ORGANIZATION OF AFRICAN UNITY

SCIENTIFIC, TECHNICAL AND RESEARCH COMMISSION

(OAU/STRC)

Assessment of the Vulnerability of Agricultural and Ecological Systems to Climate Change in Sub-Saharan Africa.

A Proposal of the

PAN-EARTH Sub-Saharan Africa
Collaborative Research Network

Submitted by
OAU / STRC Coordination Office
Semi-Arid Food Grain Research and Development
(**SAFGRAD**)
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prepared by

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PAN-EARTH SUB-SAHARAN AFRICA
Collaborative Research Network

Participating Countries

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EXECUTIVE SUMMARY

It is widely recognized that the environment in sub-Saharan Africa is severely stressed from human activities. Environmental degradation, in combination with the extremely high human population growth rates, the lack of a technological infrastructure, and increased incidence of drought over the last 30 yr, has resulted in marginal existence for millions of people. Attaining the critical goal of sustainable development in a sustainable environment will require significant improvements in all of these problem areas. Unfortunately, this will be an even more daunting task as global climate change in the next few decades is expected to increase the occurrence and duration of adverse climate in the region. *In order to begin to cope with such change, there is an urgent need to understand the potential effects of climate change on the ecological, agricultural, and human systems of Africa.*

At present, scientific assessments of climate change effects are very limited. To meet this need, the PAN-EARTH Project was established as a network of physical and biological scientists working to develop state-of-the-science assessment methodologies and to apply them in case studies on such countries and regions as China, Japan, Venezuela, and sub-Saharan Africa. The PAN-EARTH Sub-Saharan Africa Collaborative Research Network was instituted at the recent PAN-EARTH Africa Workshop at Saly, Senegal, in order to develop and implement a PAN-EARTH case study on the region. The present proposal is for the resources necessary to conduct this case study.

The central objective of the PAN-EARTH sub-Saharan Africa network is to characterize the vulnerability of African nations to global environmental change, and to ascertain the critical importance of such changes to sustainable development in the region. This will be instituted through close collaboration among PAN-EARTH and African scientists to define climate change scenarios, identify and characterize critical ecological and agricultural systems of importance in the region, and assess the effects of climate change on those systems. Specific objectives of the network are: to advance the scientific capabilities and understanding by scientists in the region to deal with climate change issues, including calibration, implementation, and training on appropriate agricultural and ecological simulation models adapted to the region; to study the potential effects of climate change on the productivity and sustainability of agricultural, ecological, and societal systems and to identify those systems of greatest vulnerability; and to interact with climatological studies to improve the capability to predict what specific climate changes will occur in the region.

These objectives will be met through a series of specified tasks, involving active collaboration among the PAN-EARTH scientists coordinated by Cornell University, USA, and the African ecological and agricultural scientists coordinated by OAU/STRC SAFGRAD in Ouagadougou, Burkina Faso. A set of study sites has been selected for representative ecological and crop systems in over a dozen different African nations. Existing data will be collated and new experimental studies initiated to provide the information necessary to adapt ecological and crop simulation models to these specific sites. African scientists will be thoroughly trained in the use of these models, and the models will be maintained on African computers for use for other ecological and agricultural issues. A broad range of sensitivity analyses will be conducted on the calibrated models to identify the vulnerabilities of the region to climate change. New, longer-term experimental needs will be identified, and research directed at those needs will be facilitated. The many facets of the PAN-EARTH Sub-Saharan Africa Case Study will be reported in a series of scientific publications in the open literature, and outreach activities will be implemented to extend the community of scientists and policy makers with interests and understanding on climate change issues.

BACKGROUND

Agricultural crisis in Africa

The agrarian crisis in sub-Saharan Africa, which has assumed alarming proportions in recent times, can be attributed to several causes. Most important are: degradation of the environment from human activities (e.g., soil depletion, deforestation, and physical alteration of land and surface water habitats); extremely high human population growth rates (with population doubling times of 20-30 years in many sub-Saharan countries); lack of technological advancement, leading to stagnation or even decline in agricultural production; and climatic change over the past few decades, especially with reduced or more uncertain precipitation. Furthermore, developing sustainability of the agro-ecological systems in the region in the next several decades is threatened because of human activities, such as accelerated deforestation and poor land use and management. In short, the quality of the environment in sub-Saharan Africa necessary for sustaining a growing human population is severely stressed at present and is experiencing continuing degradation, while at the same time, the survival of the rapidly increasing human population in the region will require much more, not less, from that environment in the future.

Superimposed on these human-environment issues will be a changing global environment. Climate change effects have already been evident in Africa over the last several decades, although they cannot be reliably attributed to human-induced global climate change. For example, there has been a general decrease in precipitation, which has culminated in the increase of desertification and aridity, southward from the Sahara. As consequence of this climatic change in the region, significant drought events have occurred repeatedly and have threatened the livelihood of millions of Africans, all too often directly leading to environmental refugees and severe incidences of hunger, malnutrition, disease, famine, and death.

Future climate change

Future anthropogenic climate change is widely regarded by climatologists to be inevitable, as humans have significantly altered the global atmospheric chemistry by adding substantial quantities of radiatively important gases (especially CO_2, CH_4, N_2O, and chlorofluorocarbons [CFCs]). These gases (except CFCs) are also naturally occurring, and natural quantities have created a greenhouse phenomenon over Earth that has been essential to the development of life. Without greenhouse gases, the Earth would be a cold,

lifeless planet similar to Mars; but too high concentrations of greenhouse gases cause a planet to be too warm, as evidenced by the temperatures and pressures on Venus, sufficient to melt lead. The Earth has been delicately balanced between these two extremes for millions of years, with fluctuations over geological time periods that have led to ice ages interspersed with warm periods. The present predicament is that humans have altered the concentrations of these greenhouse gases sufficiently to lead in the next *decades* to climate changes that have not been experienced for the past few ***million years***.

Global average temperatures are expected to increase by 1.5 to 4.5°C by the middle of the next century, with associated shifts in the distribution, timing, and amounts of precipitation occurring regionally. Other changes to be experienced will likely include an increase in sea level by about 1 meter globally, increases in storminess, shifts in monsoonal development, shifts in the inter-tropical convergence zone, shifts in ocean currents, and other physical changes. It must be recognized that whereas these physical effects will be experienced globally, the specific amounts of change will vary significantly at regional levels and over time, and effects on humans and the environment will be local- and regional-scale phenomena that must be evaluated at that scale.

