. The question of the role which Nigeria, with its estimated 80,000,000 people and considerable oil and manpower resources, will play in the region remains to be resolved.

(12) Development of a coordinated university system in West Africa would provide one means for addressing some of the advanced training and research needs of the region. There is a need for problem-focused interdisciplinary efforts directed toward the problems of the landlocked countries. These problems currently are not being met and probably cannot be dealt with adequately by the coastal university system.

(13) The French presence is being dramatically reduced in this area. The issue of relations with the European Economic Community is currently under negotiation and will be important in the future of international relations in the area. Both the drought and the EEC negotiations have increased diversification of international relations. The region is

thus at a threshold in developing new relations at both the regional and international levels.

5.6 Pastoralism in the West African Sahel

(1) A series of computer models has been generated to permit examination of the impact of a variety of livestock management policies on the populations and the amount of meat which can be removed annually from the region north of Tahoua in Niger. These models employ the systems dynamics methodology outlined in Part II of this volume.

(2) An analysis of rainfall data for the region shows that the 15 years preceding the recent drought had been characterized by above-average rainfall. Analysis also indicated that the reduction in warfare and in human and animal disease and the improvements in water supply had relaxed factors which had previously limited the growth of herds and population in the region. As a result, an explosive growth of both population and livestock occurred in the years immediately before the drought.

(3) The models indicate that, even before the drought, serious overgrazing was taking place and that a significant loss of livestock would have occurred, probably within a decade, even if the drought had not taken place.

(4) Measures such as rapid restocking of the herds to restore the losses after a drought are shown to be counterproductive in the long term.

(5) The models show that, if the number of cattle is rigidly controlled and modern pasture improvement techniques are implemented, a maximum sustainable yield of meat from the region of approximately 50 percent above the pre-drought level should be realizable. Furthermore, the return to the herdsmen could improve by a factor of five if they realized a price for their meat which was realistically related to present world prices.

(6) If maximum sustained yield is to be achieved in the Sahel, the

number of cattle returned to the range each year should be based on the condition of the range.

(7) Continuation of past policy will result in continued degradation of the range under any future rainfall pattern. Reduction in human and animal populations will continue until populations are reduced to less than a quarter of the pre-drought numbers. The possibility of ecological recovery will diminish the longer the present situation persists.

(8) One of the models permits investigation of the effects of long-term changes in the social values of the pastoralists of the area. One conclusion is that the limited production potential of the Sahel means that both sustained improvements in per capita wealth and large increases in life expectancy cannot be achieved simultaneously unless significant out-migration from the area takes place.

(9) The potential for further development of models of this type appears high, but if they are to be accepted by the policy-makers of the region, experts from the area should participated in their further elaboration and validation.

5.7 The Development and Application of Technology in the Sahel Sudan

(1) Both the level and the extent of application of technology in the Sahel-Sudan are low. As a result, agricultural productivity is low, and the human and material infrastructure necessary for the development of a substantial industrial base are lacking.

(2) Massive infusion of technologies does not appear to be an effective approach for West African development. By and large, new or advanced technologies do not offer realistic solutions because: (a) they are too costly, especially when applied in a region where the required institutional infrastructure is not yet developed; (b) they tend to create

secondary problems which, while disturbing, can be overcome in developed countries, but which might prove very serious in countries with very limited resources; (c) simpler and cheaper technological developments reaching a large proportion of the population constitute preferable alternatives for the short-term (4-5 years), and (d) the usefulness of massive technological solutions could be expected to increase as the institutional system and the human resources are developed. Efforts to assist the West African countries in adapting modern technologies to meet their special needs and conditions, together with education of the people to facilitate acceptance of new technologies are steps to which attention should now be devoted.

(3) A number of schemes for employing large-scale technological methods to accelerate development of the area have been proposed. Some of these include: (1) the program currently under way for spraying the Volta River and its tributaries to eradicate onchocerciasis (river blindness), (2) cloud seeding and other schemes to increase rainfall, (3) diversion of water from the Congo River to irrigate large areas around Lake Chad, and (4) development of the Senegal and Niger rivers to provide a waterway from the mouth of the Senegal all the way to Port Harcourt on the coast of Nigeria. Although efforts at weather modification should not be viewed with great optimism, variations of some of the schemes to divert water from the south to control the level of Lake Chad and the construction of dams to regularize the flow of the Senegal could significantly increase the land available for irrigated agriculture and relieve, at least for a time, the food problem facing the region. Further analysis of a range of these possibilities should prove advantageous.

(4) In the area of water resources, improved water management techniques could provide the needed increases in agriculture production, and reduce the risks associated with climatic variabilities, for the next

15 years. More elaborate techniques involving schemes for reducing evaporative water losses and use of large-scale pumping of ground water or desalination plans do not appear economically justifiable within this time period.

(5) The development of energy sources based on locally available materials other than wood would have important economic and social as well as ecological implications. Units to produce methane from grasses and other cellulose products appear feasible, and their development and application merit serious consideration.

(6) As stated earlier it appears that long-term weather forecasts and rainmaking techniques are still unreliable, and that their application will not have any significant impact on the development of the region in the near future. However, it might be crucial to gain a better understanding of the possible relation between the climatic changes occurring in the Sahel-Sudan and the intensity of use of the land. First results from a computer study run at M.I.T. suggest the existence of a self-reinforcing mechanism linking the climatic changes and the desertification due to overgrazing. The confirmation of the presence of such a mechanism would give added importance to the proposed controls on grazing.

(7) Several new technology-based development schemes were identified and analyzed by the project: monomolecular layers to decrease evaporation losses from water surfaces; dirigibles to decrease the transportation costs of freight; nuclear complexes to provide water, fertilizer, and electric power; greenhouse agriculture; rain-making techniques; and satellite imagery as a tool of land resource management. However, some of these technologies would reinforce the gap between the modern and traditional systems and contribute very little to the real development of the region. The remainder of this section outlines the advantages of "broad-based" technologies, i.e., technological development which

could have widespread social impact. It also argues for the development of an institutional capacity to facilitate the assimilation of new technology and link it to the social and economic development of the region.

