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GEF/WB REGIONAL CLIMATE, WATER AND AGRICULTURE:
IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA

PROJECT COMPLETION REPORT

Implementing Agency: The Centre for Environmental Economics and Policy in Africa (CEEPA), Faculty of Natural and Agricultural Sciences, University of Pretoria, republic of South Africa

CEEPA
The Centre for Environmental Economics and Policy in Africa
University of Pretoria

June 2006

PREAMBLE

This report describes the implementation and impacts of and lessons learned from the multi-country research activities conducted under the GEF funded project: *Climate Change, water and agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa*. The main goal of the project was to develop multipliable analytical methods and procedures to assess quantitatively how climate affects current agricultural systems in Africa, predict how these systems may be affected in the future by climate change under various global warming scenarios, and suggest what role adaptation could play. The project has been implemented in 11 countries: Burkina Faso, Cameroon, Ghana, Niger and Senegal in west Africa; Egypt in north Africa; Ethiopia and Kenya in east Africa and South Africa, Zambia, and Zimbabwe in southern Africa (see Figure 1). The study countries covered all key agro-climatic zones and farming systems in Africa. This is the first analysis of climate impacts and adaptation in the Africa continent of such scale and the first in the world to combine cross-country, spatially referenced survey and climatic data for conducting this type of analysis.

The Centre for Environmental Economics and policy in Africa (CEEPA) of the University of Pretoria coordinated all project activities in close collaboration with many agencies in the involved countries, the Agriculture and Rural Development (ARD) Department of the World Bank, the World Bank Institute (WBI), the Food and Agriculture Organization (FAO), Yale University, the University of Colorado, and the International Water Management Institute (IWMI). The project received supplemental funding from TFESSD, Finnish TF, NOAA-OGP and CEEPA (see Annex 3 for complete listing). We are grateful for the invaluable contributions of all these institutions and all individuals involved in this project.

The report is organized in four main sections and a number of annexes providing further details on materials presented in sections of main report.

Figure 1. GEF Climate Change and Agriculture in Africa Study Countries

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SECTION I: Basic Project Data

(1) **Date of Completion Report:** December 31, 2005

(2) **Project Title:**
Climate, Water and Agriculture: Impacts on and Adaptation of Agro-Ecological Systems in Africa

(3) **GEF Allocation:** US$0.7 million

(4) **Grant Recipient:**
Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria, South Africa

(5) **World Bank Manager / Task Team:** Dr. Arial Dinar

(6) **Goals and Objectives: (Including any changes in the objective):**
Main goals: (i) to develop multipliable analytical methods and procedures for assessing the impact of climate change on agriculture in Africa; (ii) to estimate how climate affects the current agricultural systems; (iii) project how climate change might affect this system in the future, and (iv) to assess adaptation options open to African farmers to cope with climate change
Objectives: (i) conduct national level economic analyses of impact and adaptation; (ii) conduct cross-national analysis and extrapolate results to countries not included in the sample; (iii) include water supply in the analysis; (iv) enhance the capacity of country experts; (v) facilitate an intra-country exchange of findings and policy alternatives, among various levels of decision makers from each country; and (vi) develop inter-country exchanges between all the country teams participating in the project.

(7) **Financial Information:** Total estimated budget for the study period was US$1.3 million. In addition to the GEF grant, other grants and in-kind contributions totalling US$0.493 million were received from the TFESSD, NOAA-OGP, Finnish Trust Fund, CEEPA, Yale, FAO and the University of Colorado (see Tables 1 and 2).

Table 1. Co-financing

Table A: Co-financing										
Co-financing (Type/Source)	IA own Financing (mill US$)		Government (mill US$)		Other* (mill US$)		Total (mill US$)		Total Disbursement (mill US$)	
	Proposed	Actual	Proposed	Actual	Proposed	Actual	Proposed	Actual	Proposed	Actual
Grants	**1.32**	**0.7**			**0**	**0.386**	**1.32**	**1.086**	**1.32**	**1.086**
Loans / Concessional / Market rate										
Credit										
Equity investments										
Committed in-kinds					**0**	**0.107**	**0**	**0.107**	**0**	**0.107**
Other										

Totals	1.32	0.7			0	0.493	1.32	1.193	1.32	1.193
*Other is referred to contributions mobilized for the projects from other multilateral agencies, bilateral development cooperation agencies, NGOs, the private sector and beneficiaries.										

Table 2. Details on other grants and contributions

Type	GRANTS (mil US$)			IN-KIND CONTRIBUTIONS (mil US$)			
	TFESSD	NOAA-OGP	FINNISH TRUST FUND	CEEPA	YALE[1]	FAO[2]	COLORADO[3]
3 country studies not funded by GEF	0.126						
Cape Town W'shop			0.020	0.005			
Accra W'shop	0.0254		0.030	0.005			
Cairo W'shop	0.0468	0.025		0.005			
Drakensberg W'shop	0.0339			0.005			
Zaragoza W'shop	0.0732			0.011			
Stata statistical and econometric software	0.0055						
Other contributions				0.015	0.020	0.0327	0.008
Total	0.311	0.025	0.050	0.046	0.020	0.0327	0.008
Total: Grants	0.386						
Total : Other contributions				0.107			
GRAND TOAL	0.493						

[1]Prof. Robert Mendelson's third year consultancy fees
[2]FAO contributions to the total budget for the cropwat work as per the MOU
[3] University of Colorado contributions to the total budget under Phase II of the hydrology work as per the MOU

B. Leveraged Resources

Additional resources have been leveraged to support:

- Editing and printing of 32 Working Papers (WPs) from project reports ($35,700) funded by the World Bank Research Committee
- Extraction, editing and printing of 32 Policy Notes from the published WPs ($22,100) funded by the World Bank Research Committee
- International Policy Workshop (to be organized by WBI)

These resources made it possible to disseminate findings with country teams, policy makers and other professionals from Africa and South America, and climate change experts from the international community

SECTION II. Project Impact Analysis

1. Project Impacts. The following is a brief description of the extent to which the project objectives have been met and performance indicators have been achieved.

1.1 Research Outputs

The following publications have been produced from research conducted under the project (find abstracts in Annex 1):

A. CEEPA/World Bank Working Papers

1. Pradeep Kurukulasuriya and Robert Mendelsohn (2006). A Ricardian analysis of the impact of climate change on African cropland. CEEPA/World Bank Working Paper No. 1
2. S Niggol Seo and R Mendelsohn (2006). Climate change impacts on animal husbandry in Africa: A Ricardian analysis. CEEPA/World Bank Working Paper No. 2
3. David Maddison (2006). The perception of and adaptation to climate change in Africa. CEEPA/World Bank Working Paper No. 3
4. Reneth Mano and Charles Nhemachena (2006). Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. CEEPA/World Bank Working Paper No. 4
5. Jane Kabubo-Mariara and Fredrick K Karanja (2006). The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. CEEPA/World Bank Working Paper No. 5
6. K Strzepek and A McCluskey (2006). District level hydro-climatic time series and scenario analyses to assess the impacts of climate change on regional water resources and agriculture in Africa. CEEPA/World Bank Working Paper No. 6
7. Alexander Lotsch (2006). Sensitivity of cropping patterns in Africa to transient climate change. CEEPA/World Bank Working Paper No. 7
8. D Maddison, M Manley and P Kurukulasuriya (2006). The impact of climate change on African agriculture: A Ricardian approach. CEEPA/World Bank Working Paper No. 8
9. Helmy M Eid, S El-Marsafawy and S Ouda (2006). Assessing the economic impacts of climate change on agriculture in Egypt: A Ricardian approach. CEEPA/World Bank Working Paper No. 9
10. E L Molua and C M Lambi (2006). Economic impact of climate change on agriculture in Cameroon: Ricardian analysis. CEEPA/World Bank Working Paper No. 10
11. P Kurukulasuriya and R Mendelsohn (2006). Endogenous irrigation: The impact of climate change on farmers in Africa. CEEPA/World Bank Working Paper No. 11
12. Sungno Niggol Seo and Robert Mendelsohn (2006). Climate change adaptation in Africa: A microeconomic analysis of livestock choice. CEEPA/World Bank Working Paper No. 12
13. Isidor M Sene, Mbaye Diop and A Dieng (2006). Impacts of climate change on the revenues and adaptation of farmers in Senegal. CEEPA/World Bank Working Paper No. 13

14. James Benhin and Glwadys Gbetibouo (2006). Climate Change and South Africa Agriculture: Impacts and Adaptation Options. CEEPA/World Bank Working Paper No. 14
15. Fredrik Hannerz and Alexander Lotsch (2006). Assessment of land use and cropland inventories for Africa. CEEPA/World Bank Working Paper No. 15
16. Sungno Niggol Seo and R Mendelsohn (2006). The impact of climate change on livestock management in Africa: A structural Ricardian analysis. CEEPA/World Bank Working Paper No. 16
17. M Ouedraogo, L Some and Y Dembele (2006). Economic impact assessment of climate change on agriculture in Burkina Faso: A Ricardian approach. CEEPA/World Bank Working Paper No. 17
18. Temesgen Deressa (2006). Ricardian Analysis of the economic impact of climate change on agriculture in Ethiopia. CEEPA/World Bank Working Paper No. 18
19. Pradeep Kurukulasuriya and Robert Mendelsohn (2006). Crop selection: Adapting to climate change in Africa. CEEPA/World Bank Working Paper No. 19
20. Suman Jain (2006). The economic impact of climate change on Zambian agriculture: A Ricardian analysis. CEEPA/World Bank Working Paper No. 20
21. W Durand (2006). Assessing the impact of climate change on crop water use in South Africa. CEEPA/World Bank Working Paper No. 21
22. Helmy M Eid, S El-Marsafawy and S Ouda (2006). Assessing the impact of climate on crop water needs in Egypt: The CROPWAT analysis of three districts in Egypt. CEEPA/World Bank Working Paper No. 22
23. Kidane Giorgis, Abebe Tadege and D Tibebe (2006). Estimating crop water use and simulating yield reduction for maize and sorghum in Adama and Miesso Districts using the CROPWAT model. CEEPA/World Bank Working Paper No. 23
24. Deksyos Tarekegn and Abebe Tadege 2006). Assessing the impacts of Climate Change on Water Resources of Lake Tana Sub-Basin Using the WATBAL model. CEEPA/World Bank Working Paper No. 24
25. Maï Moussa Katiella , Moustapha Amadou (2006). Use of CROPWAT model to predict SMD with climate change and analysis of CWR on main rainfed crops yield in Niger. CEEPA/World Bank Working Paper No. 25
26. Ernest L. Molua and Cornelius M. Lambi (2006). Climate, hydrology and water resources in Cameroon. CEEPA/World Bank Working Paper No. 26
27. Mbaye Diop (2006). Analysis of crop water use in Senegal with the CROPWAT model. CEEPA/World Bank Working Paper No. 27
28. Fredrick K. Karanja (2006). CROPWAT model analysis of crop water use in Six Districts in Kenya. CEEPA/World Bank Working Paper No. 28
29. L Some, Y Dembele, M Ouedraogo, F Kambire and S Sangare (2006). Analysis of crop water use and soil water balance in Burkina Faso using CROPWAT. CEEPA/World Bank Working Paper No. 29
30. E Molua and C Lambi (2006). Assessing the impact of climate on crop water use and crop water productivity in Cameroon: The CROPWAT analysis of three districts in Cameroon. CEEPA/World Bank Working Paper No. 30
31. Robina Wahaj, Florent Maraux and Giovanni Munoz (2006). Actual crop water use in project countries: A synthesis at the regional level. CEEPA/World Bank Working Paper No. 31

32. K. Yerfi Fosu and J Adu (2006). Ricardian analysis of the economic impacts of climate change on agriculture in Ghana. CEEPA/World Bank Working Paper No. 32
33. A Dinar, et al. (2006). The policy nexus between agriculture and climate change in Africa: A synthesis of the investigation under the GEF Study "Regional Climate, Water and Agriculture, Impacts on and Adaptation of Agro-Ecological Systems in Africa". CEEPA/World Bank Working Paper No. 33

B. Other Publications (Annex1)

P Kurukulasuriya, R Mendelsohn, R Hassan, J Benhin, T Deressa, Mbaye Diop, Helmy Eid, K. Fosu, G Gbetibouo, Suman Jain, A Mahamadou, Renneth Mano, Jane Kabubo-Mariara, S El-Marsafawy, E Molua, S Ouda, M Ouedraogo, I Sène, D Maddison, S. Niggol Seo, and A Dinar (2006). Will African Agriculture Survive Climate Change? ***World Bank Economic Review (forthcoming)***

P Kurukulasuriya (2005). User guide to the application of STATA Commands for statistical analyses. Unpublished project report, CEEPA, Pretoria

C. In Preparation

1. Policy Notes extracted from all published working papers listed above (expected August 2006)
2. A special issue of the African Journal of Agricultural and Resource Economics (AfJARE) on Climate Change and African Agriculture (expected June 2007)
3. Book on Climate Change and African Agriculture (expected December 2007)

D. Presentations at Conferences

(a) Kurukulasuriya, P (2005). Regional Analysis of the Impact of Climate Change on African Agriculture. Presentation made to the Capacity Development and Adaptation Cluster, UNDP-GEF, April 2005, UNDP (New York)
(b) Kurukulasuriya, P (2005). Climate change impacts in Africa. Presentation made at the Doctoral Conference, School of Forestry and Environmental Studies, Yale University (New Haven, CT), Feb 2005
(c) Benhin, J. (2003), Climate change, vulnerability and adaptation, Presentation at the Vulnerability and Adaptation Workshop, Department of Environment and Tourism (DEAT), and the Centre for Scientific and Industrial Research (CSIR), Pretoria, October.
(d) Benhin, J. (2003). Regional climate, water and agriculture: impacts on and adaptation of agro-ecological systems in Africa – Approaches and methods, Presentation at the Climate Change Capacity Buliding Workshop, South African Climate Action Network (SACAN), Johannesburg, August
(e) Benhin, J. (2004). Economic impacts assessment: Climate, water and agriculture in Africa. Presentation at the IWMI-World Bank Training Hub on "Irrigation, water, soils and natural resources management issues in Africa: Basin-based research and field experiences, Pretoria/Blydepoort, November/December.
(f) Hassan, R. and Benhin, J. (2006). Climate change and South African agriculture: A Ricardian analysis of impacts and adaptation options. Presentation at the "Agricultural sector workshop on climate change", National Department of Agriculture of South Africa, Pretoria, February.

(g) Kabubo-Mariara, J. (2006). The economic impact of climate change on Kenyan crop agriculture: A Ricardian approach. Third World Congress of Environmental and Resource Economists, Kyoto, July.
(h) Benhin, J. and Hassan (2006) (Covenors). Climate change impacts on African agriculture and adaptation options: Methodologies and Preliminary results. Mini-Symposium for the International Association of Agricultural Economists (IAAE) conference, Australia, August.

Table 3. Project Impacts Matrix

Project objective	Indicators	Evaluation of Performance
(a) Conduct national level economic analyses of impact and adaptation.	*(a) National-level analyses of CC impact on the Agricultural sector and adaptation alternatives. Results presented in workshops and reports and based on sound analytical work.*	**Output indicators confirm achievement of objective** (i) National level analyses of the economic impact on and adaptation of agriculture to climate change have been conducted in the 11 study countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe, applying the cross-section approach (ii) Additional national-level analyses of impacts of climate change on crop water yield response have been completed in the involved countries using crop simulation and hydrology modeling (iii) Many publications have been produced from these analyses and results are presented to many workshops (see section on research outputs)
(b) Conduct cross-national analysis and extrapolate results to countries not included in the sample.	*(b) Regional-level analysis of CC impact on the Agricultural sector and local and regional adaptation alternatives extrapolated to the sample countries and to countries outside the sample. Results presented in workshops and reports and based on sound analytical work.*	**Output indicators confirm achievement of objective** (i) Nine CEEPA/World Bank Working Papers have been published on regional cross-country analyses of the economic impacts of and adaptation of African crop and livestock agriculture to climate change (see section on research output) (ii) Four additional working papers have been produced presenting regional analyses of cropping patterns-hydrology-climate interactions (see section on research output) (iii) Many publications have been extracted from these analyses and results are presented to many workshops (see section on research output)
(c) Include water supply in the analysis.	*(c) A working hydrological model provides input to economic analyses.*	**Output indicators confirm achievement of objective** (i) Two main phases of river-basin hydrological modeling were conducted producing the following district-level input variables: (a) Time series for 1961 - 1990 of hydro-climatic variables (runoff, relative soil moisture storage, potential and actual evapotranspiration, streamflow, river density index and area irrigated); (b) Extending the historical time frame of the hydro-climatic time series to 2000 (ii) Derived 16 climate change scenarios using four different Synthetic or GCM models based on four different emission scenarios, which were used to determine the impact of these on runoff and actual evaporation and hence flow in the districts under study. The generated time series and scenario analyses were used for predicting likely future impacts of climate change on the agriculture in Africa (see Working Paper

Project objective	Indicators	Evaluation of Performance
		No. 6)
(d) Enhance the capacity of country experts.	*(d) All national-level work conducted by country teams. Graduate students (where applicable) complete their thesis research.*	**Output indicators confirm achievement of objective** (i) All national-level work has been conducted by country teams supported by regional and other international experts and members of national teams all reside in their respective countries (ii) Several training workshops were organized to enhance the capacity of national teams to undertake the country-level studies (see section on workshops) (iii) Several graduate theses using data and research skills provided through this project were completed (see section on capacity building activities)
(e) Facilitate an intra-country exchange of findings and policy alternatives, among various levels of decision makers from each country.	*(e) Annual regional workshops, of the study teams and policy makers and government officials for exchange of results and deliberation over policy options.*	**Output indicators confirm achievement of objective** (i) Three annual workshops were held in Cape Town, Cairo and Zaragoza mainly for exchange and discussion of results (ii) Final conference for African policy makers rescheduled for the latter part of 2006 (see section on workshops) (iii) Countries have been urged to disseminate results to policymakers
(f) Develop inter-country exchanges between all the country teams participating in the project.	*(f) Full use of a Learning and Knowledge Sharing Network (LKSN) between teams' members, and involving scientists from countries other than the study sample. Full exchange of data, findings and methodologies among country teams.*	**Output indicators confirm achievement of objective** (i) Project website to provide information to country teams and other countries not in the sample (ii) There also has been full exchange of findings and methodologies among country teams through an internal review system and dissemination of all project reports to all members of involved teams. The website also provided access to all reports to participating teams (ii) Several research planning and training workshops on methodologies used for the analyses have been organized. These workshops also provided a forum for the exchange and discussion of findings (see section on workshops and capacity building)

1.2 Capacity Building Activities and Achievements

<u>A. Project Research Planning and Training Workshops</u>

The overall objective of the research planning and training workshops was to ensure consistency in the approach and quality control necessary to provide the regional assessment of the vulnerability of African agriculture to climate change, and adaptation options, as well as to build and strengthen sustainable local capacity to address these. The number and field of expertise of people who benefited from these workshops are found in the respective sections of Annex 2.

The following three annual research planning workshops, which contained technical training sessions were held during the project period.

1. Launching and training workshop on unified methodologies and data collection needs (Cape Town, December 2002). This workshop reviewed and introduced country research teams to the three principal methodological approaches: Ricardian, crop simulation modeling and hydrological modeling (see workshop report in Annex A2.1A)
2. Training workshop on quality control for country level and regional analyses and reporting (Cairo, November 2003). This workshop followed the completion of in-country field surveys and data collection, and sought to promote consistent quality of country analyses and reporting, and correct possible methodological problems. Participants were also trained on the use of STATA, a statistical and econometric package which was utilized for the Ricardian analyses (Annex A2.1B)
3. Understanding and adapting to climate change: What can the world learn from Africa's experience (IAMZ, Zaragoza, Spain, December 2004). This workshop focussed on a (i) rigorous review and critical evaluation of the preliminary empirical results of the national studies and provided suggestions for improving the analyses and interpretation of study results and findings and their policy implications, (ii) review of and evaluation of results of the regional assessment studies on the potential economic and hydrological impacts and crop responses of climate change on agro-ecosystems in Africa and the various adaptation options (Annex A2.1C).

In addition to the above, the following two dedicated technical training workshops were conducted:

1. Training workshop on crop response simulation and river basin hydrology modeling (Accra, June 2003). In this workshop country teams were trained on the application of the CROPWAT and WATBAL models and finalized plans for implementing country level analyses using these two modeling tools (Annex A2.2A)
2. Technical training workshop on the implementation of the Ricardian analysis (KwaZulu Natal, South Africa, May 2004), which concentrated on further training on the country level Ricardian analyses using STATA (Annex A2.2B)

A final International Conference for policy makers in Africa and rest of the world is being planned in collaboration with the WBI for November 2006 in Nairobi. The aim of the conference is to disseminate the lessons learned to the agricultural and climate change communities at large, and to economists, scientists and policymakers at the regional and international levels. A special workshop for senior officials in Africa will also be conducted during this conference. This would serve to raise awareness among policy makers about climate change, impacts on Africa, various policy interventions, and their relative effectiveness and associated costs. Country teams will also present their plans for an outreach program that will be undertaken to inform local farmers following the completion of the national studies.

B. Degree Training and Research

In addition to these project workshops, several postgraduate degrees were also completed using project technical support, direct supervision and data. These include 2 PhDs at Yale University, 1 PhD at University of Colorado, Boulder, 2 MSc's at the University of Pretoria, 1 MSc at University College, London (UCL). Currently, 4 PhDs are in progress in South Africa, Burkina Faso and Senegal.

Members of country teams are also training their students in their home universities and institutions on applications of the STATA software in several courses using the manual produced by the project on applications of STATA. Examples include, the University of Zambia for statistics courses and the University of Pretoria for courses in natural resource economics for students from southern and eastern African universities who participated in CEEPA's regional master specialization course in environmental economics and policy.

C. Other Research Support Infrastructure and Networking

i. Integrated digital database

The project activities have culminated into several databases which can be used for further country, sub-regional and regional analysis of climate impacts and adaptation. The databases include the following:

(a) More than ten thousand surveys of farm households in the eleven study countries on their farming activities in the 2002 – 2004 farming seasons
(b) District level climate attributes
(c) Major and minor soils at the district level
(d) Time series of hydro-climatic attributes such as runoff, stream flow, relative soil moisture storage, potential and actual evapotranspiration, river density index and area irrigated for all districts in Africa for 1961-2000
(e) Climate scenarios for all districts in Africa for 2010 - 2100

ii. Project website

A project website http://www.ceepa.co.za/climate_change/index.html was created to provide relevant information on the project to regional and country teams and the public at large (See Annex 7 – Manual for project website). The site contains information on project activities from the eleven countries, Yale University, FAO, IWMI and the University of Colorado, and database (which would be made available to the general public soon), and the project research reports.

2. Project Sustainability.

1. Major efforts in implementing the project went into technical training of participating country teams to building technical capacity in conducting policy oriented quantitative scientific analyses of impacts of and adaptation to climate change to be able to provide the necessary expertise and professional support to within the country and participate in regional initiatives in this area
2. A number of students in the region have completed their MSC and PhD training in this field and the project also attracted more students from the

region to pursue post-graduate training in this area. This will enhance the supply of capacity needed in the region to address climate change issues

3. CEEPA at the University of Pretoria established a post-graduate research and training program on impacts of and adaptation to climate change in which a number of PhD students are currently enrolled and a couple of collaborative research projects are currently underway within this program. Examples include:
   a. The "Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa" implemented by the International Food Policy Research Institute (IFPRI) in collaboration with CEEPA, University of Addis Ababa and University of Hamburg. Three PhD students will be completing their studies under this project, two of them at CEEPA. An African post-doctoral fellow at CEEPA is also working on this project plus two others at Addis Ababa University
   b. The CEEPA adaptation to climate change research program under which three PhD students are sponsored supported by one full-time African Post-doctoral Fellow and senior researchers from CEEPA and University of Western Australia. The bulk of the funding for activities under this program currently comes from CEEPA with small complementary funding from IWMI for one site in the Limpopo River Basin. Proposals from CEEPA and collaborators for additional activities in this area in Africa have been submitted to various donors including the new initiative on Climate Change Adaptation in Africa (CCAA) of IDRC and DFID
4. One of the key researchers on the project who completed his PhD training at Yale under this project has been recruited by UNDP to coordinate work in this area in Africa, who has maintained effective involvement and participation of the regional network of expertise developed under this project. Three of the countries involved in this project (Kenya, Ethiopia and Zimbabwe) have been selected for implementing couple of major GEF funded and UNDP implemented projects (Adaptation Learning Mechanisms and Coping with Draught and Climate Change). Members of this project research teams in these countries are playing key roles in designing and implementing these projects
5. The Leader of the project and a number of its regional network members are actively involved as key resource persons in the GECAFS Southern Africa Food Systems & Vulnerability initiative
6. Further investment in supporting degree and non-degree training initiatives at CEEPA and other regional institutions on climate change impacts and adaptation would go a long way in sustaining the benefits realized from this project

3. Replicability

Most of what is said under point 3 (sustainability) above provides clear evidence of the demand for and likelihood of replicability.

4. Stakeholder Involvement

Stakeholders are many and in many countries. The project approach was to involve government (policy) directly in the work through their specialized agency (environment departments, early warning, metreological units, agric departments, etc.) and national focal points on climate change. Stakeholders were also invited to local workshops and project members also participated in related workshops organized by some of the stakeholders mentioned. One example is the efforts in SA to directly involve National Department of Agriculture (NDA), the Agricultural Research Council (ARC) and others in the project implementation team. The consequences of that was a high payoff as that helped NDA to develop a climate change strategy for SA in collaboration with CEEPA, ARC, and others. Moreover, the project findings are going to be disseminated through policy notes at the country and regional level.

Regionally and internationally, the project has always involved key stakeholders from the donor and international organizations community (UNEP, UNDP, FAO, etc.) and invited them to project planning workshops, communicated research results with them, etc. A policy conference in November 2006 is also planned in Nairobi for policy makers from the continenet

5. Monitoring and Evaluation.

The project adopted a comprehensive monitoring and evaluation (M&E) process. To effectively monitor progress of work by all teams a number of mechanisms have been employed, which included the following:

a. Contractual arrangements that clearly defines specific deliverables and time lines for their delivery with schedules of payments plans tied to successful completion of main tasks
b. Biannual workshops that provided an opportunity for all teams to meet twice every year to review progress up to then and define milestones and work plans for following period. The workshops also were used to provide the technical training necessary for successful completion of next steps
c. Constant technical backstopping provided by Yale University and CEEPA to all research teams on data cleaning, coding and analyses
d. Continuous guidance and follow up by CEEPA at all phases of implementation

These mechanisms played major role in ensuring consistency in analytical approaches and empirical methods applied by all teams implementing unified frameworks for each component of the research across all countries and continentally. They proved crucial for effective management of multi-country and multi-component research activities such as the ones implemented under this project.

Project performance has also been continuously evaluated throughout project implementation. For example, each of the research planning and technical training workshops has been evaluated (see results in Annex 4). Further more, an end of project evaluation survey has been conducted. The survey covered national and regional research teams involved, implementing agency and partners, donors and collaborators. A mail questionnaire was administered (Annex 5) the results of which are summarised below.

Almost all respondents agreed that project rationale was sensible (100%), project goals were consistent with their interest (94%) and that project design and implementation plans were sound (100%). On the other hand, about 45% of the respondents were not happy about funding arrangements (Table 4).

Table 4. Summary Results of Project Evaluation Survey

Question 3: Evaluation of Project									
		Question Number							
		3.1 PRA		3.2 PGD		3.3 PADI		3.4 PF	
		No.	(%)	No.	(%)	No.	(%)	No	(%)
Score									
Strongly agree	A	12	66.67	11	61.11	7	38.89	1	5.56
Agree	B	6	33.33	6	33.33	11	61.11	7	38.89
Disagree	C	0	0.00	0	0.00	0	0.00	5	27.78
Strongly disagree	D	0	0.00	0	0.00	0	0.00	3	16.67
No opinion	E	0	0.00	0	0.00	0	0.00	2	11.11
Not answered	F	0	0.00	1	5.56	0	0.00	0	0.00
Total		18	100.00	18	100.00	18	100.00	18	100.00

Where:
PRA: Project rationale was sensible for your organization
PGD: Project goals and objectives consistent with your organizational interest and priorities
PADI: Project activities' design and implementation plans and modalities sound
PF: Project funding arrangements adequate and satisfactory

The majority of respondents gave very high evaluations to the performance of the implementing agency and its partners in terms of planning and coordination of activities (72%), in communication of information (78%) and in provision of technical guidance (89%). About 6% rated the implementing agency and partners as poor in contractual agreements (Table 5).

Almost all respondents were very pleased with the implementing agency performance in terms of organisation and facilitation of workshops (Table 5). Performance of implementing agency and partners also ranked very high in terms of technical support to data collection and analyses, provision of necessary equipment, report writing and in review of produced research reports and guidance for revisions (Table 5).

Table 5. Summary Results of Implementing Agency Performance Evaluation Survey

Question 4: Evaluation of performance of implementing agency and partners and collaborators								
Question 4.1: Planning and coordination of project activities								
	Question Number							
	4.1i PCPA		4.1ii PCCI		4.1iii PCTG		4.1iv PCCA	
	No	(%)	No	(%)	No	(%)	No	(%)
Score								

Question 4: Evaluation of performance of implementing agency and partners and collaborators

Excellent	A	6	33.33	6	33.33	7	38.89	4	22.22
Very good	B	7	38.89	8	44.44	9	50.00	5	27.78
Good	C	4	22.22	2	11.11	1	5.56	6	33.33
Satisfactory	D	0	0.00	1	5.56	0	0.00	0	0.00
Not Satisfactory	E	0	0.00	0	0.00	0	0.00	1	5.56
Poor	F	0	0.00	0	0.00	0	0.00	0	0.00
Not Answered	G	0	0.00	0	0.00	0	0.00	1	5.56
Not Applicable	H	1	5.56	1	5.56	1	5.56	1	5.56
Total		18	100	18	100.00	18	100.00	18	100.00

Where:
PCPA: Planning of activities
PCCI: Communication and provision of information
PCTG: Provision of technical guidance and assistance
PCCA: Contractual agreements

Question 4.2: Organization and facilitation of workshops

		Question Number							
		4.2i OWPC		4.2ii OWFS		4.2iii OWAO		4.2iv OWLS	
		No	(%)	No	(%)	No	(%)	No	(%)
Score									
Excellent	A	8	44.44	8	44.44	6	33.33	11	61.11
Very good	B	6	33.33	6	33.33	7	38.89	6	33.33
Good	C	3	16.67	3	16.67	3	16.67	0	0.00
Satisfactory	D	0	0.00	0	0.00	1	5.56	0	0.00
Not Satisfactory	E	0	0.00	0	0.00	0	0.00	0	0.00
Poor	F	0	0.00	0	0.00	0	0.00	0	0.00
Not Answered	G	0	0.00	0	0.00	0	0.00	0	0.00
Not Applicable	H	1	5.56	1	5.56	1	5.56	1	5.56
Total		18	100	18	100.00	18	100.00	18	100.00

Where:
OWPC: Program and contents of workshops
OWFS: Facilitation of workshop sessions
OWAO: Achievement of workshop objectives
OWLS: Logistical support (travel, etc)

Other related activities

		Question Number							
		4.3 TGBDC		4.4 ESDARW		4.5 TGTBDAL		4.6 RRP	
		No	(%)	No	(%)	No	(%)	No	(%)
Score									
Excellent	A	3	16.67	3	16.67	5	27.78	5	27.78
Very good	B	8	44.44	7	38.89	9	50.00	4	22.22
Good	C	5	27.78	1	5.56	2	11.11	5	27.78
Satisfactory	D	0	0.00	0	0.00	0	0.00	3	16.67
Not Satisfactory	E	0	0.00	1	5.56	0	0.00	0	0.00
Poor	F	0	0.00	0	0.00	0	0.00	0	0.00
Not Answered	G	0	0.00	0	0.00	0	0.00	0	0.00
Not Applicable	H	2	11.11	6	33.33	2	11.11	1	5.56
Total		18	100	18	100.00	18	100.00	18	100.00

Question 4: Evaluation of performance of implementing agency and partners and collaborators

Where: TGBDC: Technical support in design and implementation of data collection
ESDARW: Provision of necessary equipment
TGTBDAL: Technical support in data analyses and report writing
RRP: Review of research reports and guidance for revision

While most respondents believe that in general the implementing agency and partners have either fully or partially achieved stated project objectives, some found that performance was not satisfactory or failed to particularly achieve intra-country (44%) and inter-country (33%) exchange of findings and policy alternatives (Table 6)

Table 6. Summary Results of Project Performance in Achieving Stated Objectives

Question 5: Evaluation of project performance in achieving stated objectives

		Question Number											
		5a PPCNR		5b PPCCNR		5c PPWA		5d PPCAP		5e PPEX		5f PPIC	
Score		No	(%)	No	(%)	No	(%)	No	(%)	No	(%)	No	(%)
Fully achieved	A	8	44.44	7	38.89	6	33.33	8	44.44	3	16.67	8	44.44
Partially achieved	B	6	33.33	3	16.67	6	33.33	7	38.89	4	22.22	2	11.11
Not satisfactory	C	1	5.56	2	11.11	1	5.56	1	5.56	5	27.78	5	27.78
Not achieved	D	0	0.00	1	5.56	1	5.56	0	0.00	3	16.67	1	5.56
Not applicable	E	1	5.56	3	16.67	2	11.11	0	0.00	2	11.11	1	5.56
No opinion	F	2	11.11	2	11.11	2	11.11	2	11.11	1	5.56	1	5.56
Not Answered	G	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total		18	100.00	18	100.00	18	100.00	18	100.00	18	100.00	18	100.00

Where: PPCNR: Conduct national level economic analyses
PPCCNR: Conduct cross-national analyses
PPWA: Include water supply in analyses
PPCAP: Enhance capacity of country experts
PPEX: Intra-country exchange of findings and policy alternatives
PPIC: Inter-country exchanges

The majority of the respondents (more than 70%) believed that their country and/or did get significant to good benefits from the project in enhancing capacity (83%), improved knowledge on impacts and adaptation (78%), technical research outputs (72%) and policy value of research findings (72%) (Table 7).