PAN-EARTH Project

Clearly, climate change effects are of global concern and involve complex interactions within and among nations, and across a diversity of scientific disciplines, as changes in the global environment transcend geographic, political, cultural, and scientific boundaries. Climate change effects will influence all facets of the quality of life for humans, especially in developing nations. Yet surprisingly little work has been done to assess and characterize the effects of climate change as related to agricultural production and destabilization of ecological systems. In response to this need, an international network of physical and biological scientists has been established as the PAN-EARTH Project, coordinated at Cornell University, with central objectives to develop climate change scenarios for specific regions of the world and to assess the vulnerabilities of ecological and agricultural systems to those climate change scenarios for those regions.

PAN-EARTH case studies are underway in China, Japan, Venezuela, and sub-Saharan Africa. In each case, PAN-EARTH scientists work closely with scientists from within the case study countries in mutually developing and conducting the research activities. Output from general circulation models (GCMs) for each specific region is evaluated and modified based on the expertise of local climatologists to develop appropriate climate change

scenarios for each specific site selected for assessing biological effects. Ecosystem and crop models are implemented on microcomputers in the countries, and local scientists acquire the necessary data to calibrate the models to the specific systems of concern. Once this is accomplished, a wide range of sensitivity analyses is conducted to evaluate the vulnerabilities of the biological systems to changes in temperature, precipitation, light, and several other physical parameters.

PAN-EARTH Africa case study

The Africa case study was formally established at the September 1989 workshop in Saly, Senegal, as the PAN-EARTH Sub-Saharan Africa Collaborative Research Network, coordinated by the Organization of African Unity's Semi-Arid Food Grain Research and Development Agency (OAU/SAFGRAD) (see Appendix C). A copy of the final recommendations and summary report of the workshop is attached as Appendix D. At the PAN-EARTH Africa Workshop, a working group of climatologists developed Africa-specific climate change scenarios based in part on results from general circulation models for doubled-CO_2 and nuclear winter scenarios. Greenhouse scenarios for sub-Saharan Africa include temperature increases of about 4°C, and significant shifts in the amounts, timing, and distribution of rainfall, with concomitant alterations in the growing season. Two other workgroups at the workshop in Senegal identified specific sub-Saharan ecosystems and agricultural systems to evaluate potential effects from climate change, through a concerted approach of data acquisition and analysis, computer model calibration, and extensive sensitivity analyses. Specific individuals and institutions were selected for participation in the collaborative network, and tasks assigned for each. The present proposal is for financial support to the scientific and logistical activities required over a three-year period to implement and conduct the PAN-EARTH Africa case study.

OBJECTIVES OF THE PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK

The central objective of the PAN-EARTH Project on sub-Saharan Africa is to characterize the vulnerability of African nations to global environmental change, and to ascertain the critical importance of such changes to sustainable development in the region. This will be instituted through close collaboration among PAN-EARTH and African scientists to define climate change scenarios, identify and characterize critical ecological and agricultural systems of importance in the region, and assess the effects of climate change on those systems. Some of the salient objectives of the PAN-EARTH Africa network are:

a) *To advance the awareness among scientists, institutions, and policy makers in sub-Saharan Africa of the potential impacts of global climatic changes on the sustainability of the environment in Africa.*

b) *To improve the scientific capabilities of scientists and institutions in the region to analyze the long-term climatic data base available and to relate such analyses to apparent causes of the African agrarian crises and ecological deteriorations.*

c) *To facilitate the exchange of technical information among African countries on the development, implementation, and application of computer simulation models of crop production.* A series of crop models will be implemented and calibrated to specific systems and specific sites in sub-Saharan Africa.

d) *To study the effects of plausible climatic change scenarios on the productivity and sustainability of agricultural and ecological systems.* This scientific understanding will be developed through case study analyses on a diversity of ecological and agricultural systems in the participating countries of the region. A host of methodologies will be pursued, including historical analogs, statistical models, physiological experiments, life-zone classifications, paleoecological records, computer simulation models, and expert judgment.

e) *Through extensive sensitivity analyses, to identify the most important facets of global climatic change with respect to agricultural and ecological effects in Africa,* so that climate modelers can redirect research to reduce uncertainties about those critical factors.

TASKS AND METHODS

Specific climatological, ecological, and agricultural studies under the PAN-EARTH Sub-Saharan Africa Collaborative Research Network will focus on climate change effects relevant to the African situation. The proposed project will undertake studies on sites selected to be characteristic of broadly defined ecological zones. The following tasks will be conducted:

- Task 1 — analysis of climate change scenarios for sub-Saharan Africa;
- Task 2 — analysis of climate change effects on agriculture;
- Task 3 — analysis of climate change effects on ecological systems;
- Task 4 — identification of systems most vulnerable to climate change; and
- Task 5 — facilitation of experimental research on climate change effects.

Task 1) Analysis of Climate Change Scenarios for Sub-Saharan Africa

The nature of projected climate change in sub-Saharan Africa will be characterized. At present, climatologists know general projections of future climate change on a global scale, but the specific changes that are to be experienced at particular locations and the timing and rate of such climate change are not well known. The best methodology available for assessing global-scale climate change is the use of general circulation models (GCMs) which are implemented on supercomputers at several research institutions in the U.S.A. and elsewhere.

Such GCM results are available at the PAN-EARTH Project. Outputs specific to areas of sub-Saharan Africa are being examined against historical climatological data bases to assess the applicability of GCMs to the region. Once this baseline is established, other GCM outputs for simulations of altered climate are evaluated to develop specific scenarios for climate change at each site to be analyzed for biological effects. There are significant issues that must be addressed in this process concerning the spatial and temporal distribution of climatic variables, including: daily temperatures; the timing, frequency, amount, and duration of precipitation events; and the shifts in the inter-tropical convergence zone and associated effects on monsoonal development.

Methodologies have been under development by PAN-EARTH scientists for the past several years to deal with these issues. At present, many uncertainties remain in predicting specific climate change for specific regions, especially with regard to precipitation, which is the key variable for sub-Saharan Africa. These uncertainties will be reduced insofar as possible in the PAN-EARTH case studies. For those remaining uncertainties, extensive utilization of sensitivity analyses will allow PAN-EARTH scientists to assess the range of potential effects from climate change. The general approach, then, is to develop climate change scenarios for the region, modify as appropriate for specific sites, establish the range of sensitivity analyses needed to cover the uncertainties about climate projections, and evaluate the potential biological effects of this range of climatic changes.

Task 2) Analysis of Climate Change Effects on Agriculture

The effects of climate change on important agricultural systems will be evaluated, with major emphasis on the production of staple food and export crops. The complexities of food production will be assessed, i.e., with attention to issues of potential productivity, farming practices, cultivar development, and other agricultural production and development

issues. Agricultural impact assessments cannot be done in the abstract, however, and specific sites for specific crops representative of the region have been selected to examine the potential effects of climate change, as discussed below.