(8) A diagnosis of the present patterns of technology utilization shows a dual system, with conflicts occurring between the traditional and modern technologies, and indicates that modern technology has not yet contributed significantly to overall development.

(9) The development of a technological policy and of the capacity for implementation of that policy requires considerable time and does not produce immediate returns. However, once such a capacity exists, technological choices can be delineated more easily and related more closely to national goals and objectives. In countries where development planning experience is as recent as in those of the Sahel-Sudan such goals and objectives are generally not stated explicitly.

Technological choices made in response to the urgent needs of the region should not be based solely on simple economic criteria, such as return on investment, but should also include equity and quality-of-life considerations. Such balanced development is difficult to achieve, however, even under the best of circumstances.

(10) In spite of the severe resource and manpower deficiencies that limit technological choice, the desirability for the national governments and development-oriented regional bodies to provide continuity in development efforts should be recognized. Because of the centralized nature of decision-making and the lack of a substantial private sector, government decisions are likely to have far-reaching effects on the nature and rate of introduction of new technology in the region. It is urgent therefore that governments of the region develop criteria for choosing technologies appropriate to the region.

(11) In the analysis of technologies, two types of criteria are recognized: systems criteria and criteria for selecting component tech-

nologies.

— Systems criteria include, among other things, contributions to institutional development, to structural changes and to autonomy, as well as considerations of practicality and implementability. In the criteria for component technologies which we developed, technologies are classified by type, sophistication, scale, and indigeneity. Our analysis indicates that technologies affecting the welfare of large segments of the population should be given priority over capital intensive "sophisticated" technologies which are of questionable feasibility and are expensive in terms of future research, development, and engineering costs.

(12) An interactive simulation model (Kaminski 1974) was developed as a framework to evaluate technology policies and to provide a medium for discussing and generating ideas. The model can serve to identify critical factors and to organize information. Ideas not easily quantifiable, such as regional cooperation, political alliances, and pressure groups may be explored. The costs and impacts of assistance in the form of support for technological development may be compared with those associated with capital loans or food aid.

(13) Creation of indigenous institutions for educational, scientific, and technological development emerges from this analysis as a high priority objective. The educational system, which is the source of manpower needed for development, is now characterized by low efficiency, high cost, and lack of relevance to the needs of the countries. The formal school system serves only about 15 percent of the school age population. Substantial investments would be needed to (a) improve the internal efficiency of the school system, (b) increase access to education of larger numbers of young, especially from the rural area, and (c) to increase the production of skilled manpower for development.

(14) Both formal and non-formal education programs are needed.

However, in the short- and medium-term non-formal education programs closely related to major development projects and hence to employment opportunities are likely to yield higher social benefits. Such programs will require the evolution of a selected number of subprofessional technical training institutions, including institutions devoted to the training of second-echelon public servants and supporting personnel. Indigenous instructional manpower for these institutions is an urgent need that might be met by training substantial numbers of technical teachers outside the region, especially in the coastal West African countries of Nigeria and Ghana, among others.

(15) Four types of institutions or programs which form the scientific-technological infrastructure of a country can be distinguished. These include institutions or agencies devoted to (a) generation of knowledge, (b) formulation of policy, (c) application and diffusion of technologies, and (d) exploration, facilitation, and linkage of national, regional, and international agencies and programs. Investments in basic science might appear to be a luxury for poor nations, but for a more profound understanding of the ecology, geography, geology, and climatology of the region, sustained investments in basic scientific research will be needed. The universities and branches of former French research institutions in the region have an important role to play. Participation of the countries of West Africa in the creation of an institution or institutions for joint research and training represents one attractive alternative.

(16) A basic step in improving the national capacity for technological policy-making may well be the establishment of programs for upgrading public administration, and especially for strengthening the ministries and the departments of planning, agriculture, industry and trade, and transportation. More elaborate national " councils of technology" and industrial research laboratories would become part of a long-range development effort which would become viable only when

sufficient high-level manpower in quantity and quality is available in the countries of the Sahel-Sudan region. There is already a plethora of regional institutions and agreements, the strengths and weaknesses of which will need to be further assessed. The temptation to proliferate institutions must be overcome if limited resources are to be applied constructively. In the industrial sector, the identification of indigenous entrepreneurship and the development of banking and technical assistance agencies and programs would be of interest to development agencies. There is much experience around the world and among development agencies in the stimulation of small and medium scale industries. However, specific mechanisms that may be applicable to the Sahel-Sudan region, with its dispersed populations and its traditional crafts, markets, and habits of the entrepreneurial class, need to be identified.

(17) External agencies are most likely to find that from a long-range point of view, the development of the human resources, and through them the local institutions devoted to technological policy making and implementation, is an attractive, easily scheduled, and reasonably low-cost way of assisting the countries of the region. Once national goals are established, the identification of these critical institutions and the formulation of development plans in the education, health, agriculture, and transport sectors will need to be addressed on a sector-by-sector and institution-by-institution basis. The more advanced institutions in the West African coastal countries may be looked upon as resource bases to build and interconnect institutions in the Sahel-Sudan countries among themselves and with institutions in West Africa.

5.8 Transport

(1) Despite the apparent difficulties and problems encountered in the transport sector in the region, the transport network appears to be capable of handling a substantially larger volume of traffic than it does

at present.

(2) Roads constitute the dominant transport mode in the region. They provide the major access within the region and into the coastal areas. Most of the infrastructure for road transport already exists in the region and, with proper maintenance and modest upgrading, the capacity of the network to handle larger traffic volumes could be increased significantly.