Table 7. Results of Evaluation of Project Benefits to Country and Organisation

Question 6: Project benefits to country and organization

		Question Number							
		6.1 PPRCAP		6.2 PPKN		6.3 PBTRO		6 PVPF	
Score		No	(%)	No	(%)	No	(%)	No	(%)
Significant	A	9	50.00	8	44.44	8	44.44	6	33.33
Good	B	6	33.33	6	33.33	5	27.78	7	38.89

Fair	C	1	5.56	2	11.11	3	16.67	1	5.56
Low	D	0	0.00	0	0.00	0	0.00	1	5.56
No benefits	E	0	0.00	0	0.00	0	0.00	0	0.00
No opinion	F	1	5.56	1	5.56	1	5.56	2	11.11
Not Answered	G	0	0.00	0	0.00	0	0.00	0	0.00
Not applicable	H	1	5.56	1	5.56	1	5.56	1	5.56
Total		18	100.00	18	100.00	18	100.00	18	100.00

Where: PPRCAP: Enhanced research capacity and analytical skills
PPKN: Improved knowledge and information on impacts & adaptation
PBTRO: Technical research outputs produced
PVPF: Policy value of project findings

In addition to the above assessments, respondents were also asked about their views on two main issues plus any additional comments they may have. A summary of the responses are indicated below (see Annex 6 for more details).

(a) How do you plan to use the capacity gained and results to inform policy in your country and future research?

Respondents identified the following main ways to do this:

i. Presentations at seminars and conferences on climate change and adaptation
ii. Further country level research
iii. Circulation of executive summaries and full reports to government ministeries, research institutions and other stakeholders

(b) Replicability/continuation. Assess likelihood of replication and/or extension of project activities in your country?

The responses included the following

i. Extend the study to include other districts and other sectors of agriculture, plus adaptation in Africa, and also to other continents

"*I have developed some research projects on similar lines . . . to be undertaken in Cameroon . . . .. "* (Cameron)

"*I intend to extend the analysis to livestock.*" (Kenya)

"*I hope . . . more concentration on the studies of the impact of climate change on the yield production and water needs for the main crops . . . . "* (Egypt)

"*(1) Country level extension – Two proposals have been submitted by members of Zimbabwe team to extend the research; (2) Regional level* *extension: GECAFs proposal by SADC team will extend research at the regional level . . . .”* (Zimbabwe)

“*Would be interested to repeat the project using the same methodologies, CROPWAT and DSSAT-CERES to determine the future water use of maize using different CC scenarios at the regional scale using data from UCT.*” (South Africa)

“*The project is being replicated . . . in Latin America. There is every reason to expect that a similar project in Asia would also be quite successfull. This would give the world a good grasp of some of the most important impacts of climate change in the low latitudes. It would also provide valuable information about adaptation to climate change.”* (Yale University)

“. . . further analyse the dataset and prepare lessons learnt on adaptation to climate change.” (Yale University)

ii. Further capacity building for researchers and students

“*Activities started with the project will allow us to train students in this field . . . . The training aspect will be the main continuation of the activites developed under the project*” (Senegal)

“ . . . I have included youngsters (in proposed study) *who were not involved in the GEF/WB project. This is a continuation of capacity building effort.”* (Cameron)

(c) Additional comments

These included

i. Training of trainers. The need for further training of participants especially in the application of CROPWAT and WATBAL models.

ii. Postgraduate program in climate change impacts and adaptation.

“. . . . I would like to comment that CEEPA should emphasize more on capacity building in terms of short and long term (MSc, PhD) training and tools/facilities/models needed for climate change research.” (Ethiopia)

iii. More effort needed to disseminate findings to policy makers

“*Policy advocacy work to sensitize policy makers around the theme at the national and regional levels is one of the major gaps I noted.*” (Zimbabwe).

The Bank is prepared to support such and other initiatives. In response to how the project supported their organization’s interest in climate change and adaptation, the WBI noted that:

"*Providing the opportunity for faster uptake of the studies findings and recommendations: but this is yet to be realized in the next six months since the reports were finalized only recently*".

"We would be interested in supporting extension of this work to enable the researchers disseminate results for a selected set of countries, perform more scenario analysis that would be needed for specific analytical, investment planning, and project development work by the Bank, and disseminate the results to economic policy makers." (WBI):

iv. Maintain network with CEEPA as the hub for climate change studies in Africa

"*It is strongly recommended that the group be kept together . . . and CEEPA should lead this effort, together with Yale University.*" (Yale University).

"*I think CEEPA should continue coordinating research projects building on the experience it gained and on the expert/instutional network already established under the project."* (Ethiopia)

"*Networking conducted by researchers will enable them to continue the work using other funding sources . . .*" (WBI)

6. Special Project Circumstances

Financial arrangements and dispersement of funds rules of the World Bank have been a factor affecting project implementation. This is particularly the case with trust funds as recipient is expected to pre-finance project activities before claiming dispersement of funds. A system that is unlikely to work in most countries, especially the developing world where recipients are institutions operating on limited public resources. This has affected a number of key activities, particularly organization of workshops that need careful planning ahead of time.

III. Summary of Main Lessons Learned

- Although it is still early to assess the impacts of the project as its research outputs are just being published and disseminated, significant outcomes have already been realized. Those include the created capacity in the network of professionals from the 11 countries participating in project, post-graduate degrees accomplished and increased interest in and plans to continue conducting further research in this area that is taking place in the various countries as well as regionally. More over examples given above indicate that the project has already started influencing national and regional efforts to design strategies to manage impacts and adaptation to climate change.
- The monitoring and evaluation mechanisms used in implementing the project indicate the importance of effectice coordination of the technical and methodological activities of such multi-country and multi-team study. It was clear from this project experience that regular meetings for joint planning and training, sharing of experiences and technical backstopping and support to

involved research teams were very crucial for its success. In this respect it would have been good to invest more resources and efforts in this component such as follow up visits to countries by coordinators and resource persons.

- Timing of and funding for dissemination of results would have been better planned to start earlier during project period as there is now some lag in communication of research findings to policy makers, researchers and civil and professional societies
- There is a clear need for increased investment in national and regional capacities to research the economic, social and policy aspects of impacts of climate change, especially within government

IV. Financial Management Status.

The financial statements pertaining to this project have been audited by PricewaterhouseCoopers Inc who had been given unresstricted access to all financial records and related data. Refer to Annex 8 for following audited reports: year ended 28 February 2003; year ended 29 February 2004 and; year ended 28 February 2005.

The closing audited financial statements for year 2005 - 2006 has not yet been performed due to the fact that the last and final payments under this project were only finalised in June 2006. The closing audit report is expected to be performed at the end of July 2006.

Annex 1. Project Research Outputs

CEEPA / World Bank Working Paper No. 1
"A Ricardian analysis of the impact of climate change on African cropland"
Pradeep Kurukulasuriya and Robert Mendelsohn
School of Forestry and Environmental Studies, Yale University

EXECUTIVE SUMMARY

This study examines the impact of climate change on cropland in Africa. It is based on an 11-country survey of over 9000 farmers administered as part of a Global Environment Facility (GEF) project. Five of the countries are West African: Burkina Faso, Cameroon, Ghana, Niger and Senegal; three are from Southern Africa: South Africa, Zambia and Zimbabwe; two are East African: Ethiopia and Kenya; and Egypt is the sole representative of North Africa. The study uses a Ricardian cross-sectional approach to measure the relationship between the net revenue from growing crops and climate. Net revenue is regressed on climate, water flow, soils and economic variables. The resulting regression explains the role that each variable plays today. We find that net revenues fall as precipitation falls or as temperatures warm across all the surveyed farms. Specifically, the elasticity of net revenue with respect to temperature is -1.3. This elasticity implies that a 10% increase in temperature would lead to a 13% decline in net revenue. The elasticity of net revenue with respect to precipitation is 0.4.

In addition to examining all farms together, the study examined dryland and irrigated farms separately. Dryland farms are especially climate sensitive. The elasticity of net revenue with respect to temperature is -1.6 for dryland farms but 0.5 for irrigated farms. Irrigated farms have a positive immediate response to warming because they are located in relatively cool parts of Africa. The elasticity of net revenue with respect to precipitation is 0.5 for dryland farms but only 0.1 for irrigated farms. Irrigation allows farms to operate in areas with little precipitation, such as Egypt.

The study also examined some simple climate scenarios to see how Africa would respond to climate change. These 'uniform' scenarios assume that only one aspect of climate changes and the change is uniform across all of Africa. For example, the study examined a 2.5°C warming and found that net revenues from farming in all of Africa would fall by $23 billion. It also examined a 5°C warming and found that this would cause net revenues to fall $38 billion. A 7% decrease in precipitation would cause net revenues from crops to fall $4 billion and a 14% decrease in precipitation would cause it to fall $9 billion. Increases in precipitation would have the opposite effect on net revenues.

In addition to the uniform scenarios, the study also examined three climate change scenarios from Atmospheric Oceanic General Circulation Models (AOGCMs). These AOGCM scenarios predicted changes in climate in each country over time. They reveal that African net revenues may rise by up to $97 billion if future warming is mild and wet but would fall by up to $48 billion if future climates are hot and dry. Dryland farms would be affected the most by either beneficial or harmful scenarios. Irrigated farms are relatively resilient to climate change.

Not all countries are equally vulnerable to climate change. First, the climate scenarios predict different temperature and precipitation changes in each country. Second, it is also important whether a country is already hot and dry. Any increase in temperature or reduction in precipitation in these countries leads to large impacts per farm. Third, the extent to which farms are irrigated is also important. Dryland farmers in Africa have little recourse if the climate becomes more hostile.

Although it is an important first step, this study has not captured the full dimensions of climate change impacts in Africa. It does not forecast what African agriculture may look like over the next century when climate will actually change. It does not tackle carbon fertilization effects. It does not predict changes in prices or wages that might occur if the impacts are large. It does not examine the role of technological change over the next century. It does not consider changes in trade policies, private property rights, or taxes. All these factors should be considered to get a complete picture of what might happen.

<u>CEEPA / World Bank Working Paper No. 2</u>
"Climate Change Impacts on animal husbandry in Africa: a Ricardian Analysis"
Sungno Niggol Seo and Robert Mendelsohn
School of Forestry and Environmental Studies, Yale University

EXECUTIVE SUMMARY

This analysis analyzes the impact of climate change on animal husbandry in Africa. It uses the Ricardian method, a cross-sectional approach, to examine the economics of animal husbandry in Africa. The net revenue from raising animals on small and large farms across Africa is regressed on climate, soils and other control variables to test the climate sensitivity of livestock in Africa.

The study is based on a survey of over 9000 farmers across 11 countries conducted by the Global Environment Facility (GEF) World Bank project. From this dataset, 5400 farms were found to rely on livestock. Zimbabwe had to be dropped from the livestock study because turbulent economic conditions in that country made the livestock data questionable over the survey period.

Two empirical models were tested. A single-equation model examines net revenue per farm, regressed on climate and other control variables. The second model has two equations: the first examines the value of animals owned per farm and the second the net revenue per value of owned animal. Both equations in the second model regress the dependent variable on climate and other control variables. All the estimated equations test whether small and large farms have different climate response functions. That is, the models test whether the climate coefficients of small and large farms are similar. Small farms tend to be more labor intensive, rely on native stocks and have few animals; large farms tend to be more commercial operations, with much larger stocks and more modern approaches.

The single-equation Ricardian model finds that the livestock net revenues of large farms in Africa fall as temperatures rise but that small farms are not temperature sensitive. The two-equation model finds that higher temperatures reduce both the size of the stock and the net revenue per value of stock for large farms. However, for small

farms, higher temperatures do not affect the size of the stock and they increase the net revenues per value of stock. Large farms in Africa are vulnerable to warming but small farms are not. It is likely that large farms are vulnerable to warming because they rely on species such as beef cattle that are not well suited to high temperatures. Small farms are not vulnerable to warming because they can substitute species such as goats that can tolerate high temperatures.

The single-equation model finds that increases in precipitation would reduce livestock net revenue per farm for both small and large farms. The elasticity of net revenue per farm is particularly large for small farms. The two-equation model reveals that increased precipitation reduces both the size of the stock and the net revenue per animal owned. Although higher precipitation generally increases the productivity of grasslands, it also leads to the conversion of grasslands into forest. Further, animal diseases are likely to increase with warm wet conditions. Finally, as precipitation increases, many farmers find it advantageous to shift from livestock to crops. The positive side of these precipitation findings is that if precipitation declines, livestock net revenues will increase, especially for small farmers. Livestock thus provides an important agricultural adaptation for reductions in precipitation should they occur.

The report also explores the impact of several uniform climate change scenarios that test the importance of large changes in climate in isolation. Although these scenarios are not realistic, they provide an indication of how the model behaves. A warming of 2.5℃ increases small farm livestock income by 26% (+$1.4 billion). This increase comes strictly from an expansion of the stock. If the temperature rises, the net revenues per animal fall slightly. A warming of 5℃ increases small farm income by 58% (+$3.2 billion), again largely because of an increase in the stock. By contrast, a warming of 2.5℃ reduces large farm livestock income by 22% (-$13 billion) and a warming of 5℃ reduces it by 35% (-$20 billion). This reduction for large farms is due to both a shrinking of the stock and a reduction in net revenue per animal owned. Increased precipitation of 14% reduces small farm income by 10% (-$0.6 billion) mostly due to a shrinking of the stock. The same precipitation reduction reduces large farm income by 9% (-$5 billion) due to a reduction in both the stock and the net revenue per animal owned.

The report also tested the impact of climate scenarios predicted by three Atmospheric Oceanic General Circulation Models (AOGCMs). With the relatively hot scenario predicted by the Canadian Climate Center (CCC) model in 2100, small farms would increase net revenues by 116% (+$6 billion). For the large farms, CCC leads to a 23% loss (-$14 billion) by 2100. The 2100 results for small farms under the Center for Climate System Research (CCSR) climate scenario is an increase in net income by 152% (+$8 billion). For large farms, CCSR leads to losses of a negligible amount. The Parallel Climate Model (PCM) climate scenario for 2100 leads to an increase of net income by 31% (+ $2 billion) for small farms and a decrease by 27% (-$16 billion) for large farms. In general, scenarios with low rainfall predict higher net revenues.

Warming in the AOGCM scenarios, as in the uniform scenarios, is good for small farms because they can substitute animals that are heat tolerant. Large farms, by contrast, are more dependent on species such as cattle which are not heat tolerant. The wetter scenarios are likely to be harmful to grazing animals because they imply a *shift from grasslands to forests, an increase in harmful disease vectors, and a shift from livestock to crops.*

Overall, the results indicate that livestock on large farms are vulnerable to climate change and are likely to lose net revenue unless there is substantial drying. Small farms are much less vulnerable and will probably increase net revenue from climate change. Overall, because large farms dominate the sector, African livestock net revenues are expected to fall. However, if future climates turn out to be dry, livestock net revenue will increase. At least against the risk of dryness, livestock offer a good substitute for crops.

<u>CEEPA / World Bank Working Paper No. 3</u>
"The perception of and adaptation to climate change in Africa"
David Maddison
Birmingham University

EXECUTIVE SUMMARY

It is doubtful whether farmers know immediately what constitutes the best response to climate change when such agricultural practices as it requires are outside their range of experience. Nor can they be expected to recognize immediately that the climate has changed. Together these facts point to a period of transitional losses of unknown duration as a result of adapting to climate change.

The objective of this paper is to determine the ability of farmers in Africa to detect climate change, and to ascertain how they have adapted to whatever climate change they believe has occurred. The paper also asks farmers whether they perceive any barriers to adaptation and attempts to determine the characteristics of those farmers who, despite claiming to have witnessed climate change, have not yet responded to it. The study is based on a large-scale survey of agriculturalists in 11 different African countries.

The survey reveals that significant numbers of farmers believe temperatures have already increased and that precipitation has declined. Those with the greatest experience of farming are more likely to notice climate change. This is consistent with farmers engaging in Bayesian updating of their prior beliefs. Statistical tests also reveal significant spatial clustering in the proportion of farmers claiming to have observed particular forms of climate change. Alternatively put, neighboring farmers tell a consistent story. Unfortunately evidence about whether farmers' perceptions of climate change tally with records from weather monitoring stations is somewhat equivocal. In many cases available climate records are shorter than the memories of the farmers themselves.

Among adaptations made in response to climate change, planting different varieties of the same crop and changing dates of planting are important everywhere. But stratifying the data by the precise perception of climate change (for example increased precipitation, decreased precipitation, changes in the timing of the rains, etc.) provides greater insights. When temperatures change farmers plant different varieties, move from farming to non-farming activities, practice increased water conservation and use shading and sheltering techniques. For changes in precipitation

and particularly in the timing of the rains, varying the planting date appears to be an important response. There is also evidence that adaptation measures are linked to baseline climate and that adaptation occurs mainly on those sites that are already marginal in the sense of being hot and dry.

There are important differences in the propensity of farmers living in different locations to adapt and there may be institutional impediments to adaptation in certain countries. Although large numbers of farmers perceive no barriers to adaptation those that do perceive them tend to cite their poverty and inability to borrow. Few if any farmers mentioned lack of appropriate seed, security of tenure and market accessibility as problems.

Those farmers who perceive climate change but fail to respond may require particular incentives or assistance to do what is ultimately in their own best interests. Adaptation to climate change actually involves a two-stage process: first perceiving that climate change has occurred and then deciding whether or not to adopt a particular measure. This gives rise to a sample selectivity problem since only those individuals who perceive climate change will adapt, whereas we wish to make statements about the population of agriculturalists in general.

Using Heckman's sample selectivity probit model, econometric investigation reveals that although experienced farmers are more likely to perceive climate change, it is educated farmers who are more likely to respond by making at least one adaptation. Farmers who have enjoyed free extension advice and who are situated close to the market where they sell their produce are also more likely to adapt to climate change. Land tenure has little if any impact on the propensity of farmers to adapt.

In terms of policy implications it appears that improved farmer education would do most to hasten adaptation. The provision of free extension advice may also play a role in promoting adaptation. In so far as distance to the selling market is a significant determinant of whether a farmer adapts to climate change, it may be that improved transport links would improve adaptation although the precise mechanism underlying this is unclear. Better roads may allow farmers to move from subsistence farming to cash crops, or facilitate the exchange of ideas through more regular trips to the market. There are many country specific differences in the propensity of farmers to adapt and further analysis would be required to understand the underlying factors. Adaptation, however, is something undertaken only by those who perceive climate change. The perception of climate change appears to hinge on farmer experience and the availability of free extension advice specifically related to climate change. But while the policy options for promoting an increased awareness of climate change are more limited the perception of climate change is already high.

<u>CEEPA / World Bank Working Paper No. 4</u>
"Assessment of the economic impacts of climate change on agriculture in Zimbabwe: a Ricardian approach
Reneth Mano and Charles Nhemachena
Respectively, Department of Agricultural Economics & Extension, University of Zimbabwe; and CEEPA, University of Pretoria

EXECUTIVE SUMMARY

This study uses the Ricardian approach to examine the economic impact of climate change on agriculture in Zimbabwe. The approach regresses net farm revenue against various climate, soil, hydrological and socio-economic variables to help determine the factors that influence variability in net farm revenues. The study was based on data from a survey of 700 smallholder farming households interviewed across the country. The temperature and precipitation data came from the Africa Rainfall and Temperature Evaluation System (ARTES) (World Bank 2003) and soil data was obtained from FAO (2003). Data concerning the hydrology was obtained from the University of Colorado (Strzepek & McCluskey 2006).

The empirical results show that climatic variables (temperature and precipitation) have significant effects on net farm revenues in Zimbabwe. In addition to the analysis of all farms, the study also analyzed the effects on dryland farms and farms with irrigation. Marginal analysis indicates that net farm revenues are affected negatively by increases in temperature and positively by increases in precipitation. The results from sensitivity analysis suggest that agricultural production in Zimbabwe's smallholder farming system is significantly constrained by climatic factors (high temperature and low rainfall). The elasticity results showed that the changes in net revenue are very high for dryland farming compared to farms with irrigation. The elasticity of summer temperature and precipitation for dryland farms was -7.26 and 12.16 respectively compared to -3.79 and 9.81 for irrigated farms. The results showed that farms with irrigation are more resistant to changes in climate, indicating that irrigation is an important adaptation option to help reduce the impact of further changes in climate.

The study examined some simple climate scenarios to see how agricultural production in the country would respond to climate change. These 'uniform' scenarios assume that only one aspect of climate changes and that change is uniform across the country. The uniform scenarios showed that a 2.5°C increase in temperature would result in a decrease in net farm revenues by US$0.4 billion for all farms and increase net revenue from farms with irrigation by US$0.3 billion. The study also examined the impact of a 5°C increase in temperature and the results showed that net revenues would decrease across all farms, dryland farms and farms with irrigation by US$0.4 billion, US$0.5 billion and US$0.003 billion respectively. A 7% and a 14% decrease in precipitation would result in a decrease in net farm revenue by US$0.3 billion for all farms.

The study also examined the impacts of three SRES climate change scenarios, namely CGM2, HadCM3 and PCM. These predicted that by 2100 net farm revenues would decrease across all farms by respectively US$0.8 billion, US$1.3 billion and US$1.4 billion. An overview of farmer adaptation to changing climate indicates that farmers are already using some adaptation strategies – such as dry and early planting, growing drought resistant crops, changing planting dates, and using irrigation – to cushion themselves against further anticipated adverse climatic conditions.

One important policy message from the empirical findings is that there is a great need for the government, through the meteorological department, research and extension, the private sector and NGOS, to provide adequate extension information services to ensure that farmers receive up-to-date information about rainfall patterns in the

forthcoming season so that they make well-informed decisions on their planting dates. Another is that the government, research and extension, the private sector and NGOs can improve net farm performances for smallholder farms by ensuring increased farmer training and more access to credit and aid facilities and by helping farmers acquire livestock and other important farm assets. Furthermore, ensuring the availability and accessibility of fertilizers and crop seeds before the onset of the next cropping season can significantly improve net farm performances across households.

CEEPA / World Bank Working Paper No. 5
"The Economic Impact of climate change on Kenyan crop agriculture: a Ricardian approach", Jane Kabubo-Mariara and Fredrick K Karanja
Respectively, School of Economics, University of Nairobi; and Department of Meteorology, University of Nairobi

EXECUTIVE SUMMARY

This paper measures the economic impact of climate on crops in Kenya. We use cross-sectional data on climate, hydrological, soil and household level data for a sample of 816 households. To collect the requisite household data, we adopted the common questionnaire used by all countries in the regional GEF/World Bank project. The countries involved in the project adopted the same survey design in terms of sampling and used the same questionnaire designed jointly by the School of Forestry and Environmental Studies of Yale University and the Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria. Climate satellite data were provided by the US Department of Defense and we used data from the Africa Rainfall and Temperature Evaluation System (ARTES). The monthly means were estimated from approximately 14 years of data (1988–2003) to reflect long-term climate change normals (Basist et al. 1998, 2001). The hydrological data were obtained from the International Water Management Institute and the University of Colorado. The runoff and flow data estimates were based on monthly values from 1961–1990 time series data. The final values were estimated using hydrological models for Africa (Strzepek & McCluskey 2006). Soil data were obtained from the Food and Agricultural Organization (FAO 2003).

Since we did not discover any important impact of dry and wet condition climate variables on revenue, we settled for a seasonal Ricardian model. Our results show that climate affects agricultural productivity. Increased winter temperatures are associated with higher crop revenue, but increased summer temperatures have a negative impact. Increased precipitation is positively correlated with net crop yield. The results further show that there is a non-linear relationship between temperature and revenue on the one hand and between precipitation and revenue on the other. Further, our results suggest a hill-shaped relationship between mean flow and net crop revenue. Andosols, irrigation and household size are positively correlated with revenue, but livestock ownership, farm size and wage rates are inversely correlated with crop revenue.

Estimated marginal impacts of climate variables suggest that global warming is harmful for agricultural productivity and that changes in temperature are much more important than changes in precipitation. This result is confirmed by the predicted impact of various climate change scenarios on agriculture. For prediction purposes, *we use two Global Circulation Models: the Canadian Climate Model (CCC) and the Geophysical Fluid Dynamics Laboratory (GFDL) model, which predict 3.5°C and 4°C changes in temperature by the year 2030 respectively. The models both predict a 20% change in precipitation over the same period. The prediction results confirm that global warming will have a substantial impact on net crop revenue, and that the impact will be more pronounced in medium and low potential zones than in high potential zones. Based on the CCC model, we predict a 1% (US$3.54 per hectare) gain in high potential zones but a 21.5% (US$54 per hectare) loss in medium and low potential zones. The GFDL model predicts a loss of US$32 per hectare in high potential zones compared to losses of US$178 in medium and low potential zones by the year 2030. The results further confirm that the temperature component of global warming is much more important than precipitation.*

We analyze farmers' perceptions of climate variations and their adaptation to these, and also constraints on adaptation mechanisms. The results suggest that farmers in Kenya are aware of short-term climate change, that most of them have noticed an increase in temperatures, and that some have taken adaptive measures. The analysis also shows differences in perceptions and adaptations between farmers in medium/low potential zones and those in high potential zones. Diversification (changes in crop mix) is the most common adaptation measure, particularly in high potential zones, while water conservation, irrigation and shading/sheltering of crops are the main adaptation measures in drier regions. The analysis shows, however, that credit constraints, poverty and lack of information hinder households from taking the most important adaptive measures, such as water management.

The key policy lesson from this study is that global warming will have adverse effects on agriculture in Kenya. Given the difficulties of averting global warming, adaptation to climate change is essential to counter the expected impacts of long-term climate change. We argue that the government must play a critical role in encouraging adaptations to climate change if farmers are to counter the expected impact of global warming. Critical interventions would be monitoring climate change and disseminating information to farmers through agricultural extension, to encourage both short- and long-term adaptations. Improved management and conservation of available water resources, water harvesting and recycling of waste water could generate more water for irrigation, which is especially important in the arid and semi-arid areas. This would help to lessen the expected repercussions of global warming. Policies for credit provision and improved household welfare are also a priority for both short- and long-term adaptation measures.

One limitation of this study is that it is based on general crop agriculture and does not model the impact of climate change on individual crops and livestock, which would be important for assessing the full impact of climate change on arid and semi-arid areas. The study also does not model the impact of adaptations that farmers make to counter the repercussions of climate change. We recommend future research in these areas. Future research that uses panel//time series data may also be expected to provide better estimates of the impact of climate change on Kenyan agriculture.

CEEPA / World Bank Working Paper No. 6
"District level hydroclimatic time series and scenario analysis to assess the impact of climate change on regional water resources and agriculture in Africa"

Kenneth Strzepek and Alyssa McCluskey
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EXECUTIVE SUMMARY

This report summarizes the methods and findings of the hydrological assessment component of the project studying likely impacts of climate change on water resources and agriculture in Africa funded by the Global Environment Facility (GEF) and the World Bank and coordinated by the Centre for Environmental Economics and Policy in Africa (CEEPA) of the University of Pretoria. The research work reported here was conducted in two phases. The first phase of the hydrology component was undertaken by the International Water Management Institute (IWMI) and the University of Colorado and consisted of the development of time series of hydroclimatic variables for future derivation of parameters for use in Ricardian assessment of economic impacts of climate change. By examining the relationship between climate and a range of other determinants, the Ricardian approach attempts to isolate the link between climate and land value or farm revenue and so determine the implications of climate change.

The study employed a version of a conceptual rainfall-runoff model called WatBal (Water Balance), applied to gridded data to simulate changes in soil moisture and runoff across the whole continent of Africa rather than to any particular catchment or water resource system. The model inputs were the climate variables of the 1961–1990 climatology and physiological parameters (e.g. soil properties and land use) derived from global datasets for each of the 0.5^o latitude/longitude cells across the continent. The primary model output comprised a time series (monthly time step) of simulated runoff for all the grid cells for each of the districts in the countries of interest. The first phase of the hydrology component generated the following data at district level: runoff (in mm); relative soil moisture storage - z (0–1): 1 is fully saturated; potential evapotranspiration (in mm); actual evapotranspiration (in mm); temperature (in degrees Celsius); precipitation (in mm) and streamflow (in m^3). This data was generated for the 11 countries in the study on a monthly time step from 1961 to 1990. Additional results included a river density index (indicator of stream frequency and hence surface water availability within each district) and the area irrigated (an estimate of the percentage area irrigated within each district.)

The second phase of the study extended the hydrology analyses to update the above hydroclimatic series to the year 2000 using updated input data. To ascertain the possible impacts of climate change within the districts being investigated this study used synthetic or GCM-based climate change scenarios as input to the WatBal model. A subset of the 20 scenarios produced by the Climate Research Unit (CRU) for which data are available at 0.5^o x 0.5^o for the globe was employed to represent a range of equally plausible future climates with differences attributable to the different climate models used and to different emission scenarios that the world may follow. This study derived 16 scenarios using four different models (i.e. CSIRO2, HadCM3, CGCM2, ECHAM and PCM) based on four different emission scenarios (i.e. A2 & B2). The WatBal model was used to determine the impact of these different scenarios on runoff and actual evaporation and hence flow in the districts under study. The generated hydroclimatic series and scenario analyses were used as inputs into various

Ricardian regressions measuring likely impacts of climate change on the agricultural economies of Africa.

CEEPA / World Bank Working Paper No. 7
"Sensitivity of Cropping patterns in Africa to transient climate change"
Alexander Lotsch
Development Research Group, Infrastructure and Environment, The World Bank

EXECUTIVE SUMMARY

Agriculture is an important pillar of economic development in Africa and many countries in the region face significant socio-economic and technological challenges to promote growth in rural areas. In addition, climate change has been recognized as an important factor that has the potential to threaten development efforts in the agricultural and rural sector in many African countries, in particular in regions with a high percentage of rainfed cropping systems.

The detailed analysis of current cropping areas in Africa presented here reveals significant climate sensitivities of cropland density and distribution across a variety of agro-ecosystems. Based on empirical climate–croplands relationships, cropland density responds positively to increases in precipitation in semi-arid and arid zones of the sub-tropics and warmer temperatures in higher elevations. As a result, marginal increases in seasonal precipitation lead to denser cropping areas in arid and semi-arid regions. Warmer temperatures, on the other hand, tend to decrease the probability of cropping in most parts of Africa (the opposite is true for increases in rainfall and decreases in temperatures relative to current conditions).

While current climate–cropland relationships allow the geographic delineation of temperature and precipitation sensitivities, projections of climate parameters derived from coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a sound basis for assessing the impact of future climate. Despite discrepancies and uncertainties in climate model output, the analysis suggests that cropland area in Africa is likely to decrease significantly in response to transient changes in climate. The continent is expected to have lost on average 4.1% of its cropland by 2039, and 18.4% is likely to have disappeared by the end of the century. In some regions of Africa the losses in cropland area are likely to occur at a much faster rate, with northern and eastern Africa losing up to 15% of their current cropland area within the next 30 years or so. Gains in cropland area in western and southern Africa due to projected increases in precipitation during the earlier portions of the century will be offset by losses later on. In conjunction with existing challenges in the agricultural sector in Africa, these findings demand sound policies to manage existing agricultural lands and the productivity of cropping systems.

CEEPA / World Bank Working Paper No. 8
"The impact of climate change on African agriculture: a Ricardian approach"
David Maddison, Marita Manley and Pradeep Kurukulasuriya
Respectively, the Department of Economics, University of Birmingham; the UK Department of Trade and Industry; and the UN Development Program

EXECUTIVE SUMMARY

This paper uses the Ricardian approach to examine how farmers in 11 different countries in Africa have adapted to existing climatic conditions. It then estimates the effects of predicted changes in climate while accounting for whatever farmer adaptation might occur.

This study differs from earlier ones by using farmers' own perceptions of the value of their land. Previous research, by contrast, has relied on either observed sale prices or net revenues, sometimes aggregated over geographically large tracts of terrain. The study also makes use of high resolution data describing soil quality and runoff. Furthermore it tackles the challenges involved in modeling the effect of climate on agriculture in a study that includes countries in the northern and southern hemispheres, as well as the tropics.

The study confirms that African agriculture is particularly vulnerable to climate change. Even with perfect adaptation regional climate change by 2050 is predicted to entail production losses of 19.9% for Burkina Faso and 30.5% for Niger. By contrast, countries such as Ethiopia and South Africa are hardly affected at all, suffering productivity losses of only 1.3% and 3 % respectively. The study also confirms the importance of water supplies as measured by runoff, which, being affected by both temperature and precipitation, may itself be highly sensitive to climate change.

<u>CEEPA / World Bank Working Paper No. 9</u>
"Assessing the economic impacts of climate change on agriculture in Egypt: a Ricardian approach"
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EXECUTIVE SUMMARY

This study employed the Ricardian approach to measure the economic impacts of climate change on farm net revenue in Egypt. This approach was based on regressing farm net revenue against climate, soil, socio-economic and hydrological variables to determine which factors influence the variability of farm net revenues. A survey was done by interviewing 900 households from 20 governorates. The standard Ricardian model was applied, in addition to another three models each representing an adaptation option that could be used to reduce the harmful effects of temperature stress. A further adaptation strategy was tested: raising livestock on the farm to cope with the harmful effects of climate change. Besides this, the effects of two climate change scenarios (MAGICC/SCENGEN and GCMs – General Circulation Models) were considered.

The empirical results from the standard Ricardian model (Model 1) showed that a rise in temperature would have negative effects on farm net revenue in Egypt. Adding the linear term of hydrology (Model 2), the linear and quadratic terms of hydrology (Model 3) and the hydrology term and heavy machinery (Model 4) to the analysis improved the adaptability of farm net revenue to high temperature. Marginal analysis

indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis. The marginal impact of temperature was -$968.94, +$26.17, +$150.96 and -$77.78 per hectare for the four models respectively. The results also indicated that raising livestock on the farm to cope with climate change was not effective, probably as a result of small farm ownerships. The results from Models 2 and 3 showed that irrigation could defeat the adverse effect of higher temperatures and increase net revenue, and those from Model 4 showed that using irrigation and investing in heavy machinery could reduce the harmful effects of global warming and improve farm revenue.

The results from the two climate change scenarios showed that high temperatures will constrain agricultural production in Egypt. Irrigation and technology are therefore the recommended adaptation options. However, warming may also affect water resources and that would pose another problem for agricultural production. A policy should be developed to cope with the adverse effects of climate change on agriculture. It should focus on three areas: crop management, water management and land management.