A central emphasis of the PAN-EARTH Sub-Saharan Africa Collaborative Research Network is to assist African scientists and institutions in the implementation, development, training, and calibration of agricultural simulation models. This effort will rely substantially on the computer simulation models developed under auspices of the International Benchmark Sites Network for Agro-technology Transfer (IBSNAT) Project, which has been funded for over ten years by US AID. IBSNAT has produced 'generic crop models' for key crops; here *generic* means that these models are physiologically based, and, with proper input of a minimum data set regarding soil characteristics, meteorological data, and crop cultivar characteristics, can be calibrated to a specific crop at a specific site. Such calibration has been done in many regions of the world, with reasonably accurate simulation of crop phenology and productivity. These models contain explicit treatment of the climate change parameters, and, consequently, are best among the existing methodology for assessing climate change effects.

Crop models are available now through PAN-EARTH for maize, millet, sorghum, soybean, rice, peanut, and wheat, and will be available for cassava in the future. These models are being implemented on microcomputers in Africa, and African scientists are being trained in their calibration and use. The existing SAFGRAD/ICRISAT/ IITA/WARDA commodity-oriented networks (i.e., networks that are in place for maize, cowpea, sorghum, millet, and rice) will be strongly utilized, to acquire the data to calibrate these models to fit specific cropping systems as well as to provide the expert judgment necessary for crop assessment and evaluation. Once these models are appropriately calibrated, extensive sensitivity analyses will be used to evaluate the potential effects on crop phenology (development during the growing season) and production from changes in the variety of physical parameters characterizing climate change. The sensitivity analyses will be done using a paired scheme; i.e., for each analysis, a calibrated model will be simulated for normal climatic conditions, and a matched simulation will be conducted with everything else identical, including the stochastic forcing functions for the model, except the single parameter being altered to represent an aspect of climate change. Some simulations will also include changes in several parameters simultaneously, to represent the effects of changes in linked climatic variables. Since the simulations are done relatively quickly on microcomputers, a very large number of simulations can be accomplished.

Through such extensive sensitivity analyses, the full response of agricultural systems to the range of possible climatic conditions to be experienced in the next few decades will be characterized.

In the process of implementing the crop models for African sites and conducting the sensitivity analyses, an additional benefit will be that African scientists will have a new capability to assess crop development and production as a function of many other variables, including not only climate change, but also such issues as changes in farming practices, development of new cultivars, planting in new regions, and many other factors affecting food production.

In addition to the use of crop simulation models, the PAN-EARTH Project will utilize a variety of other methodologies to assess potential effects of climate change on crop production. An important example is the use of historical analogs, in which data from past crop production and growing season meteorology are evaluated to relate how differences in the climate over different growing seasons have led to differences in crop development or production. This approach relies primarily on the data bases and knowledge of the agricultural scientists in national and international institutes in Africa. Similarly, data from laboratory physiological experiments of crop development and crop production as functions of different temperature, lighting, and soil moisture regimes can be used to evaluate the sensitivity of particular crops and cultivars to changes in climate. Again, primary reliance is on the local scientists and data bases. Finally, expert judgment will be drawn upon, focused in a major workshop on agricultural effects from the climate change scenarios developed for the region.

Task 3) Analysis of Climate Change Effects on Ecological Systems

To assess the potential effects of climate change on the sustainability of ecological systems will be the focus of a task similar to the previous one. One of the methodologies for this is to use computer simulation models. However, ecosystem models are much less developed as generic tools than are crop models. PAN-EARTH does have access to the GRASS model, implemented at Colorado State University for savannah ecosystems in eastern Africa, the CENTURY model, a grassland physiological model, as well as a simulation model of the pastoral livestock ecosystem of sub-Saharan Africa. These three models were demonstrated at the Saly workshop and will be calibrated to sites selected for the studies. These models will be implemented on microcomputers for the use of African scientists and,

consequently, will provide a new capability for African scientists to study these ecosystems for climate change effects and for the responses of the ecosystems to other perturbations.

Because for most of the ecosystems of interest in sub-Saharan Africa there are no ecosystem simulation models already available, other methodologies for effects assessments will be primarily relied upon. One approach is to use life-zone classifications, a technique of classifying the landscape at the biome level based on climatological and biological data. Controlling parameters include annual temperature, annual precipitation, and timing and length of the rainy season. Knowledge of the distribution of these parameters can lead to classifying the potential ecological systems across the region, and can be verified through remote sensing. Once this is done, shifts in the values of these parameters, representing changes in climate, can be evaluated to project how the boundaries between ecosystem types will shift at equilibrium. This technique has been successfully used for reconstructing paleoecological climate-ecosystem relationships, and offers promise for evaluating the effects of anthropogenic climate change on ecological systems. However, this approach can only suggest equilibrium changes, i.e., changes that will ensue once the climate and the associated ecosystem distribution patterns have stabilized, a process that could take centuries. Evaluating how biomes will shift during the few-decade period of greenhouse changes requires considerable expert judgment.

Other approaches to evaluating ecological responses will be used, relying on historical records of biome shifts associated with past and ongoing climate change in sub-Saharan Africa. Also, physiological data bases can be drawn upon using expert judgment to evaluate the vulnerable species and ecological systems. A major workshop will be convened to familiarize participating NARS scientists in Africa with methodologies to assess the vulnerability of ecological systems to climate change.

Task 4) Identification of Systems Most Vulnerable to Climate Change

Once the above three tasks are well underway, identification of the ecological and agricultural systems in sub-Saharan Africa that are most vulnerable to climate change effects can then be started. This evaluation will be done by examining the effects assessments described above and, through a focused workshop for data analysis and synthesis, a consensus among the PAN-EARTH Africa network scientists will be reached. Included will be an assessment of the full range of ecological and agricultural systems in sub-Saharan Africa, including the arid, semi-arid, and humid regions, analyzed by statistical and simulation models, historical precedent, and expert judgment. Effects on

pasture land, livestock, locust and other pest outbreaks, hydrology, desertification, and human interactions with the specific ecosystems will each receive attention.

By identifying the most vulnerable systems, advice can be given to policy makers concerning the potential impacts on human populations and systems. Further, in some cases mitigative or remedial activities can be planned to help reduce the impacts of climate change on those biological systems. Finally, by identifying the most vulnerable systems, and by characterizing the uncertainties in each aspect of the analyses (climatological, ecological, and agricultural), particular research activities that need to be initiated to improve the predictive capabilities, focused on those systems and uncertainties of greatest importance to humans, can be specified.