(3) Improvements in the road system require extensive planning for construction and maintenance of the feeder roads connecting agricultural production areas to main access roads and to markets and distribution centers. Substantial benefits can be realized from improved and well-planned feeder road systems. At present, the lack of feeder roads is a major barrier to increased agricultural potential, since traditional animal transport is too costly for large-scale shipment of food. Apart from their role as social integrators, feeder roads can play a significant role in increased agricultural production and help the farmers to shift from subsistence to market activities. Increased access to markets provides the farmers with the incentive to utilize agricultural technology and thereby increases their production and revenues. The national economy will benefit from reduced transport costs as well as from increased production.

(4) The main road system connecting urban and market areas to one another and to production zones and ports can be improved by better maintenance operations, better drainage facilities, and staged reconstruction and expansion programs. Development of more extensive storage facilities to spread peak loads would also permit better utilization of available transport.

(5) Among the major problems relating to the road network of the region is the lack of proper maintenance. This deficiency is due in large part to frequent breakdowns and ineffective utilization of equipment. Therefore, the feasibility of using local materials and labor intensive

techniques in the construction, maintenance, and reconstruction of roads should be studied from both engineering and economic viewpoints. Training programs for personnel and better road maintenance workshop operations are necessary to keep the major roads operational over longer periods of time.

(6) River transport does not constitute a very significant portion of total traffic within the region because the navigability of the rivers is subject to large seasonal variations. Some improvements can be achieved by regulating water levels to make the major rivers navigable over extended distances and for longer periods of the year. Modern vessels could be introduced along with these improvements. However, river traffic will continue to provide only a small part of the total transport, at least over the next decade or two.

(7) Improved management and operation of the railroad system is needed to make this mode more efficient. Traffic volumes are presently too small to justify major expansions in the network, and, except for specific mining or industrial activities, no such expansion appears to be required within the next decade.

(8) A serious transport problem facing the landlocked countries of the region lies outside of these countries. Improvements in transport routes which provide access to the major ports as well as improvements in the ports themselves are crucial to gain substantial cost savings and efficiences for import and export. Currently, the commodities destined for, or originating from, landlocked countries are not in themselves of sufficient volume to justify major improvements in the ports or inland transport links in the transit countries. Joint arrangements between the transit and landlocked countries must be made to provide incentives for operation of the railroads, roads, and ports of the transit countries. Some of these are already in effect, such as the Niger railroad, but improvement of the port facilities, including storage and loading and unloading equipment, is necessary.

(9) Because of the long distances involved and the dispersed traffic volumes within the region, air transport can be an attractive mode if used effectively in conjunction with the road network. Many landing strips already exist, and others can be built at a minimal cost to provide access to remote areas and to transport high-value commodities into or out of those areas.

(10) Technological innovations such as high-volume, lighter-than-air vehicles may in the future prove economically attractive for the transport of high-value agricultural products, such as vegetables and meat, to European markets. Interest in these facilities has recently increased because of the minimal infrastructural requirements and the large economies of scale and relatively high speeds that can be realized.

(11) For short-range activities, air cushion equipment such as the Hovercraft can be utilized to reach remote areas rapidly to distribute food or medical supplies, circumventing the need for infrastructural investments. Conceivably, long-term application of such techniques could be planned, but the economies of their specific application must be carefully considered.

5.9 Water Resources

(1) The water resources analysis outlined a systems framework for water-resource planning in the Sahel-Sudan. Both supply and demand models were developed, and depending upon the availability of the necessary data, such models may be useful to determine whether projected demand requirements can be met and, if so, what types of water sources should be developed. The results of computer studies utilizing these models would enable decision-makers to examine a variety of alternative development possibilities and determine the costs associated with various alternatives. More detailed work in terms of specific sub-regions would be needed to test their applicability.

(2) From the results obtained using these preliminary models and analysis of existing data on the water resources of the area, several points relating to water resource development are evident:

(a) Lack of water-resource development significantly retards agricultural development in the riparian areas.

(b) The potential for major expansion in the use of water for domestic and agricultural needs and for improved river transport exists.

(c) Considerable amount of quantitative data are available describing the major river systems of the Sahel-Sudan area.

(d) Data on the availability of ground water supplies throughout the area are much more limited, and development of effective programs for ground water utilization will require improved knowledge of aquifer characteristics, including depth of water, realizable pumping rates, and water quality.

(e) The Senegal river basin, in particular, has been studied extensively, but most of the effort has been project-oriented and directed at study of a delta dam and dams at several upstream locations. The upstream dams would make it possible to develop considerable areas for irrigated agriculture and to improve river transportation. However, previous studies have not included an overall water demand-supply for the region which would be of considerable help in developing long-range plans for the area.

5.10 Energy and Mineral Resources

The manner in which energy is supplied and utilized will influence many aspects of the development of the Sahel-Sudan area, including the rate at which deforestation proceeds, the cost of mechanization of agricultural production, and the balance of payments. This analysis was

aimed at reviewing the possibilities for developing alternative energy sources, and further examines the broad implications of different policies for energy use and mineral resource development. The principal findings of cur study include:

(1) Wood is the basis of 90 percent of total energy consumption in the Sahel-Sudan region. It will continue to be the principal source of energy until the last decade of the century, when energy from other sources might exceed that from wood.

(2) The use of wood as a fuel is beginning to have detrimental effects on forests. Upper Volta and, to a lesser degree, Mali may be on the verge of a significant deforestation. Desertification is accelerating around population centers, and programs are needed to restore the forests around urban centers. Almost three million hectares of managed forests might be needed by the end of the century.

(3) Recent increases in oil prices have caused energy to constitute a major foreign currency drain for these countries. This trend is likely to worsen. Our analysis indicates that the foreign currencies required for energy and energy distribution systems will be increasing at rates between 9 and 11 percent, while exports are projected to grow at less than 6 percent.

(4) The balance of trade problems could be reduced if special agreements could be made with the oil-producing countries or with West African coastal countries to supply oil or hydroelectric power at stable prices for an extended period of time.