The survey also revealed that Egyptian farmers have noticed a change in temperature and rainfall patterns, through their own experience and/or with the help of the agricultural extension teams. The results indicated that 85% of the selected 900 households noticed a change in temperature in the form of heat waves in the summer, and an increase in the winter minimum temperature. Furthermore, 65% of the sample observed shortages in the amount of rainfall per season. The favored option for adapting to increased temperatures is irrigation. Some farmers adjust their crop sowing dates to avoid the expected high temperatures. To adjust to shortages in rainfall, farmers said they used crop varieties with high water use efficiency and/or early maturing varieties.

<u>CEEPA / World Bank Working Paper No. 10</u>
"Economic Impact of climate change on agriculture in Cameroon: Ricardian analysis"
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EXECUTIVE SUMMARY

Cameroon's economy is predominantly agrarian and the exploitation of agricultural and other natural resources remains the driving force for the country's economic development. Fluctuations in national income are not due merely to the decline in world demand for Cameroon's traditional agriculture exports or from mistakes in economic policy making, but also due to the vagaries of weather. Since farming is a vital sector involving 80% of the country's poor and contributes about 30% of Cameroon's income, and shifts in temperature and precipitation would be critical parameters to the nations economic destiny, this study examines the impact of climate change on cropland in Cameroon. The study relies on farm-level survey of over 800 farms.

We employ a Ricardian cross-sectional approach to measure the relationship between the net revenue from growing crops and climate. Net revenue is regressed on climate, *water flow, soils, and economic variables. The resulting regression explains the role that each variable plays today. We find that net revenues fall as precipitation falls or as temperatures warm across all the surveyed farms. The study also examined some simple climate scenarios to see how Cameroon would respond to climate change. These "uniform" scenarios assume that only one aspect of climate changes and the change is uniform across all of Cameroon. The empirical analysis reveals that for a 2.5˚C warming and net revenues from farming in Cameroon would fall by \$0.5 billion. The study also examined a 5˚C warming and found that it would cause net revenues to fall \$1.7 billion. A 7% decrease in precipitation would cause net revenues from crops to fall \$1.96 billion and a 14% decrease in precipitation would cause net revenue from crops to fall \$3.8 billion. Increases in precipitation would have the opposite effect on net revenues.*

In addition to the uniform scenarios, the study also examined fifteen climate change scenarios. These scenarios reveal that net revenues may rise by up to \$2.9 billion if future warming is mild and wet but that net revenues in Cameroon would fall by up to \$12.6 billion if future climates are hot and dry. This study reaffirms that agriculture in Cameroon is often limited by the seasonality and magnitude of moisture availability. In as much as the other physical factors such as soil and relief are important in influencing agriculture, climate remains the dominant factor that influences the crop types cultivated and the various types of agricultural systems practiced. Hence, climatic factors cannot be dissociated from agriculture since its various elements (rainfall, sunshine, humidity and temperature) are very essential for the survival of crops and of man. The problems that plague agriculture in Cameroon which are of climatic origin must be factored into production plans and catered for, if agricultural output is to be maximized.

<u>CEEPA / World Bank Working Paper No. 11</u>
"Endogenous irrigation: the impact of climate change on farmers in Africa"
Pradeep Kurukulasuriya and Robert Mendelsohn
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EXECUTIVE SUMMARY

Previous Ricardian analyses of agriculture have either omitted irrigation or treated irrigation as though it is exogenous. In practice, it is a choice by farmers that is sensitive to climate. This paper develops a choice model of irrigation in the context of a Ricardian model of cropland. We first examine how climate affects the decision to employ irrigation and then how climate affects the net revenues of dryland and irrigated land. This Ricardian 'selection' model, using a modified Heckman model, is then estimated across 8400 farmers in Africa. We explicitly model irrigation, but we control for the endogeneity of irrigation that plagues a recently suggested remedy.

We find that the choice of irrigation is sensitive to both temperature and precipitation. Simulating the welfare impacts of several climate scenarios, we demonstrate that a model which assumes irrigation is exogenous provides a biased estimate of the welfare effects of climate change. If dryland and irrigation are to be estimated separately in the Ricardian model, irrigation must be modeled endogenously.

The results also indicate that African agriculture is sensitive to climate change. Many farmers in Africa will experience net revenue losses from warming. We find that the elasticity of net revenue with respect to temperature is -0.82 for dryland farms. That is, a 10% increase in temperature will lead to a loss in net revenues per hectare, on average, of 8.2%. Irrigated farms, on the other hand, are more resilient to temperature change and, on the margin, are likely to realize slight gains in productivity. However, any reduction in precipitation will be especially deleterious to dryland farmers, generally the poorest segment of the agriculture community. Dryland farms are sensitive to precipitation (elasticity of 0.28) whereas precipitation has virtually no effect on the net revenues of irrigated farms. As long as there is sufficient water, irrigation appears to buffer farms from precipitation. This is a consistent result across all the models tested in this paper.

Our results indicate that irrigation is an effective adaptation against loss of rainfall and higher temperatures provided there is sufficient water available. This will be an effective remedy in select regions of Africa with water. However, for many regions there is no available surface water, so that warming scenarios with reduced rainfall are particularly deleterious.

<u>CEEPA / World Bank Working Paper No. 12</u>
"Climate change adaptation in Africa: a microeconomic analysis of livestock choice"
Sungno Niggol Seo and Robert Mendelsohn
School of Forestry and Environmental Studies, Yale University

EXECUTIVE SUMMARY

This paper uses quantitative methods to examine the way African farmers have adapted livestock management to the range of climates found across the African continent. We use logit analysis to estimate whether farmers adopt livestock. We then use three econometric models to examine what species they choose: a primary choice multinomial logit, an optimal portfolio multinomial logit, and a demand system multivariate probit. The 'primary animal' model examines the choice of the single species that earns the greatest net revenue on the farm. The 'optimal portfolio' model examines all possible combinations of animals that farmers can choose. The demand system model examines the probability that a farmer will choose a particular species.

Using data from over 9000 African livestock farmers from ten countries, we find that farmers are more likely to choose to have livestock as temperatures increase and as precipitation decreases. Cooler temperatures and wetter conditions, in contrast, favor crops. Across all methods of estimating choice, livestock farmers in warmer locations are less likely to choose beef cattle and chickens and more likely to choose goats and sheep. As precipitation increases/decreases, cattle and sheep decrease/increase but goats and chickens increase/ decrease. Places with more rain in Africa are more likely to be forest than savanna. The savanna favours cattle and sheep whereas the forest favours goats and chickens.

We then simulate the way farmers' choices might change with a set of uniform climate changes and a set of climate model (AOGCM) scenarios. The uniform scenarios predict that warming and drying would increase livestock ownership but that increases in precipitation would decrease it. Warming would encourage livestock *farmers to shift from beef cattle and chicken to goats and sheep. Increases/decreases in precipitation would cause livestock owners to decrease/increase dairy cattle and sheep but increase/decrease goats and chickens. The AOGCM (Atmospheric Oceanic General Circulation Model) climate scenarios predict a decrease in the probability of beef cattle and an increase in the probability of sheep and goats, and they predict that more heat-tolerant animals will dominate the future African landscape.*

Comparing the results of the three methods of estimating species selection reveals that the 'primary animal', 'optimal portfolio', and 'demand system' approaches yield similar results. The demand system and optimal portfolio analyses appear slightly more responsive because they measure the presence of a particular species, rather than whether it is the primary animal. The optimal portfolio approach also differs from the other two methods in predicting warming will have a harmful effect on dairy cattle and goats and a larger beneficial effect on sheep.

<u>CEEPA / World Bank Working Paper No. 13</u>
"Impacts of climate change on the revenues and adaptation of farmers in Senegal"
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EXECUTIVE SUMMARY

This study examines the economic impact of climate change on small farmers' net revenue in Senegal. The purpose of the study is to understand how climate affects current Senegalese farmers. Agriculture in Senegal is mainly dependent on rainfall conditions. Farmlands represent only 19% of the country's area (3.8 million hectares). Annually an average of about 2.5 million hectares (65% of the farmlands) is farmed, among which 98% is rainfed and 2% irrigated. It is a particularly extensive agriculture, based essentially on the activity of the small rainfed farms (≤ 1 ha) which concern almost all the rural households.

Traditional agriculture does not practice irrigation. Three uses of water are known: the flooded rice growing in Casamance (in the southern part of the country), the truck farming in the Niayes zone, and the subsidence agriculture in the dry season along the river valleys (Senegal, Gambia and Casamance). The agricultural sector contributes only 8% of GDP, and occupies 59% of the working population (DPS 2004). It is actually an overcrowded sector, and the growth rate of agricultural production (2.4%) is lower than the population growth. The study was undertaken during the 2002 agricultural season, which was marked by poor production because of a long dry spell throughout the country between the beginning of July and 10 August.

This study uses the Ricardian method to measure how climate affects net revenues. Using empirical data about current farmers, it is designed to predict how climate change is likely to affect future farmers in Senegal. The Ricardian method is a cross-sectional technique that measures the factors that determine farmers' net revenues (Mendelsohn et al. 1994). An inquiry into 1080 sampled households, distributed across many different climate zones so that there would be a great deal of climate variation, shows that farmers in Senegal have a low net revenue and suggests that *small rainfed farms are highly vulnerable to climate change. The Ricardian models used show that net revenue depends on crop harvest, humidity and temperature. The study also reveals that farmers have several ways of adapting to climatic constraints: diversifying crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, praying, and so on.*

Section 1 briefly reviews the theory behind the damage caused by climate change and the general agro-economical situation of the country. Section 2 discusses physical aspects of the country and Section 3 the general characteristics of the agriculture. Section 4 describes the analytic framework for Ricardian method and reviews the literature. Section 5 presents the regression models and the results. Section 6 examines the marginal impacts of climate variables on net revenue and Section 7 the farmers' adaptations to climate change. Section 8 concludes with policy implications and general observations.

<u>CEEPA / World Bank Working Paper No. 14</u>
"Climate change and South African agriculture: impacts and adaptation options"
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EXECUTIVE SUMMARY

Statistical evidence suggests that South Africa has been getting hotter over the past four decades, with average yearly temperatures increasing by 0.13^{0}C a decade between 1960 and 2003 with relatively higher levels for fall, winter and summer periods. There has also been an increase in the number of days with warmer temperatures and a decrease in number of cooler days. Moreover, average rainfall in the country is very low, estimated at 450 mm per year well below the world's average of 860 mm per year, while evaporation is also comparatively high. In addition surface and underground water are very limited with more than 50% of available water resources been used for only 10% of the country's agricultural activities.

Climate change which may lead to higher temperatures, reduced amount of rainfall and also change in the timing of the rainfall may therefore put more pressure on the country's scarce water resources with implications for agriculture, employment and food security. Not only South Africa will be affected but also the sub-region given that more than half of the regions staple – maize is produced in South Africa.

This study attempts an economic impact assessment of the extent to which the expected adverse changes in the climate will affect crop farming activities in the country. The study estimates a revised Ricardian model for South Africa using farm household crop farming data from selected districts in the nine Provinces, long term climate data, major soil types in the country, and runoff in the districts plus adaptation-related variables such as irrigation, livestock ownership, access to output markets and access to public and other extension services.

The analysis indicated that there are significant difference between the impact of climate change on irrigated farms and dryland farms. Irrigated farms are cushioned from climate effects because of the availability of alternatives to rain water. To some *extent there is also a difference in the impacts on large and small-scale farmers, but such differences are blurred by the influence of irrigation or dryland farming.*

The results also show that climate variables, especially for precipitation, have a nonlinear relationship with crop net revenues in South Africa. Certain soil types, such as Vertisols and Xerosols may be harmful to crop farming and therefore aggravate the negative impacts of climate change while other types such as Acrisols and Arenosols may help reduce harmful climate effects. Runoff will also benefit crop farming, but when it is excessive it could be harmful.

In general adaptation-related variables such as irrigation may help reduce the harmful effects of climate change. However, if not properly implemented may aggravate the harmful effects. Of important relevance is public extension service which was found to rather negatively affect crop net revenues. The import is that the information provided by this service may not be very relevant to farmers, even though it is an important tool for controlling the harmful effects of climate change if properly managed.

One important result is that there are seasonal differences in the climate effects and this must not be overshadowed by only looking at the mean annual effects. Increased temperatures will have harmful effects in the summer farming season but would be beneficial in the winter farming season. The overall annual effects will therefore depend on the relative magnitudes of the positive and negative effects. There is therefore the possibility to take advantage of the positive effects while controlling or reducing the negative effects. By so doing one expect that temperature changes will rather be beneficial rather than harmful to the country. Some of the adaptation strategies identified in the study could help in achieving this. Changes in precipitation will also have similar difference in seasonal impacts. Again there is the need to tune policy to take advantage of the relative benefits.

The analysis also indicates that the impacts of both changes in temperature and precipitation may be different for the different farming systems in the country – irrigated, dryland, large-scale and small-scale farms. There would also be difference in the impacts at the Provincial levels. Knowledge of this is important to know how and where to direct relevant policies to control the effects of climate change.

Using selected climate scenarios, the study also predicted that crop net revenues are expected to fall by as high as 90% by 2100 and small-scale farmers are the most to be affected. However, if proper adaptation takes place, these losses are expected to be reduced.

Analysis of the perception of farmers of climate change indicate that most farmers across the country are aware of changes in the climate citing increased temperature, reduced volume of the rain and changes in the timing of the rainfall as indications of this change. Given these perceptions farmers are using different strategies to cope with these perceived changes. It is important for policy makers to be aware of these strategies farmers are currently using, assess their effectiveness and find ways of improving the strategies so to limit the harmful effects and enhance the benefits from climate change.

In general, climate change are expected to be harmful to crop farming in South Africa, however, there are expected to be seasonal gains and losses, farming system specific gains and losses, and different gains and losses at the Provincial levels. If policy makers and farmers are able to identify where the gains and losses are and direct appropriate policies and adaptation strategies there is the possibility that the overall expected negative effect will be reduced or even a positive impact will be expected from climate change for the agriculture sector in South Africa.

<u>CEEPA / World Bank Working Paper No. 15</u>
"Assessment of land use and cropland inventories for Africa"
Fredrik Hannerz and Alexander Lotsch
Respectively, Department of Physical Geography & Quaternary Geology, Stockholm University, Sweden, and Development Research Group – Infrastructure and Environment, The World Bank

EXECUTIVE SUMMARY

For many African countries agriculture will remain an important engine for economic development for decades to come, and the livelihood of rural populations and the welfare of entire countries critically depend on agricultural productivity. At the same time, agricultural practices have enormous consequences for natural systems and threaten the natural resource endowment in many regions. Given the importance of agriculture for sustainable development in Africa it is paramount to develop baselines of land use to monitor and assess the natural and economic impacts of environmental change. This paper critically examines estimates of cropping patterns and cropland extent for Africa produced using various sources of remotely sensed data and compares them with non-spatial statistical inventories of cropland at the continental, regional and local scales. The analysis reveals substantial discrepancies across alternative sources of information about land cover in both the extent and location of croplands, and pinpoints shortcomings in currently available inventories of land cover and land use data derived from remote sensing. These inconsistencies have important implications for downstream analyses that use land use data and they highlight the need to strengthen technological and statistical capacity in the regions to provide the basis for informed policy decisions.

<u>CEEPA / World Bank Working Paper No. 16</u>
"The impact of climate change on livestock management in Africa: a structural Ricardian analysis"
Sungno Niggol Seo and Robert Mendelsohn
School of Forestry and Environmental Studies, Yale University

EXECUTIVE SUMMARY

This paper develops the structural Ricardian method, a new approach to modeling agricultural performance using cross-sectional evidence, and uses the method to study animal husbandry in Africa. The traditional Ricardian approach measures the interaction between climate and agriculture (Mendelsohn et al. 1994; Seo et al. 2005) but it does not reveal how farmers actually adapt. It is consequently difficult to compare traditional Ricardian results with microeconomic models built from the

details of agronomic research (e.g. Adams et al. 1990, 1999; Reilly et al. 1996). The Structural Ricardian Model is intended to estimate the structure beneath Ricardian results in order to understand how farmers change their behavior in response to climate. In this African livestock example, the Structural Ricardian Model estimates which species are selected, the number of animals per farm, and the net revenue per animal. All three of these elements are climate sensitive.

A three-equation model is developed to estimate each of the choices facing a farmer. For each farm, a primary animal is defined as the species that is observed to earn the greatest net revenue on that farm. A multinomial logit is then estimated to predict which primary animal each farmer selects. Given the primary animal chosen, the second equation estimates the number of animals of that type per farm. The final equation estimates the net revenue per animal by species.

The model is used to study the sensitivity of African animal husbandry decisions to climate. A survey of over 5000 livestock farmers in ten countries reveals that the selection of species, the net income per animal, and the number of animals are all highly dependent on climate. As climate warms, net income across all animals will fall but especially across beef cattle. The fall in net income causes African farmers to reduce the number of animals on their farms. The fall in relative revenues also causes them to shift away from beef cattle and towards sheep and goats. All farmers will lose income but the most vulnerable farms are large African farms that currently specialize in beef cattle.

Small livestock and large livestock farms respond to climates differently. Small farms are diversified, relying on dairy cattle, goats, sheep and chickens. Large farms specialize in dairy and especially beef cattle. Estimating a separate multinomial logit selection model for small and large farms reveals that the two types of farm choose species differently and specifically have different climate response functions. The regressions of the number of animals also reveal that large farms are more responsive to climate.

Several climate scenarios are tested using the estimated three-equation model. Some simple uniform climate change scenarios are tested that assume a warming of 2.5°C or 5°C and a change in precipitation of +15% or -15%. The purpose of these scenarios is to see how different districts across Africa respond to identical changes in climate. Uniform warming causes the probability of choosing beef cattle to fall where these are currently being chosen. In contrast, warming causes the probability of choosing sheep to rise, especially across the Sahel. Warming causes the number of animals to fall but especially beef cattle. Finally warming causes the net revenue from all animals to fall, but especially from beef cattle. Increasing precipitation causes the probability of choosing beef cattle, dairy cattle and sheep to fall and that of goats and chickens to increase. Wetter climatic conditions reduce the desired number and net revenue of beef cattle, dairy cattle, sheep and chickens, but not goats. This effect is most likely due to the change in landscape, associated with more precipitation, from savanna to forest. Combining all these changes, a 2.5°C warming results in a 32% loss in expected net income and a 5°C warming leads to a 70% loss in expected net income. Increasing precipitation by 15% results in a 1% loss in expected net income.

We also examine climate change impacts using the separate regressions for small and large livestock farms. With warming, small farms are expected to shift away from dairy cattle and chickens to goats and sheep. Net incomes will fall for all animals except for sheep. The number of animals will also fall. Expected income will fall by 13% with a warming of 2.5℃, but recover with more warming to current levels of income. A 15% decrease in precipitation is expected to increase small livestock farm incomes by 6%. For large farms, warming will cause a shift to dairy cattle and sheep and away from goats, chickens and especially beef cattle. The income per animal falls for all species as temperatures rise. With higher temperatures, large farms choose to have fewer beef, chickens and sheep and choose more goats and dairy cattle. Large farmers' incomes are expected to fall by an average of 26% with a 2.5°C warming and by 67% with a 5°C warming, but a 15% decrease in precipitation is expected to increase these farmers' incomes by 2%.

The study also examines the consequences of a range of climate predictions from three Atmospheric Oceanic General Circulation Models (AOGCMs). These models predict that climate change will cause beef cattle to decrease in Africa and sheep and goats to increase. In general, the climate models predict that the overall number of animals will fall although the number of goats may increase. They also predict that the net revenue per animal will fall. Combining all of these effects, the climate models predict average losses of 22% ($8 to $23 billion) in expected net income from livestock by 2020. These damages increase to 31% ($9 to $24 billion) by 2060, and to 54% ($25 to $40 billion) by 2100.

Examining the effect on small and large farms reveals that small farms will choose dairy cattle and sheep more often and goats and chickens less often as the primary animal. The income per animal will tend to fall over time except for sheep. The number of animals will tend to fall with warming with a few exceptions. The changes in the number of goats and sheep are relatively negligible. The expected income for small farms will tend to increase over time with the Canadian Climate Center (CCC) scenarios (34%), but fluctuate with the Parallel Climate Model (PCM) and Center for Climate System Research (CCSR) scenarios depending on precipitation. Large farmers, in contrast, will shift away from beef cattle and chickens in favor of dairy cattle, sheep and goats. Net revenues will fall across animals, but especially for beef cattle. The numbers of beef cattle and chickens will fall by large amounts, but the numbers of goats and sheep will increase depending upon the scenarios. Putting all these results together, CCC will lead to a $6000 reduction in expected net revenue per large farm (77%), CCSR to a $2700 reduction (34%), and PCM to a $3400 reduction (43%) by 2100.

The results indicate that warming will be harmful to commercial livestock owners, especially cattle owners. Owners of commercial livestock farms have few alternatives either in crops or other animal species. In contrast, small livestock farms are better able to adapt to warming or precipitation increases by switching to heat tolerant animals or crops. Livestock operations will be a safety valve for small farmers if warming or drought causes their crops to fail.

<u>CEEPA / World Bank Working Paper No. 17</u>
"Economic impact assessment of climate change on agriculture in Burkina Faso: a Ricardian approach

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EXECUTIVE SUMMARY

This study aims to assess the impact of climate change on agriculture in Burkina Faso. It uses the Ricardian cross-sectional approach to measure the relationship between climate and net revenue from growing crops. It regresses the net revenue of crops on several variables: climate, soil, relevant hydrology and socio-economics. It tests three models (one without adaptation, one with adaptation and one with a dummy zone variable). From the estimated models, we determine the marginal climatic effects and their elasticity in order to examine the sensitivity of net revenues from crops to temperature and precipitation. The study determines how Burkina Faso farms would respond to climate change based on the Intergovernmental Panel on Climate Change scenarios (IPCC 2001) and scenarios of the hydrology component of the GEF/World Bank Project, Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa. The IPCC scenario is a uniform scenario that supposes a uniform change of temperature in Africa. It makes it possible to compare the effects in the countries involved in the GEF/WB project. The scenarios of the hydrology component of this project are specific to each country. The study's findings of the study give a lot of information about the sensitivity of agriculture in Burkina Faso to climate variables.

The marginal effect of temperature on revenue is 19.9 US$/ha and the marginal impact of precipitation on revenue is 2.7 US$/A according to the adaptation model at all farms level. This means that if the temperature increases by 1°C, revenue will fall by 19.9 US$/ha. If precipitation increases by 1 mm, net revenue increases by 2.7 US$/h. The elasticity shows that agriculture is very sensitive to precipitation in Burkina Faso. For example, an increase in temperature of 5°C (IPCC scenarios) is very critical for agriculture: farms would lose 135% of their net revenue from crops. Farms would lose their entire net revenue from crops if precipitation decreased by 14%. The scenarios of decreasing rainfall and increasing temperature are critical for crop yields because Burkina Faso's climate is already hot and dry.

The study reveals that some variables used in the regression can be effective as adaptation options. Extension service and irrigation are significant and positively affect net revenue. The study does not capture the full dimensions of climate change impacts in Burkina Faso, but constitutes an important start in understanding how climate change will affect crop yields and how farmers will respond to the change.

<u>CEEPA / World Bank Working Paper No. 18</u>
"Ricardian Analysis of the economic impact of climate change on agriculture in Ethiopia"
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EXECUTIVE SUMMARY

This study utilized the Ricardian approach that captures farmer adaptations to varying environmental factors to analyze the impact of climate change on Ethiopian agriculture. Out of the 30-agro ecological zones, 10 agro ecological zones, representing more than 74 % of the country were selected and total of 1240 farmers from 62 districts were interviewed. Net revenue was regressed on climatic and control variables. The independent variables include the linear and quadratic temperature and precipitation terms for the four seasons (winter, summer, spring and Autumn), the temperature precipitation interaction terms, household variables (household size, level of education of the head of the household, distance from market, livestock ownership, extension visit for crop and livestock, and the number of farm plots), the mean run-off, mean flow and soil types. The results show that climatic, soil types, flow mean, run-off and household variables have significant impact on the net revenue per hectare of farmers under Ethiopian condition. Moreover the marginal analysis was undertaken to see the seasonal impact of a unit change in temperature and precipitation. The result of the marginal analysis indicated that increasing both temperature and precipitation during winter and spring seasons have positive impact where as increasing both temperature and precipitation during autumn and summer seasons have negative impact on net revenue per hectare of Ethiopian farmers.

<u>CEEPA / World Bank Working Paper No. 19</u>
"Crop selection: adapting to climate change in Africa"
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EXECUTIVE SUMMARY

This paper examines whether the choice of crops is affected by climate in Africa. Using a multinomial logit model, the paper regresses crop choice on climate, soils, and other factors. The model is estimated using a sample of over 7000 farmers across 11 countries in Africa.

The study finds that crop choice is very climate sensitive. For example, farmers select sorghum and maize-millet in the cooler regions of Africa, maize-beans, maize-groundnut, and maize in moderately warm regions, and cowpea, cowpea-sorghum, and millet-groundnut in hot regions. Further, farmers choose sorghum, and millet-groundnut when conditions are dry, cowpea, cowpea-sorghum, maize-millet, and maize when medium wet, and maize-beans and maize-groundnut when wet. As temperatures warm, farmers will shift towards more heat tolerant crops. Depending upon whether precipitation increases or decreases, farmers will also shift towards drought tolerant or water loving crops, respectively.

There are several policy relevant conclusions to draw from this study. First, farmers will adapt to climate change by switching crops. This will inherently reduce the damages from climate change as farmers move away from crops that cannot perform well in the new climate towards crops that can. Governments and farmers should anticipate that new crops will be grown in places that experience climate change.

Second, global warming impact studies cannot assume crop choice is exogenous. For example, agronomic studies or studies that use weather as a proxy for climate, implicitly assume that crop choice will not change as climate changes. Unless these *studies treat crop choice as endogenous, they will seriously overestimate the damages from warming.*

Third, this study only examines choices across current crops. Future farmers may well have more choices. There is an important role for agronomic research in developing new varieties more suited for higher temperatures. Future farmers may have even better adaptation alternatives with an expanded set of crop choices specifically targeted at higher temperatures.

<u>CEEPA / World Bank Working Paper No. 20</u>
"The economic impact of climate change on Zambian agriculture: a Ricardian analysis"
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EXECUTIVE SUMMARY

Agriculture is a major economic sector for many african nations. It constitutes about 30% to the GDP of Africa. About 70% population of the continent depends on this sector for their livelihood. Most agricultural production on the continent is rain dependent.

The increasing concentration of greenhouse gases in earth's atmosphere is changing global and regional climate. Global mean temperature has increased by over 0.5^0 celcius since the nineteenth century. Higher trend in temperature rise has been noted at regional scale for Africa. Rainfall quantity by volume and distribution over season are also varying from year to year on the continent and are showing erratic patterns. Droughts have become more frequent in the last thirty years. Such climatic changes have enormous consequences on the food security of the continent. Lack of capital and technology are serious constraints to adapt to climate change for poor countries in Africa.

The three years Global Environment Facility (GEF) funded project ' CLIMATE, WATER AND AGRICULTURE: IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA' started in December 2002 to assess the economic impacts of climate change on African agriculture. Other sources of funding were Agricultural and Rural Development Department of World Bank, World Bank Institute, The Africa Region World Bank, The Centre for Environmental Economics and Policy in Africa, United Nations Food and Agricultural Organization, International Water Management Institute and National Oceanic and Atmospheric Administration. Eleven African countries including Zambia participated in the project. These countries represented diversity in climate and agricultural practices across the continent.

This report concerns the assessment of economic impacts of climate change on agriculture in Zambia. The assessment analyses is based on an empirical approach known as Ricardian method which measures effect of climate on value of agricultural land. For a country like Zambia with abundant free farming land for subsistence farming , it is difficult to attach a value to land. Therefore, Ricardian approach has been modified to replace land value by net farm revenue as suggested in Mendelsohn

R, Nordhaus W, Shaw D, 1994, The impact of Global Warming on Agriculture: A Ricardian Analysis, The American Economic Review 84 (88).

A multiple linear regression model on net farm revenue as response variable has been fitted with climate, hydrological, soil and socio-economic variables as explanatory variables. Considering plant growth in three stages namely germination, growing and maturing, which require different amounts of water and temperature, the climate variables included in the model are averages of periods November and December, January and February, March and April. Assuming non linear relationship of farm revenue with the climate variables, quadratic terms for climate variables were added in the model equation.

The results indicate that some climate variables and the corresponding quadratic variables are significant in the model. Further findings are that increase in mean temperature in December January and decrease in mean precipitation in January February have negative impacts on net farm revenue where as increase in January February mean temperature and mean annual runoff have positive impacts on net farm revenue.

<u>CEEPA / World Bank Working Paper No. 21</u>
"Assessing the impact of climate change on crop water use in South Africa"
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EXECUTIVE SUMMARY

The study indicated that CROPWAT can successfully be used as tool to calculate the impact of climate change on crop water use in South Africa. South Africa already possesses an extensive database on climate variables and certain crop parameters needed as inputs to the model. However the input data available for area and production on magisterial level for different crops under dryland and irrigation was of low quality. Crop water use for agricultural production was successfully calculated for 34 districts of South Africa. Results indicate that some areas were large scale irrigation is practiced are in what can be termed arid or semi arid areas, such as those found along the Orange and Vaal rivers. Future crop water use in these areas will not only be affected by climate change within the area but also by the effect a change in climate has on run-off in the catchment areas of the river and thus irrigation water availability.

Maize is a staple food in South Africa with an increase in demand of 3 % per annum. It is also the most important cash crop and with maize production covering 58 % of the cropping area its importance on the South African economy must not be underestimated. Already maize production is showing a CV of up to 30 %. With the bulk of maize being produced in the "drier" North West province (38%) and Free State (34%) any impact future climate will have is thus of great importance. Using CROPWAT as tool crop water use was assessed for three districts, i.e. Lichtenburg in the Northwest Province (MAP 570 mm), Kroonstad in the Free State (MAP 622 mm) and Middelburg in Mpumalanga (MAP 651 mm). If maize would have to be irrigated to attain full potential yield more than 2000 cubic m/ha would be necessary whilst sunflower uses 60% less water. High stress values of 70 % for maize produced in *these districts using the 1993 Agricultural census statistics are an indication of the effect the drought of the 1991/1992 season had on crops which preceded the census.*

The effect of climate change, through the accumulative effect of CO_2 and projected temperature increases of between 2.5 to 3°C, on development phases of maize becomes evident when these are projected to be shortened by up to two to three weeks. Using CROPWAT as tool, for four climate change scenarios (GEN, CSM,HadCM2N and HadCM2S it was calculated that due to this the same a amount as current or even less water will be used by the maize crop. This is good news on the water budgeting side however a reduction in the growth development time of maize may make it more susceptible to environmental stress such as short periods of drought or abnormal weather during pollination. This is also indicated in that the stress factor still is at around 45%.

Using CERES-maize in a pilot run, with no adaptations to genetic coefficients in the light of climate change, but using the same climate data for the four climate change scenarios, potential maize yield was simulated for farms in the three districts of Lichtenburg, Wesselsbron and Middelburg. All four climate change scenarios had a negative effect on maize yield but the most severe was in the Lichtenburg district were future maize production might become totally uneconomical.

In the end knowledge is the only tool we have to be pre-emptive on the impact of climate change. Farmers mainly adapt to changing weather patterns on a season to season base. They are already adapting, crop and cultivar choice, planting dates and are excluding marginal lands. It is however important that adaptation takes place at all levels from farm, community to national level to make a impact. In future it will be important that despite the position of the producer, whether smaller-scale grower or commercial entrepreneur who provide localized production and income to smaller communities, should receive governmental assistance to adapt to the impacts of climate change and that that land which has the capability to produce food for the nation, is not compromised by political inspired land tenure options and always will be cultivated to its true production potential and will not be over or under exploited.

<u>CEEPA / World Bank Working Paper No. 22</u>
"Assessing the impact of climate on crop water needs in Egypt: the CROPWAT Analysis of Three Districts in Egypt"
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Soil, Water & Environment Research Institute (SWERI), ARC

EXECUTIVE SUMMARY

The future of agriculture in Egypt is thus hard to project even assuming the continuation of current climate conditions. The task is made all the more difficult by the possibility of a significant warming expected to result from the enhanced greenhouse effect. Egypt appears to be particularly vulnerable to climate change, because of its dependence on the Nile River as the primary water source, its large traditional agricultural base, and its long coastline, already undergoing both intensifying development and erosion.

The potential impact of climate change on crop seasonal ET was evaluated using CropWat model. Wheat, maize and cotton were selected for the study since they represent different growing seasons and water needs. The evaluation was carried out in the three main agricultural regions of Egypt, Delta region (Lower Egypt) represented by Khafr ElSheikh Governorate; Middle Egypt represented by Giza Governorate and Upper Egypt represented by Sohag Governorate. According to the present study in Egypt, the impact of climate change on water use of wheat, maize and cotton increased in the three selected locations. Wheat ET increased about 10.8, 11.4 and 10.3% for Khafr El-Sheikh, Giza and Sohag, respectively as compared with wheat ET under current conditions. Maize ET for the same respective regions increased 7.8, 7.8 and 8.0% as compared with ET under current climate conditions. Cotton ET increased 8.4 and 7.6 for Khafr ElSheikh and Sohag, respectively compared to cotton ET with the current climate. At the same time, increasing temperature caused some yield reduction specially in the stage # 3 with the summer crops (maize and cotton).

Finally, climate change impacts could increase crop water use and yield reduction. A number of adaptation policies are suggested here. The policies address specific measures in water resources and agriculture. These measures could be reduced the potential adverse effects of climate change on crop ET and yield.

<u>CEEPA / World Bank Working Paper No. 23</u>
"Estimating Crop Water Use and Simulating Yield Reduction for Maize and Sorghum in Adama and Miesso Districts using the CROPWAT Model"
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Ethiopian Agricultural Research Institute and National Meteorological Agency, Ethiopia

EXECUTIVE SUMMARY

This research report examined impact of climate change on crop production on two districts based on the FAO CROPWAT model and assessed adaptation measures in the areas. Now day's climate change is a big issue in any part of the world and its impact is pronounced in every activities of human being. Agricultural practices are one of the activities that are highly subjected to climate change. Its effect is more noticeable on those countries which are dependent on rain-fed agricultural systems. Hence to assess the impact of climate change on crop production and adaptation measures, the CROPWAT model was used to simulate yield reduction for maize and sorghum crops in two districts Adama and Miesso.