Task 5) Facilitation of Experimental Research on Climate Change Effects

The final aspect of the PAN-EARTH Africa case study is to identify specific experimental research and model developments that are needed to advance the capability to understand climate change and its effects on sub-Saharan Africa. In the process of identifying uncertainties and vulnerabilities, attention will be directed to specific research needs. Where possible, experiments will be initiated within the PAN-EARTH Sub-Saharan Africa Collaborative Research Network to address these needs. If required, additional funding will be sought through proposals specific to the research tasks; in other cases, research will be initiated as a part of the ongoing research networks coordinated by OAU/SAFGRAD. Moreover, new model development for climatological, ecological, and agricultural assessments is continually being conducted by many of the scientists associated with the PAN-EARTH Project. An important synergism is created when such model development is done in close collaboration with field and laboratory experiments, as the models may be used to identify specific hypotheses for experimentation, and the experiments may provide new insights in model formulation. Wherever possible, efforts will be made to facilitate the collaborative development of these two approaches to scientific research, not only in the context of the Africa-specific studies, but also for more generic issues of climate effects assessments.

STUDY SITES

The PAN-EARTH sub-Saharan Africa workshop convened at Saly, Senegal on 11-15 September 1989, included as a major objective the identification of specific sites for ecological and agricultural assessments. Participants at the workshop included scientists

from thirteen sub-Saharan African countries: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea-Bissau, Kenya, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. These representatives, through the ecological and agricultural workgroups, not only agreed to establish the collaborative research activities through the PAN-EARTH Project, but also identified the major crop and ecosystem sites for assessment of impacts of climatic change. These sites were selected at the Saly workshop (Table 1) based on the criteria of:

- importance of the crop for the region;
- representativeness of the site for the crop in the region;
- availability of data bases on the crop, soils, and climatology of the site;
- availability of a specific scientist or institution with responsibility for those data and with appropriate scientific expertise.

Specific ecological sites have been selected (Table 2) with similar criteria as for the agricultural sites, specifically:

- importance of the ecosystem to the region;
- representativeness of the specific site for the ecosystem type;
- availability of a data base on the ecosystem and climatology at the site;
- availability of specific individuals or institutions with responsibility for the data and with appropriate expertise.

Table 1. Agricultural Effects Assessment Zones, Sites, and Cooperating Institutions

Zone of Agricultural Production (annual precipitation)	*Main System of Production*	*Cooperating Institutions and Sources of Data Bases*
1.0 Sahel Savanna		
N. Sahel <400 mm.	• Nomadic-Pastoral	ILCA, NARS
S. Sahel 400-700 mm.	• Millet-Cowpea	ICRISAT, AGRHYMET, SAFGRAD, NARS, CILSS, IITA (Nigeria, Mali, Niger, Senegal, Burkina Faso)
	• East Africa Millet	ICRISAT/SAFGRAD (Kenya, Sudan, Uganda)
2.0 Sudan Savanna		
700-1100 mm.	• Sorghum-based systems (West and East Africa)	SAFGRAD/ICRISAT, NARS (Nigeria, Mali, Cameroon, Burkina Faso, Tanzania, Ethiopia, Sudan, Uganda)
	• Maize-based systems (West and Central Africa)	IITA/SAFGRAD, NARS (Nigeria, Cameroon, Ghana, Togo, Côte d'Ivoire, Benin, Zaire)
	• Maize-based systems (East Africa)	CIMMYT, NARS (Tanzania, Kenya, Ethiopia)
	• Groundnuts	ICRISAT, ISRA, NARS (Senegal, The Gambia, Mali, Guinea-Bissau)
3.0 Guinea Savanna		
>1100 mm.	• Maize-based systems (West and Central Africa)	IITA/SAFGRAD, NARS (Nigeria, Cameroon, Ghana, Togo, Côte d'Ivoire, Benin, Zaire)
	• Maize-based systems (East Africa)	CIMMYT, NARS (Tanzania, Kenya, Ethiopia)
	• Rice, different systems of cultivation (irrigated, upland, and floating)	WARDA, NARS (Senegal, Côte d'Ivoire, Liberia, Mali, Guinea-Bissau, Sierra Leone, Tanzania)
	• Root and Tuber Crops (Cassava)	IITA/SAFGRAD (Zaire, Nigeria, Ghana, Cameroon)

Table 1. Agricultural Effects Assessment Zones, Sites, and Cooperating Institutions (continued)

Zone of Agricultural Production (annual precipitation)	*Main System of Production*	*Cooperating Institutions and Sources of Data Bases*
4.0 Humid Coastal Zone 1500-2000 mm.	Tree crops:	
	• Plantain/Banana	IITA, INIBAB (Ghana, Togo, Cameroon, Nigeria, Uganda)
	• Oil Palm	IRA, Cameroon (Côte d'Ivoire, Zaire, Cameroon, Nigeria)
	• Coffee	IRCC (Institute of Research for Coffee and Cocoa), Inter-African Coffee Association, Institute of Agricultural Research-Ethiopia, Kenya Coffee Research Institute (Côte d'Ivoire, Kenya, Ethiopia)
	• Cocoa	Ghana Cocoa Research Institute, similar research institute in Côte d'Ivoire (Ghana, Côte d'Ivoire, Nigeria, Sierra Leone)
	• Coastal Fisheries	Research institute to be identified (Cameroon, Senegal, Ghana, Côte d'Ivoire, Sierra Leone, Mauritania)
5.0 Eastern Africa Highlands 800-2000 mm.	• Teff-based systems	IAR, Debre-Zeit Agricultural Research Centre (Ethiopia)
	• Wheat	IAR, Debre-Zeit (Ethiopia, Kenya)

Table 2. Ecological Effects Assessment Sites and Cooperating Institutions.

Ecological Zone	*Sites*	*Cooperating Institutions and Scientific Coordinators*
1.0 Arid and Semi-Arid Ecology		
	• Niamey (Niger)	ICRISAT/INRAN — M.V.K. Sivakumar
	• Oursi (Burkina Faso)	IRBET, INERA — E. Bonkoungou
	• Ferlo (Senegal)	ISRA, ORSTOM — M. Diagne
	• Maroua (Cameroon)	IRA — M. Eyog
	• Lamto (Côte d'Ivoire)	University of Abidjan Faculty of Science — R. Verattoux
	• Turkana (Kenya)	KARI, KREMU, also Colorado State University, Natural Resource Department. — J. Ellis, D.M. Swift, M.B. Coughenour
2.0 Humid Zones		
	• Tai (Côte d'Ivoire)	Institute for Tropical Ecology — Y. Sangare
	• Yaounde (Cameroon)	Faculty of Science, IRA — P. Nkwi
	• Makoukou (Gabon)	IRET — P. Posso
	• Moguga (Kenya)	EAFRO, KARI

ORGANIZATIONAL STRUCTURE OF THE PAN-EARTH AFRICA CASE STUDY

- PAN-EARTH International Network — Coordinated by Cornell University under direction of Dr. Mark Harwell, Director of the Global Environment Program and International Coordinator of the PAN-EARTH Project