(5) Local energy resources can be developed to reduce balance of trade problems. Although hydroelectric and geothermal resources are rather limited and will offer only a partial solution to the energy problem, their early development could prove very advantageous, but should be coordinated with urban growth. Exploitation of known coal deposits for local consumption should also be considered. Even if the cost of local

coal is somewhat higher than that of imported coal, the savings in foreign exchange and jobs created by developing the local resources may outweigh the cost disadvantage.

(6) Development of solar and wind energy for rural utilization would have limited economic impact but would help reduce degradation of the ecology by reducing the demand for wood.

(7) Development of wind energy sources around urban and industrial centers would have large economic impacts. However, solar energy sources for commercial energy production are still considered "far-out" technologies. Both of these types of energy require associated energy storage capacity or alternate sources to assure continuity of service.

(8) New sources of energy using photosynthesis processes are of potential interest for the region. The production of methane from agricultural and urban wastes has been shown to be technically and economically attractive in other parts of the world. This energy source could be developed on a commercial or even on a single household basis. The physical compaction of grass to form a wood substitute might also prove feasible. Models developed as part of the study show that development of such resources could be very important, especially if the prices of hydrocarbons increase again towards the end of the century.

(9) Continued exploration for oil should be encouraged, but even if oil is found, efforts to develop other forms of energy should not slacken. The availability of oil should be viewed as providing a fortunate time interval permitting development of the other resources mentioned and not as a replacement for them.

(10) Because of the high capital cost of nuclear plants and the fact that their advantages are best realized in very large plants, nuclear energy is unlikely to find application in this area in the near future. However, the development of an agro-industrial nuclear complex should be evaluated if areas containing large, high-quality deposits of minerals

such as manganese, copper, and iron are found. In the coastal areas such a complex could use the high temperature steam produced from the reactor to run turbines for electric power generation and use the steam discharged from the turbines to desalinate brackish or sea water.

(11) Development of local capacity for the formulation and implementation of energy policies is critical for long-term perspectives of the region. National energy policies should take into account the long recovery times resulting from different forms of overexploitation of the land. Balance of trade problems, which could hamper development, should also be taken into account in developing energy policies. Coordination of urban growth and energy policies is also needed, in order to optimize the utilization of local resources.

(12) It is not possible to rely on mineral resources to stimulate the development of the region. The region contains many minerals, but deposits are generally of poor to fair quality, i.e., not highly concentrated. Lack of data, coupled with high transport and power costs, makes it difficult to develop the deposits. The value of minerals now produced is about $100 million a year, but this may be expected to increase to $300 million by 1990. However, only a small fraction of the value represents government or private indigenous earnings which are reinvested within the region. Therefore the total mineral production is equivalent to only about $1 per capita of foreign assistance.

(13) Although production of uranium is increasing rapidly and prospects for finding oil are good, it is not possible to estimate the likelihood of major findings or to base development plans upon exploitation of these potentially high-value products.

(14) The economic value realized from the mineral resources could be increased by developing the needed institutional structures and managerial capacity. Such local institutions could accelerate and direct surveys of ways to further local needs. They could also suggest integrated

regional studies, which may transform several uneconomic mining projects into a viable association of mining and water, power, industrial, and possibly agricultural projects.

(15) While the number of geologists in the region is small, it is the broad engineering and managerial talents which are more needed. These talents and improved institutional capacities both need to be developed if exploitation of mineral and energy resources is to proceed satisfactorily.

APPENDIX A

Basic Data for the Count .es of the Sahel-Sudan Region of West Africa

The tables in this appendix provide basic data on the six countries of theWest Africa Sahel-Sudan region with which this study has been concerned. These tables are included to provide the reader with quantitative data to assist in understanding the text. It should, however, be recognized that there is no single agreed upon set of data for the region. Even population figures are subject to differences because they are not based on a complete and accurate census. Trade figures are aggregated in different ways by different groups and tend to be distorted by trade which is unrecorded so that it will not be taxed. Compilation of data also lags with the result that current figures are not available for many items. Most of the data presented here has been checked in several sources and represents what we believe are the best figures available.

TABLE 1

Population estimates, annual rates of increase in percent, and population projections for seven west African countries

	Chad	Gambia	Mali	Mauritania	Niger	Senegal	Upper Volta	Total
Population (in 1,000)								
1960	2,975	362	4,089	950	2,913	3,110	4,400	18,799
1965	3,306	389	4,530	1,050	3,513	3,490	4,858	21,136
1969	3,571	421	4,943	1,146	3,914	3,837	5,278	23,110
1970	3,640	429	5,049	1,171	4,016	3,925	5,384	23,614
1971	3,744	438	5,166	1,201	4,121	4,024	5,513	24,207
1972	3,851	448	5,286	1,231	4,229	4,125	5,645	24,815
1975	4,199	479	5,668	1,330	4,579	4,452	6,058	26,765
1980	4,843	539	6,488	1,518	5,287	5,086	6,883	30,644
Annual Average Rate of increase (in percent)								
1960-65	2.1	1.5	2.0	2.1	4.0	2.3	2.0	
1965-70	1.9	1.9	2.2	2.2	2.7	2.3	2.0	
(60-70)	2.0	1.7	2.1	2.1	3.3	2.3	2.0	
*Current Rate	2.4	2.0	2.4	2.3	3.0	2.4	2.0	

Sources: United Nations Special Sahelian Office 1974;

* Agency for International Development 1974.

The figures included in this table are the tentative estimates, based on the latest available information of population in the seven Sudano-Sahelian countries, as of 1973. The figures are subject to change when complete census figures become available and the effects of the drought are known.