The simulation of yield reduction and estimation of crop water use has been done based on ten year crop and meteorological data using the model. Accordingly, the crop water use for both crop in the two districts are lower by far from the crop water need. This effect is pronounced on the simulated yield reduction percentage. The result shows that yield lose as a result of the decrease in evaporation rate is account to 40 – 70%. This yield reduction is caused by the effect of climate change. The increment of evaporative demand of the atmosphere due higher temperature, reduction of rainfall and lower water availability in soil medium result in contradiction between demand and supply of water. Hence, the effect of this contradiction is marked on the overall condition of the pant and on its yield. In response to this situation, different adaptive measure has been taken in the districts as

well as all over the country. Some of the adaptive measures are: using supplementary irrigation like small irrigation and water harvesting, minimizing of evaporative demand using mulch, applying different soil moisture conservation technique and different crop management practices that reduces sensitivity to water stress.

Most of these adaptive measures would be under taken at farm level. This can be depending on farmers' perception to the water stress conditions. In the two districts farmers already aware the situations and respond to using different mechanism as mentioned above. They tried to adjust planting density; timing of various operations, use of conservation tillage and intercropping are the major one. They introduce traditional irrigation and water harvesting methods to cope up water stress problem during crop growing period. At current time government are responding to change the agricultural activities from rain-fed production system to irrigation one. Such situation is the right way to adapt the water stress and drought condition at country level. Hence many small water tanks are constructed in two districts and all over Ethiopia to supplement crop production during moisture stress conditions. Efforts to adapt to climate impacts may be modeled on current variability mitigation efforts. The major difference is that climate shift is likely to permanent, whereas climate variability is often concerned with only temporary setbacks. With climate variability, some solution can be temporary until the weather returns to being suitable again. However, with climate change, the problems are more permanent and so more permanent solutions must be given more weight.

<u>CEEPA / World Bank Working Paper No. 24</u>
"Assessing the impacts of Climate Change on Water Resources of Lake Tana Sub-Basin Using the WatBal Model"
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EXECUTIVE SUMMARY

Ethiopia with a total area of about 1.1 million sq. km is divided in 12 watersheds. The water resources potential and the size of each Basin differ widely. To assess the impacts of climate change on the water resources and thereby to recommend adaptation measures a Lake Tana sub–basin have been chosen. The vulnerability of runoff to climate change has been assessed using the WatBal hydrological water balance model. Different climate change scenario and their impact on the water resources and the possible adaptation measures are presented in the report.

L.Tana area water resource is highly vulnerable to climate change especially in the distribution of runoff through out the year, In other words the seasonality of the runoff will greatly increase and as a result small streams might completely dry up for some of the year. This will cause high impact on the socio-economic of the sub-basin as the agriculture is totally depend on rainfall, and the rural water supply sources are mostly small streams and springs. The adaptation options identified above are subject to various constraints. The major constraints are capital required for the construction of dams and other flood protecting works. Other constraint is social like on the option of relocating of settlements from vulnerable areas. The physical constraint includes the availability of suitable land for relocating settlements.

CEEPA / World Bank Working Paper No. 25
"Use of CROPWAT model to predict SMD with climate change and analysis of CWR on main rainfed crops yield in Niger"
Katiella Maï Moussa and Amadou Moustapha
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EXECUTIVE SUMMARY

According to the literature review, all these main crops are mixed in all the cultivated areas and in all the studied districts. This crop association allow to forcast the risks related to the amount and repartition of the rainfall during cropping season as all these selected crops are exclusively cultivated during the rainy season. There is no chance for irrigation, even if the rainfall deficit is critical, as farmers cannot afford the required input. In all the districts the fertile areas in the field are allocated for cash crops like okra, tobacco, sesame, galingale, Maize etc. These cropping systems are common and known at national level as a confirmed adaptation strategies to climate change and variability. According to the above, the CROPWAT model is applicable in Niger country conditions even if irrigation is not common with less than 60 000 ha for irrigated agriculture.

These results show a significant difference between scenario with climate change (2025) and without Climate change for Aguié in terms of soil water availability and soil moisture deficit but this difference is not significant for Gaya where the decreasing in rainfall with this scenario (2025) will maintain adequate soil water availability for subsistence crops production.
Somehow, for all the district, except Gaya, where water there is a little chance for irrigation for these subsistence crops in the future. These findings may have important implications for Niger's agricultural policy. Based on these intermediary conclusions, the following recommendations are made:

To adopt and build adaptation strategies to climate change and variability at community, district and national level there is need to improve the cropping systems by changing to irrigation system for crops that are not adapted to sahelian conditions. there is need to help small farmers into big units (cooperatives) to increase the irrigation efficiency. Water resources management should be considered as the main constraint for crop productivity in the country.

CEEPA / World Bank Working Paper No. 26
"Climate, hydrology and water resources in Cameroon"
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EXECUTIVE SUMMARY

Cameroon can be grouped into ten major ecological regions. These ten ecological regions have been classified under four regional units which are differentiated by their geography, climate and vegetation characteristics. These are: the sudano–sahelian zone, savanah zone, Coastal aid maritime zone, tropical forest zone;

degraded forest of Centre - Littoral, and tropical rain forest of the South West and East. The two rainfall regimes (unimodal and bimodal regimes) in the country show a gradual reduction in amount from the coastal region in the south to the Chad Plain in the north. In addition to these, the country possesses enormous amount of water resources both groundwater and surface water. The well–watered southern region with metamorphic and igneous rocks is dominated by surface water resources. In contrast to this, the semi–arid less–watered northern region (lowland) with sedimentary rocks is the zone of ground water, its origin having been facilitated by the permeability of the sedimentary materials. However, streams exist but their flow is highly ephemeral given the prolonged dry season period of this region especially the Yaeres of the Logone-Shari plain which is part of the Chad basin. The major catchment areas in the country as well as the river courses have been modified significantly. This modification has come from land use intensification and the construction of dams along river courses. Such transformations have allowed the regular pattern of flow of most rivers in this part of the country which has equally affected other forms of human activities.

The diversity of ecological zones in Cameroon affects agricultural output in two ways. In the well watered southern portion, agricultural production flourishes. But in the progressively dry and arid north where the Potential Evapo-Transpiration is high, agricultural output is adversely affected. Farming in the sudano-sahelian zone of Cameroon largely depends on the amount of rainfall received. The shifting of the climatic belts southward is likely to affect hydrological processes such as evapo-transpiration, runoff, infiltration percolation and groundwater flow. An increase in temperatures is likely to raise the rate of potential evapo-transpiration but much reduced actual evapo-transpiration. This leads to a fall in the amount of rainfall with a corresponding reduction in runoff. A 2°C decrease in temperature would result in a 21% decrease in the annual runoff. Rivers such as Mayo Tsanaga and Mayo Sara would cease to flow completely. This would lead to a reduction in the volume of runoff in the River Benue together with the Logone flowing into Lake Chad. These would be accompanied by a corresponding fall in the level of Lake Chad which is likely to become almost non-existent by 2060.

CEEPA / World Bank Working Paper No. 27
"Analysis of crop water use in Senegal with the CROPWAT model"
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EXECUTIVE SUMMARY

This work was part of the GEF/WB project named "Regional Climate, Water and Agriculture Project: Impacts on/and Adaptation of Agro-Ecological Systems in Africa". The objectives was to study the crops water use with the FAO CROPWAT model and to evaluate the impact of climate change on crops. This work emphasized on the millet and the groundnut (the main crops in Senegal), but also on the corn which is being developed with the policy of diversification introduced a few years ago.

To run the CROPWAT model, we have used the FOA climate data, the FAO crop data combined with crop coefficients from Dancette and soil parameters given by Forest. Considering the actual climate context, the crop water use is more important in the southern part of Senegal (represented by Kolda), where rainfall is abundant and here the soils presents some organic and mineral richness, compared to the half northern part (represented by Diourbel), where water resources are weak and soils poorer. Thus, considering actual evapotranspiration of crops, the values are low in the half northern part and high in the half southern part.

The IPCC findings on climate change are used as inputs into CROPWAT model to assess the impact of climate change on agriculture. Considering millet, a 1.5°C increase in temperature has no effect in the half northern part of the country, but causes a reduction of actual evapotranspiration and consequently of the yield.

CEEPA / World Bank Working Paper No. 28
"CROPWAT Model Analysis of crop water use in Six Districts in Kenya"
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EXECUTIVE SUMMARY

The crop water requirements in six selected agricultural districts distributed across six provinces of Kenya engaged in farming activities was evaluated based on the CROPWAT methodology. The districts considered were Kiambu, Makueni, Kwale, Laikipia, Vihiga and Migori, representing the provinces of Central, Eastern Coast, Rift Valley, Western and Nyanza respectively. The composition of these districts also reflects the diversity of agro-ecological zones of the country. The objective of the selection was to evaluate crop water requirements for varied agro-ecological zones due to their likely different responses to climatic change/variability scenarios. This follows their demonstrated differences in the levels of crop productivity over time.

The results show that climate change will increase the amount of crop water use. It is observed that the percentage change in crop water use increases with increasing temperature. The proportions representing change in crop water use from the output of CCCM scenario were lower than those from the GFDL3 for all the districts considered. Within a set temperature scenarios, change in rainfall didn't demonstrate any evidence of its impact on the change in crop water use. Its effect could however, be implicit in the demonstrated decline in the amounts of irrigation water requirements following an increase in the amount of rainfall.

Patterns of irrigation water requirement and field water supply deviated from the aforesaid trend. In general, increasing rainfall by 20% of the original amounts, for each of the two models decreased the irrigation water requirement for the crops studied. Irrigation water requirement increased for a climate change scenario associated with a decrease in rainfall by 20% of the original long-term climatological mean. This is likely to be due to the fact that the increase in rainfall satisfies a greater portion of crop water requirement hence lower values of irrigation water requirement. In general, field water supply was higher during climate change scenarios associated with lower rainfall amounts (-20% of the original climatological mean). The original output had the lowest values of field water supply across the districts.

CEEPA / World Bank Working Paper No. 29
"Analysis of crop water use and soil water balance in Burkina Faso using CROPWAT"
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EXECUTIVE SUMMARY

Located in the semi-arid tropical zone in West Africa, Burkina Faso stretches from the ninth to the fifteenth parallel in the northern latitudes. The country is subject to a

high degree of both climate variability and population growth (2.3 % / year). The main climatic features of the country are a low level of rainfall, spatial and temporal variability, high level of evapo-transpiration and high temperatures particularly during the dry season.

The different climatic elements are variation in rainfall, temperature, humidity, sunshine and the air masses. On a whole, the temperatures and temperature-ranges increase as one move from South towards the north.

There is latitudinal sliding of all isohyets towards the South, translating to a reduction of 100 mm in average rainfall. During the last decades, the 400 mm isohyets rose up to northern border of the country and the 1100 mm isohyets reappeared in the South. This rainfall dynamics has implications on crop production and food security in Burkina Faso.

Six provinces out of forty five have been selected for this study: Houet (Bobo-Dioulasso), Poni (Gaoua), Gourma (Fada N' Gourma), Kadiogo (Ouagadougou), Yatenga (Ouahigouya) and Seno (Dori).

The Cropwat software was used in calculating crop water requirements (maximum evapotranspiration MET), effective rainfall, referential evapo-transpiration (ET0), irrigation needs, soil water balance (useful reserve and easily useable reserve) and soil water deficit. It uses monthly averages of the climatic parameters. The ET0 is calculated using the Penman-Monteith's method and effective rain is estimated to be 70 % of rainfall amount taking into account the average rate of runoff. Irrigation is applied when 80 % of easily useable reserve is exhausted and has 100 % efficiency. The maximum depth of crop roots is 1.20 m. An average soil depth was considered for simulation in the different regions. Data on crop coefficients are provided by the software. Sorghum, maize, groundnut, millet, cowpea and cotton have been selected for the simulation.

This study attempts to assess the relationship and comparative differences between the six provinces and between crops with climate variables. This hinges on the premise that weather variability and uneven distributions of precipitation strongly influence crop yield.

Given that crop water requirements and crop water productivity in rain fed and irrigated agriculture are essential indicators in assessing the impact and role of climate on crop production, the goal of the research is thus three-fold: i) to evaluate water use efficiency and crop water productivity under prevailing rain patterns and traditional farm practices; ii) to assess the impact of rainfall variability and climatic change on crops' yield; iii) and define options for farm improvements and appropriate strategies to optimize yields and reduce risks of crop failure related to crop choice, planting time, soil cultivation and crop cultural practices.

The main outcome of this study shows that soil water reserves naturally increase according to rainfall. But in general soil water holding capacity is low. In the southern part of the country represented by the three stations of Bobo, Gaoua and Niangoloko, water requirements for cereal crops and groundnut are met by the rainfall. In the Sudan-Sahelian and in the Sahelian regions, water deficits are *experienced towards the end of the rainy season. Supplementary irrigation is needed to enable cereal crops to finish their cycle normally. In the cotton-belt, irrigation needs for cotton and maize are very low, but in the Center, in the North and in the Sahel irrigation needs at the end of the season are substantial.*

<u>CEEPA / World Bank Working Paper No. 30</u>
"Assessing the impact of climate on crop water use and crop water productivity in Cameroon: the CROPWAT analysis of three districts in Cameroon"
Ernest L. Molua and Cornelius M. Lambi
Department of Economics and Management, University of Buea, Cameroon

EXECUTIVE SUMMARY

Located, on the Gulf of Guinea, Cameroon stretches from the second to the thirteenth parallel in the northern latitudes. The country experiences the quasi totality of inter-tropical climates. The different climatic elements are variation in rainfall, temperature, humidity, sunshine and the air masses. On a whole, the temperatures and temperature-ranges increase as one move from South towards the north and from the coast to the hinterlands. Contrary to temperature, rainfall in Cameroon reduces from coast towards the north and interior of the country. Humidity of course is usually also very low in north than in the south, explained by the different air masses that blow across the country. Similarly, soils in Cameroon are diverse examples of tropical soils.

Since the impact of climate variation on crop yield has recently gained prominence given significant trends of global warming and impending climate change, this study attempts to assess the relationship and comparative differences between regions and between crops with climate variables. This hinges on the premise that weather variability and uneven distributions of precipitation strongly influence crop yield. Cameroon, offering practically whole range of intertropical climates influenced by mountains and by proximity of the ocean, offers immense opportunity for agronomic studies examining the role of real-time and satellite climate. Given that crop water requirements and crop water productivity in rainfed and irrigated agriculture are essential indicators in assessing the impact and role of climate on crop production, the goal of the research is thus three-fold: to evaluate water use efficiency and crop water productivity under prevailing rain patterns and traditional farm practices; to assess the impact of rainfall variability and climatic change on yield and production; and define options for farm improvements and appropriate strategies to optimize yields and reduce risks of crop failure related to crop choice, planting time, soil cultivation and crop cultural practices.

Cameroon is important for this kind of study, for it is home to a variety of natural vegetation and wildlife distributed amongst different regions of the country depending of course on the variation in annual rainfall. However, whether relief, climate or nitrogen is considered, from its central position and great length from north to south, Cameroon offers a diversity that is on a small scale the microcosm of Africa. Agriculture forms the main economic activity in the country, with over 80% of the population involved in agriculture, and agricultural products account for significant contribution to household and national incomes. The variation in physical conditions

in Cameroon is evidence for the varied cropping systems and variety of crops cultivated in different parts of the country.

Three agro-ecologies are thus sampled for analysis. For comparative analysis, we select the farming district of Ambam in the humid moist forest zone, the farming community in Bamenda in the high savanna zone and farmers in the sahel savanna zone in Garoua. These study zones offer diverse information on temperature, rainfall, sunshine and wind speed that allows for the examination of their influence on the cropping patterns and crop specific crop requirements. In addition, these three zones contribute a significant share of 25% in Cameroon's agricultural GDP.

In the course of the modelling process, we describe in detail the principal agrometeorological embodiments of the study zones, the agronomic requirements of the selected crops studied, the analytical framework and the nature of the data used. Crop simulation methods are then used to ascertain crop water requirements and the influence of climatic variables in plant growth and development. The simulation procedures incorporate micro-crop models that incorporates crop physiologic and phonological development processes accounting for photosynthetic assimilation, partitioning and respiration, and root growth and the water balance processes that simulate the way water from rain or irrigation infiltrates the soil, is taken up by the roots for transpiration and percolates deeper layers. Principally, the study employs the guidelines and methodologies from the FAO Land and Water Development Division on crop water management at the farm level. This hinges essentially on the methodologies for the calculation of crop water requirements and crop water productivity in irrigated and rainfed agriculture. Owing to the difficulty in obtaining accurate field measurements, the estimation of crop water requirements were derived from estimating crop evapotranspiration according to standardized crop and climatic conditions.

The field observations reveal diverse farming patterns. In terms of rotational features, fallow system can be distinguished from perennial cropping, shifting cultivation and permanent farming. Based on the provision of water, rainfall farming and irrigation farming are identified. And according to degree of commercialization, subsistence, partly commercialized, semi-commercialized and highly commercialized farming emerges. Of course, total nomadism as well as semi or partial nomadism are common in savannah zones. Terracing predominates in some parts of the country especially highland areas. The conscious and deliberate cultivation of more than one plant on one piece of land at the same time (mixed or mélange farming) as well as strictly growing of one crop at a time on a piece of farmland (monoculture or plantation) are broad categories in which all the above farming systems can be identified pitting a case for mixed cropping against monoculture, shifting cultivation and permanent cropping.

The differing climate regimes across the ecological zones in the country lead to varying consequences in productivity and efficiency. From the crop-water simulation, three major crops are identified for analysis: maize, groundnuts and soybean The reference evapotranspiration (ETo) figures obtained for maize differ across the selected farming districts, ranging from 413 mm, 570.1 mm and 890.1 mm in Ambam, Bamenda and Garoua, respectively. The average crop coefficient (Kc) for maize is 0.67 and the yield reduction factor (ky) is 1.25. The Evapotranspiration of the maize *crop (ETc) is 276.9 mm for Ambam, 381.9 mm for Bamenda and 596.4 mm for Garoua farming district. The soil water loss is thus highest for Garoua. Reference Evapotranspiration (ETo) figures obtained for groundnut, differing across the selected farming districts, ranging from 427.1 mm, 588.7 mm and 919.8 mm in Ambam, Bamenda and Garoua, respectively. The Reference Evapotranspiration (ETo) under soybean are 413.3 mm, 570.1 mm and 890.1 mm in Ambam, Bamenda and Garoua, respectively. The average crop coefficient (Kc) for soybean is 0.68, and the yield reduction factor (ky) is 0.85. The Evapotranspiration of the soybean crop (ETc) is 281.03 mm in Ambam, 387.7 mm in Bamenda and 605.3 mm in Garoua.*

The findings of this study are interesting with some important ramifications for farmers, extension services and for future studies. While farmers may be adapting to the climatic variation, there is need for improvement in governmental effort in aiding the adaptation process by making available the necessary resources and providing irrigation infrastructure especially in the drier northern parts of the country, to cushion the debilitating impact of low soil moisture, peaking daily temperatures and runaway evapotranspiration. To ease water constraints and enhance productivity, there is need to consider improving crop patterns and cultivate crops with less water requirements, as well as there is need to improve the irrigation efficiency by changing traditional irrigation system to more efficient systems such as drip irrigation and pipe irrigation. Water resources management should be considered in different aspect, such as supplying management, demand management, and construct management. Crop water demand must be met as this strongly determines crop emergence, development and survival in the tropical regions.

<u>CEEPA / World Bank Working Paper No. 31</u>
"Actual crop water use in project countries: a synthesis at the regional level"
Robina Wahaj, Florent Maraux and Giovanni Munoz
Land and Water Development Division of FAO (Food and Agriculture Organization of the United Nations) and Visiting Scientist from CIRAD (Centre de coopération internationale en recherche agronomique pour le développement) to FAO.

EXECUTIVE SUMMARY

This report aims to synthesize the results of a crop water use study conducted by country teams of the GEF/World Bank project Regional Climate, Water and Agriculture: Impacts on and Adaptation of Agro-ecological Systems in Africa. It also presents the results of the second phase of the study based on climate change scenarios, conducted by the South Africa country team.

The actual evapotranspiration of five commonly grown crops – maize, millet, sorghum, groundnuts and beans – in two selected districts were analyzed by six country teams. In addition, two country teams also analyzed other crops grown in the districts. The regional analysis shows that the actual yield of the different crops – specifically of maize and groundnuts – improves with an increase in actual evapotranspiration, although the gap remains wide between actual and potential yield and actual and maximum evapotranspiration, especially for the rainfed crops. This highlights the importance of improved water management if agriculture is to play an important role as a source of food security and better livelihoods.

In general, the study results give realistic evapotranspiration and actual yield values for maize, sorghum, millet, beans and groundnuts. The average values for crop water productivity for these crops are within the common published ranges, with maize and sorghum being the most water efficient crops in terms of water use. It is important, however, to highlight the vulnerability of maize to water stress and the increased risks to the viability of rainfed farming systems based on this crop.

The first phase of the study provided a framework for the analysis of future crop water use as affected by climate change in Africa. The second phase of the analysis, that includes climate change impact on crop water use, was conducted by the South Africa country team. This analysis was performed for maize, using the methodology developed by the FAO (Food and Agriculture Organization) that is used together with CROPWAT to assess future crop water requirement and use. The results of the second phase of analysis show that a 2°C increase in the temperature and a doubling of CO_2 concentration in the atmosphere will shorten the growing period of maize, which will result in decreased crop water requirement and use.

It is recommended that this analysis is extended to the other crops as well as to the other countries to be able to get a clearer picture of the changing pattern in crop water use of the major crops grown in the project countries.

<u>CEEPA / World Bank Working Paper No. 32</u>
"Ricardian analysis of the economic impacts of climate change on agriculture in Ghana"
K Yerfi Fosu and J K Adu
University of Ghana and Animal Research Institute, CSIR, Accra, Ghana.

EXECUTIVE SUMMARY

This interim research report has provided the rationale for conducting research on the effects of climate change on water and agriculture in Ghana. It has described the spatial pattern of climate indicators (specifically, temperature and rainfall), agricultural resources and agricultural production in Ghana. The Ricardian modelling approach is employed. The agricultural household survey for generating the relevant data for estimating the Ricardian model for Ghana has been described in detail.

The perception of farmers concerning climate change, their adaptation strategies and the constraints to efficient adaptation are identified and described. On the empirical level, the present study observes that most of the farmers have observed long term climate change (specifically, rising temperatures and declining amounts of rainfall). The adaptation strategies employed by the farmers include the following: reduction of farmland area cultivated, planting of trees to provide shade and cooling of crops, mulching with crop residues and compost, using fertilizer or organic manure, switching to new short duration crops and crop varieties, migration to other places, diversification into livestock and non-agricultural activities, inter alia.

The constraints to efficient adaptation comprise inadequate financial resources, inadequate availability and access to labour, improved seed, fertilizer, organic manure, compost and crop residues, inadequate access to irrigable land at dam sites, *inadequate access to water for irrigation (some farmers have to walk long distances to fetch water with water cans and buckets). Some farmers lack information on expected rainfall and temperature as well as information on the efficient adaptation strategies, inter alia.*

At this preliminary stage of the present research project, concrete policy recommendations await the complete empirical results of the Ricardian model which are about to be obtained. This is also an outstanding research activity.

Forthcoming in World Bank Economic Review (WBER) 2006

"Will African Agriculture Survive Climate Change?"
Pradeep Kurukulasuriya, Robert Mendelsohn, Rashid Hassan, James Benhin, Temesgen Deressa, Mbaye Diop, Helmy Mohamed Eid, K. Yerfi Fosu, Glwadys Gbetibouo, Suman Jain, Ali Mahamadou, Renneth Mano, Jane Kabubo-Mariara, Samia El-Marsafawy, Ernest Molua, Samiha Ouda, Mathieu Ouedraogo, Isidor Sène, David Maddison, S. Niggol Seo, and Ariel Dinar

Abstract: Quantitative measurement of the likely magnitude of the economic impact of climate change on African agriculture has been a challenge and was absent for quite some time. Using data from a survey of over 9000 farmers across eleven African countries, a cross-sectional approach estimates how farm net revenues (revenue from livestock, dryland crops, and irrigated crops) are affected by climate. Evaluated at the current mean temperature for each farm type, dryland crops and livestock revenues fall with warming (temperature elasticity of –1.9 and -5.4 respectively). However, irrigated crop revenues increase with temperature (elasticity of 0.5) because these crops are buffered by irrigation and they are located in relatively cool parts of Africa. Revenues from all farm types increase with precipitation; irrigated crop, dryland crop, and livestock revenues have elasticities of 0.1, 0.4, and 0.8 respectively. At first, warming has little net aggregate effect as irrigation gains offset dryland and livestock losses. Warming, however, will likely reduce Sub-Saharan farm income immediately. Final effects will also depend on changes in precipitation. Because irrigated farms are less sensitive to climate, where water is available, irrigation is a practical adaptation to climate change in Africa.

Annex 2. Project Workshops' Reports

A2.1. Annual Research Planning Workshops

A. Cape Town 2002

LAUNCHING AND TRAINING WORKSHOP ON UNIFIED METHODOLOGIES AND DATA COLLECTION NEEDS

ORGANIZED BY

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA), UNIVERSITY OF PRETORIA, SOUTH AFRICA

FUNDED BY THE GLOBAL ENVIRONMENT FACILITY (GEF)

WITH COMPLEMENTARY SPONSORSHIP FROM:

THE FINISH TRUST FUND
THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA)
THE AGRICULTURAL AND RURAL DEVELOPMENT DEPARTMENT, WORLD BANK
THE AFRICA REGION, WORLD BANK
THE WORLD BANK INSTITUTE
INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI)
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION – OFFICE OF GLOBAL PROGRAMS (NOAA-OGP)
UNITED NATIONS FOOD AND AGRICULTURE ORGANIZATION (FAO)

CAPE TOWN, SOUTH AFRICA, 4 – 7 DECEMBER 2002

Compiled by

James Benhin, Rashid Hassan and Glwadys Gbetibouo
The Centre for Environmental Economics and Policy in Africa (CEEPA)

1. Objectives

Workshop 2002 is the launching workshop of a GEF funded study of climate change impact in eleven countries in Africa cutting across different climatic conditions. This study is one of the first analyses of climate impacts and adaptation in Africa and is intended to provide empirical evidence on the role that climate plays in Africa today and how that might change with global warming.

Workshop 2002 intended the following purposes:

(a) To provide and standardized data needs and analyses for all country studies;
(b) To enhance the capacity of the research teams responsible for conducting country studies in the application of the proposed methodological approaches;
(c) To define the nature and scope of planned regional economic and hydrological analyses;
(d) To develop standardized format and plans for an integrated regional database.

2. Venue

The workshop was held at the Holiday Inn Cape Town at Cape Town, South Africa.

3. Workshop Program (see at end)

4. Participants: (see list at end)

Participants came from universities, research and government institutions of eleven African countries; Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia, and Zimbabwe,

Other participants were from: the Agricultural and Rural Development Department and the Africa Region of the World Bank, UN Food and Agriculture Organization (FAO), United Nations Development Program (UNDP), Yale University, International Water Management Institute (IWMI), University of Minnesota, Instituts Rabat in Morocco, University of Southern Denmark, and the University of Cape Town,

5. Brief Summary of Workshop 2002 Proceedings

The workshop started in the afternoon of 4 December 2002 and ended in the afternoon of 7 December 2002. For the four days, seven sessions were planned, but the last two sessions were collapsed into one session, making up a total of six sessions for the four days.

The first day was devoted to introducing participants to the three approaches to assessing climate change impacts on agriculture as specified in the project document: Economic impact assessment models with emphasis on the Ricardian method, river basin hydrology models, and biological crop response simulation models.

The first part of the second day was devoted to a detailed exposition of the Ricardian model, an empirical application of the method in the USA, Brazil and India, and a discussion of the variables that may be needed to apply the method in the current study. Discussions also centred on how such data were to be collected, the expected problems associated with applying the method in a developing country, such as countries in Africa, and data collection problems. The second part of the day was devoted to country presentation and discussions for Ethiopia, Egypt, South Africa and Zambia.

The morning of day three concentrated on the river basin hydrology models and crop response simulation models. In the river basin hydrology presentation alternative models, which could be used to capture climate change impacts at the basin level were discussed, with supporting empirical evidence from Tanzania. The presentation concluded with identifying how the models could be applied to the current study and how they can be linked with the Ricardian model. The afternoon of the day was devoted to country presentations and discussions for Niger, Senegal, Ghana and Burkina Faso.

Day four focussed on the presentation and discussion of the synthesis and conclusions on the unified approaches and standardized analytical methods for the country studies with respect to the three approaches. Time was also spent on the data collection approach. The workshop concluded with a stipulation of the way forward and unanimous decision to hold next year's workshop in Egypt.

6. General Issues Agreed Upon

(A) The three approaches were to be applied in the study at different but related levels. The Ricardian approach was to be concentrated at the regional level, while the crop response simulation models will be applied both at the national and regional levels. The river basin hydrology model was found to be more applicable at the regional level and will provide some input into the Ricardian analysis. Further details on how the river basin hydrology model was to be implemented was to be decided in due course.
(B) The implementation of the three approaches will run parallel to each other during the course of the study
(C) A major part of 2003 to be devoted to questionnaire preparation, data collection, coding and collation.
(D) A website for the project soon to be operational. One important aspect of the website is that it will be a forum for the discussion and exchange of ideas by participants.
(E) Plans to be made for more technical workshops for smaller groups within the year.
(F) Egypt as the venue for Workshop 2003.

7. Ricardian Method: Specific Issues Agreed Upon

a) The Ricardian approach adopted for assessment of the economic impacts of climate change on agriculture

b) The Ricardian analysis would be based on assessment of cross-sectional data on variations in climate (weather) attributes and consequent implications for agricultural production activities
c) The cross-section information should capture spatial diversity in climate attributes, economic, social and political characteristics, and agricultural practices
d) Net farm revenue would be the primary response variable measured to reflect climate change impacts on agriculture
e) Other response analyses recommended using other attributes of potential agricultural sector adjustments to climate change. Examples of which include percent land under crops, percent cultivable area grown to food crops, cereals, etc.
f) Spatial diversity would be measured at district level within each country (or a better suited definition of the smallest unit of data collection as country-specific circumstances may dictate)
g) The application of the Ricardian approach would require efforts of primary data collection through surveys (guidance for which is provided below)
h) Country teams would administer data collection employing unified data schedules (questionnaires) to be collectively designed with CEEPA taking responsibility of coordinating the process of questionnaire design
i) All data compiled by involved country teams will be integrated in a regional database to be managed by CEEPA, which will support the regional analysis. All participating countries will have access to this database.
j) Country level analyses will be conducted by country teams looking at country-level aspects of climate change impacts on agriculture
k) Regional analysis will better observe spatial diversity across countries and will be conducted using the integrated regional database with the Yale University team taking the lead on the regional assessment in collaboration with country teams and African Experts.

7.1 Design of the Survey and Data Collection Activities

a) In addition to available meteorological stations' data, satellite information on climate attributes will be made available through Yale University.
b) Satellite climate data are available: rainfall for 1948 onwards and wetness and temperature for the 1989 onwards period.
c) Primary data on net revenue should be compiled from country level surveys for the most recent 12-month period. Each team will decide which 12-month period best represents a crop year for their country. If the last 12 months were not a normal year, farmers will also be asked what happens during a normal year.
d) Sources of secondary data on various aspects of agricultural production activities are to be tapped in all countries for as many years as possible during the 1989 onwards period
e) The primary data collection efforts at country level should survey farm households in the predominant FARM TYPES in each district (suitable unit)
f) A typology of representative farm types is to be established by country teams to capture key features of agricultural production activities such as scale (reflecting technology), cropping system, land tenure regimes, etc

g) The following survey design was proposed to guide country level data collection efforts:
   a. The number of data collection units such as **districts** (**DS**) is to be **within the range of 30 - 60.** This will require some aggregation or dis-aggregation of available boundaries of survey units. In countries where the number of districts is less than 30, all the districts must be included in the sample.
   b. Aggregation / dis-aggregation of sampling units should be guided by a gradient of climate attributes (i.e. significant change in temperature)
   c. Within each survey unit (a district for example), a **minimum of two farm types** – **FT** (i.e. large and small) and a **maximum of five farm types - FT** (allowing for other farming characteristics of relevance to climate change impact analysis such as cropping system, etc.) are to be surveyed
   d. The survey of farming entities within each farm type should target typical farm households in the selected category. It is proposed that a sample of **within the range of 5 - 10 households** (**HH**) for each farm type is to be surveyed
   e. The sample size should have a trade-off between the number of households and the number of districts – more households (**HH**) and less districts (**DS**) on one hand, and less households (**HH**) and more districts (**DS**) on the other, keeping in mind each county must spend between $20,000 and $25,000 dollars on this activity.
   f. A budget of US$ 25 per questionnaire was suggested. This means a sample size for each country in the range of 800 and 1000
   g. For example, if a country has 30 districts given three farm types it will require a sampling of 10 households per district for a total sample size of 900.
   h. Another example, if a country has 60 districts given three farm types it will require a sampling of 5 households per district for a total sample size of 900.
   i. Country teams to advise on budget suggestions
h) The unified database format will report data per HH to be aggregated by FT and consequently by DS
i) The country level and regional analysis will accordingly be able to use as many data points as possible from the proposed sample design depending on statistical performance

7.2 Variables to be Measured

A. Response variables

- Net revenue defined as: sum of annual price times quantity minus costs of production (labor, fertilizer, seeds, pesticides but not land or loans)
- % of cropped land: net sown land / area
- % of cropped land cultivated by major crop

B. Regressors

1. National level
    - Market access (ports, import restrictions by foreign countries)
    - National agricultural policies (the presence of crop subsidies, input subsidies, and crop restrictions)
    - National economic factors (inflation, interest rates)
    - Water policies
        i. Inefficient allocation of water between sectors
        ii. Inefficient allocation amongst farmers
        iii. Inefficient infrastructure – dams, canals
2. District level
    - Climate attributes (Monthly temperature and precipitation (soil moisture)
    - Socio-economic (household income, population density, proximity to markets)
    - Market access (distance to markets, quality of roads, transport costs)
    - Political stability and proximity to politically unstable countries (as measured by the existence or non-existence of armed struggle, percent of population who are refugees)
    - Limited access to capital
        i. Rural banks
        ii. Informal credits
        iii. Collateral security
    - Disease rates (AIDS, malaria, denghi fever, trypanoosomiasis)
    - Literacy rates
3. Farm level
    - Soil characteristics
    - Family size
    - Communal pasture or forest lands
    - Cultivation history
    - Farm size
    - Type of ownership of farm (family, commercial, tenant)
    - Farm type (cropping, integrated livestock, pastoral)
    - % of irrigated cropland
    - % of farm for grazing
    - % of farm production consumed
    - % of tenant farmers
    - % of products sold in local markets vs wholesale
    - Household type (male or female head)
    - Religious affiliation
    - Property rights to land
        i. The degree of limitations to private ownership
        ii. % of private property
        iii. % of communal property

In addition, the survey instrument may be designed in a way that it can capture the knowledge, attitudes and practices of farmers towards adaptation options.