- Africa Network - PAN-EARTH Sub-Saharan Africa Collaborative Research Network — Coordinated by OAU/SAFGRAD under direction of Dr. Taye Bezuneh, Director of Research for OAU/SAFGRAD and PAN-EARTH Sub-Saharan Africa Case Study Coordinator

- Advisory Committee for the PAN-EARTH Sub-Saharan Africa Collaborative Research Network:

  - Dr. Messan Gninginvi, Chairman (Togo)
  - Dr. Moussa Traoré, Member (Mali)
  - Dr. Paul Nchoji Nkwi, Member (Cameroon)
  - Dr. Edouard G. Bonkoungou, Member (Burkina Faso)
  - Dr. M.V.K. Sivakumar, Member (ICRISAT)
  - Dr. Naju, Member (Kenya)
  - Dr. Taye Bezuneh, Ex Officio, Africa Coordinator (SAFGRAD)
  - Dr. Mark Harwell, Ex Officio, PAN-EARTH Coordinator (Cornell, USA)
  - AGRHYMET Representative, Observer
  - IITA Representative, Observer
  - INSAH Representative, Observer

Project Management

Project funds will be managed and accounted for by the SAFGRAD Coordination Office (SCO) based in Ouagadougou, Burkina Faso. The SCO will be responsible for the execution of the technical and financial aspects of the project. Supervision of project implementation would be carried out by senior staff of SAFGRAD and national coordinators at the field level. In order to maintain continuous access to technology, activities of this network would be linked to:

- Global PAN-EARTH Research Network and its world-wide collaborating scientists;

- International and regional research programs of (e.g., ICRISAT, IITA, AGRHYMET, etc.);
- NARS scientists and centers identified as field-level coordinators to implement the assessments of climate change effects on agricultural and ecological systems.

Furthermore, the Director of Research of SAFGRAD will be directly responsible for the technical supervision of the project according to the agreed schedule of implementation. The case study coordinator to be employed through the project, will supervise, coordinate and monitor the implementation of the project at the field level.

Functions of the Advisory Committee

Project implementation will also be guided by the Advisory Committee of the PAN-EARTH Africa Network.

Although these would be elaborated more fully at a later date, its immediate functions include:

- To review and approve annual work plans;
- To follow up the technical implementation of the project according to its scheduled plan of action;
- To review progress reports and to address issues that may emanate in the course of project implementation.

FINANCIAL REQUIREMENTS

The financial assistance through this project would enable OAU/STRC-SAFGRAD and national institutions participating in the PAN-EARTH Sub-Saharan Africa Collaborative Research Network to provide technical support to enhance the assessment of the vulnerability of agricultural and ecological value systems to climate change.

The specific allocation of funds to different national research programs and sites will be based on actual needs as identified by the Case-Study Coordinator and the Advisory Committee of the Network. Technical and administrative support will be provided by the SCO, the International PAN-EARTH Network, and collaborative scientists. This

will involve program review and analysis, organizing training workshops, special seminars, and overall supervision for implementing activities of the project.

Donors

SAFGRAD was conceived as a multi-donor program. Since its inception, major funding has been provided by the United States Agency for International Development (USAID), with a total sum of about US$21 million during phase I. Since 1984, the International Fund for Agricultural Development (IFAD) has maintained about one million US dollars a year to support Farming Systems Research (FSR) in three countries, including coordination of SAFGRAD research activities, while the French Government through its Aid and Cooperation Fund (FAC) has continued to support on-farm testing activities in the Republic of Togo.

Since 1986, the major thrust of SAFGRAD activities has been to strengthen NARS research capabilities through collaborative research networks. Five networks are currently operational, namely the West and Central African Maize and Cowpea Networks; the Eastern African Sorghum and Millet Research Network; and the West and Central African Sorghum Network. Since 1987, IDRC of Canada has become an additional donor to SAFGRAD by supporting the West African Farming Systems Research Network. In 1989, the African Development Bank became a new SAFGRAD donor to support a program on the application of improved agronomic practices to intensify food grain production in sub-Saharan Africa. The OAU provides the administrative and political umbrella for SAFGRAD to expedite the movement of germplasm, exchange of technology, and travel of NARS and IARC scientists, and OAU provides direct financial support to SAFGRAD.

Member countries hosting SAFGRAD projects (for example Burkina Faso, Nigeria, Mali, Cameroon, Benin, Senegal, and Kenya) have continued to provide logistics support, personnel, and funds to facilitate the implementation of research and on-farm trials in their respective countries.

The management entities of SAFGRAD include the following participatory mechanisms:

i) The Council of Directors of Agricultural Research of the 26 member countries of SAFGRAD. This meets biennially to provide policy guidance on research matters and common agricultural production problems.

ii) The Oversight Committee (seven members) comprising senior research administrators, scientists, and university professors elected during the Directors' Conference. It monitors the management and implementation of SAFGRAD in general and the activities of the SCO in particular. This committee usually meets at least once a year.

iii) The Steering Committee is a technical unit of relatively full-time researchers. Each network has its own Steering Committee which sets priorities on research activities, develops the particular network program, and provides technical guidance to ensure that appropriate technologies of regional and national interest are made available to participating NARS. The committee for each network meets at least once a year.

iv) The SAFGRAD Coordination Office (SCO), the implementing unit of SAFGRAD, is autonomous in its technical execution of projects. The SCO also serves as secretariat for the above-mentioned technical management entities.

Appendix A

Estimate of PAN-EARTH Africa Case Study Budget Requirements (in Thousands of U.S. Dollars)

		Years			
		1	2	3	Total
1.0	Project Coordination				
1.1	Assistant Coordinator[1]	$50	$50	$50	$150
1.2	Secretary	10	10	10	30
1.3	Travel[2]	30	25	20	75
2.0	Support to Field Level Case Studies[3]				
2.1	Agriculture	30	30	30	90
2.2	Ecology	25	25	25	75
2.3	Climatology	20	20	20	60
3.0	Training and Workshops[4]				
3.1	Ecological Effects Assessment Training and Agricultural Effects Assessment (Combined Workshop)	50	0	0	50
3.2	Crop Modeling Workshop	0	50	0	50
3.3	Climatological Data Analysis Training and Workshop	30	0	0	30
3.4	Data Analysis and Synthesis Workshop	0	0	60	60

1 Post-doctoral associate in residence at SAFGRAD Headquarters in Ougadougou. Includes $25,000 annual salary plus $25,000 for housing and fringe benefits.

2 Travel for PAN-EARTH International and Africa Coordinators and Africa Assistant Coordinator.

3 Grants of approximately $2,500 each to be given to field coordinators for each ecological and agricultural site and for climatology coordinators for supplies, communications, and travel expenses.