TABLE 2

Per capita GNP, per capita GDP at current prices,

population estimates and real product growth rates

Country	Per Capita GNP 1972 (dollars)	Per Capita GDP 1970-71 (dollars)	Average annual growth rates of total real product 1960-70 (in percent)	1968-71 (in percent)	1970-72* (in percent)	Population 1974 (millions)	Average annual growth rates of per capita real product 1960-70 (in percent)	1968-71 (in percent)	1970-72* (in percent)
Chad	85	78	0.5	1.0	2.7	4.08	-1.8	-1.3	0.2
Mali	70	70	5.2	5.0	3.5	5.60	3.0	2.8	11.2
Mauritania	175	148	6.9	3.8	5.2	1.28	4.6	1.6	3.0
Niger	120	88	2.4	-2.4	-5.0	4.34	-0.3	-5.0	-7.5
Senegal	285	209	1.0	-3.8	1.0	4.13	-1.4	-6.1	-1.5
Upper Volta	70	59	0.7	2.9	2.0	5.83	-1.4	0.8	0.0
Total of Above			2.3	0.1	1.5	25.26	0.0	-2.2	-0.9
Total Developing Countries	211		5.1	6.0	5.5		2.5	3.3	2.7

Sources: United Nations Special Sahelian Office 1974; United States Agency for International Development 1974.

* Tentative estimates

TABLE 3

GDP at current factor cost by industry, 1968 to 1970
(in U.S. $ million)

Country	Year	Agriculture	Mining	Manufacturing[1]	Construction	Commerce	Transport	Total including other
**Chad	1968	109.1	-	14.4	8.3	33.5	6.1	215.0
	1969	135.0	-	17.6	8.3	37.1	6.5	259.3
	1970	136.8	-	18.4	8.6	47.5	8.3	283.0
	1971	135.8	-	23.0	9.4	44.6	9.4	287.4
**Mali	1966/67	102.2	-	15.6	11.1	38.7	7.2	203.3
	1967/68	117.3	-	24.6	11.1	62.4	8.0	255.1
	1969	114.7	-	24.8	12.1	63.7	10.6	264.9
	1970	131.6	-	31.7	10.9	68.8	11.1	298.3
	1971	142.1	-	33.4	10.5	77.8	12.3	326.3
	1972	147.6	-	36.1	10.9	83.1	13.5	345.6
*Mauritania	1968	64.7	41.6	4.0	11.0	10.0	3.0	154.0
	1969	67.0	46.0	4.0	13.0	11.0	3.0	166.0
	1970	71.0	57.0	4.0	16.0	12.0	4.0	189.0
*Niger	1968	156.0	-	17.0	14.0	30.0	7.0	263.0
	1969	165.0	-	18.0	17.0	32.0	8.0	281.0
	1970	175.0	-	19.0	20.0	33.0	9.0	300.0
**Senegal	1967	290.9	8.3	113.4	12.6	117.4	42.8	765.9
	1968	253.1	8.3	121.7	13.7	135.8	44.6	759.8
	1969	272.9	7.9	123.5	13.3	132.5	43.9	778.9
	1970	230.1	7.9	127.8	19.1	142.2	43.9	759.4
	1971	301.8	10.4	128.9	19.1	143.3	42.8	840.4
*Upper Volta	1968	108.0	-	19.0	9.0	30.0	9.0	207.0
	1969	122.0	-	22.0	12.0	34.0	10.0	235.0
	1970	119.0	-	24.0	15.0	38.0	11.0	245.0

Sources: *United Nations Special Sahelian Office 1974;
**Agency for International Development.

1 Manufacturing Industry and Electricity Production.

TABLE 4

Structural Components of Gross Domestic Product

		Year	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Six country total	Total: developing countries
The Agricultural Sector										
Agricultural labour as share of total labour force	(in percent)	1970	92	91	87	93	80	87	88	65
Agriculture as share of total GDP	(in percent)	1970	46	44	38	58	30	49	42	27
Average annual growth rate of total production	(in percent)	1963-70	0.3	0.8	2.0	3.4	-2.6	2.1	1.0	2.8
Average annual growth rate of food production	(in percent)	1963-70	0.0	0.4	2.0	2.4	-3.1	0.8	0.4	2.9
The Manufacturing Sector										
Share of manufacturing in GDP	(in percent)	1970	8	8	2	6	16	10	10	18
Growth rate of manufacturing in GDP	(in percent)	1960-69	5.2	6.5	12.2	4.1	5.3	1.5	5.0	7.1

/...

TABLE 4 (cont'd)

Structural Components of Gross Domestic Product

		Year	Chad	Mali	Mauritania	Niger	Senegal	Upper Volta	Six country total	Total: developing countries
Gross Domestic Investment										
Share in GDP	(in percent)	1970	12.7	14.1	27.9	20.2	15.3	19.5[a/]	17.0	17.0
Real growth rate	(in percent)	1960-69	2.7	8.8	2.9	6.6	5.3	11.2	6.1	6.9
Share of Gross National Savings in GDP										
Average	(in percent)	1968-70	-2.8	11.9	23.0	1.3	4.3	8.9	6.9	16.2
Average annual change	(in percent)	1960-70	-0.7	0.6	3.0	-1.2	-0.2	0.7	0.2	0.2

Source: United Nations Special Sahelian Office 1974.

a/ 1969

TABLE 5

Exports, imports and balance of trade summary

Country	Exports* value 1972 (in millions US dollars)	Imports** value 1972 (in millions US dollars)	Trade balance 1972	Share of exports in GNP 1972 (in percent)	Share of imports in GNP 1972 (in percent)	Growth rates of export value 1968/71 (in percent)	Growth rates of import value 1968/71 (in percent)	Export Value per capita (in US dollars)	Import value per capita (in US dollars)	Principal exports % of total 1970/72
Chad	39	61	-22	12	18	-1.0	22.2	10	16	cotton, 67%
Mali	44	70	-26	12	19	47.1	14.1	8	13	livestock, 35% cotton, 20%
Mauritania	106	69	37	50	32	7.7	17.7	87	57	iron ore, 78%
Niger	54	66	-12	11	13	9.4	8.7	13	16	peanuts and products, 51%
Senegal	216	280	-64	19	25	-6.1	6.[illegible]	55	71	peanuts, 47% phosphates, 9%
Upper Volta	20	61	-41	5	16	-8.7	7.6	4	11	livestock, 35% cotton, 24%

Source: Agency for International Development 1974.