C. Some variables are to be measured at district level (% of land, % of population, etc) while others are to be measured at HH level (net revenue, labor use, etc.)
D. Averages for farm types and/or average district measures to be derived from survey data

7.3 Workplan for Year One (2003)

A. Questionnaire to be developed and distributed by February 2003
B. Farm typology, sample design and budget to be proposed by country teams by choosing districts (March 2003)
C. Testing of survey questionnaires (March-April 2003)
D. Final questionnaire (May 2003)
E. Administration of surveys (June – October 2003)
F. Integrated database format (July 2003)
G. Data coding and collation (September 2003)

8. Crop Response Simulation Models: Main Issues

A. There was a great demand by national teams to undertake the crop simulation model at the national level. The shortcomings for this demand were
    a. Budget limitations
    b. Concerns about expertise in most countries, especially for more sophisticated models, such as CERES.
    c. Availability of software and data

B. In response to the above concerns, the adoption of more sophisticated models such as CERES will initially be limited to certain countries and certain crops. FAO and other experts will be involved in training all countries on using this model in later stages of the study.

C. The less demanding CROPWAT model will provide a valid alternative in estimating variability in yields in the various districts included in the survey for each country. FAO will make available data and software for this to be done at the country level. The cooperation FAO has established with a number of key modellers under its crop water productivity programme would further contribute to provide relevant assistance in this field.

D. FAO would make accessible its databases on soils, climate, water and agriculture and relevant publications available in FAO to country teams through CEEPA. FAO will provide expert guidance for the use, interpretation and processing of the required data.

E. FAO in consultation with the project management is to draft a plan of work and initiate fundraising activities to support this part of the project.

9. River basin hydrology Models: Main Issues

A. The water resources/hydrology model is a collaborative effort between IWMI and the project.
B. The hydrology analysis is expected to produce an assessment of the spatial distribution of climate change impacts on runoff and availability of water within and across countries.
C. The study is to be undertaken on a regional basis.
D. IWMI is to take the lead in collaboration with country teams.
E. A consultative group of experts (10 – 15 members) is to be set up to advise IWMI.
F. IWMI and project management are to work on a detailed proposal and study guide.

SUMMARY OF SESSIONS

10. DAY ONE, WEDNESDAY, 4 DECEMBER 2002:

SESSION 1: INTRODUCTION TO APPROACHES TO CLIMATE CHANGE IMPACTS ANALYSIS

The session was co-chaired by Prof. Rashid Hassan, director of CEEPA and leader of the project, and Dr. Charles Cormier from the World Bank Institute and member of the project advisory group, both giving opening addresses.

Welcome Notes and Opening

Rashid welcomed all the delegates to Workshop 2002 and stated that he was excited by the opportunity to work with such a diversity of individuals with specialised disciplines and noted that he was looking forward to a challenging and rewarding study.

Charles noted that it was good news to get the study going after many years of tireless work by several individuals. He was happy about the increasing number of countries who have ratified the Kyoto Protocol, an indication of how serious countries across the globe are taking climate change. He noted that in the last conference on climate change held in Dehli, India, the approach to climate change has shifted toward efforts to understanding adaptation mechanisms. The current study will therefore be an invaluable input towards this shift in emphasis.

Charles also noted that climate change is central to development issues and should be of most interest to countries in the African region, which will be more affected by climate change. It is therefore important, he observed, that Africa lead the way with such study. He noted also that the study results will not only be a valuable input to the discussions on adaptation mechanisms but will improve upon the capacity for national and regional assessment of climate change on agriculture.

Charles further noted that in the course of the study participants will have the opportunity to interact and learn from each other through workshops and the project's website which would soon be in operation.

Workshop Objectives and Program

The theme of Dr. James Benhin's presentation on the workshop objectives and program was "Getting things right from the very beginning". James indicated that understanding clearly the focus of the study, the specific objectives, and how the three methodologies: Ricardian approach, crop response simulation modeling, and the river basin hydrology modeling, were to be adapted for the study analysis were very essential for the smooth running and successful outcome of the study. He hoped that at the end of Workshop 2002 there would be an agreement on the part of participants that this is exactly what had been achieved.

In addition, Rashid urged all participants to get fully involved in the four-day discussions so that a consolidated agreement on the course of the study could be reached. He also took the opportunity to apologize for the printer's error, which excluded the following items from the program:

- Session 1: Martin Smith as presenter for the "Introduction to Biological Crop Response Simulation" at 16:30 – 17:00
- Session 3: Zambia presentation and Prof. Suman Jain as the presenter at 16:30 – 17:00, and the Discussions on the South African and Zambian presentations at 17:00 – 17:30.

Introduction to Economic Impact Assessment Models: Prof. Robert Mendelson, Yale University

Prof. Robert Mendelsohn of the Yale School of Forestry and Environmental Studies, made a presentation on an integrated model of greenhouses gases. With respect to climate change Robert noted that the temperature is expected to increase from 1.5 C to 4.5 C by 2100 and this would have both market and non-market impacts. Countries to be affected more by such global warming are those in the developing world with the agricultural sector been the most affected. In Africa, especially, he noted that the continent is already hot and therefore further warming will render most agricultural activities highly impossible.

Robert supported these assertions with examples of climate projections from General Circulation Models, such as CSIRO (Australia), CCSR (Japan), CCC (Canada), HAD2 and HAD3 (UK). He observed that, in spite of the differences in the estimates of these models, all of them predict a bleak picture for Africa with serious consequences for agriculture on the continent.

Robert further presented two approaches currently in use to investigate the economic impacts of climate change on agriculture: experimental and cross-sectional, assessing their strengths and weaknesses. The main strength of the cross-sectional approach, he noted was the inclusion of adaptation and therefore reducing the degree of over-estimation of impacts, which is a weakness of the experimental approach. However, the main weakness of the cross-sectional approach is its inability to control unwanted variables in the analyses making it difficult to clearly dissociate the impact of climate change in the estimates.

Robert observed, however, that very few of these assessments have been undertaken in the tropics where agriculture is a very important sector and the brunt of global warming is to be felt. The reason is why the current study is important.

Introduction to River Basin Hydrology Models: Matthew McCartney (IWMI)

Matthew McCartney stood in for Prof. Ken Strzpek, who sent his apologies for his inability to be present at the workshop. In his presentation, Matthew focussed on the explanation of the hydrological cycle, types of hydrological models and model selection and how the basin hydrological modeling is related to the current study. He noted that among the main factors affecting basin hydrology is climate (i.e. rainfall, temperature, evaporation), which in turn influences the seasonal pattern of river flows, affecting the availability of water for crop production. In hydrological modeling, he noted, one of the objectives is to quantify changes in catchment's response as consequence of changes in climatogical inputs and land management strategies.

Matthew mentioned and explained three main types of hydrological models (i.e. conceptual (lumped) models, physically-based models and physical-conceptual models) and noted that the choice of any of the models depends on whether they simulate important processes controlling catchment's response to precipitation and whether they are consistent with the accuracy required and available data. He also presented different climate change scenarios based on estimated greenhouse gases (GHG) emission. In his conclusions he noted the following:

- In Africa climate variability has major impacts on human well-being because of its effect on agriculture production which majority of the population depend on
- In assessing prospects for the future there is the need to know how climate variability will alter (i.e. will extreme conditions become more or less frequent). With this knowledge it is possible to estimate the expected impacts on economic activities such as agriculture.
- Hydrological models linked to climate change scenarios indicate how flows and water availability may be altered in basins, and therefore how this will affect the availability of water for crop production in the catchment's areas.
- Magnitude of impact is determined by social and economic vulnerability of communities. The distribution of impacts and the degree of adaptability is essential for policy makers.

Introduction to Biological Crop Response Simulation: Martin Smith (FAO)

Martin Smith of the Food and Agriculture Organization (FAO) presented a brief description of crop simulation models, citing some examples of the models, their objectives, inputs and outputs. Martin noted that crop simulation models attempt to describe crops behaviour (physiology and development) as function of environmental conditions, such as weather factors (rainfall and radiation or sunshine): soil data (fertility, water holding capacity) and crop data under the control of farmers such as planting dates and rates of application of fertilizer.

The objective of crop simulation models, according to Martin, is often to estimate a yield at the regional level and by using several techniques the yield-output model can be converted to regional averages. And in order to carry out meaningful crop yield estimates at the regional scale, all inputs have to be converted to the same spatial scale and the method used for this is the gridding technique.

However, Martin noted that model outputs need not necessarily be yields, other outputs can be used instead, such as crop water consumption measured in terms of crop evapotranspiration, average soil moisture, water excess/deficit at critical growth stages. One of these models with such an output, the CROPWAT model, is the simplest, which can easily be applied in the current study. The model is a water balance based computer programme use to calculate crop water requirements and irrigation water requirements from climate and crop data based on FAO procedures. This water balance procedures allow an assessment of effective rainfall and an evaluation of rainfed production through calculated yield decreases and water balance procedures.

Observations from the three Introductory Presentations

The main observation from the three presentations was that guidance was needed to determine exactly how to apply the models in the current study. At the country level there were suggestions that the following specific questions needed further discussion:

(a) What efforts already exist in the study countries in terms of the application of the models discussed, especially with respect to the crop response simulation models?
(b) How much data was there to implement any of the approaches; Ricardian, river basin hydrology and crop response simulation models? If data was not available, how to go about collecting needed data.
(c) What is the existing capacity in the respective countries in terms of the application of the various models, and how can this capacity be developed in all the countries?
(d) If the workshop agreed on a cross-sectional analysis then there was the need to think about classification of systems; that is what system of classification the study need to use; what type of regions – based on climate variability that will allow the study to establish a link between climate change and crop production.
(e) Cross-sectional data that will be able to assess variation of climate change on agriculture production was, however, not available in most of the study countries.
(f) Was there a possibility of linking the three approaches and how could that be done in this particular study in order to present a holistic picture of climate change impact on agriculture?

These observations and questions set the stage for the rest of the workshop discussions.

11. DAY 2: THURSDAY, 5 DECEMBER 2002

SESSION 2: METHODS OF ECONOMIC IMPACT ASSESSMENT

The Chairperson for this session was Prof. Rachid Doukkali of the Institut Agronomique et Veterinaire in Morocco. The session was divided into three main parts and was led by Robert Mendelson and Pradeep Kurukulasuriya, both from Yale University, USA. The first part focused on a comparison of the agronomic-economic and cross-sectional methods for assessing climate change impacts, a description of the Ricardian approach (a cross-sectional method) with an empirical example from the USA. The second was a presentation of an empirical application of the Ricardian approach in Brazil and India. The third part dealt with how the technique would be applied to Africa, the data requirements, and problems to be encountered and how these problems were to be handled.

Robert noted that for an economic assessment of climate change impacts of agriculture two main methods could be used: Agronomic-economic and Cross-sectional. He reiterated that the main drawback of the agronomic-economic methods is their tendency to over-estimate the impacts of climate change mainly because of the neglect of adaptation mechanisms.

However, cross-sectional methods, such as the Ricardian approach, are difficult to apply in small landscapes. Given that climate change is obvious when the method is applied on a larger landscape, the empirical application of this method in the current study has to be applied on a regional level and based on the agro-ecological zones of the districts in all the countries.

According to Robert, the Ricardian approach examines the impact of climate and other variables on land values and farm revenues or values (net rent), which is the present value of future rents. By directly measuring farm prices or revenues, the approach is able to account for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptations to different climates.

The main strength of the Ricardian approach is that it is easy to use. However, it was observed that the approach has some weaknesses. The main weakness is that certain variables, relevant for estimating the net revenues, such as costs associated with capital goods and family labour, and other transitory costs are difficult to include in the estimation. The method also loses important underlying insights, such as adaptation and crop switching, which are important for policy making.

In presenting the application of the method in the USA, Robert observed that there was an apparent over-estimation of the adverse effects of climate change on agriculture by agronomic-economic models. The Ricardian approach projections, in fact indicated that global warming maybe slightly beneficial to the USA agriculture. He also observed that satellite information was found to provide better climatic data than weather stations. The current study may therefore depend on satellite data for climatic information rather than weather stations in each of the study countries.

Given this background to the Ricardian approach, it was suggested that the approach be adopted for the economic assessment of climatic change impacts for the current study. Net revenue was to be the response variable and data needed to estimate the net revenue must be collected in each country. It should also be possible to include transitory cost in the estimation. In response to the observation that the approach does lose valuable insight, it was noted that such insights could easily be found through investigation at the micro-level by finding out information about activities such as changes in planting time and crops, and related technologies. Another problem observed in the application of the approach to the current study was the difficulty in getting past years' net revenues in most of African countries. The workshop therefore had to decide on how far back information on net revenue could be collected, given the problem associated with memory lapse if information is collected too far back in the past.

Pradeep presented a summary of Mendelsohn et al 1994 paper ("The impact of global warming on agriculture: a Ricardian analysis", *The American Economic Review* 84(4): 753-771) with emphasis on the estimations on page 760 of the paper. He also presented the empirical study undertaken in Brazil and India.

In the third part of the presentation Robert submitted to the workshop the data hurdles that needs to be overcome in the current study in Africa and suggested solutions to these data problems to make it possible to apply the Ricardian method. The variables and solutions to the hurdles were as follows

(a) Climate data
- temperature by season by district
- Precipitation or soil moisture by district

Solution: To rely on satellite data because of the shortcomings of weather stations. These data for Africa are to be provided by Yale University (Robert) for the period 1989 to the present time, plus the mean and the variance.

(b) Soil data
- There are different classifications of soil types: for example the American way, the British way and the French way, such that the English speaking African countries may have different soil classifications of soil to the French speaking countries.
- Consistent measures by district

Solution: FAO soil map for Africa for consistency

(c) Net revenue per hectare by district
- Annual net revenue per hectare of land

Solution: Survey of farmers

(d) Cropland by district

Net Sown Cropland by area

(e) Socio-economic
- household income
- population density
- proximity to markets

Further discussions on the presentation had the following observations

(a) Additional variables which needs consideration:
- Social factors such as literacy rates, disease rates such as HIV/AIDS, family size and household type
- Farm size

- National economic factors (inflation/interest rates)
- Market accessibility – domestic and international
- Access to credit with emphasis on the informal sector
- % of land under rainfed and irrigation
- revenues from irrigated agriculture and rainfed agriculture
- Livestock and cropland: that is the role of livestock in farming systems
- Religious affiliation
- Property rights: percentage of private property and percentage of communal land
- The extent of arm struggle in a country
- The effect of arm struggle in neighbouring countries estimated by the number of refugees in the country
- mixed cropping, land equivalent ratio can be used to estimate net revenue
- Impact of food aid

(b) Net revenues were to be measured in national currencies and later converted using the exchange rate or the purchasing power parity
(c) Cultivation history to give an idea of any adaptation mechanisms
(d) Net revenues data in the previous year's agricultural seasons for each country to be collected in the first year of the study, that is 2003.
(e) Further discussions needed on how to allocate resources to collect the data. The suggestion was that substantial amount of the country allocated budget was to be spent on data collection in the first year.
(f) CEEPA in consultation with Yale University was to develop the questionnaire to be pre-tested and finalized for the survey
(g) Guidelines on the data collection activity were to be provided by the regional analysis team from Yale University.

SESSION 3: PLANS OF WORK FOR COUNTRY STUDIES 1

This session was the first of two sessions for country teams to make presentations. The country presentations were expected to follow certain guidelines.. Dr. David Maddison of the Institute of Economics, University of Southern Denmark chaired the session, which consisted of two main parts. In the first part the country team leaders of Ethiopia and Egypt made their presentations, which was followed by a discussion. Similarly, in the second part discussions followed the presentations by the country team leaders from South Africa and Zambia.

In response to a question whether the teams were confidence in applying the Ricardian model, Prof. Helmy Eid, the team leader of Ethiopia gave his full approval to the application of the model for the economic assessment. Both James Benhin, the co-leader of the South Africa team, and Prof. Suman Jain, the leader of the Zambia team, noted that they were confidence in the capability of their teams in applying the Ricardian model. Abebe Tadege, the team leader for Ethiopia, noted that with the inclusion of an economist in their team this should not be a problem, at which Ariel noted that finding an economist in Ethiopia to join the team should not be very difficult.

On a question on the availability of data in South Africa, Wiltrud, a member of the South Africa team, noted that there was a vast amount of agriculture data at the district level which could easily be tapped.

Given the different distribution of each country's landscape in terms of administrative and hydro-meterological regions, it was observed that the workshop has to decide on a uniform categorisation of the unit of analysis for all the countries involved in the study.

12. DAY THREE: FRIDAY, 6 DECEMBER 2002

SESSION 4: CROP SIMULATION AND RIVER BASIN HYDROLOGY APPROACHES

This session was chaired by Dr. Martin Krause from the UNDP-GEF Climate Change Division, who stood in for Dr. Arne Dalfet of the World Bank. There were two main parts for this session: a presentations by Matthew McCartney and Daniel Yawson both from IWMI on river basin hydrology, followed by a presentation by Martin Smith of FAO on crop response simulation models. Both presentations were followed by discussions.

In their presentations, Matthew and Daniel outlined the theoretical background to river basin hydrology with a case study from the Great Ruaha River in Tanzania. They also cited examples of models that link hydrological models and climate change at the basin level, such as WATBAL, WEAP, and ACRU, and how these models can also be linked with the GCMs and crop simulation models. Among the models they presented they identified WEAP as the simplest, which can easily be adopted for the current study, depending on data availability.

Martin's presentation had two main parts. In the first part he provided an overview of FAO methodologies that have been developed and promoted for the computation of crop water requirements and crop water productivity under adequate and deficit water supply, and for irrigation requirements and scheduling. In the second part he cited the kinds of programs and data that FAO can make available for the current study.

With reference to evapotranspiration, which comprise of the simultaneous movement of water from the soil and vegetation surfaces into the atmosphere through evaporation and transpiration, in the first part of his presentation, Martin noted that four methods for the calculation of reference evapotranspiration were adopted by the FAO in 1971 and 1972. These methods have been revised over the years and currently other options exist such as the FAO Penman-Monteith method, Dual step-single coefficient and the dual crop coefficient methods. The choice of these models depends on the availability of data.

With regards to yield response to water models, he cited several models which can be used to assess climate change impact on agriculture, such as CROPWAT, CERES and CROPSYST, and reiterated the point that CROPWAT was the simplest of the models which can easily be adapted for the current study. He further noted that the CROPWAT model could be applied at the district level.

He concluded this first part by noting that the meeting has to decide on how the Ricardian method simulation can incorporate the CROPWAT model

In the second part of Martin's presentation, he outlined the programs and types of data FAO can make available for the study. The data include: climatic data, crop statistics, soil and land use. Most of these data are either on the web or on CD-ROMS:

(a) Agriculture (FAOSTAT which has information on agriculture statistics at national level such as crop production, inputs, etc)
(b) Water (AQUASTAT, Water resource and irrigation in Africa)
(c) Land (TERRASTAT, Digital soil maps, Soil and terrain databases)
(d) Climate (FAO CLIM2, LOC CLIM). The LOC CLIM is a computer programme that estimates any climate on earth via extrapolation. These estimates can be compared with the satellite data to be provided by Yale University (that is Robert Mendelsohn).
(e) Crop yield map
(f) Crop condition map
(g) Climatic indicators
(h) METART
(i) World reference base for soil resources (this is on-line and one can request the information directly. The data is compiled at national level but there is the possibility of downloading district level information.

SESSION 5: PLANS OF WORK FOR COUNTRY STUDIES II

Dr. Slim Zekri of the Department of Applied Economics, University of Minnesota, chaired the session. Niger, Senegal, Ghana and Bukina Faso made country presentations.

The main discussion of the presentations centred on adaptation mechanisms. In the case of Burkina Faso the main adaptation mechanisms in the country included: improved crop varieties, field water harvesting techniques in the drier zones, and *Zai* techniques to restore degraded lands and improve crop yields. In Niger the main adaptation mechanism is the extension in land for agriculture given the limited nature of crop variety in the country. However, in areas where land movement is limited, farmers have resorted to modern farm techniques. In Senegal, adaptation mechanisms included extension in land, and the movement of crops from one region to the other, for example the movement of the production of groundnuts from the northern parts of the country to the southern part. And for some crops, changes in sowing dates. It was noted that all the study countries should try and identify such adaptation mechanisms.

13. DAY FOUR: SATURDAY, 7 DECEMBER 2002

SESSIONS 6 AND 7: SYNTHESIS AND CONCLUSIONS ON UNIFIED APPROACHES AND STANDARDIZED ANALYTICAL METHODS AND DATA

Following the preceded three days discussions the planned two sessions for the day were revised into just one session and was chaired by Ariel Dinar from the World

Bank and member of the project advisory group. The session had two main parts. The first was the presentation and discussion of the "workshop guidance on unified approach to the application of the Ricardian method" The second part was a presentation and discussion of the "Synthesis of unified approach to the application of the river basin hydrology model and crop simulation model. These were followed by a discussion on the way forward.

On the first presentation the following were agreed (*Ricardian approach*):

(a) Adoption of the Ricardian method for the assessment of the economic impact of climate change on agriculture using district and household data
(b) Data for the analysis to be provided through sample surveys from each of the countries involved in the study
(c) Adoption of the guidelines for the survey design to guide the country level data collection. The main point here was that sample units for each country should consist of 5 – 10 household for each of 2 – 5 farm types within a range of 30 – 60 districts. It was estimated that each household survey would cost $25. However, total expenditure on the survey for each country must be in the range of $20,000 - $25,000. In this respect, there should be a trade-off between the number households and the number of districts included in the sample unit, without losing the representative nature of the sample. All farms types in a country should, however, be included in the sample. The sample size for each country should consist of at least 800 units. The sampled districts should scientifically represent the country in terms of climate variation, altitude gradient, etc. However, where the number of districts in a country, such as it pertains in Egypt is less than 30, then all the districts must be include in the sample unit. The range of 30 – 60 districts was proposed as a limit on countries with very large number of districts.
(d) Questionnaire development, testing and administration of questionnaire, and data coding and collation to be started and completed between January 2003 and September 2003.
(e) Where the situation in a county is such that the sampling design could not be implemented, then the country must submit a revised sampling design, stating the reasons for such revisions. The revised design will then be circulated to the project's international experts and the country teams for discussions after which a final decision would be taken.
(f) Country teams to select their sample units with respect to farm types and households based on informed nature of agriculture in each district.
(g) On the question of how far back questions must be asked given the different cropping year in each country, it was agreed that questions must make reference to the last 12 months. Further questions to find out whether the last 12 months was a "normal" or "abnormal" since the study wants to capture information on "normal" years. If the last 12 months was an "abnormal year", then further questions may be asked for information on a "normal year", possibly the 12 months before the last 12 months. It is hoped that that at least one of the12 months cropping seasons in the last 24 months would be a normal year. The idea of sticking to the maximum of the last 24 months was to avoid memory lapse on the part of farmers which may lead to inaccurate information been provided. However, this may change in individual country

circumstances, which may require a 12-month period beyond the last 24 months.

(h) A point was raised as to the inability of the Ricardian model to capture the following important issues:
   (i) Adaptation
   (ii) Adaptation costs – transitionary costs
   (iii) How people should or do adapt to climate change, e.g. extension efforts
   (iv) CO_2 effects – which is very important in climate change
   (v) Distributional effects of climate change

With regards to adaptation, it was noted that the questionnaire could be designed in a way that farmers can be asked about their knowledge, attitudes and practices (KAPS) towards some adaptation mechanisms. With regards to adaptation costs or true adaptation costs, it was noted that the analysis captures transitional costs in the form of the cost of inputs for different crops and different farm types. With respect to CO_2, it was noted that cross-sectional techniques as been applied in the Ricardian analysis could not capture CO_2 effects. However, CO_2 levels in all the countries included in the study are the same so the inability to capture CO_2 effects would not invalidate the results. With respect to distributional effects, it was noted the inclusion of different farm types in the sample unit would capture such effects at the district level. Moreover, the regional analysis will also capture distributional effects at the country level.

Additional points:

(a) A critical report on the surveys can be published as a report (Martin Smith)
(b) The website will have both a public section a private section. In the private section, country team members will be able to pose questions and exchange ideas about the study. This section will be limited to only individuals involved in the project. The collated data will also be made available in this section. In the public section, reports on the project, such as the workshop, country and regional reports, and the methodology will be posted. The site will also have a digital library, which will be accessible to all.
(c) Methodology Document: By the time the surveys are completed, CEEPA in consultation with the Yale team will make available to all teams a guidance report on the Ricardian model.

After several discussions on the presentation of the "synthesis of unifies approach to the application of the river basin hydrological model and crop simulation model" the following were agreed upon:

River basin hydrology:

(a) Funding – Project management was to work on securing funding for this aspect of the project.
(b) Runoff data – CEEPA to coordinate with IWMI to provide runoff data to national teams and the regional economic analysis
(c) Consultative team – This team will comprise of 10 – 15 individuals with expertise in this area to advise IWMI

Crop simulation model:

(a) Applying the CROPWAT is an excellent opportunity for the project to test the model in all the districts in the study countries.
(b) FAO to provide data and advise country teams on how to apply the model. This is to be coordinated by CEEPA.
(c) CERES model to be applied in just a small number of countries with expertise in this area in the initial stages and later extended to other countries
(d) Training in modelling – Helmy Eid of the Egypt team and Wiltrud Durand of the South African team offered to train country teams in some of the complex models such as the CERES. However, it was agreed that the project first concentrates on the simplest FAO's crop response simulation modelling approach, after which the analysis could be extended to other complex modelling approaches.
(e) Funding – FAO (Martin Smith) was confident in securing additional funds to support this aspect of the project.

13.1 *Cameroon, Morocco and Tunisia studies*

There was brief presentation on similar studies undertaken in Cameroon, Morocco and Tunisia. The emphasis of the presentations was on the design of survey instruments, data collection and data collection problems.

The Cameroon study was undertaken in only one Province of the country – the south-western region on 120 farms. In the study, secondary data was mostly used based on six climatic zones. In Morocco, 40 locations over a 18 year period in provinces and not districts were used in the analysis and net revenue per province was used and not per farm. In Tunisia secondary data was supplemented with field survey. The secondary data covered a period of 8 years at district levels. Net revenue based on farm types per district was the response variable. Dr. Ernest Molua agreed to provide CEEPA with the questionnaire he used in the Cameroon study to help in drafting the current study's questionnaire.

13.2 *Concluding Remarks*

Rashid made the following remarks:

(a) He commended all participants for their good efforts, which made it possible for a good progress to be made with the study during Workshop 2002.
(b) CEEPA will follow-up on this good progress with respect to the tasks and guidelines for implementing the Ricardian model
(c) CEEPA will work with IWMI to draft the proposal for this aspect of the study
(d) CEEPA to work with FAO through Martin Smith in supporting the work on the crop response simulation modelling.
(e) Website address for the climate change study stated as http://www.ceepa.co.za/climatechange.html. The site was to ready in due course.

With regards to the website, Charles reiterated that there will be a private section and a public section. The private section will only be accessible to country teams, to be used mainly as an instrument to continue the discussion started at the workshop. Team members can also pose questions and exchange ideas on the site.

On funding, Charles noted that he is intensifying his efforts in this direction and hope that some funds may be available for smaller size training workshops in the course of the year before Workshop 2003. It is hoped that these smaller size workshops will be more technical in nature.

13.3 *Vote of Thanks*

Rashid again commended all the participants for their good efforts, which has made it possible for the project to make a good progress. He extended his special appreciation to Ariel Dinar, Charles Cormier and Arne Dalfelt, all of the World Bank for their tireless efforts in the implementation of the study. He also said thanks to Robert Mendelsohn, Martin Smith, IWMI and the International experts for their contributions. He made a special mention of Daléne du Plessis, the workshop coordinator, thanking her for all the work she put into making the workshop a very successful one.

Charles also expressed his appreciation to Rashid and his team at CEEPA for steering the project and organizing a very fruitful workshop.

Ariel expressed his appreciation to everyone who participated in the workshop. He noted the complicated and challenging nature of the project but said he was very pleased with the enthusiasm of the delegates and was hopeful and assured that the same enthusiasm will be carried through the length of the project for a very successful outcome.

13.4 *Venue for next workshop*

Delegates agreed unanimously that Workshop 2003 be held in Egypt. The specific details were left to the project management in consultation with the Egypt team to finalize.

13.5 *End of Workshop 2002*

Workshop 2002 ended at approximately 13:00 on Saturday, 7 December 2002.

Workshop Program

DAY ONE	**WEDNESDAY, 4 December 2002**
08:30 – 12:30	Arrival and Check-in at Hotel
12.30 - 13.30	Luncheon at Hotel
13:30 – 14:00	Registration of Participants
14:00 – 17:30	**SESSION 1: INTRODUCTION TO APPROACHES TO CLIMATE CHANGE IMPACTS ANALYSIS**

Chair: Rashid Hassan

14:00 – 14:30	Welcome notes and opening **Charles Cormier & Rashid Hassan**
14:30 – 14:45	Workshop Objectives and Program

	James Benhin
14:45 – 15:30	Introduction to Economic Impact Assessment Models
	Robert Mendelsohn
15:30 – 16:00	Afternoon Refreshments
16:00 – 16:30	Introduction to River Basin Hydrology Models

Kenneth Strzepek

16:30 – 17:00	**Introduction to Biological Crop Response Simulation Approaches**
	Martin Smith
17:00 – 17:30	**Discussion**

DAY TWO **THURSDAY, 5 December 2002**

8:30 – 13:00 **SESSION 2: METHODS OF ECONOMIC IMPACT ASSESSMENT**

Chair: Rachid Doukkali

08:30 – 10:00	**Robert Mendelsohn & Pradeep Kurukulasuriya**
10:00 – 10:30	Discussion
10:30 – 11:00	Morning Refreshments
11:00 – 12:15	**Robert Mendelsohn & Pradeep Kurukulasuriya**
12:15 – 13:00	Discussion
13:00 – 14:00	Luncheon
14:00 – 17:30	**SESSION 3: PLANS OF WORK FOR COUNTRY STUDIES I**

Chair: David Maddison

14:00 – 14:30	Ethiopia
	Abebe Tadege
14:30 – 15:00	Egypt
	Helmhy Eid
15:00 – 15:30	Discussion
15:30 – 16:00	Afternoon Refreshments
16:00 – 16:30	South Africa
	James Benhin
16:30 – 17:00	Zambia
	Suman Jain
17:00 – 17:30	Discussion

EVENING PROGRAM

DAY THREE **FRIDAY, 6 December 2002**

8:30 – 13:00 **SESSION 4: CROP SIMULATION AND RIVER BASIN HYDROLOGY APPROACHES**

Chair: Arne Dalfelt

08:30 – 10:00	River basin hydrology - **Kenneth Strzepek, Matthew McCartney & Daniel Yawson**
10:00 – 10:45	Discussion
10:45 – 11:15	Morning Refreshments
11:15 – 12:30	Crop response simulation models
	Martin Smith
12:30 – 13: 00	Discussion
13:00 – 14:00	Luncheon
14:00 – 17:00	SESSION 5: PLANS OF WORK FOR COUNTRY STUDIES II
	Chair: Slim Zekri
14:00 – 14:30	Niger **- Katiella Mai Moussa**
14:30 – 15:00	Senegal **- Diop Mbaye**
15:00 – 15:30	Discussion
15:30 – 16:00	Afternoon Refreshments
16:00 – 16:30	Ghana **- Joseph Adu**
16:30 – 17:00	Burkina Faso **- Leopold Some**

17:00 – 17:30 Discussion
EVENING PROGRAM

DAY FOUR SATURDAY, 7 December 2002
08:30 – 12:30 SESSION 6: SYNTHESIS AND CONCLUSIONS ON UNIFIED APPROACHES AND STANDARDIZED ANALYTICAL METHODS AND DATA

Chair: Ariel Dinar
08:30 – 10:30 Country Studies
Facilitating Panel: Rachid Doukkali, Slim Zekri, Reneth Mano & Ernest Molua
10:30 – 11:00 Morning Refreshments
11:00 – 12:30 Regional Studies
Facilitating Panel: Robert Mendelsohn, Kenneth Strzepek, Martin Smith, David Maddison & Fredrick Karanja
12:30 – 13:30 Luncheon
13:30 – 15:30 SESSION 7: CONCLUSION
Chair: Charles Cormier
13:30 – 14:00 Summary of unified approaches and data needs

Rashid Hassan & James Benhin
14:00 – 14:30 Discussion
14:30 – 15:00 The way forward
Ariel Dinar & Rashid Hassan
15:00 – 15:30 Discussion
15:30 Closing Remarks
Ariel Dinar & Rashid Hassan

DEPARTURE

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B. Cairo 2003

GRAND HYATT CAIRO, CAIRO, EGYPT
10 - 13 NOVEMBER 2003

ORGANIZED BY

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA), UNIVERSITY OF PRETORIA, SOUTH AFRICA

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AGRICULTURAL AND RURAL DEVELOPMENT DEPARTMENT, WORLD BANK
WORLD BANK INSTITUTE (WBI)
FOOD AND AGRICULTURE ORGANIZATIO (FAO)

Prepared by

James Benhin

1. Background and Objectives

In December 2003, a GEF funded study on climate change impact and adaptation on agro-ecological systems in Africa was formally launched in Cape Town, South Africa. The three-year study which covers eleven African countries, representing all of the ecological zones on the continent, is intended to provide empirical evidence on the role that climate plays in Africa today and how that might change with global warming. It also intends to assess the adaptation options open to African farmers in helping to mitigate the impact of global warming

The study is using four main methods of analysis to provide this empirical analysis. Two methods are intended generate estimates of the quantitative impacts of climate change (Ricardian approach, crop response simulation modeling). In addition, hydrological modeling will supplement the analysis by providing runoff estimates. Further, microeconomic modeling will be used to identify how African farmers already adapt to climate. The overall objective is to improve national and regional assessment of the economic impact of climate change on the agriculture sector in Africa and to determine the economic value of various adaptation options.