4 Each workshop to be held at an African site; costs include travel, hotel, meeting rooms, translators, report preparation, and supplies.

		Years 1	2	3	Total
4.0	Equipment				
	4.1 Computers[5]	40	10	0	50
	4.2 Vehicle[6]	15	0	0	15
5.0	Publications	10	10	15	35
6.0	SUBTOTAL	310	230	230	770
7.0	Project Technical Support from PAN-EARTH (10% of subtotal)[7]	30	20	20	70
8.0	Project Supervision and Indirect Costs at SAFGRAD (15% of subtotal)[8]	45	35	35	115
9.0	Contingency (5% of subtotal)	15	10	10	35
	TOTAL	$400	$295	$295	$990

5 IBM-PC compatible 286 or 386 machines with battery power, hard disks, math coprocessors, and software to be given to eight field coordinators in year 1 (approximate costs $5,000 each) and two more in year 2. These computer packages will allow running of crop and ecosystem models, as well as data storage and analysis, word processing, and graphics.

6 A 4-wheel drive vehicle will be purchased at SAFGRAD for the Coordinator and Assistant Coordinator to travel to the ecological and agricultural research sites.

7 Includes travel, data analysis, communications, and software for PAN-EARTH coordination unit.

8 Includes project supervision, accounting, supplies, communications, duplicating, and other logistical costs of PAN-EARTH Africa coordinating unit.

APPENDIX B. PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK SCHEDULE OF ACTIVITIES

	ACTIVITY	APPROXIMATE PERIOD (in months)					
		6	12	18	24	30	36
(1)	Research program review and planning						
	• Agriculture	X	X	—	X	—	X
	• Ecology	X	X	—	X	—	X
(2)	Training workshops on crop and ecological modeling	—	X	X	—	—	—
(3)	Establishment of field level assessment research studies	X	X	X	X	—	—
(4)	Assessments of climate change effects at field level	X	X	X	X	X	—
(5)	Training workshops on climate data analysis	—	X	—	X	—	—
(6)	Seminars on data analysis and assessment	—	X	X	X	—	X
(7)	Global workshop on data evaluation and synthesis	—	—	—	—	X	—
(8)	Preparation of the annual and final reports of the project	—	X	—	X	—	X

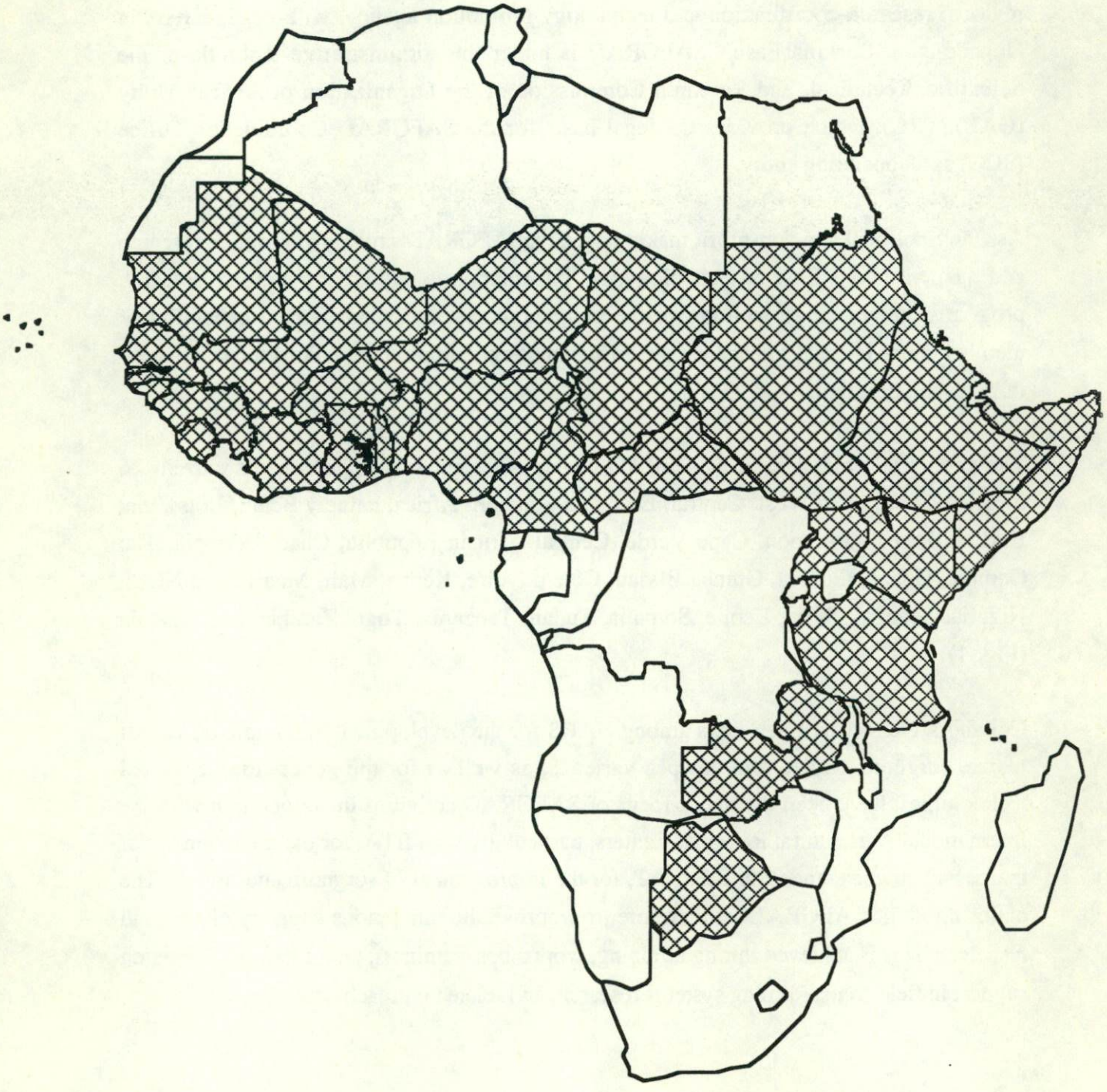
APPENDIX C. INSTITUTIONAL SETTING OF THE SEMI-ARID FOOD GRAIN RESEARCH AND DEVELOPMENT AGENCY (SAFGRAD)

Following an OAU Ministerial decision in 1976, SAFGRAD was created in 1977 as a regional research-coordination and technology-promotion agency, with headquarters in Ougadougou, Burkina Faso. SAFGRAD is under the administrative umbrella of the Scientific, Technical, and Research Commission of the Organization of African Unity (OAU/STRC), which provides the legal basis for the SAFGRAD Coordination Office (SCO) as an operating entity.