* F.O.B.
**C.I.F.

TABLE 6

Net flow of loans and grants[a/]

Country	Totals ($ million) Average	1969	1970	1971	Per capita ($) Average 1965-68	1969	1970	1971	Net flow as share of GNP 1971[b/] (in percent)	Net flow as share of imports 1971 (in percent)	Net flow as share in gross investment 1971 (in percent)
Chad	23.47	21.99	21.26	29.28	6.9	6.1	5.7	7.7	11.3	47.2	86.1
Mali	20.42	20.82	20.11	36.82	4.4	4.3	4.0	7.2	7.2	66.9	96.9
Mauritania	8.76	18.52	17.63	4.77	8.0	16.2	15.1	4.0	2.7	8.4	8.2
Niger	22.38	36.01	45.06	49.48	6.1	9.2	11.2	12.0	15.7	91.6	76.1
Senegal	50.16	49.12	40.76	58.49	14.0	13.0	10.37	14.5	8.4	26.8	47.9
Upper Volta	19.14	24.03	21.89	29.29	3.8	4.6	4.1	5.3	9.6	58.6	53.3
Total of above[c/]	144.33	170.49	166.71	208.13	6.7	7.5	7.2	8.8	9.2	41.8	55.9
Total Developing Countries	7566.98	8662.29	9570.55	11366.89	4.8	5.2	5.7	6.5	3.2	18.5	(18.9)

Source: United Nations Special Sahelian Office 1974.

a/ Bilateral and multilateral official loan and grant receipts plus guaranteed private export credits (data on a net disbursement basis).

b/ 1970 GNP and gross investment figures used as denominator.

c/ Excluding approximately $40 million per year in recent years from France to the following five least developed countries: Chad, Mali, Niger, Upper Volta and Dahomey. The available data do not show the allocation among them.

TABLE 7

Sources of Financing of Development Plans (in percent)

	Domestic	Foreign
Chad		
1966-70 Development Plan	37.0	63.0
Mali		
1970-73 Development Programme	17.0	83.0
Mauritania		
Investments 1970-72	5.6	94.4[a]
Niger		
Public Investment Expenditure 1967/68-1970/71	15.8	84.2
Senegal		
Public Sector Investment 1969/70-1972/73	39.3	60.7
Upper Volta		
Development Plan 1967-69	29.2	70.8

Source: United Nations Special Sahelian Office 1974.

a/ Includes private foreign investments by Société des Mines de Fer de Mauritania (MIFERMA), exploiting iron ore and copper deposits.

TABLE 8

Sources of Government revenue, 1971

	Tax Share in GDP (in percent)	Direct Taxes	Production and consumption taxes	Export and Import Taxes	Others
		(distribution in percent)			
Chad	17.1	28.7	16.4	45.2	9.6
Mali	13.4	17.6	32.8	35.2	14.5
Mauritania	16.6	19.9	8.7	54.0	17.5
Niger	12.9	27.6	17.6	36.3	18.4
Senegal	18.7	23.3	22.0	46.9	7.8
Upper Volta	10.8	21.9	20.0	45.0	13.1

Source: United Nations Special Sahelian Office 1974.

TABLE 9

Total ODA flows and grant shares in ODA from individual donors and multilateral agencies

	Total ODA ($ million)				Grants as per cent of ODA			
	1965-68[a]	1969	1970	1971	1965-68[a]	1969	1970	1971
Bilateral donors								
Australia	-	-	-	-	-	-	-	-
Austria	0.06	0.13	0.06	0.05	100.0	100.0	100.0	100.0
Belgium	0.10	0.37	0.56	0.70	100.0	100.0	100.0	100.0
Canada	1.25	2.56	9.25	12.86	100.0	100.0	77.0	58.5
Denmark	-	0.05	0.07	0.16	-	-	-	-
France[c]	78.25	90.00	68.00	66.70	95.3	87.8	96.9	102.1
Germany, Fed.Rep.	3.52	12.43	6.88	10.60	66.5	30.7	69.8	54.8
Italy	0.03	0.08	0.23	0.20	66.7	100.0	100.0	100.0
Japan	0.01	0.04	0.01	0.02	100.0	100.0	100.0	100.0
Netherlands	-	-	0.25	0.19	-	-	100.0	100.0
Norway	0.01	-	-	-	100.0	-	-	-
Portugal	-	-	-	-	-	-	-	-
Sweden	-	-	-	-	-	-	-	-
Switzerland	0.12	0.29	0.15	0.29	100.0	100.0	100.0	100.0
United Kingdom	0.30	0.17	0.28	0.34	40.0	100.0	100.0	100.0
United States	9.78	13.00	6.00	15.00	94.3	92.3	66.7	100.0
A. Total bilateral	93.43	119.12	91.74	107.11	94.0	82.6	90.9	91.7

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TABLE 9 (continued)

Total ODA flows and grant shares in ODA from individual donors and multilateral agencies