Workshop 2003 is the second of the three training workshops which forms part of the project activities aimed at ensuring consistency in approach and quality control necessary to provide a regional assessment of the vulnerability of African agriculture to climate change, and adaptation options, and to strengthen the local capacity to address these issues.

Workshop 2002 clearly defined specific objectives that need to be attained for the first year of the project within the broad goals of the study for the three of the four main approaches: Ricardian, crop response simulation modeling and the hydrological modeling. The main target was the completion of the farm household surveys in selected districts of the eight of the eleven study countries: Burkina Faso, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa and Zambia. Another target was the provision of runoff and other relevant data by the river basin hydrological modeling to feed into the Ricardian analysis. The role and responsibilities of each of the country and regional teams in achieving these objectives were also clearly defined

To help in achieving the objectives set in Workshop 2002, a training workshop on CROPWAT and WATBAL modeling for the crop response simulation modeling and the river basin hydrological modeling respectively was organised in June 2003 in Accra, Ghana. Eight countries of the eleven countries who were currently been funded were tasked to apply the CROPWAT modeling in two of the selected districts for the farm household surveys and a report on the exercise presented at Workshop 2003.

Workshop 2003 was therefore a form of evaluating how well the project has performed in the preceded year, to assess the shortcomings and what corrective measures to take to make sure the project is on track its short and long term objectives.

In addition, Workshop 2003 intended the following specific objectives:

(1) To improve the consistency of data and uniformity of analytical frameworks to be followed for completion of the country case studies and regional research;
(2) To make decisions on the best design and operation of an African-wide integrated database for the study.

2. Venue

The workshop was held at the Grand Hyatt Cairo in Cairo, Egypt from 10 – 13 November 2003.

3. Workshop Program (see at end)

4. Participants (see list of participants at end)

Participants were from universities, research and government institutions of the eleven African study countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia, and Zimbabwe.

Other participants were from: Agricultural and Rural Development Department, and the Climate Change Team (ENV) both of the World Bank, UN Food and Agriculture Organization (FAO), Yale University, the International Water and Management Institute (IWMI), the University of Colorado, Boulder and the University of Southern Denmark.

5. Brief Summary of Proceedings

The workshop started in the morning of Monday, 10 November 2003 and ended in the afternoon of Thursday, 13 November 2003, covering 13 main sessions.

The first day focussed on presentations and discussions of reports by the country teams on the farm household surveys, and preparations been made by Cameroon, Kenya and Zimbabwe to participate in the study. There was also a panel led discussions on the shortcomings of the surveys and how to bridge gaps in the data. The conclusions were based on the reports presented the eleven countries could be classified into four main groups:

(a) Countries which have completed their survey and data entry
(b) Countries which have completed their surveys and started with their data entry
(c) Countries which completed their surveys but yet the begin their data entry
(d) Countries which have yet to start their surveys

It was noted these different groups should share their experiences, as a way of improving each other performances. There was a consensus, however, that country teams have done an excellent work in spite of the several problems they encountered during the survey. It also worthy of note the serious preparation which have been made by Cameroon, Kenya and Zimbabwe to participate in the study as soon as funds are made available.

The first part of day 2 concentrated on a discussion of the progress report from IWMI and the University of Colorado with respect to the provision of runoff and other relevant dataset to feed into the Ricardian analysis, and future plans for the river basin hydrological modeling aspect of the project. In addition, there was a presentation by Frank Sperling of the Vulnerability and Adaptation Resource Group (VARG) of the World Bank on addressing vulnerability to climate change. In the second part of day 2 the discussions shifted to the database organization and the non-economic data required for the Ricardian analysis, and the theory and practice of the country and regional level analysis. The day ended with an introductory training in STATA, a statistical software package to be used for the Ricardian analysis. The training in STATA continued in the evenings of the rest of the workshop.

Day 3 focused on the progress report by the FAO on the application of the CROPWAT model and the future plans of work. In addition there were presentation and discussions on country teams report on the application of the CROPWAT to the two selected districts in their respective countries as tasked by the Accra workshop. There was also a presentation on climate model predictions with respect to the economic impact assessment.

In the first part of day 4 there was an exposition on the fourth approach for the analysis, that is the theory and practice of microeconomic analysis of farmers' adaptation and response. Participants then broke into three main groups with focus on the three main approaches for the analysis: Ricadian, crop response simulation modeling and the river basin hydrological modeling. The main task of the group was to clearly define the project objectives for the coming year given the presentation and discussions in the preceded three days.

In addition to these sessions there were presentations on similar studies by Frank Sperling from the World Bank on addressing vulnerability to climate change and Roland Schulze from the University of Natal in South Africa on bridging agricultural and water resources divides across scales of space and time in climate change impacts modeling. The workshop concluded with a discussions and a consensus on the reports from the three breakaway groups on the way forward with a clear definition of the task and responsibilities of the country and regional teams. Project management were then task with the responsibility of deciding on the venue for the coming year's annual workshop

6. Main issues agreed upon

Following discussions on the recommendations by the three breakaway groups on the Ricardian approach, the crop response simulation modeling and the River Basin Hydrology modeling, Workshop 2003 agreed on the following tasks with corresponding deadlines for 2004/2005

Economic impact assessment and adaptation analyses Plans for 2004-05

1. Completion of data entry, and submission of data file and copies of completed questionnaire to CEEPA by the first seven country teams (Burkina Faso, Egypt, Ghana, Niger, Senegal, South Africa, and Zambia) latest by **January 31, 2004**.
2. Cleaning of data by CEEPA and Yale and cleaned data sent back to country teams **(January/February 2003).**
3. For Ethiopia, Cameroon, Kenya and Zimbabwe it is expected that surveys and data entry will be completed by March-April and submission of data file and copies of completed questionnaire to CEEPA by end of **May 2004**
4. Given the bulkiness of completed questionnaires and the cost involved in sending them to CEEPA participants agreed that randomly selected completed questionnaires and problematic questionnaires identified during the data cleaning process in (2) will initially be sent to CEEPA. However, copies of all the completed questionnaires should eventually be sent to CEEPA. **May – July 2004.**
5. A 3-day technical training workshop on implementation of the Ricardian analysis for country team members responsible for the Ricardian component (one member per team). The objectives of the workshop include developing and implementing the estimation of a common model, construction of key variables to be used in the estimation and analysis, running basic diagnostic statistical tests on the chosen variables (i.e. multicolinearity, etc.) using Stata software. Date proposed is the **First week of May 2004 and possibly in South Africa.**
6. Country reports on four key sections of the Ricardian and adaptation analyses components need to be submitted by the 11 country teams for an internal review process (comments from all team members involved) no later than mid-**February 2004**. The four sections required are:

   A. Introduction and motivation to the Ricardian study section
   B. The analytical framework adopted for implementing the Ricardian economic impact assessment component and how it is adapted to country situations
   C. Methods employed for survey design and sampling for collection of the data
   D. Report on preliminary analyses of the adaptation section 7 of the survey (with the exception of Cameroon, Kenya and Zimbabwe)

7. Comments on these draft sections will be provided before and discussed during the **May 2004** analysis workshop.
8. Analysis and write up expected to be completed and first draft of the full country study reports submitted for internal review by end of **September 2004**.
9. Feedback and comments on full country study report drafts received before and discussed during the third annual workshop in **November/December 2004**
10. Comments of the internal review to be incorporateded by country teams in preparation of final drafts to be considered for publication as Working/Discussion Papers series **during 2005 (possibilities include joint publications by WB/CEEPA/GEF, etc.)**
11. First draft of the regional economic impact assessment study to be received and circulated for internal review **(End of October 2004)**
12. Microeconomic analysis of farmers' response and adaptation behaviour to be further investigated at the Ricardian analysis workshop in May 2004
13. Country teams to explore the data as much as possible, for undertaking multi-country or a sub-regional analyses in addition to planned research products

Crop Response Simulation Modeling

1. Continue using the CROPWAT model to complete the rest of the analysis making every effort to address its deficiencies in dealing with management/adaptation options and feedback effects of carbon emissions/concentrations.
    a. FAO to investigate the possibility of incorporating CO_2 effects in the CROPWAT analysis by adding a carbon concentration effects module.
    b. Assessment of management/adaptation options to be considered in the exercise include, changes in crop patterns and changes in technology.
2. Completion of the CROPWAT exercise for the two selected districts as agreed at the Accra Workshop and a report submitted to the FAO **(December 31, 2003)**
3. Extension of the country CROPWAT exercise to a minimum of one district in each of the defined agro-ecological zones plus districts with irrigation in the eleven countries. This exercise should be completed by **March 2004** and a progress report on the exercise from the FAO be submitted to CEEPA.
4. Extension of the CROPWAT exercise to all the selected districts for the country farm household survey and a progress report submitted to FAO **(May 2004)**
5. Dataset for the analysis for (2), (3) and (4) should be for the period 1961 – 1990, the same range of dataset been used by the river basin hydrological modeling.
6. Conduct an assessment of the impact of the selected CGM scenarios plus agreed upon sensitivity analyses scenarios by all country teams. Additional scenarios at country or regional levels may be evaluated as different country teams or regional teams may choose to do.
7. First drafts of country technical research study report on the above exercise must be received from FAO by CEEPA for internal review by **end of October 2004**.
8. Final reports on the above exercise must be ready and presented at the November/December 2004 workshop

River Basin hydrological modeling

The following plans for the hydrology component of the CC impact assessment are negotiated with the Colorado University Team:

1. IWMI (in collaboration with Colorado) to submit to CEEPA and country teams the following deliverables as per the current contractual agreement between CEEPA and IWMI): district level data on runoffs, stream flows and soil moisture plus a technical report on their work (**End of December 2004)**
2. To use the same Defence dataset to extend the runoff, stream flow, soil moisture and river density series generated for 1961-90 up to 2000
3. To generate CC scenarios prediction impacts on runoff and stream flows by district
4. To apply the lumped version to at least one basin in each country.
5. To compare the results of the lumped version with the gridded version. A draft report on this to be submitted to CEEPA (**June 2004)**
6. Country teams to undertake a qualitative description of water issues in respective countries as agreed at the Accra Workshop to be completed and a draft report submitted to CEEPA **(April 2004)**
7. Colorado to provide gridded data to country teams to undertake WATBAL analysis at the country level and a draft report submitted to CEEPA by country teams (**May 2004**)
8. Final reports on the above tasks to be ready and presented at the November/December 2004 workshop.

Other issues:

1. Country and regional teams to suggest outlines for policy briefs from country and regional reports. These suggestions should be sent to CEEPA
2. Country teams to provide a list of country officials and NGOs to be approached to participate in the final conference in 2005. The list should be sent to Ariel Dinar and CEEPA for the necessary follow-ups to be made in time before the 2005 workshop

Workshop Program

DAY ONE	**MONDAY, 10 November 2003**
08:30 – 09:00	Registration of Participants
09:00 – 09:30	Welcome notes and opening
	Ariel Dinar & Rashid Hassan
09:30 – 09:45	Workshop Objectives and Program
	James Benhin
09:45 – 16:00	**SESSION 1: FARM HOUSEHOLD SURVEYS**

Chair: Robert Mendelsohn

09:45 – 10:00	Ethiopia - **Abebe Tadege**
10:00 – 10:15	Egypt - **Helmy Eid**
10:15 – 10:30	Discussion
10:30 – 11:00	Morning Refreshments
11:00 – 11:15	South Africa **- James Benhin**
11:15 – 11:30	Zambia - **Suman Jain**
11:30 – 11:45	Discussion
11:45 – 12:00	Niger **- Katiella Mai Moussa**
12:00 – 12:15	Senegal - **Mbaye Diop**
12:15 – 12:30	Discussion
12:30 – 13:30	Luncheon
13:30 – 13:45	Ghana **- Joseph Adu**
13:45 – 14:00	Burkina Faso **- Leopold Somé**
14:00 – 14:15	Discussion
14:15 – 15:30	**PRESENTATIONS BY CAMEROON, KENYA & ZIMBABWE**
14:15 – 14:30	Cameroon - **Ernest Molua**
14:30 – 14:45	Kenya - **Fredrick Karanja**
14:45 – 15:00	Zimbabwe - **Reneth Mano**
15:00 – 15:30	Discussion
15:30 – 16:00	Afternoon Refreshments
16:00 – 17:30	**SESSION 2: FARM HOUSEHOLD SURVEYS: PANEL DISCUSSION**

	Chair: Robert Mendelsohn
	Facilitating Panel: **Rashid Hassan, Ariel Dinar, David Maddison & Pradeep Kurukulasuriya**
17:30	**End of Day One**
DAY TWO	**TUESDAY, 11 November 2003**
08:30 – 10:00	**SESSION 3: RIVER BASIN HYDROLOGY MODELING**
	Chair: David Maddison
08:30 – 09:00	Progress report (Dataset for Ricardian analysis using WATBAL): **IWMI**
09:00 – 09:30	Plans for future work: **IWMI**
09:30 – 10:00	Discussion
10:00 – 10:30	Addressing vulnerability to climate change: Inter-agency cooperation on mainstreaming adaptation into development practices - **Frank Sperling**
10:30 – 11:00	Morning Refreshments
11:00 – 12:30	**SESSION 4: ECONOMIC IMPACT ASSESSMENT: RICARDIAN**

Chair: David Maddison

11:00 – 11:30	Non-economic Data - **Pradeep Kurukulasuriya**
11:30 – 12:00	Database organization - **Pradeep Kurukulasuriya**
12:00 – 12:30	Discussion
12:30 – 13:30	Luncheon
13:30 – 15:30	**SESSION 5: ECONOMIC IMPACT ASSESSMENT: RICARDIAN**
	Chair: David Maddison
	Theory and Practice of Country Level and Regional Analysis **- Robert Mendelsohn & Pradeep Kurukulasuriya**
15:30 – 16:00	Afternoon Refreshments
16:00 – 17:00	**SESSION 6: ECONOMIC IMPACT ASSESSMENT: RICARDIAN**
	Chair: David Maddison

Climate Model Predictions - **Robert Mendelsohn**

17:00	**End of Day Two**
DAY THREE	**WEDNESDAY, 12 November 2003**
08:30 – 09:45	**SESSION 7: CROP RESPONSE SIMULATION MODELING**
	Chair: Frank Sperling
08:30 – 09:00	Progress report on CROPWAT - **Giovanni Muñoz**

09:00 – 09:15 Plans for future work - **Giovanni Muñoz**

09:15– 09:45 Discussion

09:45 – 13:00 SESSION 8: CROP RESPONSE SIMULATION MODELING – COUNTRY STUDIES

Chair: Giovanni Muñoz

09:45 – 10:00 Ghana **- Joseph Adu**

10:00 – 10:15 Burkina Faso **- Leopold Some**

10:15 – 10:30 South Africa - **Wiltrud Durand**

10:30 – 11:00 Morning Refreshments

11:00 – 11:15 Senegal **– Mbaye Diop**

11:15 – 11:30 Niger **- Katiella Mai Moussa**

11:30 – 11:45 Egypt - **Helmy Eid**

11:45 – 12:15 Discussions

12:00 – 12:15 Zambia - **Tamala Kambikambi**

12:00 – 12:15 Ethiopia - **Kidane Georgis**

12:15 – 13:00 General discussion of plans for further work on crop response

13:00 – 14:00 Luncheon

14:00 – 15:30 SESSION 9:ECONOMIC IMPACT ASSESSMENT: RICARDIAN – PREDICTIONS OF IMPACTS

Chair: Giovanni Muñoz

- Robert Mendelsohn & Pradeep Kurukulasuriya

15:30 – 16:00 Afternoon Refreshments

16:00 – 17:00 SESSION 10: ECONOMIC IMPACT ASSESSMENT

Chair: Giovanni Muñoz

Microeconomic Theory and Adaptation - **Robert Mendelsohn**

17:00 End of Day Three

EVENING PROGRAM

DAY FOUR THURSDAY, 13 November 2003

08:30 – 10:00 SESSION 11: ECONOMIC IMPACT ASSESSMENT

Chair: Ariel Dinar

08:30 – 10:00 Microeconomic Analysis of Farmers' Adaptation and Response Strategies - **Pradeep Kurukulasuriya**

10:00 – 10:30 Morning Refreshments

10:30 – 12:30 SESSION 12: BREAK AWAY GROUPS ON THE THREE APPROACHES

Group 1: Ricardian Approach led by Yale University

Group 2: River basin hydrology modeling led by IWMI

Group 3: Crop response modeling led by FAO

12:30 – 13:30	Luncheon
13:30 – 15:30	**SESSION 13: GROUPS REPORTS AND DISCUSSION OF GROUPS RECOMMENDATIONS**
	Chair: Rashid Hassan
	Facilitating Panel - **Yale University, IWMI, FAO**
13:30 – 13:45	**Group 1: Report**
13:45 – 14:00	Discussion of Group 1 Report
14:00 – 14:15	**Group 2 Report**
14:15 – 14:30	Discussion of Group 2 Report
14:30 – 14:45	**Group 3 Report**
14:45 – 15:00	Discussion of Group 3 Report
15:00 – 15:30	General discussion on the way forward
15:30 – 16:00	Afternoon Refreshments
16:00 – 17:00	**SUMMARY AND CONCLUSIONS ON THE WAY FORWARD**
	Chair: Ariel Dinar
16:00 – 16:15	Summary report - **Rashid Hassan & James Benhin**
16:15 – 17:00	Discussion
17:00 – 17:30	Closing Remarks - **Rashid Hassan & Ariel Dinar**

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<u>C. Zaragoza 2004</u>

UNDERSTANDING AND ADAPTING TO CLIMATE CHANGE: WHAT CAN THE WORLD LEARN FROM AFRICA'S EXPERIENCE

MEDITERRANEAN AGRONOMIC INSTITUTE (IAMZ), ZARAGOZA, SPAIN, 13 – 16 DECEMBER 2004

ORGANIZED BY

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA), UNIVERSITY OF PRETORIA, SOUTH AFRICA

IN COLLABORATION WITH THE MEDITERRANEAN AGRONOMIC INSTITUTE (IAMZ)

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AGRICULTURAL AND RURAL DEVELOPMENT DEPARTMENT, WORLD BANK
AFRICA REGION, WORLD BANK
WORLD BANK INSTITUTE
FOOD AND AGRICULTURE ORGANIZATIO (FAO)

Prepared by

James Benhin

1. Background and Objectives

In December 2002, the GEF funded study on climate change impact and adaptation on agro-ecological systems in Africa was formally launched in Cape Town, South Africa. The three-year study covers eleven African countries, which represents all the different climatic regions and the diverse agricultural activities across the continent. The study is one of the first analyses of climate impacts and adaptation in Africa. It is intended to provide empirical evidence on the role that climate plays in Africa today and how that might change with global warming and to determine the economic value of various adaptation options (see GEF Africa agriculture and climate change project document (2002 - 2005)).

The study uses four methods of analysis. Two generate estimates for the quantitative impacts of climate change – Ricardian approach and the crop response simulation modelling. Hydrological modelling supplements these analyses by providing hydro-climatic data for the Ricardian model. And, microeconomic modelling identifies how African farmers already adapt to climate change.

Workshop 2004 is the final of the three annual training workshops, which form part of the project activities aimed at ensuring consistency in approach and quality control necessary to provide a regional assessment of the vulnerability of African agriculture to climate change, and adaptation options, aimed at strengthening local capacity to address these issues.

The first annual training workshop, Workshop 2002, clearly defined specific objectives that needs to be attained for the first year of the project within the broad goals of the study for three of the four main study methodologies: Ricardian, crop response simulation modelling and the hydrological modelling. The main target was the completion of the farm household surveys in selected districts of the eight of the eleven study countries: Burkina Faso, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa and Zambia. Another target was the provision of runoff and other relevant hydro-climatic data by the river basin hydrological modeling to feed into the Ricardian analysis. The role and responsibilities of each of the country and regional teams in achieving these objectives were also clearly defined (see Cape Town workshop report – INSERT website).

To help in achieving the objectives set in Workshop 2002, a training workshop on CROPWAT and WATBAL modeling for the crop response simulation modeling and the river basin hydrological modeling respectively, was organised in June 2003 in Accra, Ghana. Eight of the eleven countries with initial funding for their country studies were tasked to apply the CROPWAT modeling in two districts in their sample for the farm household surveys and report on the exercise at the annual workshop in 2003.

Workshop 2003 was therefore a form of evaluating how well the project has performed in the preceded year, assess the shortcomings and what corrective measures to take to make sure the project is on track to meeting its short and long term objectives.

In addition, Workshop 2003 achieved the following specific objectives: (i) consistency in country level and other relevant data and, uniformity of analytical frameworks to be followed for completion of the country case studies and regional research; (ii) Finalize decisions on the best design and operation of an African-wide integrated database for the study.

Given this backdrop, Workshop 2004 focused on (i) a rigorous review and critical evaluation of the preliminary empirical results of the national studies and provide suggestions for improving the analyses and interpretation of study results and findings and their policy implications; (ii) a review and evaluation of the results of the regional assessment studies on the potential economic and hydrological impacts and crop responses of climate change on agro-ecosystems in Africa and the various adaptation options. The discussions were complemented by presentations of similar studies in Latin America and Israel, as well as adaptation studies by the Environment Department of the World Bank.

2. Venue and date

The workshop was held at the Mediterranean Agronomic Institute (IAMZ) in Zaragoza, Spain, from 13 – 16 December 2004.

3. Workshop Program (see at end)

4. Participants (see list at end)

Participants were from universities, research and government institutions of the eleven African study countries: Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia, and Zimbabwe.

Other participants were from: Agricultural and Rural Development Department, and the Climate Change Team (ENV) both of the World Bank, World Bank Institute, Yale University, UN Food and Agriculture Organization (FAO), the University of Colorado, Boulder, University College, London (UCL), Hebrew University of Jerusalem, Israel, and seven Latin American countries – Brazil, Chile, Argentina, Ecuador, Venezuela and Uruguay.

5. Brief Summary of Proceedings

The workshop started on the morning of Monday, 13 December 2004 and ended in the afternoon of Thursday, 16 December 2004, covering 11 main sessions.

The first day focussed on presentations and discussions of the survey and data entry reports from Ethiopia, Cameroon, Kenya and Zimbabwe. The other seven countries: Burkina Faso, Egypt, Ghana, Niger, Senegal, South Africa and Zambia, made presentations on their preliminary country level estimated Ricardian models. These initial estimates were necessary for comparative purposes in order to assess the impact of annual temperature and precipitation variable on net revenues. Countries were tasked to build on the initial estimations to investigate models which best describe agricultural activities in their respective countries by the inclusions of specific climate variables (either annuals or seasonals), soils variables following the approach from Zambia, hydrology variables (runoffs and/or flows – though flows were find to be more appropriate), and other socioeconomic variables. The Latin American countries also benefited from the shared experiences of the 11 African countries on the problems they encountered administering the farm household questionnaires and how they dealt with them.

Day two was initially planned for three main sessions. Given the absence of Prof. Alberto Garrido and Dr. Ana Igesias, both from the Universidad de Madrid to speak on "Vulnerability and adaptation to climate change in the Mediterranean: implications for drought management", the day was devoted to other two main sessions. The first session focused on the presentation and discussion of the regional analyses – economic impact assessment (Ricardian), river basin hydrology modelling (WATBAL) and the crop response simulation modelling (CROPWAT). The second session discussed the preliminary finding of the country level implementation of the CROPWAT with the focus on (i) implications of the estimated crop water use for agricultural activities in the selected two districts; (ii) summary of the crop water use for selected important crops in other districts in the sample and; (iii) implications of the estimated crop water use of the selected important crops for agricultural activities in the respective countries.

There were four main sessions on day three. In the first session, Prof. David Maddison presented initial results from the GEF project's study on perception of and adaptation to climate change by African farmers. Dr. Habiba Gitay, who stood in for Dr. Fareeq Iqbal also made a presentation on "A screening and design tool to help project managers take account of climate change". The second session of the day focussed on presentations from related studies from Israel by Dr. Aliza Fleischer, and from participants from Latin America. The third session was a four group breakout sessions to discuss and make suggestions on the planned integrated regional analysis and the contents of other outputs for the project. The day ended with a training session on the Ricardian approach using the Stata statistical software.

On the final day the reports from the breakout groups were presented and discussed. There was also a consensus on the plans for the final year of the project. Possibilities for extending the project for an in depth analyses of the perception and adaptation of climate change by African farmers at the country and regional level was also discussed.

6. **General Issues Agreed Upon**: Plans and targets for 2005

6.1. PLANS:

- Produce research results
- Continue capacity strengthening and promote more networking
- Publicize and communicate policy implications
- Extend the life of the project (fund another phase)

6.1.2 Research products

- Lead paper in Science (Yale and all Ricardian teams)
- Special Journal issue (Environment and Development Economics (EDE), all teams)
- Project reports
    - Economic impact
        - Regional (Yale)
        - Country reports (11)
    - Hydrological impacts (2 – Colorado and IWMI)
    - Perceptions and adaptations (Maddison)
    - Crop response (FAO and country teams)
        - Regional synthesis and country reports (possibly with Ricardian reports)

6.1.3 Capacity support and networking

- Technical training workshop
- Stata Program code guide
- Promote more networking and collaboration (Sub-regional teams)

    - West
    - East and South
    - Egypt & Israel
    - Other

6.1.4 Dissemination of research results

- Lead paper for international publicity
- Policy briefs
    - Continental
    - Sub-regional (SADC, ECA, etc)
    - Country level
- Final conference (under discussion)
- The future beyond 05 (maintain and expand network and research)
    - Proposal and communication with donors

6.2. TARGETS:

6.2.1 February 2005

- All data in
    - Kenya, Zimbabwe, Ethiopia, Cameron
        - Complete surveys and data entry
    - South Africa – additional surveys
    - Colorado (Hydrological impact)
        - Improved climate variables (Runoff, Flow, etc.)
    - Yale (Economic impact)
        - Complete cleaning of data of first seven countries
        - Explore the potential of first sub-regional analysis for West Africa

6.2.2 March 2005

- Colorado
    - Hydrological impacts of climate scenarios
- Yale and country teams
    - Finalize cleaning of new data
    - Cleaning of perceptions-adaptation data
    - Climate scenarios for country teams
    - Stata program codes guide for data processing and analysis
- CEEPA
    - Template and style guide for project reports
    - Publish the Stata program codes guide (printed and electronic)
- Submit lead paper to Science

6.2.3 April – June 2005: Data Analyses

- First draft of all project reports in by June 15
    - Yale and country teams (economic impact assessment reports)
    - Colorado (hydrological impacts report)
    - FAO and country teams (CROPWAT reports)
    - Maddison (perception and adaptations report)
- Special issue articles received for review (some will come earlier as they are ready)

6.2.4 July 2005

- Cleaning of livestock data (Yale and country teams)
- Mid-year technical training and research workshop
    - Training on micro analyses of farmers' adaptations

  - Training on Ricardian analyses of livestock data
  - Comments on first draft project reports
- Remaining Special Issue manuscripts out for review

6.2.5 August – September 2005
- Completing analyses
- All project reports final drafts in (September 30)
- Revised Special Issues manuscripts received from authors (September 30)

6.2.6 October – December 2005
- Publish project reports – printed and website (CEEPA)
- Produce and publish policy briefs from project reports (A. Dinar)
- Finalize the Special Issue (expect printing in Nov-Dec)
- Final conference (may be December 2005)
- Secure funding for extension of project

Workshop Program

DAY ONE MONDAY, 13 December 2004

09:00 – 09:15 Registration of Participants

09:00 – 09:45 Welcome Remarks and Opening Comments

Ariel Dinar, Cary Anne Cadman, Rashid Hassan & Dunixi Gabina

09:45 – 10:00 Workshop Objectives and Program

James Benhin

10:00 – 11:30 SESSION 1: ECONOMIC IMPACT ASSESSMENT - COUNTRY SURVEY REPORTS

Chair: David Maddison

10:00 – 10:15 Ethiopia: **Temesgen Deressa**

10:15 – 10:30 Zimbabwe: **Reneth Mano**

10:30 – 10:45 Kenya: **Fredrick Karanja**

10:45 – 11:00 Cameroon: **Ernest Molua**

11:00 – 11:15 Discussion

11:15 – 11:30 Morning Refreshments

11:30: – 17:15 SESSION 2: ECONOMIC IMPACT ASSESSMENT – PRELIMINARY FINDINGS OF COUNTRY ANALYSES

Chair: Robert Mendelsohn

11:30 – 11:45 Datasets for country analyses – **Pradeep Kurukulasuriya**

11:45 – 12:00	Discussions
12:00 – 12:15	Zambia: **Suman Jain**
12:15 – 12:30	South Africa: **James Benhin**
12:30 – 12:45	Discussant: **David Maddison**
12:45 – 13:00	Discussion
13:00 – 14:00	Luncheon
14:00 – 14:15	Ghana **- Yerfi Fosu**
14:15 – 14:30	Senegal **- Diop Mbaye**
14:30 – 14:45	Discussant: Rashid Hassan
14:45 – 15:00	Discussion
15:00 – 15:30	Afternoon Refreshments
15:30 – 15:45	Niger: **Ali Mohamadou**
15:45 – 16:00	Burkina Faso **- Mathieu Ouedrago**
16:00 – 16:15	Discussant: **Ariel Dinar**
16:15 – 16:30	Discussion
16:30 – 16:45	Egypt: **Samia El-Marsafawy**
16:45 – 17:00	Discussant: **Pradeep Kurukulasuriya**
17:00 – 17:15	Discussion

End of Day one

DAY TWO	**TUESDAY, 14 December 2004**
09:00 – 13:30	**SESSION 3: REPORTS ON REGIONAL STUDIES**
	Chair: Cary Anne Cadman
09:00 – 09:30	River basin hydrology modeling - **Colorado**
09:30 – 09:50	Discussion
09:50 – 10:30	Economic Impact Assessment - **Yale**
10:30 – 11:00	Discussion
11:00 – 11:30	Morning Refreshments
11:30 – 12:00	Crop response simulation modeling (CROPWAT) - **FAO**
12:00 – 12:20	Discussion
12:20 – 13:00	**SESSION 4: CLIMATE CHANGE IMPACTS – RELATED STUDIES IN EUROPE**
	Chair: Cary Anne Cadman
12:20 – 13:00	Vulnerability and adaptation to climate change in the Mediterranean: Implications for drought management **– Alberto Garrido and Ana Iglesias, Universidad Politecnica de Madrid**
13:00 – 13:30	Luncheon

13:30 – 17:45	**SESSION 5: CROP RESPONSE SIMULATION MODELING (CROPWAT) – PRELIMINARY FINDINGS OF COUNTRY STUDIES (TWO DISTRICTS AND EXTENSIONS)**
	Chair: Giovanni Munoz
13:30 – 13:45	Ghana **- Joseph Adu**
13:45 – 14:00	Burkina Faso **- Leopold Some**
14:00 – 14:15	South Africa - **Wiltrud Durand**
14:15 – 14:30	Discussion
14:30 – 14:45	Senegal **- Diop Mbaye**
14:45 – 15:00	Niger **- Katiella Mai Moussa**
15:00 – 15:15	Egypt - **Helmy Eid**
15:15 – 15:30	Discussion
15:30 – 16:00	Afternoon Refreshments
16:00 – 16:15	Zambia – **Suman Jain**
16:15 – 16:30	Ethiopia - **Kidane Georgis**
16:30 – 16:45	Kenya - **Fredrick Karanja**
16:45 – 17:00	Discussion
17:00 – 17:15	Cameroon - **Cornelius Lambi**
17:15 – 17:30	Zimbabwe - **Emmanuel Manzungu**
17:30 – 17:45	Discussion

End of Day Two

EVENING PROGRAM

DAY THREE	**WEDNESDAY, 15 December 2004**
09:00 – 11:00	**SESSION 6: ADAPTATIONS TO CLIMATE CHANGE**
	Chair: Rashid Hassan
09:00 – 09:30	Perceptions and adaptation to climate change in Africa – **David Maddison**
09:30 – 09:45	Discussions
09:45 – 10:15	A screening and design tool to help project managers take account of climate change - **Fareeha Iqbal**, **Consultant, The World Bank**
10:15 – 10:30	Discussions
10:30 – 11:00	Morning Refreshments
11:00 – 14:00	**SESSION 6: CLIMATE CHANGE IMPACTS – RELATED STUDIES IN AFRICA, EUROPE, LATIN AMERICA AND ISRAEL**
	Chair: Rashid Hassan
11:00 – 11:30	Climate change and land use in Africa **– Guenther Fischer, IIASA**
11:30 – 12:00	Climate change and land use in Latin America **- Latin American Group**

12:00 – 12:30	"Global Warming and Technological Innovations - Survey Preparation and Preliminary Results from Israel" – **Aliza Fleischer, Hebrew University of Jerusalem**
12:30 – 13:00	Discussion
13:00 – 14:00	Luncheon
14:00 – 15:30	**SESSION 8: BREAKOUT GROUPS ON INTEGRATED SUB-REGIONAL ANALYSES** **Group 1: Western Africa – Burkina Faso, Cameroon, Ghana, Niger, Senegal** **Group 2: Eastern Africa – Ethiopia, Kenya** **Group 3: Northern Africa - Egypt** **Group 3: Southern Africa – South Africa, Zambia, Zimbabwe**
15:30 – 16:00	Afternoon Refreshments
16:00 – 17:30	**SESSION 9: ECONOMIC IMPACT ASSESSMENT: TRAINING ON APPLICATIONS OF THE RICARDIAN ANALYSIS TO COUNTRY LEVEL (CAMEROON, ETHIOPIA, KENYA, ZIMBABWE, LATIN AMERICA AND ISRAEL)** - **Yale**

End of Day Three

DAY FOUR	**THURSDAY, 16 December 2004**
09:00 – 12:00	**SESSION 10: CONCLUSIONS AND THE WAY FORWARD**
	Chair: Ariel Dinar
09:00 – 11:45	**Planning for project outputs**
09:00 – 09:10	Country studies report – **James Benhin**
09:10 – 09:20	Regional studies report (Economic impact assessment) - **Yale**
09:20 – 09:30	Regional studies report (River basin hydrology modeling) - **Colorado**
09:30 – 09:40	Regional studies report (Crop response simulation modeling - CROPWAT) – **FAO**
09:40 – 09:50	Regional studies report (Perceptions and adaptation) – **David Maddison**
09:50 – 10:10	Discussion
10:10 – 11:00	Sub-regional reports – **Rashid Hassan** - Report back from breakaway groups - Discussion
11:00 – 11:15	Morning Refreshment
11:15 – 11:45	Book - **Rashid Hassan**
11:45 – 12:30	**Other products and dissemination**
11:45 – 12:00	Policy briefs, Papers / articles
12:00 – 12:15	Final Conference
12:15 – 12:30	What next? Extension of work to complete perception and adaptation study
12:30 – 13:00	**Closing Remarks: Ariel Dinar, Cary Anne Cadman & Rashid Hassan**
13:00 – 14:00	Luncheon

14:00 – 16:30 **SESSION 11: ECONOMIC IMPACT ASSESSMENT: TRAINING ON APPLICATIONS OF THE RICARDIAN ANALYSIS TO COUNTRY LEVEL (CAMEROON, ETHIOPIA, KENYA, ZIMBABWE, LATIN AMERICA AND ISRAEL)**

- **Yale**

DEPARTURE

List of Participants: ZARAGOZA, SPAIN 13 – 16 DECEMBER 2005-05

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A2.2 Project Training Workshops' Reports

A. Accra 2003

TRAINING WORKSHOP ON CROP RESPONSE SIMULATION AND RIVER BASIN HYDROLOGY MODELING

ACCRA- GHANA, 23 - 26 JUNE 2003

ORGANIZED BY

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA), UNIVERSITY OF PRETORIA, SOUTH AFRICA

IN COLLABORATION WITH THE
INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI) - GHANA

CO-FUNDED BY
THE MACARTHUR FOUNDATION AND THE FINNISH TRUST FUND

WITH COMPLEMENTARY SPONSORSHIP FROM:

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA)
INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI)
UNITED NATIONS FOOD AND AGRICULTURE ORGANIZATION (FAO)

Prepared by

James Benhin

11. Background and Objectives

Agriculture and agro-ecological systems are the most vulnerable sectors because the climates of many African countries are already hot. Further warming is consequently expected to reduce crop productivity adversely. This is of particularly concern also because of weak adaptability of farmers and agricultural production systems in Africa. The GEF funded study of climate change impact in eleven countries in Africa cutting across different climatic conditions is one of the first analyses of climate impacts and adaptation in Africa and is intended to provide empirical evidence on the role that climate plays in Africa today and how that might change with global warming. (See GEF Africa agriculture and climate change project document (2002 - 2005))

The launching and training Workshop of the project held in Cape Town, South Africa, 4 - 7 December 2002, adopted the Ricardian analysis to assess the economic impact of climate change on African agriculture. It was also recommended to initiate parallel analyses in crop response simulation and river basin hydrology modeling. To make the latter possible it was agreed to organize a training workshop to improve upon the capacity of country teams to apply these two approaches for the study. (See Cape Town Workshop Report). The "Training workshop on crop response simulation and river basin hydrology modeling" (Accra Workshop), is a realisation of this objective. The workshop also forms part of the project's activities aimed at ensuring consistency in approach and quality control necessary to provide regional assessment of the vulnerability of African agriculture to climate change, and adaptation options, and to strengthen the local capacity to address these issues.