As a non-political and non-profit making agency, SAFGRAD's role is to promote research and the continuous flow of technology and information to and among national research programs (networking); to improve the indigenous research management capability of member countries; and to enhance the diffusion of agricultural innovations through its on-farm testing program.

The geographic mandate of SAFGRAD covers the semi-arid regions of its current 26 member countries in West, Central, East, and Southern Africa, namely Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Central African Republic, Chad, Ethiopia, The Gambia, Ghana, Guinea, Guinea Bissau, Côte d'Ivoire, Kenya, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Zambia, and Uganda (Fig. 1).

Collaborative research networks among NARS for the development and improvement of maize, sorghum, millet, and cowpea varieties, as well as for the generation of related technologies, have been the major focus of SAFGRAD activities in cooperation with the International Agricultural Research Centers, particularly with IITA, for the improvement of maize and cowpea, and with ICRISAT, for the improvement of sorghum and millet. The major thrust of SAFGRAD is, therefore, to improve the indigenous capacity of national research. This is achieved through training, workshops, seminars, direct technical research support in field trials, farming systems research, and related outreach activities.



SAFGRAD Member Countries

APPENDIX D

PAN-EARTH/OAU/SAFGRAD/ISRA Workshop
On the Effects of Climate Changes
On Agricultural and Ecological Systems in Sub-Saharan Africa

Saly, Senegal
11-15 September 1989

Final Recommendations

This workshop on global climate change effects on the sub-Saharan environment, held in Saly, Senegal,

ACCEPTING the following existing situations:

- significant climate change has occurred in sub-Saharan Africa over the past few decades;
- the sub-Saharan Africa environment is experiencing substantial degradation;
- there is a critical need for agricultural development in sub-Saharan Africa to keep pace with the very rapid population growth rate;

RECOGNIZING that global climate change in the next several decades is expected to be unprecedented in human history and will significantly affect all facets of agriculture and food production, forestry, environmental quality, the human quality of life, and sustainable development in sub-Saharan Africa as a consequence of increased stresses on an already difficult situation,

and *FURTHER RECOGNIZING* the urgent need to evaluate the nature and magnitude of potential environmental, agricultural, and human impacts of climate change in sub-Saharan Africa, and that such a scientific evaluation has not yet taken place, although the data and the methodologies presently exist to begin such an interdisciplinary assessment:

HEREBY ESTABLISHES the PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK, coordinated by OAU/SAFGRAD in cooperation with the international PAN-EARTH Project headquartered at Cornell University, USA,

and *RECOMMENDS* the following:

1) the establishment of a network of scientific activities among African scientists and international collaborators, including environmental, ecological, agricultural, climatological, and social scientists, to identify the vulnerable ecological and agricultural systems of concern in sub-Saharan Africa and to conduct assessments of climate change and its impacts on humans and the environment;

2) the improvement of the agricultural, ecological, and climatological data bases for sub-Saharan Africa, including drawing upon existing data bases and research activities in national, regional, and international institutes and organizations;

3) that international and national organizations affiliated with the PAN-EARTH Sub-Saharan Africa Collaborative Research Network provide insofar as possible logistical and other support to these activities;

4) that existing training programs be strengthened and new training programs be developed within international, national, and other appropriate organizations to improve the scientific capabilities relevant to environmental issues, especially for collecting and analyzing data and conducting effects assessments;

5) that the additional, specific scientific recommendations included in the body of the PAN-EARTH Africa Workshop Report are implemented forthwith;

6) that a Pan-Africa conference be convened consisting of scientists and policy leaders from throughout sub-Saharan Africa on the topics of climate change, its effects on humans and the environment, and the policy implications, responses, and planning strategies for governments in the region;

7) that sub-Saharan African governments recognize the seriousness of the potential consequences of climate change on agricultural production, environmental degradation, and human impacts, and that these governments are called upon to provide concerted support to the network of scientific activities recommended herein to address global climate change impacts; such support should include field-level activities related to PAN-EARTH and affiliated activities, logistical support, encouraging scientists in research institutions to participate in the network of activities, and political support for these activities;

8) that the World Bank and African financial institutions, such as the African Development Bank and affiliated units, recognize the critical importance of climate change and environmental degradation in their long-term development projects;

9) that the donor community, given their essential involvement in Africa for the promotion of agriculture and food production, restoration and protection of the environment, and initiatives towards sustainable development, provide support to the PAN-EARTH Sub-Saharan Africa Collaborative Research Network with whatever financial resources that can be brought to bear on these critical issues.

SUMMARY REPORT

PAN-EARTH/OAU-SAFGRAD/ISRA WORKSHOP ON THE EFFECTS OF CLIMATE CHANGES ON AGRICULTURAL AND ECOLOGICAL SYSTEMS IN SUB-SAHARAN AFRICA

11-14 SEPTEMBER 1989
SALY, SENEGAL

The PAN-EARTH Sub-Saharan Africa Workshop, convened by the PAN-EARTH Project, OAU/SAFGRAD, and ISRA, was held in Saly, Senegal, from 11-15 September 1989. This workshop focused on the effects of global climate changes on the agriculture and ecology of the countries of sub-Saharan Africa. The workshop participants came from thirteen African countries: Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea-Bissau, Kenya, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. There were also representatives from the PAN-EARTH climate change case studies in Japan and Venezuela, and from the United States.

Major institutions represented at the workshop include: ICRISAT, OAU/SAFGRAD, PAN-EARTH Project, UNDP, UNESCO, and US AID. Funding for the workshop coordination, travel, hotel expenses, and publications was provided by: International Development and Research Center/Canada, Ford Foundation, Rockefeller Brothers Fund, U.S. Agency for International Development, and the U.S. Environmental Protection Agency.

Dr. Joseph Menyonga, OAU/SAFGRAD International Coordinator, delivered welcoming remarks. The workshop was officially opened by Cheikh Abdoul Khadre Cissoko, Senegal Minister of Rural Development, who welcomed the participants in the name of President Abdou Diouf of Senegal. The Minister expressed his interest in and support for establishing a research network on the important effects of climate change on the fragile ecological and agricultural systems of the sub-Saharan countries, both from global warming from the greenhouse effect, and from nuclear winter following nuclear war.

During the first day's sessions, climatologists discussed the functions of general circulation models, which model global climate processes. The potential use of these models and other methodologies for defining future climate change scenarios for sub-Saharan Africa was explored. Various models were compared and limitations were noted. The causes of greenhouse-effect climate change, from emissions of CO2 (carbon dioxide), CH4 (methane), and CFCs (chlorofluorocarbons), were discussed, and questions brought out important information about various sources of these emissions: vehicles; use of coal, oil, and other fossil fuels; and burning of firewood without reforestation to compensate. Many of these sources are growing parts of the sub-Saharan African economy, both industrial and community-based, especially because of population growth. Scenarios based on smoke and dust production from nuclear weapons explosions, leading to nuclear winter, were also discussed. The climatologists concluded that for sub-Saharan Africa, changes in precipitation patterns and amounts are expected to have more important consequences than are temperature changes.