	Total ODA ($ million)				Grants as per cent of ODA			
	1965-68[a]	1969	1970	1971	1965-68[a]	1969	1970	1971
Multilateral donors								
IBRD	-2.89	-5.84	-5.92	-7.16	--	--	--	--
IFC	1.23	8.40	9.70	-0.30	--	--	--	--
IDA	1.82	8.01	8.86	12.16	--	--	--	--
IDB	--	--	--	--	--	--	--	--
AFDB	-1.53	-0.66	-0.54	0.46		--	--	--
ASDB	--	--	--	--	--	--	--	--
EIB		5.04	6.55	0.21)	100.0	--	--	--
EDF		33.09	37.46	57.50)		98.8	98.1	97.1
UNDP		8.38	8.26	10.41)		100.8	101.1	101.1
UNICEF	6.50	1.12	0.79	0.88)		102.7	103.8	108.0
UNRWA		--	--	--)	100.0	--	--	--
UNHCR		0.16	0.36	0.12)		106.3	100.0	100.0
WFP		1.09	2.23	3.96)		100.0	100.0	100.0
Other United Nations agencies		--	--	0.86))		--	--	100.0
B. Total Multilateral	5.13	58.79	67.75	79.10	..	74.1	71.6	91.4
C. = A + B Grand Total	98.56	177.91	159.49	186.21	..	79.8	82.7	91.6

Source: United Nations Special Sahelian Office 1974.

a/ Total official flows.
b/ As percent of total official flows.
c/ Excluding approximately $40 million per year in recent years from France to the following five least developed countries: Chad, Mali, Niger, Upper Volta and Dahomey. The available data do not show the allocation among them.

TABLE 10

Fuel Imports as Percentage of Total Imports[a/]

(total and fuel imports in thousands U.S. dollars)

Country	1967	1968	1969	1970
Chad				
(a) Total Imports	37,464	33,469	46,160	55,723
(b) Fuel Imports	5,518	5,528	7,596	8,621
(c) (b) as percent of (a)	14.7	16.5	16.5	15.5
Mali				
(a) Total Imports	34,190	34,298	38,912	44,799
(b) Fuel Imports	2,607	2,662	3,435	4,007
(c) (b) as percent of (a)	7.6	7.8	8.8	8.9
Mauritania				
(a) Total Imports	36,885	35,298	45,174	55,855
(b) Fuel Imports	1,348	2,616		4,322
(c) (b) as percent of (a)	3.7	7.7		7.7
Niger				
(a) Total Imports	45,972	41,471	48,700	58,368
(b) Fuel Imports	2,732	2,320	2,067	2,318
(c) (b) as percent of (a)	5.9	5.6	4.2	4.0
Senegal				
(a) Total Imports	157,357	180,381	198,648	192,429
(b) Fuel Imports	1,150	5,556	14,842	9,621
(c) (b) as percent of (a)	0.7	3.1	7.5	5.0
Upper Volta				
(a) Total Imports	36,094	41,003	49,834	46,659
(b) Fuel Imports	2,357	2,762	3,300	3,825
(c) (b) as percent of (a)	6.5	6.7	6.6	8.2

Source: United Nations Special Sahelian Office 1974.

a/ Special Imports C.I.F.

TABLE 11

Technical assistance disbursements

(Bilateral contributions from DAC member countries plus contributions from multilateral agencies)

Country	Totals ($ million)				Per capita ($)			
	Average 1962-66	1969	1970	1971	Average 1962-66	1969	1970	1971
Chad	1.6	10.8	9.7	12.3	0.5	3.0	2.6	3.2
Mali	2.9	7.1	7.7	9.3	0.7	1.4	1.5	1.8
Mauritania	0.4	5.0	4.2	4.6	0.4	4.4	3.6	3.8
Niger	2.0	11.8	12.9	11.9	0.6	3.0	3.2	2.9
Senegal	2.6	21.2	20.1	20.2	0.8	5.6	5.1	5.0
Upper Volta	2.6	9.5	8.0	9.6	0.5	1.8	1.5	1.7
Total of above	12.1	65.4	62.6	67.9	0.6	2.9	2.7	2.9
Total Developing Countries	1080.7	1838.4	1794.2	2051.9	0.7	1.1	1.1	1.2

Source: United Nations Special Sahelian Office 1974.

TABLE 12

Sectoral composition of national development plans

Country	Total expenditures planned	Agricultural and rural development	Mining Industry and Energy	Economic infra-structure[a]	Health Welfare Education	Administrative services and other
		(as a percent of total planned investment)				
Chad (in billions CFA francs)						
1966-1970 Plan original estimate	47.2	28.4	14.1	33.5	23.5	.5
1966-1970 Plan revised estimate	26.2	31.8	16.6	28.4	22.1	1.1
1971-1980 Targets (tentative)[b]	57.8	36.2	11.6	42.7[c]	9.5	2.0
Gambia (in millions Dinasi)						
2nd Development Programme 1967/68-70/71	22.9	14.0	25.0	39.0	17.0	5.0
3rd Development Programme 1971/72-73/74	26.8	21.0	7.7[d]	54.0	9.1	8.2
Mali (in millions Mali franc-)						
1970-1973 Plan original estimate	77.6	25.8	19.2	32.1	12.9	10.0
1970-1973 Plan revised estimate	99.4	23.9	24.0	33.1	13.5	5.5
Mauritania (in billions CFA francs)						
1970-1973 Plan revised estimate	55.0	16.5	33.4	33.9	16.2[j]	[k]
Niger (in billions CFA)[e]						
Public investment expenditure 1967/68-70/71	19.2	32.0[f]	3.0[g]	33.0	14.0	18.0
Senegal (in billions CFA francs) (public investment only)						
3rd Development Plan 1969/70-72/73	121.9	35.3	-	39.6[h]	12.0	17.7
4th Development Plan 1973/74-76/77	177.4	50.0	9.0	29.0[i]	10.0	2.0
Upper Volta (in billions CFA francs)						
1967-1970	27.5	26.0	20.0	30.2	17.8	3.8
1972-1976	63.2	30.0	20.6	28.8	13.4	7.2

Source: United Nations Special Sahelian Office 1974.

Footnotes on next page.

