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

prepared by

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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, 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 future 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 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 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 hundreds of 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 few *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 are 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 existing network for Semi-Arid Food Grain Research and Development (OAU/SAFGRAD). A copy of the workshop summary and recommendations is attached as Appendix B. At the PAN-EARTH Africa Workshop were developed specific climate change scenarios based in part on results from general circulation models for doubled-CO_2 and nuclear winter scenarios. 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 identified specific sub-Saharan ecosystems and agricultural systems to evaluate for potential effects from climate change, through a concerted approach of data acquisition and analysis, computer simulation 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 its critical importance 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 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.

Focus and Methods

Specific climatological, ecological, and agricultural studies under the PAN-EARTH Sub-Saharan Africa Collaborative 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:

- analysis of climate change scenarios for sub-Saharan Africa;
- analysis of climate change effects on agriculture;
- analysis of climate change effects on ecological systems;
- identification of systems most vulnerable to climate change; and
- facilitation of experimental research on climate change effects.

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

The nature of 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. and elsewhere.

In the PAN-EARTH Project, we have access to these GCM results. 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 us 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 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 impacts 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. 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.

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 reasonable simulation of crop phenology and productivity. These models contain explicit treatment of the climate change parameters, and, consequently, are among the best 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 on physiological experiments in laboratories of crop development and production as functions of different temperature, lighting, and soil moisture regimes can be used to evaluate 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. 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.

One of the methodologies to assess potential ecological effects from climate change 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 models were demonstrated at the Saly workshop and will be calibrated to sites selected for the PAN-EARTH 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 we do not have 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 by PAN-EARTH to facilitate this full suite of methodologies and the proper inclusion of the expert judgment of the ecological scientists in the region.

Task 4) Identification of Systems Most Vulnerable to Climate Change

Once the above three tasks are well underway, we can begin to identify the ecological and agricultural systems in sub-Saharan Africa that are most vulnerable to climate change effects. 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, 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 our analyses (climatological, ecological, and agricultural), we can specify particular research activities that need to be initiated to improve our predictive capabilities, focused on those systems and uncertainties of greatest importance to humans.

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 development 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, we will direct attention 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, we will seek 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, Cameroun, Cote d'Ivoire, Ghana, Guinee-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 at global level through PAN-EARTH Project, but also identified the major crop and ecosystem sites for assessment of impacts of climatic change as outlined in Tables 1 and 2.

Organizational Structure of the PAN-EARTH Africa Case Study

- 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

- PAN-EARTH 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

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

  - Dr. Messan Gninivi, Chairman (Togo)
  - Dr. Moussa Traore, Member (Mali)
  - Dr. Paul Nchoji Nkwi, Member (Cameroun)
  - 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)

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, CILS, 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, Cameroun, Burkina Faso, Tanzania, Ethiopia, Sudan, Uganda)
	• Maize-based systems (West and Central Africa)	IITA/SAFGRAD, NARS (Nigeria, Cameroun, Ghana, Togo, Cote d'Ivoire, Benin, Zaire)
	• Maize-based systems (East Africa)	CIMMYT, NARS (Tanzania, Kenya, Ethiopia)
	• Groundnuts	ICRISAT, ISRA, NARS (Senegal, Gambia, Mali, Guinee-Bissau)
3.0 Guinea Savanna		
>1100 mm.	• Maize-based systems (West and Central Africa)	IITA/SAFGRAD, NARS (Nigeria, Cameroun, Ghana, Togo, Cote 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, Cote d'Ivoire, Liberia, Mali, Guinee-Bissau, Sierre Leone)
	• Root and Tuber Crops (Cassava)	IITA/SAFGRAD (Zaire, Nigeria, Ghana, Cameroun)

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, Uganda)
	• Oil Palm	Institute of Agronomy, Cameroun (Cote d'Ivoire, Zaire, Cameroun, Nigeria)
	• Coffee	IRCC (Institute of Research for Coffee and Cocoa), Inter-African Coffee Association, Institute of Agricultural Research-Ethiopia, Kenya Coffee Research Work (Cote d'Ivoire, Kenya, Ethiopia)
	• Cocoa	Ghana Cocoa Research Institute, similar research institute in Cote d'Ivoire (Ghana, Cote d'Ivoire, Sierra Leone)
	• Coastal Fisheries	Research institute to be identified (Cameroun, Senegal, Ghana, Cote 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, CSE, ORSTOM — M. Diagne
	• Maroua (Cameroun)	IRA — M. Eyog
	• Lamto (Cote d'Ivoire)	University of Abidjan Faculty of Science — R. Verattoux
	• Turkana (Kenya)	KRI, KARI, KREMU, also Colorado State University, Natural Resource Department. — J. Ellis, D.M. Swift, M.B. Coughenour
2.0 Humid Zones		
	• Tai (Cote d'Ivoire)	Institute for Tropical Ecology — Y. Sangare
	• Yaounde (Cameroun)	Faculty of Science, IRA — P. Nkwi
	• Makoukou (Gabon)	IRBET — P. Posso
	• Moguga (Kenya)	EAFRO, KAKI

Appendix A

Estimate of PAN-EARTH Africa Case Study Budget Requirements (in Thousands of 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/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, Cameroun, Cote d'Ivoire, Ghana, Guinee-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 Cote 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 Nino 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, Cameroun, 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.

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

Dr. Mark A. Harwell

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