Important issues for determining biological effects, both for ecological and agricultural systems, were examined. It was concluded by several speakers that while precise climatological data are still uncertain, the range of future climate change is fairly well determined. The consensus emerged that identification and analysis of biological systems vulnerable to climate change effects within this expected range cannot be delayed until all

climatological figures are exact, as negative effects on biological systems translate quickly into harmful effects on human society, especially in economies that are not robust.

Dr. Taye Bezuneh, Director of Research, OAU/SAFGRAD, presented background information on the PAN-EARTH Project and its connections with OAU/SAFGRAD. He detailed the existing crop networks in sub-Saharan Africa and explained the interconnections with the proposed PAN-EARTH Sub-Saharan Africa Collaborative Research Network. Dr. Mark Harwell, Cornell University, International Coordinator of the PAN-EARTH Project, presented an overview of the Project, as well as the scientific issues and methodologies involved. The PAN-EARTH studies are centered around sustainability issues for ecology and agriculture, blending the efforts of scientists from these disciplines with climatological information to integrate methodologies and look at systems holistically.

The second day's sessions gave an opportunity for African scientists to present papers detailing valuable information on sub-Saharan ecology and agriculture and possible effects of global climate change, much of which was based on research previously done for drought effects. Presented papers covered a wide variety of topics, such as effects of climate change on: crops in the Sudano-Sahelian zone, forest ecosystems in Côte d'Ivoire, coastal systems of Benin and Togo, Sahelian ecology, human behavior, and crop production in north Guinean and Sudan savanna zones. Other topics covered included relating climate change effects in Kenya to El Niño events and the effects of human activities on the climate of Togo. Questions from the participants led to interesting discussions of these research topics and plans for further exchange of such relevant information as will assist in the analyses of climate change effects.

The third day's sessions began with presentations on the progress of the PAN-EARTH case studies already established in Venezuela, Japan, and China. Then a simulation model for grasslands was presented, and data needs were detailed. A pastoral model for semi-nomadic livestock in eastern Africa was also presented. The crop simulation models developed for the IBSNAT/DSSAT program, funded by US AID, were presented in detail, and the remainder of the day was spent demonstrating use of and discussing data acquisition for these essential models.

The participants divided into three working groups for the fourth day, examining in detail plans for analyzing ecological, agricultural, and climatological effects. The groups were charged with developing climatological data needs and lists of agricultural and ecological sites suitable for research on climate change effects. Coordinators for each crop type were designated and coordinators and contact scientists were listed for each ecological site. Reports from these working groups were presented on the final day, on potential climatological scenarios, agricultural and ecological sites, and key personnel in many countries and institutions.

The assembled scientists unanimously voted to establish the PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK, coordinated by OAU/SAFGRAD in cooperation with the international PAN-EARTH Project headquartered at Cornell University, USA. The assembled participants also adopted the following as a part of their final recommendations, presented on behalf of the participants by Dr. R.A.D. Jones, National Agricultural Research Coordinator, Sierra Leone:

- the formal establishment of a network of scientific activities among African scientists and international collaborators to identify the vulnerable systems of concern in sub-Saharan Africa and to conduct assessments of climate change and its impacts on humans and the environment;

- the improvement of agricultural, ecological, and climatological data bases and research activities in national, regional, and international institutes and organizations;

- that the PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK affiliates provide logistical and other support to these activities, insofar as possible;

- that existing training programs be strengthened and new training programs be developed, especially for collecting and analyzing data and conducting effects assessments;

- that a Pan-Africa conference be convened on the topics of climate change, effects on humans and the environment, and policy implications, responses and planning strategies for governments in the region; and

- that sub-Saharan governments, the World Bank, African financial institutions, and the donor community recognize the seriousness of the potential consequences in long-term development projects and provide support with whatever financial resources that can be brought to bear on these critical issues.

In addition, a number of specific scientific recommendations, included in the working group reports, was adopted by the participants.

The workshop Final Communique, presented by Dr. Paul Nchoji Nkwi, Scientific Technical Advisor, Ministry of Higher Education, Computer Services, and Scientific Research, Cameroon, affirmed the establishment of the PAN-EARTH SUB-SAHARAN AFRICA COLLABORATIVE RESEARCH NETWORK, and was adopted by the participants. The workshop was adjourned by Dr. Messan Gninivi, Solar Energy Laboratory, Lome, Togo.

APPENDIX E

ACRONYMS

AGRHYMET	Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (Regional Center for Training and Application of Agricultural Meteorology and Hydrology)
CFC	Chlorofluorocarbon
CILSS	Comité Inter-Etats de Lutte contre la Sècheresse dans le Sahel (Permanent Interstate Committee for Drought Control in the Sahel)
CIMMYT	International Maize and Wheat Improvement Center
EAFRO	East African Agricultural and Forestry Research Organization
FAC	French Aid and Cooperation Fund
FSR	Farming Systems Research
GCM	General Circulation Model
IAR	Institute for Agricultural Research
IARC	International Agricultural Research Centre
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICRISAT	International Center for Research in the Semi-Arid Tropics
IDRC	International Development Research Centre (Canada)
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Center for Africa
INERA	Institut National d'Etudes et de Recherches Agricoles
INIBAP	International Network for the Improvement of Banana and Plantain
INRAN	Institut National pour la Recherche Agronomique au Niger
INSAH	Institut du Sahel
IRA	Institut de Recherche Agronomique
IRBET	Institut de Recherche en Biologie et Ecologie Tropicale
IRCC	Institut des Recherches pour Café et Cacao

IRET	Institut de Recherche en Ecologie Tropicale
ISRA	Institut Sénégalais de Recherche Agricoles
KARI	Kenya Agricultural Research Institute
KREMU	Kenya Rangeland Ecological Monitoring Unit
NARS	National Agricultural Research System
OAU/STRC	Organization of African Unity/Scientific, Technical and Research Commission
ORSTOM	Institut Français de Recherche Scientifique pour le Développement en Coopération
PAN-EARTH	Predictive Assessment Network for Ecological and Agricultural Responses to Human Activities
SAFGRAD	Semi-Arid Food Grain Research and Development
SCO	SAFGRAD Coordination Office
UNDP	United Nations Development Programme
UNESCO	United Nations Educational and Scientific Organization
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association

1990-01

Assessment of the Vulnerability of Agricultural and Ecological Systems to Climate Change in Sub-Saharan Africa

Bezuneh, Taye

OAU/STRC - SAFGRAD