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TABLE 12 (continued)

Sectoral composition of national development plans

(footnotes)

a/ "Economic infrastructure" includes transportation and communication;
b/ Priority I - public investment only - targets being revised;
c/ Includes 10 percent for "public utilities";
d/ Includes estimate of two percent for manufacturing, included in the plan in Agriculture;
e/ Actual public investment within the framework of 10-year "Development Perspectives";
f/ Includes water resources development;
g/ Mining exploration was chiefly financed by private investment not included here;
h/ Of which 21.5 percent for housing;
i/ Of which 15 percent is for housing and water development;
j/ Includes "defense" (5.8), information and miscellaneous (4.3 percent);
k/ Included in other sectors.

TABLE 13

Culture Clusters, Population, and Country Distribution

	Total Population	% Country
CHAD (1967)		
Arab type Shuwa	1,570,000	46%
Sudanic cluster Sara	955,000	28%
Nilotic cluster Wadai	324,000	9.5%
Saharan cluster Teda	239,000	7%
MALI (1967)		
Mande-Bambara Mande-Malinke	2,040,000	43%
Fulani	949,000	20%
Senufo	712,000	15%
Soninke (Sarakole)	380,000	8%
Tuareg	303,000	6%
Songhai	289,000	6%
MAURITANIA (1967)		
Moor (Zenaga)	902,000	82%
Tukulor-Fulani	143,000	13%

	Total Population	% Country
NIGER (1967)		
Hausa	1,631,000	46%
Djerma-Songhai	674,000	19%
Fulani	461,000	13%
Tuareg (Asben)	355,000	10%
Kanuri	177,000	5%
SENEGAL (1967)		
Wolof type	1,358,000	37%
Tukulor-Fulani	880,000	24%
Serer	587,000	16%
Diola	330,000	9%
Mande type (Malinke)	257,000	7%
UPPER VOLTA (1967)		
Mossi	2,542,000	50%
Western Mande (Bobo)	880,000	16%
Senufo type	363,000	7%
Grunshi (Kusasi)	341,000	6%
Fulani	313,000	6%
Lobi	291,000	5%
Gurma	275,000	5%
Busansi (Bisa)	272,000	5%

Source· Godiksen 1974

REFERENCES

Godiksen, Lois H. 1974. A Framework for Evaluating Long-Term Strategies for the Development of the Sahel-Sudan Region, Annex 6, "Socio-Political Factors in Ecological Reconstruction." M.I.T. December 31.

United Nations Special Sahelian Office 1974. An Approach to Recovery and Rehabilitation of the Sudano-Sahelian Region. ST/SSO/28. New York. November 8.

United States Agency for International Development 1974. Economic Growth Trends. October.

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REFERENCES

Bryson, R.A. 1973. Climatic Modification by Air Pollution, II: The Sahelian Effect, Institute for Environmental Studies. University of Wisconsin. Madison, Wisconsin. Report 9, pp. 1-12.

Bryson, R. A. 1974 "A Perspective on Climatic Change". Science 184 (4138): 753-760.

Bryson, R. A. and L. Gioroano. 1974. A Three-Layer, Nonequilibrium Hemispheric Mean Temperature Model with Variable Transmissivity. Unpublished draft.

Chenery, H.B. and P.G. Clark. 1959. Inter-Industry Economics. John Wiley and Sons.

Chenery, H.B. and A. M. Strout. 1966. "Foreign Assistance in Economic Development." American Economic Review. Vol. LVI, Number 4, Part 1, September.

Dalky, N. and O. Helmer. 1963. "An Experimental Application of the Delphi Method to the Use of Experts." Management Science. Vol. 9.

Eckaus, R.S. and K.S. Parikh. 1968. Planning for Growth. M.I.T. Press Cambridge, Mass.

Forrester, J. W. 1961. Industrial Dynamics. M.I.T. Press. Cambridge, Mass.

Forrester, J.W. 1969. Urban Dynamics. M.I.T. Press. Cambridge, Mass.

Gordon, T. J. et al. 1970 Research on Cross Impact Techniques with Application to Selected Problems in Economics, Politcal Sciences, and Technology Assessment. Institute for the Future. Report R-12.

Hardin. G. 1968. "The Tragedy of the Commons." Science. Vol 162, pp. 1243-1248.

Hamilton, H.R. et al. 1969. System Simulation for Regional Analysis, M.I.T. Press. Cambridge, Mass.

Holland, E. P. 1961. Simulation of an Economy with Development and Trade Problems. Center for International Studies. M.I.T. Press. Cambridge, Mass.

Kaminski. C., Jr. 1972. Dynamic Model of Resource Industries: A Case Study of Bolivian Tin. Thesis. Department of Electrical Engineering. M.I.T. Cambridge, Mass.

Kaminski, C., Jr. 1974. Modeling and Gaming for Regional Planning: A Maine Study. M.I.T. Sea Grant Program. Report No. MITSG 74-25. M.I.T. Cambridge, Mass.

Kamrany, N. M. 1973. "Economic Growth and Environmental Impact." Socio-Economic Planning Sciences. Pergamon Press. Vol. 7. pp. 37-53.

Lieftinch, P., A. R. Sadove and T. C. Creyhe. 1969. Water and Power Resources of West Pakistan. Johns Hopkins Press. Baltimore, Md. Vol. III.

Leontief, W. et al. 1953. Studies in the Structure of the American Economy, Theoretical and Empirical Explorations in Input-Output Analysis. Oxford University Press. Oxford, England.

Manetsch, T. J. et al. 1971. A Generalized Simulation Approach to Agricultural Sector Analysis with Special Reference to Nigeria. Michigan State University. East Lansing, Michigan.

Meadows, D., D. Meadows, J. Randers and W. Behrens III. 1972. The Limits to Growth. Universe Books. New York.

Miller, J. R. III. 1967. A Systematic Procedure for Assessing Worth of Complex Alternatives. Defense Document Center. (AD622001)

Millword, R. E. 1968. "PPBS: Problems of Implementation." Journal American Institute of Planners XXXIV.

Picardi, A. C. 1972. A Demographic and Growth Model for Bolivia. Thesis. Department of Civil Engineering. M.I.T. Cambridge, Mass.