The Accra workshop focused mainly on training participants in the use of CROPWAT and WATBAL models for the crop response simulation and the river basin hydrology aspects of the project respectively.

The Accra workshop intended the following specific purposes:

(e) To provide further training to country teams on two of the study methodologies and data needs;
(f) To further harmonize the technical capacity of the national teams to ensure quality of the country analyses and reports with respect to the use of the two methodologies;
(g) To allow transfer of experience between the international experts and African experts; and
(h) To exchange information on data potential-problems and discuss possible solutions to the problems.

12. Venue

The workshop was held at the Novotel Hotel in Accra, Ghana.

13. Workshop Program (see at end)

14. Participants: (see list at end)

Participants came from universities, research and government institutions of eleven African countries; Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia, and Zimbabwe,

Resource persons from the UN Food and Agriculture Organization (FAO), and the International Water Management Institute (IWMI) in South Africa led the training sessions.

A representative from the IWMI office in Ghana opened the workshop with the closing address delivered by the FAO Ghana representative.

15. SUMMARY OF PROCEEDINGS

The workshop started on the morning of 23 June 2003 and ended in the afternoon of 26 June 2003. The four-day training was divided into two main parts of two-day each consisting of seven main sessions. The first two days was devoted to the river basin hydrology modeling which was led by Matthew McCartney and Daniel Yawson, both of IWMI – South Africa. The last two days focused on training in crop response simulation modelling and was led by Giovanni Muñoz from the FAO. Also on the last day, participants discussed the way forward with respect to how these two approaches were to be adopted for the study, what data problems were envisaged and how these problems were to be addressed.

The training session had four main parts: theoretical; practical; hands-on practical sessions in which each participant had the opportunity to undertake some modelling with the CROPWAT and WATBAL; and a fourth part which focused on discussion on the application of the models to the current study.

The first day was devoted to:

- A brief overview of hydrological processes affecting runoff and how these might be influenced by climate change;
- Principles of rainfall–runoff modelling and different types of model; and
- Introduction to the WATBAL model.

In both the morning and afternoon sessions, presentations on the topic under consideration were interspersed with group discussions of relevant issues emanating from the sessions. Group discussions focussed on the links between climate and runoff, how climate change might impact on runoff and the possible impact of changes in hydrology on agriculture. These discussions were animated and highlighted participants understanding and perception of climate and hydrology. The interactive nature of the workshop allowed participants ample opportunity to ask supplementary questions and discuss issues, particularly as they relate to this GEF study.

The first part of the second day was devoted to the computer exercise for the river basin hydrological modeling (i.e. practical and hands-on practical sessions). This provided the opportunity for participants to get hands-on experience of using the WATBAL software. The exercise took the participants through the following steps:

- Installing the software;
- Preparing data for input to the model;
- Calibrating the model;
- Validating the model; and
- Using the model to simulate the impact of a climate change scenario on runoff.

The afternoon of the second day focussed on discussion of using the "gridded" version of the WATBAL model, linked to a river network generated by a digital elevation model, for the current study. This alternative was recommended for the study because of the difficulty in modeling runoffs within each district separately. There were also discussions on the data required to successfully undertake this exercise and country teams' responsibilities in providing the required data. Finally, there were discussions on potential problems that may be faced by country teams in their attempt to provide the needed data.

To make the above possible, each participant was provided with the following materials:

- Copies of all the presentations given;
- Guidelines on the use of WATBAL;
- A copy of the WATBAL software;
- A copy of the training exercises developed for the course

The third day was devoted to presentations on the crop response simulation modeling. The presentations focused on the importance of water to agriculture for the attainment of food security, the role of the FAO in promoting responsible water use, through to how to estimate crop water requirements for higher crop productivity as well as minimizing the waste of scare water resources. The following specific topics were discussed:

- No agriculture without water;
- Introduction to FAO/AGLW programme on crop water productivity;
- Introduction to modeling: Crop modeling –potential production;
- The FAO monitoring and forecasting approach;
- DSSAT-Cropping System Model;
- Soil water balance of a cropped soil; and
- Evapotranspiration: calculating the crop water requirements.

The following FAO databases and software were also distributed to country teams:

- Working towards unlocking the water potential of agriculture;
- FAO agriculture information management series;
- Digital soil map of the world and derived soil projections;
- The multilingual soil profile database;
- Atlas of water resources and irrigation in Africa;
- World-wide agro-climatic database;
- LOCCLIM – Local climate estimates; and
- CROPWAT software.

Country teams also received from CEEPA, by courtesy of the International Maize and Wheat Improvement Centre (CIMMYT), CD copies of AWHERE-ACT (a software package of datasets and query tools targeted for use in agriculture and natural resource management activities) and the "Africa Maize Research Atlas."

The morning of day four concentrated on various internet-based databases from the FAO, which could be used for the project. The main focus of the day, however, was on estimating crop water requirement using the CROPWAT. The afternoon focused on the discussion of the plan of work on the crop response simulation modeling for the project.

During the four-day session, country representatives together with Pradeep Kurukulasuriya, member of the Regional Economic Assessment team also made time to discuss comments from the pre-tests of the survey instrument and finalized the instrument for the country-level farm household surveys.

16. General Issues agreed upon

6.1 River Basin Hydrology modeling (WATBAL):

It was reiterated, following the conclusions reached at the December 2002 Workshop in Cape Town, that the WATBAL modeling would be undertaken at the regional level. This stems from the difficulty of modeling runoffs within each district individually and so a “gridded” form of the WATBAL model, linked to a river network generated by a digital elevation model should be more appropriate.

However, there was a feeling among some country teams of been only used as data collectors and not been involved in the analysis. In response to this, the experts from IWMI agreed to investigate the possibility of providing the country teams with a gridded version of the model which could be could applied at the country level to make possible the participation of the country team in the analysis. However, it was agreed that in the mean time the main responsibility of country teams is to provide relevant data to IWMI, which will be used to generate runoff data and soil moisture content, as variables within the Ricardian analysis. Country teams were also assured that given that the Ricardian analysis would also be applied at the country level and the hydrology modeling will feed into the analyses they are fully involved in the study analyses and not only in data collection activities.

WATBAL Data Requirements

Following the discussion on the afternoon of 24 June the following were a prioritised list of data to be provided by country teams to feed into the hydrological modeling component of the study.

- Time series (monthly time step) from twenty flow-gauging stations located on the main rivers around the country
    - The selected stations should ideally reflect a reasonable spatial distribution across the whole country
    - For each station a nearly complete record for a 30-year period 1961 to 1990, but continuing as close to present day as possible
    - For each gauging station selected: the latitude, longitude, catchment area and name of the river on which it is located
- Maps (electronic if possible) showing the main river network in the country and the location of the selected gauging stations
- GIS coverage showing the land-use in the country (to be provided by Pradeep Kurukulasuriya)
- GIS coverage of the districts selected for the socio-economic data collection (to be provided by Pradeep Kurukulasuriya)
- A brief description of the main hydrological features of the country – agro-ecological zones, rainfall patterns, drainage network and primary drainage basins and Impacts of major droughts and floods over the last 30-40 years.

All items requested should be sent to IWMI by mid-August 2003. It was anticipated that the meteorological data required for the hydrological modeling would be obtained from existing databases (e.g. UEA LINKS dataset and FAO’s CLIMWAT dataset).

6.2 Crop Response Simulation Modeling: Country Team Activities with CROPWAT

Following the discussions on 26 June, it was agreed that each country team would compile a set of basic data from two selected districts and compile and process district data with CROPWAT, according to the list below (July – October 2003). The objective will be to calibrate model coefficients to reflect as closely as possible the amount of water currently used by crops. For this part of the study FAO will assist the country teams in the processing of data with CROPWAT. Country teams at the annual meeting scheduled for November 2003 would present a report on the results of this exercise.

At the beginning of 2004, each country team will also use the model for data processing in other districts and farming systems in line with guidelines provided by FAO and prepare a report on the outcome to be presented in the annual meeting foreseen in December 2004.

CROPWAT Data Requirements

District information:

- Proposed number of districts
- General description of agriculture in the district
- Agro-ecological zoning

Climate information:

- Name of climate stations in the concerned district, with coordinates and elevation
- Mean monthly rainfall data for at least 10 years
- Mean monthly Temperature (Minimum & Maximum) data, if available a time series of 10 years)
- Mean monthly humidity, sunshine, and wind data

Crops information:

- List of main crop to be considered
- Cropping patterns
- Sowing and harvesting data of each crop
- District yield data of main crops for last 10 years

Soil information:

- Dominant soil types in the district for farming system considered
- Relevant soil characteristics (soil retention capacity)

The workshop ended at approximately 17:30 GMT on 26 June 2003.

SUMMARY OF DAILY SESSIONS

17. DAY 1 - MONDAY, 23 JUNE 2003: RIVER BASIN HYDROLOGY MODELING

The workshop began with an opening address by James Benhin the Project Technical Coordinator, and Marc Andreini of the IWMI-Ghana office following the registration of participants. The rest of the day was then devoted to theoretical issues relating to river basin hydrology modeling with a focus on the WATBAL model.

Welcome Notes and Opening

In his opening address James noted that, the workshop was in fulfilment of a promise made by Project Management in Cape Town, South Africa, to organize training in the two other methodologies the project is using for the study analysis. He hoped that by the end of the workshop the two methodologies would be clearer and data needs and problems for the two methodologies would also be addressed. He expressed appreciation to the MacArthur Foundation and the Finnish Trust Fund for funding the workshop, and the additional support from CEEPA, FAO and IWMI. He also said special thanks to IWMI-Ghana for agreeing to host the workshop and to all participants for attending. James extended best wishes for a successful workshop from Rashid Hassan, the Project Leader, and Ariel Dinar, Charles Cormier and Arne Dalfelt, all members of the Project Advisory Group.

In his address, Marc welcomed all participants to Ghana and to the workshop. He noted that IWMI is undertaking a similar work on climate impacts in Ghana "the Glowa Volta Project (http://glowa-volta.de) and therefore was delighted to be invited to participate in the workshop and to also learn about the GEF project. He wished all participants very successful sessions and formally opened the workshop. This was then followed by self-introductions by each of the participants.

Workshop Objectives and Program

James Benhin noted that the workshop is mainly for training, training and training on "crop response simulation and river basin hydrology modelling", specifically on CROPWAT and WATBAL modeling. He outlined four main objectives of the workshop as follows:

(a) To provide further training to country teams on two of the study methodologies and data needs;
(b) To further harmonize the technical capacity of the national teams to ensure quality of the country analyses and reports with respect to the use of the two methodologies;
(c) To allow transfer of experience between the international experts and African experts, and;
(d) To exchange information on data potential-problems and discuss possible solutions to the problems.

He further noted that the training would take the form of theoretical and practical sessions, hands-on practical sessions and discussion on how the models were to be applied for the current study. The workshop was also to identify what data problems there might be, and how best these problems were to be addressed. He noted that, by the end of the workshop all country teams would be very clear on how these approaches were to be applied for the study and the specific roles of each country team in the application of the two approaches.

Session 1: River basin hydrology modeling

The session was divided into three sub-sessions and was led by Matthew McCartney and Daniel Yawson both from IWMI.

Session 1.1: Introduction

This sub-session focused on presentations on the following topics: the hydrological cycle; hydrological processes; runoff generation; flow regimes; the influence of climate on runoff/flow; and the implication of climate change.

Discussion on the hydrological cycle centred on surface flow and groundwater flow and what influences the level of these flows. Snow, ice, precipitation were noted to increase the level of these flows, while transpiration and evaporation are decreasing contributors to the two flows. The hydrological process then refers to the influences on the water circulation, and the main biophysical processes are evaporation, infiltration/percolation groundwater flow and runoff. Hydrological responses were also noted to be climatic regimes (temperate, subtropical, tropical and equatorial vegetation) specific. Such responses influence the availability of water for plant growth in each given zone. For example, even though the desert savanna vegetation zone has the least amount of precipitation (300 mm) it has the highest proportion of evaporation (93%), with a very limited amount infiltrating into groundwater (1%) and only 6% as surface runoff. The implication is that the proportion of evaporation from any given precipitation will influence the level of water availability for groundwater and surface flow and therefore the availability of water and soil moisture for agriculture production.

The presentation also indicated that higher amounts of precipitation do not always imply higher availability of water. For example in the mixed forest vegetation (temperate climate regime) the annual average amount of precipitation is 750 mm while it is as high as 1000 mm in the dry savanna (subtropical/tropical climate regime). However, groundwater and surface runoff is only 13% (130 mm) in the dry savanna but 33% (250 mm) in the mixed forest. It follows that more water is available for agriculture from each unit of precipitation in the mixed forest vegetation than in the dry savanna in spite of the relative higher precipitation in the later vegetation zone.

Presentations were also made on different flow regimes and the estimation of mean annual runoff, which is the mean flow expressed in depth of runoff per year. Related to this term is the coefficient of runoff, which is the index of the proportion of the rainfall that is converted into runoff. A higher proportion of this index implies higher availability of water for agriculture.

Participants were then divided into three groups to discuss issues relating to climate change and the hydrological cycle .

The presentations then continued with the observation that the influence of climate on runoff/flow duration curves are useful for assessing the implications of climate change on flows. Of important mention were the *Lamboun* and the *Falloch* curves. The main human influences on climate were noted as water resource development, land-use change, groundwater extraction, and greenhouse gas emissions. The uncontrolled nature of these activities leads to climate change with possible impacts on water resources, especially in Africa, where it is anticipated that in some areas of water scarcity, climate change will exacerbate levels of criticality. Possible impacts of climatic extremes include: higher maximum temperature and more hot days over nearly all land areas; higher minimum temperatures and fewer cold days over nearly all land areas; more intensive precipitation events; increased summer continental drying and associated drought risk and; generally more frequent and severe floods and more frequent and severe droughts. These imply the need for proper management of water resources and adaptations to the given level of water supply. Adaptation options may include the construction/modification of physical infrastructure and adaptative management of existing water supply system. There should also be adaptations in the demand for water with respect to policy, conservation, efficiency and technology, for domestic, agriculture, industry and energy (hydro-power) uses.

Session 1.2: Principles of river basin/rainfall-runoff modelling

The session focused on: different types of hydrological model, their strengths and weaknesses, the use of hydrological models for climate change research and the requirements of the current study (that is the hydrological inputs into the Ricardian approach).

It was observed that hydrological models simulate the transformation of precipitation into runoff on spatial and time scales for long-term planning for water resources and prediction of extreme events such as droughts and floods. Three main types of hydrological models were noted: conceptual (lumped) models, physically-based models, and physical-conceptual models. The model chosen must fulfil three main objectives: stimulate important processes controlling catchment response to precipitation; appropriate for spatial-temporal scale of interest; and consistent with data available. The problem is the difficulty to decide on a specific model given the complexities of climate change and data problems in Africa.

Conceptual rainfall-runoff models, such as the WATBAL, was noted, aims to convert inputs of rainfall and evaporation into flow and comprise one or more stores (reservoirs). Model parameters also control flow rates into and out of the stores and the models require calibration at a location where there is an observed flow. In predicting climate change, Global Climate Models (GCMs) outputs using baseline 1961-1990 could be used as input to hydrological models to predict impact on flows. GCM scenarios for Africa such as the Percentage change in potential evapotranspiration (Pet) and Percentage change in mean annual rainfall (Precipitation) could also be applied. This process is the main link between GCMs and hydrological models.

For the GEF project, the selected model should fulfil the following requirements: account for major processes affecting runoff; provide time series of monthly "naturalised" flow; and be able to stimulate runoff under conditions of altered climate. It was noted that the project needed to downscale the result of the large area GCM to the district-level in order to get the required data input for the Ricardian analysis. The modelling steps to achieve the objective for the project include: simulation of flows at gauged locations; calibration/validation of model parameters; stimulation of flow at ungauged locations (districts); simulation of impact of changed climate on basin runoff.

The presentation was interspersed with more group discussions on: the degree of model complexity required; the terms of the water balance the model required to make predictions; the time interval of interest; the data available for input to the model and; the possible implications of changes in hydrology on agriculture; what hydrological information were required for the Ricardian Approach – precipitation and temperature (monthly, seasonal and yearly), potential evapotranspiration, soil moisture/water table, and surface runoff and whether these data are available in each country. The discussions culminated in the main issues agreed upon as indicated in section 6.1 of this report.

Session 1.3: Introduction to WATBAL

Presentation focussed on: background to WATBAL; theory underlying WATBAL; loading the WATBAL model; the interface dialogue boxes; and the options for use. The presentations were done with reference to Yates, D.N. (1996), “WatBal: An integrated water balance model for climate impact assessment of river basin runoff.”

The WATBAL model was noted to be a one-dimensional water accounting system, which uses monthly time-step data. The main inputs used in the model include: monthly precipitation; temperature; soil moisture; relative humidity; radiation; observed runoff to estimate runoff. The discussion focused on the conceptualisation of the model, estimations of the water budget and evapotranspiration. The water budget is a function of effective precipitation, surface runoff (length/time), sub-surface runoff (length/time), evaporation (length/time), maximum storage capacity (length) and relative storage and potential evapotranspiration. Three different ways of determining evapotranspiration were observed to be: Penman-Monteith, Thornwaite, and Priestley-Taylor. The last two approaches are a simplification of the first approach. The most recommended approach by the FAO is the Penman-Monteith.

It was further explained that total runoff is the summation of surface runoff, sub-surface runoff, direct runoff and the baseflow, while surface runoff is a function of rainfall and “wetness” of catchment. Sub-surface runoff, on the other hand is a function of wetness of the catchment while the direct runoff is a function of effective rainfall and is equivalent to direct rainfall onto the stream. Three key parameters could be optimised with automatic routine in the model while other parameters such as the sub-surface runoff power term, direct runoff coefficient, and the baseflow had to be fixed manually.

LOADING THE MODEL: The model is a Visual Basic Macro in EXCEL with two main dialog boxes. Dialog box 1 is the Water balance model consisting of the following sections: title, precipitation, Pet, runoff, and the output. The Pet section consists of two main areas (*gras* and *forst*) that could be used to assess the extent of human activity on runoff. Dialog box 2 is the output box and provide ways of determining what output data are written to spreadsheet.

18. DAY 2 - TUESDAY, 24 JUNE 2003: RIVER BASIN HYDROLOGY MODELING

There were four main sessions on day two, which were devoted to the practical application of the WATBAL model. All participants had the opportunity to work on a WATBAL exercise. There was also a discussion of the gridded version of the WATBAL, limitations of the model and the data requirements for the application of the model to the project, anticipated problems and probable solutions.

Session 2.1: Using WATBAL (1)

The session was devoted to hands on practical of the WATBAL model. The aim of the exercise was to provide hands on experience of the WATBAL hydrological model and demonstrate its use for studying the impact of the potentially altered climate on river basin runoff. There were five main steps in the exercise: installing the software; preparing the data for the model; calibrating the model; validation of the model; running a climate change scenario. The exercise used data from the Pungoe catchment, which is an area of 15,046 km^2 located at 19^0N. The catchment is predominantly grassland/pasture, but approximately 10% of the catchment is bare soil, with mean annual precipitation approximately 980 mm and falls predominantly in a wet season that extends from October to March .

Participants were provided with the WATBAL software on a disk and were guided through the installation process, after which they followed given steps to prepare the Pungoe catchment data for calibration and validation using the Calib/Valid Dialog box. The objective of the model calibration was to optimise the model parameters in order to obtain the best "fit" possible between the observed and the simulated runoff. Normally, the calibration process continues until one has the best possible model fit (i.e. the lowest error, R^2 and/or possible visual comparison). However, it was noted that, it is usually not possible to optimise all objective functions simultaneous. Consequently, it is a personal judgement to decide on the best fit possible. Validation involves checking whether the calibrated model performs reasonable well using the data for another time period. It is therefore important not to use all the raw data for the calibration but to leave part of the data for the validation exercise. The validated model was then used to run climate change scenarios in a decade time-step and its effect on the Pungoe catchment in terms of impact of hypothetical climate change scenarios on mean monthly evaporation, and mean monthly volumes of runoff from the Pungoe catchment.

Session 2.2: Using WATBAL (2)

The hands-on practical session on the WATBAL model using data from the Pungoe catchment continued in this session. This was followed by discussions on the gridded version of WATBAL, how it differs from the catchment version and limitations of the WATBAL.

It was observed that the gridded version works on the same principles as the lumped version and in the Pungoe catchment exercise, and uses the same model parameters. However, the main difference between the gridded version and the lumped version is that the gridded version is programmed in C and has no user interface but run from a command line. Two main types of data could be used for the modeling: digital (tables, databases, spreadsheets of flows, and GIS coverage) or analogue (charts of flows, rainfall and paper maps for example catchment boundaries and soils). Specific data needed for the gridded version are: input data (digital time series for flows, rainfall and temperature) plus spatial dataset (GIS coverage); LINK dataset produced by the University of East Anglia (UEA) global data (0.5^o * 0.5^o grid) for 1961 – 1990 (+ anomalies) – precipitation, temperature and data required for Penman-Monteith (Pet).

Limitations of WATBAL noted include the following:

- Conceptual model – many processes not explicitly simulated;
- Model parameters must be calibrated and this may be time consuming;
- As with all models, is only good as the input; and
- No explicit allowance is made for land-use change and water resource management in a catchment.

Sessions 3.1 and 3.2: Application of WATBAL to the GEF project, data, problems and solutions

It was agreed that the gridded version of WATBAL will be applied for the GEF project, and GIS dataset will mostly be used. The main data problems that may be associated with using the gridded version of WATBAL model for the GEF study was that the districts, the unit of analysis, may be smaller than the grid size. Moreover, many time series data may not incorporate data beyond 2000. So it would not be possible to have an exact correspondence with the period of socio-economic data collected for the Ricardian analysis. IWMI therefore, has the responsibility to use the grid size to provide the required corresponding district level dataset for the Ricardian analysis.

Country teams have the responsibility to identify clearly the districts for the study and provide the following spatial and time series data:

Spatial data:

- Map of the major river basins within the country
- Map of the river network within the country
- Map of the location of principle flow gauging stations in the country
- Map of the location of principal meteorological stations in the country
- Map of the land-use in the country

Time series data:

- Time series of monthly flow data from gauging stations
- Time series of monthly rainfall and temperature
- Monthly mean of sunshine hours, albedo, relative humidity, net radiation and wind speed (for each selected district)

In addition each country was to undertake a brief description of the main hydrological features of the country – agro-ecological zones, rainfall patterns, drainage network and primary drainage basins and provide a brief summary of impacts of major droughts and floods over the last 30 – 40 years.

With respect to the next steps for the hydrological modeling, in addition to the specific tasks for IWMI and country teams, corresponding specific dates were also agreed upon for the provision of the necessary data for IWMI (August 15, 2003), model set up and testing/validation of the model (September 2003), completion of model simulation runs (November 2003) and provision of the hydrological data to be included in the Ricardian Analysis (December 2003).

19. DAY 3 - WEDNESDAY, 25 JUNE 2003: CROP RESPONSE SIMULATION MODELING

The third day, which was the first of the two-day session on the crop response simulation modeling training, was devoted to the theoretical aspects and background to the CROPWAT. The fourth day and the second day of the crop response training focussed on the hands-on-practical sessions on the CROPWAT, how the model was to be applied for the project, data needs, envisaged data problems, and possible solutions. Giovanni Muñoz from the FAO led the two-day session.

Giovanni also provided all the relevant databases on CDs that the FAO promised country teams at Workshop 2002 plus the CROPWAT software. He also referred participant to FAO websites where more databases could be found and downloaded and other relevant publications.

There were seven main presentations on day three by Giovanni on the crop response simulation modelling: Introduction – no agriculture without water; Crop water productivity; Introduction to modelling; Monitoring and forecasting; DSSAT; Soil water balance and; Evapotranspiration. The presentations were interspersed with examples from Africa. The following is a brief summary of the presentations.

Part I: Introduction – no agriculture without water.

The presentation was in four parts: (a) Water for secure and viable agriculture, which focussed on the importance of water for food security and FAO projections on how to meet future food demands; (b) New approaches in agriculture management, which focussed on FAO's role in promoting technologies, management and policies; (c) Pro-poor and affordable water management with examples on how simple and affordable techniques could help the rural poor increase their food supply and; (d) Managing environmental and health impacts from irrigated agriculture, that is, the need for more responsible management of irrigated agriculture.

On water for secure and viable agriculture, Giovanni noted the following:

- Average water required per person to produce daily food, including meat and proteins (1000 – 5000 litres/day), is considerably higher than for drinking and domestic purposes (42 - 404 litres/day)
- Only 8% of the world's fresh water resource are currently withdrawn for agriculture, industries and cities, but only 50% are reasonable accessible for human use.
- Water use for agriculture is about 69%, and as high as 85% - 95% in most developing countries. Irrigated agriculture represents only 20% of cultivated land but contributes about 40% and 60% of world food supply and cereals respectively.
- Human pressures on water resource are spatially different. Access to water also varies in time, due to seasonal variations and extreme periods with droughts and floods. For example, the near east, North Africa and parts of Africa are more subject to water stress as compared to water abundance in Latin America. In sub-Saharan Africa the percentage of agriculture water use is low due to the low development of irrigated agriculture.

Giovanni observed that new approaches in agriculture management should include techniques and technologies that leads to a more efficient use in both rainfed and irrigated agriculture, as well as greater involvement of farmers and supporting policies in the following ways:

- More production per unit of water;
- Soil and water conservation techniques to reduce runoff of rain, increased water infiltration to store more water for effective crop growth;
- Crop selection and crop adaptation - bio-technology may be helpful in this direction;
- Modernisation of irrigation systems and more demand driven water supply at the scheme level;
- At the farm level, increased investment in irrigation techniques such as sprinkler and drip irrigation;
- Crop water management practices such as irrigation scheduling, improved cultural practices and better inputs from certified seeds and fertilizer;
- Participatory water management which should involve the participation of farmers, capacity building and training, and the empowerment of women;
- Supporting water policies and irrigation such as clearly defined policies on water rights, efficient water pricing, improved water quality, environmental impact assessment and international water agreements; and
- Ensuring the financial sustainability of irrigation systems to make it more attractive given their high initial investment costs.

Giovanni also noted that intermediate technologies would also help in controlling water use. But for such technologies to be efficient they should be available, affordable, locally produced, low cost and simple. Examples of such technologies include conservation agriculture, water harvesting, low cost well drilling, water lifting and, family-kit drip irrigation.

However, irrigation which is a good source of water for agriculture production may have unintended health hazards through water logging and salinization. To mitigate such health hazards there is the need for improved water management, treatment of drainage and waste management, education, training and communication, with respect to drinking water and sanitation.

Concluding this part of the presentation, Giovanni noted the following:

- Need for strategic use of water, which should be demand-driven;
- Need for improved water management;
- Increased participation in water management;
- Minimization environmental impacts of agriculture water use through irrigation;
- Increased investments in irrigation development and modernisation.

Part 2: Introduction to FAO/AGLW program on Crop Water Productivity (CWP)

The following points were noted

- Global water crisis has led to three World Water forums (Marakech, March 97; The Hague, September 2000 and; Tokyo, March 2003) and several programs addressing crop water requirements (CWP) by IWMI, CGIAR and the FAO.
- The latest on the CWP by the FAO is the No. 46 CROPWAT model (1992) which focuses on crop water requirements and water balance (irrigation scheduling and estimating yield reductions under rainfed)
- These methods have been reviewed several times with the latest been the second CWP meeting in February 2003.
- Further information on the FAO CWP program could be found on http://www.fao.org/landwater/aglw/watermanagement/

Part 3: Introduction to modelling – potential production

This part of the presentation focused on the effect of temperature on plant growth. The following points were noted:

- The ecosystem is both a contributing and limiting factor to agriculture production
    - Contributing factors – climate factors (radiation. temperature and rainfall); physiographic components (topography, sunshine exposure and slope)
    - Limiting factors – Biotic components (producers and consumers)
- Modelling should be understood as a form of a continuum from empirical (statistical) models to explanatory models which involve the summary of data, prediction by interpolation, research management, prediction by extrapolation and interpretation of experimental results (**see Whisler et al, 1986**)
- Procedures for the simulation of agriculture systems include DSSAT and CERES (**Jones et al, 1987)**
- Three production levels influence plant growth. The interaction among these three levels influences the difference between potential plant growth and actual plant growth and should be considered in the modelling process.
    - Production level 1: Solar radiation – amount of sunshine hours captured by the plant
    - Production level 2: Soil moisture
    - Production level 3: limiting factors – water deficit or excess, nitrogen deficit, deficit of potassium and other minerals, and pests and disease.
- The following needs to be considered in assessing the influence of temperature
    - All organisms grow within a temperature range

    - Temperature controls the rate of growth
    - All organisms require a fixed amount of heat for their growth (physiological time)
    - Physiological time is expressed in thermal time (TT)
- Modeling restrictions include
    - Incomplete representation of the real world
    - May be misleading due to the quality of data
    - Not simple to calibrate and use due to high data requirements
- Modeling advantages include
    - Interdisciplinary approach which makes for better understanding of plant growth
    - Improvement in understanding of biological and physical process
    - Human resource development

Part 4: FAO crop monitoring and forecasting)

The following monitoring and forecasting tools were said to be in use

- Food security and early warning systems:
    - Global information and Early warning system – regular reports on food outlook, food crops and shortages, and food supply situation and crop prospects in sub-Saharan Africa
- Trends in cereal production – Between 1960 and 2000 there has been an increase in world cereal production in tons/ha
- Although difficult to predict global food production due to ignorance, surprise and volition, there are variability of potential production from place to place due to the following reasons:
    - Inter-annual variability of yield due to constraint on land use, constraint on land, solar radiation and civil conflicts
    - Scale issues and the importance of weather
    - Crop monitoring and forecasting approaches and products
    - Technology and management (which accounts for 80% of variability, with climate/weather direct effects (10%) but accounts for 100% in semi-arid areas; pests, disease and weeds (15%) and; extreme events (less than 1%))
- Agrometeorological approaches and products, remote sensing approaches, and other software such as *LocClim*

Part 5: Decision Support System for Agrotechnology Transfer (DSSAT)

- DSSAT is a general cropping system model (CSM) for simulating crop growths and development and soil and plant water, nitrogen and carbon dynamics. The model is produced and distributed by ICASA (see www.icasa.net)
- Description of DSSAT components and modular structure
    - Weather module – reads and generate minimum and maximum air temperature, solar radiation, precipitation, relative humidity and wind speed.
    - Soil module – integrates information from soil water, soil temperature, soil carbon, nitrogen and soil dynamics. All these are sub-module of the soil module
    - Template crop module (CROPGRO 1 and 2) – a generic approach for modeling crops as it is a set of procedures that could predict the growth of different crops

  - Management module – determines where field operations are performed, for example, planting, harvesting, application of inorganic fertilizer, irrigation, etc. It also involves multiple crops and management strategies for crop rotation and sequencing
  - Pest module: information is used to simulate the effects of the specified pest and disease on growth and yield
- Use of DSSAT models
  - Adapt to local conditions
  - Cropping sequence simulation
  - Analysis of trends overtime
  - Risk assessment and uncertainty
- Data requirements
  - Data for model operation: site description, daily weather during growing season, characteristics of the soil, field initial conditions, management of the crops
  - Data for model evaluation: detailed phonological development, soil water (measurement versus time at selected depths) and, soil nitrogen (measurement versus time)
- Several problems associated with model evaluation and testing in Africa and Asia due mainly to data availability
- Links between WATBAL and CROPWAT (see Strzepek, K.M. et al (1999), "New methods of modeling water availability for agriculture under climate change: The US cornbelt", *Journal of the American Water Resources Association* 35:6.) – Climate change influence on streamflows which is modelled by WATBAL has implications for water availability for crops as modeled by CROPWAT

Part 6: Soil water balance of a cropped soil

This relates to water inflow (through rainfall, irrigation, run-on, sub-surface inflow, and capillary rise) and outflow (through transpiration, evaporation, runoff, sub-surface outflow and deep percolation)

It was observed that crop growth is influenced by the soil physical characteristics, which is determined by the soil water content and soil water retention, soil water movement (the soil water balance) and therefore crop water intake. Different soils water balance has implications for plant growth. A model could be used to assess plant growth in different soils.

Part 7: Evapotranspiration – calculating crop water requirements

- Water used by crops from irrigation is only about 45%. The rest is lost through field application, field distribution and conveyance losses. This, to a large extent, explains the difference between actual crop yields and potential yields for both irrigated and rainfed crops
- Evapotranspiration (ET) is due to
  - Weather parameters (ETo)
  - Crop characteristics (ETc), which is formulated as ETo multiplied by well watered crops (Kc) (optimal agronomic conditions)
  - Management and environmental factors (ETc adj), which is ETo multiplied by the water and environmental stress.
- Recommended methods for ETo determination could be found in **I & D No. 24, 1977** but this has some limitations (**see Jensen et al, 1990**).
- FAO Penman-Montieth equation for calculating ETo

  - Programs for ETo determination – CROPWAT
  - Crop evapotranspiration - ETc = Kc * ETo. Kc is a crop coefficient, which integrates crop height, crop soil surface albedo, bulk surface resistance, soil evaporation – bare soil
  - Different development strategies for different crops
  - Procedure for ETc determination – The key variables are Kc, and the stress factor coefficient which is used to assess the points at which crops goes into water stress
    - There is the possibility for double crop coefficients
    - A matrix for the general selection of a single and dual crop coefficients include the following: the purpose of the calculation, time-step, and the solution method.

20. DAY 4 - THURSDAY, 26 JUNE 2003: CROP RESPONSE SIMULATION MODELING

The morning and first part of the day was devoted to the practical aspects of the CROPWAT, its application, with examples and hands-on-practicals. The last part of the day was the closing session for the four-day workshop.

Part 1: CropWat for Windows

The presentation was made with reference to Clarke, D. et al (1998), "*CropWat for Windows – User Guide*", with addition information form www.fao.org/ag/agl/aglw/wcrop.htm

CropWat for Windows was noted to be a program that uses the FAO (1992) Penman-Monteith method for calculating reference crop evapotranspiration. These estimates are used in crop water requirements and irrigation scheduling calculations.

The CropWat for Windows differs from the CROPWAT 7.0 even though both use the same equations. The main difference stems from the menu systems and the type of calculations permitted. Some of the interpolation methods used are slightly different to those in CROPWAT 7.0 and so calculations can occasionally differ by up to 2%. This difference may be bigger if interpolation methods are changed.

Part 2: Installation of CropWat for Windows

All participants were given the opportunity to install the software on their laptops. Giovanni then explained the user interfaces and the data needs for the calculations as follows:

- Data needs: CropWat for Windows uses monthly data to estimate evapotranspiration. This data is smoothed into daily values. Monthly rainfall is divided into a number of rain storms for each month
- Type of data and scheduling procedures needed:
  - For Crop water requirements (CWR)
    a) Reference crop evapotranspiration (ETo)
    b) Cropping patterns
    c) Monthly rainfall
  - For irrigation scheduling, data in (a) – (c) plus
    d) Soil type
    e) Scheduling criteria, that is specification of the basis on which the scheduling was to be carried out (e.g. 100mm every 14 days, or irrigate to return the soil back to its field capacity when all the easily available moisture have been used)

- The results from the calculations could be displayed on the screen in a tabular and graphical form. It could also be saved in an ASCII (text) or .CSV (export) files. If saved in a .CSV file, it could easily be exported into other spreadsheets (e.g. Microsoft excel) for further analysis
- A calculated example from Kurnol in India was explained to participants (**see Clarke et al, 1998).**
- Crop Water requirements: A graphical form of ETo, crop water requirements and irrigation requirements could be used to indicate irrigation water requirement (IWR) and also the effective rainfall needed, which is the difference between CWR and IWR
- Cropping patterns: CropWat for Windows could also calculate crop water requirements or irrigation schedules for up to 30 crops. It could also be used to examine CWR for all crops
- Irrigation scheduling: This helps to calculate an optimal irrigation schedule for efficient use of irrigation, that is when to and how much to irrigate
- Examples from Turkey and Morocco were explained to participants

On the discussion of climate data for such analysis it was noted that

- Data from *Climwat* is comparable to *FAOClim* data
- *LocClim* has a CROPWAT format so one could get climate data from there. One could use this to estimate average climate data for selected districts and the best estimate for districts could be estimated by putting limits on the distance and altitude.
- Countries may have to change the original files – crop and climate files to capture or reflect exactly what is being done on the field. This meant that each country needs to do the following:
    - Obtain local data
    - Find the best value to fit the data
    - Find estimated for variables needed for the estimation
        - Kc values for each crop
        - Length of the crop stages
        - Ky values – for this study already available values would be used
    - The question was whether these variables are available for all countries. It was agreed that FAO has the responsibility to help countries without these values to find good approximations.
- Each country was given the responsibility to select two districts and apply the CROPWAT model using the following data:
    - Climate data – to use *FAOClim* data, however, there was also the possibility of getting better local data
    - Soil data – relevant soil characteristics (soil retention capacity). If this information was not available then country teams need to refer to Strzepek et al (1999) to get an idea on approximate estimation using predominant soils in the given district.

Closing Session

The way forward

The discussions focussed on targets for country teams, IWMI and the FAO with respect to the WATBAL and the CROPWAT, and the crop response simulation modeling and river basin hydrology modeling in general. The conclusions are summarized in section 6 of this report.

Closing Remarks

The closing remarks were to be delivered by the World Bank and the FAO representatives in Ghana. However, the World Bank representative was unable to attend the session and sent his apologies.

The FAO representative, Mr. Anatolio Ndong Mba, in his remarks noted that he was pleased to be invited to deliver the closing remarks for three main reasons

- FAO has been involved in the organisation and implementation of the training workshop;
- Ghana was selected to host the workshop;
- Because of the importance of the objective of the workshop to Africa, that is the assessment of the vulnerability of African agriculture to climate change, adaptation options and strengthening the local capacity to address these issues.

He also noted the following:

- The vulnerability of Africa agriculture and agro-ecological system to climate change in Africa
- That Africa continues to experience changes in climate, notably variation in temperature, rainfall, humidity, wind speed and direction, photoperiodicity, and solar intensity with effects on agriculture
- The need to adapt efficiently and cost effectively to climate change and variability for appropriate agriculture production raises the following questions:
    - What has been the nature of climate change and variability on the availability of water in African countries?
    - What has been the effect of climate change and variability on Africa's agriculture and agro-ecological systems as well as economic welfare on the continent?
    - How do crops and agro-ecological systems respond to climate change?

Mr Ndong Mba hoped that following the meeting future workshops would continue to help in improving the national and regional assessment of the economic impact of the changing climate on the agricultural sector in Africa.

On behalf of the FAO representation in Ghana, he expressed his appreciation for all those who have been directly and indirectly involved in the organisation of the workshop. Of notable mention were the Ghana office of IWMI for hosting the meeting, the McArthur Foundation, the Finnish Trust Fund, World Bank and CEEPA, representatives from the eleven African countries and the Project Technical Coordinator.

He concluded by thanking all participants for coming to the Ghana workshop and wished everyone safe flights and journeys back home. He hoped each participant would bear in mind the various discussions held at the workshop and what needs to be done in order to attain the targets set at the workshop.

In his closing remarks, the Project Technical Coordinator noted that the past four days has focussed on training in WATBAL and CROPWAT. By this, the project has clearly defined how the study was going to apply the crop response simulation modeling and the river basin hydrological modeling in the study. The country teams' roles in each of the approaches and the time periods to achieve set objectives have also been agreed upon.

He again acknowledged with deepest gratitude the financial support from the McArthur foundation and the Finnish Trust Fund, and additional support from the FAO, IWMI and CEEPA. He thanked the Ghana office of IWMI for agreeing to host the workshop in spite of the very short notice. Special thanks also to Matthew McCartney and Daniel Yawson both of

IWMI, and Giovanni Muñoz of the FAO for their excellent presentations and training on the two models. He also thanked the FAO representative in Ghana, Mr. Ndong Mba for taking time off his very busy schedules grace the workshop with his closing remarks. To all the country participants, the Coordinator said many thanks for coming to the training workshop and also to Pradeep Kurukulasuriya for attending the workshop to help with the finalization of the farm household survey instrument. Last but not the least, he said special thanks to the Workshop Coordinator, Dalène du Plessis for an absolutely wonderful work in ensuring the smooth running of the workshop.

Concluding, the Coordinator also wished everyone a safe trip back home and declared the workshop officially closed at approximately 17:30 GMT.

DAY ONE **MONDAY, 23 JUNE 2003**

08:30 – 09:30 Registration of Participants

09.30 - 10.00 Welcome notes and opening

James Benhin, World Bank Ghana Representative, Marc Andreini

10:00 – 10:30 Workshop Objectives and Program

James Benhin

10:30 – 11:00 Morning Refreshment

11:00 – 17:30 **SESSION 1: RIVER BASIN HYDROLOGY MODELING**

Matthew McCartney and Daniel Yawson

11:00 – 12:30 Session 1.1: Introduction

- **The hydrological cycle**
- **Hydrological processes**
- **Runoff generation**
- **Flow regimes**
- **The influence of climate on runoff/flow**
- **The implications of climate change**

12:30 – 13:00 Discussion

13:00 – 14:00 Luncheon

14:00 – 15:00 Session 1.2: Principles of river basin/rainfall-runoff modeling

- Different types of hydrological model: strengths and weaknesses
- Use of hydrological models for climate change research
- Requirements of the current study (hydrological inputs to Ricardian Approach)

15:00 – 15:30 Discussion

15:30 – 16:00 Afternoon Refreshment

16:00 – 17:00 Session 1.3: Introduction to WATBAL

- Background to WATBAL
- Theory (i.e. processes simulated/model parameters etc.)
- Loading the model
- The interface – dialogue boxes
- Options for use

17:00 – 17:30 Discussion

DAY TWO **TUESDAY, 24 JUNE 2003**

8:30 – 13:00 **SESSION 2: RIVER BASIN HYDROLOGY MODELING**

Matthew McCartney and Daniel Yawson

08:30 – 10:00 Session 2.1: Using WATBAL (1)

- Summary of day 1 – refresher/questions
- Practical use of the model – model parameter calibration and validation, working through examples, how does modifying climate inputs affect flow regimes?

10:00 – 10:30 Discussion

10:30 – 11:00 Morning Refreshments

11:00 – 12:30 Session 2.2: Using WATBAL (2)
- Continuation of practical
- Gridded version of WATBAL
- Differences to catchment version
- Limitations of WATBAL

12:30 – 13:00 Discussion

13:00 – 14:00 Luncheon

14:00 – 17:30 SESSION 3: RIVER BASIN HYDROLOGY MODELING

Matthew McCartney and Daniel Yawson

14:00 – 15:00 Session 3.1: Application of WATBAL to this project
- Data requirements
- Spatial datasets and the derivation of inputs for GRIDDED WATBAL
- Linking GIS coverage of districts to other datasets

15:00 – 15:30 Discussion

15:30 – 16:00 Afternoon Refreshment

16:00 – 17:00 Session 3.2: Data, Problems and Solutions
- What data can the country teams provide to assist with model calibration/validation?
- Next steps

17:00 – 17:30 Discussions

DAY THREE WEDNESDAY, 25 JUNE 2003

08:30 – 13:00 SESSION 4: CROP RESPONSE SIMULATION MODELING

Giovanni Munoz

08:30 – 10:00 Session 4.1: Theoretical

10:00 – 10:30 Discussion

10:30 – 11:00 Morning Refreshment

11:00 – 12:30 Session 4.2: Practical

12:30 – 13: 00 Discussion

13:00 – 14:00 Luncheon

14:00 – 17:00 **SESSION 5: CROP RESPONSE SIMULATION MODELING**

Giovanni Munoz

14:00 – 15:00 Session 5.1: Hands on

15:00 – 15:30 Discussions

15:30 – 16:00 Afternoon Refreshment

16:00 – 17:00 Session 5.2: Hands on

17:00 – 17:30 Discussion

DAY FOUR	**THURSDAY, 26 JUNE 2003**
08:30 – 16:00	**SESSION 6: CROP RESPONSE SIMULATION MODELING**
	Giovanni Munoz
08:30 – 10:00	Session 6.1: Theoretical
10:00 – 10:30	Discussion
10:30 – 11:00	Morning Refreshment
11:00 – 12:30	Session 6.2: Practical
12:30 – 13: 00	Discussion
13:00 – 14:00	Luncheon
14:00 – 15:00	Session 6.3: Hands on
15:00 – 15:30	Discussions: Data, Problems and Solutions
15:30 – 16:00	Afternoon Refreshment
16:00 – 17:30	**Closing Session**
16:00 – 17:00	The Way Forward
	Matthew McCartney, Daniel Yawson &
	Giovanni Munoz
17:00 – 17:30	Closing Remarks

James Benhin, World Bank Ghana Representative, FAO Ghana Representative

List of Participants: Accra, Ghana, 23 – 26 June 2003

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B. Natal, South Africa 2004

TECHNICAL TRAINING WORKSHOP ON IMPLEMENTATION OF THE RICARDIAN ANALYSIS

DRAKENSBERG - KWAZULU-NATAL, SOUTH AFRICA, 23 - 26 JUNE 2003

ORGANIZED BY

THE CENTRE FOR ENVIRONMENTAL ECONOMICS AND POLICY IN AFRICA (CEEPA), UNIVERSITY OF PRETORIA, SOUTH AFRICA

IN COLLABORATION WITH THE WORLD BANK INSTITUTE (WBI)

Funded by the World Bank's TFESSD

With complementary sponsorship from: CEEPA, the Agricultural and Rural Development Department (ARD)of the World Bank, and the World Bank Institute (WBI)

1. Background

The first of the project's annual workshops was held in December 2002 in Cape Town, South Africa and the second was held in November 2003 in Cairo, Egypt. In addition, the first technical training workshop took place in June 2003 in Accra, Ghana, which focused on training of participants on the application of CROPWAT model and WATBAL model for the crop response simulation modeling and the river basin hydrology modeling components of the project respectively. This second technical training workshop focus on the implementation of the Ricardian approach

The workshop had the following objectives:

(a) To discuss and finalize the country level data for the Ricardian analysis;
(b) To provide further training to country teams on the statistical package to undertake the Ricardian analysis;
(c) To decide on the functional forms of the country level Ricardian model and run initial country level Ricardian regressions; and
(d) To provide guidance on how to undertake the microeconomic analysis.

2. Venue and Date

The workshop was held at the Champagne Sports Resort, Drakensberg in the Kwazulu Natal Province of South Africa, May 3 – 6, 2004

3. Workshop Program (see at end)

4. Participants: (seelist at end)

A total of 15 participants attended the workshop from universities and research institutions of eight African countries; Burkina Faso, Cameroon, Egypt, Ghana, Niger, Senegal, South Africa and Zambia

Other participants were from: the Agricultural and Rural Development Department and the Development Research Group of the World Bank, Yale University, and the University of Southern Denmark.

Participants to the workshop were selected in accordance with the Project Document and the World Bank's procedure for the selection of consultants for the study and were approved by the Bank prior to their attendance to the workshop.

5. Summary of Workshop Proceedings

The workshop started in the morning of 3 May 2004 and ended in the afternoon of 6 May 2004. For the four days, 13 sessions were planned, but some revisions were made to the program in accordance with the technical nature of the training.

The first half of day 1 was devoted to presentations by country teams on their country-level surveys and datasets. The second half of the day, led by Pradeep

Kurukulasuriya, focused on the approach used in cleaning the datasets, and a review of the Stata statistical software. Robert Mendelsohn chaired both sessions.

From the country presentations, it was observed that all the countries have completed their surveys except for Ethiopia, Cameroon, Kenya and Zimbabwe. Ethiopia has just commenced their surveys while the delays with the three other countries have been caused by the lack of funds. However, with the World Bank's TFESSD having made funds available for the three country studies, their surveys are scheduled to begin very soon.

From the country reports, almost all the countries were able to reach the target sample of 800 – 1000 farm households, except for South Africa with a sample of 416 farm households due to the constraint of inadequate funds. All the data have also been entered into an excel worksheet prepared by CEEPA and Yale and the cleaning process is also on-going.

One area of focus from the country presentations was the section on the perception of farmers to climate change and their adaptation strategies. It was observed that there were very interesting adaptation strategies taking place in all the countries, which were clearly presented in the report by Burkina Faso. The other countries were encouraged to revise their report on adaptation strategies following the approach by Burkina Faso. It was discussed that the section could be developed into a regional study and David Maddison agreed to lead this study.

With respect to the data cleaning exercise, Pradeep noted that the process has gone fairly well and six of the seven countries which have completed their surveys have received comments from him, in which he identified gaps in the data that needs to be addressed by the country teams.

In the last session of day 1, Pradeep introduced participants to the Stata do-files and various Stata commands useful for cleaning the data and getting summary information about all the variables in the dataset.

In the first session of day 2, Pradeep led participants to explore their survey data using various Stata commands introduced on the first day. Participants undertook this exercise using their own country datasets. Countries that were yet to complete their surveys, used datasets from other countries. The objective was to make participants familiarise themselves with the various commands for exploring the data.

In the second session, Robert Mendelsohn presented a review of the Ricardian approach, and explained how the approach would be adapted for the country level analyses. In his presentation, Robert noted that several approaches have been used to assess climate impacts and several shortcomings have been identified with these approaches. One of these approaches is the experimental response approach based on projections, have observed that Africa would be the most affected by global warming, with adverse impact on agriculture. He noted, however, that most of these studies have not been based on empirical work, and the current work, which is the first empirical work on Africa to be undertaken to assess climate impact on agriculture, would clearly established the expected impact.

With reference to crop response functions with respect to climate variables such as temperature, Robert noted that this function has an inverse U-shape for both high technology and low technology systems. Africa is said to be a low technology system and also lie on the left side of the curve. The implication is that further warming will be worse for crop farming and agriculture as a whole on the continent.

What the Ricardian approach therefore does is to estimate in quantitative terms this response function, using net revenue as the response variable, to help assess the climate impact on agriculture through changes in land productivity.

With respect to the current country studies, he noted that one need to be cautious on how net revenue is calculated. One of the problems that may be encountered is assessing the cost of household and shared labour, the main sources of farm labour for most African countries. The approach to solving this problem is to run through a series of regressions given different estimates for net revenues (by step by step introducing different types of costs) to assess the robustness of the estimates and the reliability of the different costs. Yale will be leading country teams through this process.

During discussions it was observed that it would be good if countries run two types of Ricardian regressions. The first will be a standard one to be run by all the countries to help in the comparison of results. The second is a country-specific Ricardian regressions taking into consideration country-specific situations. It was also discussed to use two different climate measures: weather stations and satellite data, to compare the results. However, it was noted that satellite data have been found to be a better technique for agriculture studies and it provides a much more accurate data than weather stations data.

In the third session of the day, Pradeep run through the approach to the estimating gross revenue and the various estimates of the net revenue. In all he identified five different levels of net revenues depending on what type of cost one included in the calculation. He then led participants to run initial Ricardian regression estimates using the gross revenue and the first of the net revenues as the response variable with temperature and precipitation as the only exogenous variables.

In the fourth session of the day, Alex Lotsch introduced participants to the GIS software. He reviewed the three windows in the ARCGIS software namely, ArcCatelog, ArcMap, and ArcToolbox. One important aspect of the software for the current study is the presentation of results spatially which makes for easy understanding of the results especially for policy makers.

In the fifth session of the day, Pradeep led participant through the Stata program used for estimating the data for the various variables in the Ricardian models (gross revenue, variable costs, etc,), and how to merge the different sets of data: household survey data, climate data, soil data and runoff data into a complete set to run the Ricardian Regression. Further estimations of the Ricardian regression, by the country teams, were also undertaken using also the different estimates of net revenues and introducing additional exogenous variables in the model including soil data, runoffs and socio-economic characteristics of households.

In the last session of the day, Alex completed the final part of the training in the GIS software and explained how one could link the regression results with the spatial information.

Robert Mendelsohn started the final day with how the project was going to approach the microeconomics analysis. He noted that underneath the Ricardian approach, are several farmers' decision-making process, such as input choice, crop choice, etc, in response to climate change and these could only be assessed through microeconomic analysis. Such analyses are very useful for policy making. He noted that the combination of all these decisions which influences the net returns from farm activities merge into the Ricardian approach.

Rashid continued with the discussion on the microeconomic analysis, by identifying various forms of farmers' decision making in response to climate change that could be assessed. Pradeep proceeded with the discussions by showing an example of how this could be done using the Stata software.

In the next session, David Maddison led the discussion on how to approach the regional study on farmers' perception of climate change and adaptation strategies. David identified several perceptions and adaptation strategies, which he has observed from the presentation of Burkina Faso and a sample of the completed questionnaire from some of the other countries. He noted that the perceptions and adaptation strategies may be different from country to country, however, it should be possible to have a comprehensive list which incorporates all these perceptions and adaptation strategies to help in the regional study. He accepted to draft a list of this perceptions and adaptation strategies, which would be circulated to country teams for comments before a comprehensive list is drawn up. Country teams will then receive from CEEPA and David these coded list together with an excel worksheet file which they would enter responses to the adaptation strategies part of section 7 of the questionnaire.

Participants then proceeded to discuss the plan for the way forward and reached a consensus with respect to the tasks and responsibilities as indicated in 6 below. It was also agreed that the next annual workshop scheduled for November/December 2004 would be held in Senegal.

In his closing remarks, Rashid Hassan expressed his appreciation for an excellent workshop and noted that participants have benefited and learnt a lot from the 4 days. Given the proceedings he observed he had no doubts at all that the workshop attained its stated objectives. He applauded the high quality of presentations by country teams, and thanked Pradeep and James for organizing a very successful workshop. He also thanked Robert, Alex and David for their immense contribution towards the success of the workshop. He also expressed his appreciation to Daléne du Plessis for the able manner in which she coordinated the workshop activities.

The workshop concluded at approximately 14:00 hours.

6. Consensus reached at the workshop

A. What remains to be accomplished between now and November 2004?

1. Economic impact (Ricardian) analysis. TASKS

- Cleaning the data. What needs to be done to support this?
    - Stata commands (code file) to be provided to country teams - Yale (May 15)
    - Cleaning of other data that would support the micro analysis. This would help teams to experiment with analyzing some micro decisions and adaptation responses – Country teams and Yale (May 31)
    - Country level questionnaires on agriculture and environmental policies to be completed and sent to CEEPA - Country teams, Yale, and CEEPA (May 31)
    - Original questionnaires brought to CEEPA. Given that some countries brought a selection of the original copies of their completed questionnaires, and considering the fact that they need to code the responses to the adaptation strategies section of the questionnaires, copies of the last two pages of their completed questionnaires are to be sent back them - CEEPA (May 15)

- Update missing-get better data
    - Entering of data from question 7.0 of the completed questionnaires on worksheet 12 – Country teams (May 31)
    - Actual price data to calculate gross revenue and crosscheck farmers' estimates of gross revenue - Country teams (May 31)
    - Stata program for estimating implicit price to be provided to country teams – Yale (May 31)
    - Dealing with missing data - Yale, CEEPA, country teams (May 31)
    - Additional climate data - rainfall, etc. - Yale and World Bank (A. Lotsch) (May 31)
        - Satellite monthly data – identify country specific months for country survey.
        - Weather station data – monthly data
    - Dataset on disease rates by district to be incorporated in the dataset - World Bank (A. Lotsch) and Yale (May 31)

- Replace/update/revise runoff data
    - Incorporate new analysis by Colorado group into the data base - Yale (July 31)

- Generate climate scenarios and predictions
    - Climate scenarios for 2050 and 2100 (Yale)
    - Predictions of consequent changes in runoff (Colorado)
    - Update database with climate predictions (Yale) – November

- Conduct preliminary analysis
    - Stata program for the standard Ricardian model to be provided to country teams – Yale (June 30)

- o Construct and run the standard macro Ricardian model – Country teams (July 31)
- o Sharing preliminary results and feedback of estimated standard macro Ricardian model (August)
- o Construct and run country specific macro Ricardian models – Country teams (End of September)
- o Sharing preliminary results and feedback of estimated country specific macro Ricardian models (October)
- o Revise and prepare advanced first draft reports for both the standard and the country specific macro Ricardian models for the November/December annual workshop
- o Conduct selected micro analyses following presentation by R. Hassan. Sample cases Stata codes to be provided to country teams – Yale. (Electronic copies of R. Hassan's presentation to be sent to country teams - CEEPA)

2. Farmers' perception and adaptation strategies regional study. TASKS

- List of farmers' perception of climate change and potential adaptation strategies and coding - D. Maddison (May 30)
- Geographical location of surveyed villages on the map plus interviewer IDs to be sent to CEEPA and D. Maddison – Country teams (June 7)
- Variable lists, codes for farmers perception of climate change and potential adaptation strategies and worksheet for data entry to be prepared and sent to country teams - CEEPA (June 15)
- Data entry including location of villages and interviewer ID – Country teams (end of June)
- Develop agreed report outline and share - D. Maddison (end of July)
- Draft study report - D. Madison (before end October)
- Share draft report with all project team members
- Discuss report at November/December workshop for possible revisions

B. Products planned/expected from project

- Project reports (during the course of 2005)
    - o Country studies of economic impacts (Ricardian analyses)
    - o Regional analysis of economic impacts (Ricardian analysis)
    - o Sub-regional analysis of economic impacts (Ricardian analysis)
    - o Regional farmers' perception and adaptations study (CEEPA-WB Working Paper)
    - o Crop-water response models' study report (s)
    - o Hydrological impacts study report (s)
    - o GIS–based analyses (A. Lotsch)
    - o Other reports

- Policy briefs (during 2005)
    - o Expect one from each of the above listed reports

- Papers/articles/etc. (from now into a few years to come)
    - Encourage and expect that each of the reports will lead to at least one publication in international, regional or local journals

- Book (s) – possibility of two books (second one on micro responses and farmers' adaptations)
    - First book plan for 12 chapters (2005-06)
        - Introduction
        - Methods (emphasis on the new and distinguishing features of the Africa cross-section study approach)
        - Continental economic impact study 1
        - Continental economic impact study 2
        - Sub-regional economic impact study (thinking about four chapters done by some interesting grouping of countries)
        - Hydrological impacts
        - Crop-water response modeling
        - Conclusions and policy recommendations (possibility of two separate chapters
    - Second book (2006-07)
        - Funding for an extension of project to complete this work
    - Potential publishers to be approached

C. November/December 2004 workshop to be held in Senegal

Workshop Program

DAY ONE	**MONDAY, 3 MAY 2004**
08:00 – 08:30	Registration of Participants
08:30 – 09.00	Welcome notes and opening **GEF Focal Point, Department of Agriculture Representative, Ariel Dinar, Rashid Hassan**
09:00 – 09:15	Workshop Objectives and Program **James Benhin**
09:15 – 13:00	**SESSION 1: COUNTRY-LEVEL SURVEYS AND DATASETS** **Chair: Robert Mendelsohn**
09:15 – 09:30	Ghana: **Yerfi Fosu**
09:30 – 09:45	Egypt: **Samiha Ouda**
09:45 – 10:00	South Africa: **Glwadys Gbetibouo**
10:00 – 10:15	Zambia: **Suman Jain**
10:15 – 10:30	Discussion
10:30 – 11:00	Morning Refreshment
11:00 – 11:15	Niger: **Ali Mahamadou**
11:15 – 11:30	Senegal: **Diop Mbaye**
11:30 – 11:45	Ethiopia: **Temesgen Deressa**
11:45 – 12:00	Burkina Faso: **Matthieu Ouedraogo**
12:00 – 12:15	Discussion
12:15 – 12:30	Cameroon: **Ernest Molua**
12:30 – 12:45	Kenya: **Joseph Karugia**
12:45 – 13:00	Zimbabwe: **Reneth Mano**
13:00 – 13:15	Discussion

13:15 – 14:15	Luncheon
14:15 – 15:00	**SESSION 2: CLEANING OF COUNTRY-LEVEL DATASETS** **Pradeep Kurukulasuriya**
15:00 – 17:30	**SESSION 3: STATA STATISTICAL SOFTWARE – A REVIEW** **Pradeep Kurukulasuriya**
15:00 – 16:00	Essential knowledge of STATA do files
16:00 – 16:30	Afternoon Refreshment
16:30 – 17:30	STATA commands

End of Day 1

DAY TWO	**TUESDAY, 4 MAY 2004**
08:30 – 10:30	**SESSION 4: EXPLORING SURVEY DATA USING STATA** **Pradeep Kurukulasuriya**
08:30 –- 09:30	Using various Stata commands to explore data
09:30 – 10:30	Exploring country-level datasets
10:30 – 11:00	Morning Refreshment
11:00 – 12:30	**SESSION 5: RICARDIAN ANALYSIS (COUNTRY-LEVEL MODELS) – A REVIEW**

Robert Mendelsohn

12:30 – 13:30	**Luncheon**
13:00 – 16:00	**SESSION 6: RUNNING REGRESSIONS USING STATA**

Pradeep Kurukulasuriya

13:00 – 14:00	OLS models and interpretation of results
14:00 – 15: 00	Regression diagnostics
15:00 – 16: 00	Dichotomous choice models (Probit/Logit)
16:00 – 16:30	Afternoon Refreshment

End of Day 2

DAY THREE	**WEDNESDAY, 5 MAY 2004**
08:30 – 10:30	**SESSION 7: MICROECONOMIC ANALYSIS** **Robert Mendelsohn & Rashid Hassan** **Chair: Ariel Dinar**
10:00 – 10:30	Discussion
10:30 – 11:00	Morning Refreshment
11:00 – 13:00	**SESSION 8: ESTIMATION OF COUNTRY-LEVEL RICARDIAN MODELS USING STATA (PART I)** Pradeep Kurukulasuriya
13:00 – 14:00	Luncheon
14:00 – 16:00	**SESSION 9: ESTIMATION OF COUNTRY-LEVEL RICARDIAN MODELS USING STATA (PART II)** **Pradeep Kurukulasuriya**
16:00 – 16:30	Afternoon Refreshment
16:30 – 17:30	**SESSION 10: GIS SOFTWARE** **Pradeep Kurukulasuriya and Alexander Lotsch** • Importing base maps • Importing survey data • Merging survey data and base maps • Mapping variables • Producing images for publication

End of Day 3

DAY FOUR	**THURSDAY, 6 MAY 2004**
08:30 – 13:00	**SESSION 11: DISCUSSION OF ESTIMATED COUNTRY-LEVEL RICARDIAN MODELS** **Chair: David Maddison**
08:30 – 08:45	Ghana: **Yerfi Fosu**

08:45 – 09:00	Egypt: **Samiha Ouda**
09:00 – 09:15	Discussion
09:15 – 09:30	South Africa: **James Benhin**
09:30 – 09:45	Zambia: **Suman Jain**
09:45 – 10:00	Niger: **Ali Mahamadou**
10:00 – 10:30	Discussion
10:30 – 11:00	Morning Refreshment
11:00 – 11:15	Senegal: **Diop Mbaye**
11:15 – 11:30	Ethiopia: **Temesgen Deressa**
11:30 – 11:45	Discussion
11:45 – 12:00	Burkina Faso: **Matthieu Ouedraogo**
12:00 – 12:15	Cameroon: **Ernest Molua**
12:15 – 12:30	Discussion
12:30 – 12:45	Kenya: **Joseph Karugia**
12:45 – 13:00	Zimbabwe: **Reneth Mano**
13:00 – 13:15	Discussion
13:15 – 14:15	Luncheon
14:15 – 14:45	**SESSION 12: COUNTRY-LEVEL AND REGIONAL-LEVEL REPORTS ON THE RICARDIAN APPROACH** **Chair: Ariel Dinar**
14:15 – 14:30	Expected reports: **James Benhin**
14:30 – 14:45	Discussion
14:45 – 15:30	**SESSION 13: CONCLUSIONS ON THE WAY FORWARD** **Chair: Ariel Dinar**
14:45 – 15:00	The way forward: **Rashid Hassan**
15:00 – 15:30	Closing remarks: **Department of Agriculture Representative, Rashid Hassan Ariel Dinar.**

DEPARTURE

PARTICIPANTS LIST - WORKSHOP ON RICARDIAN ANALYSIS
CHAMPAGNE SPORTS RESORT, CENTRAL DRAKENSBERG, SOUTH AFRICA
3 – 6 May 2004

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2. Lotsch, Alexander	Development Research Group Infrastructure & Environment World Bank, 1818 H Street, NW, MC2-632, Washington DC; 20433 Tel: +202 473 0434 Fax: +202 522 3230	alotsch@worldbank.org	**WORLD BANK**	LH572 1 May 08:50
3. Hassan, Rashid	CEEPA, University of Pretoria, PRETORIA, 0002; South Africa Tel: +27 12 420 3317 Fax: +27 12 420 4958	rhassan@postino.up.ac.za	**CEEPA**	2 days
4 Benhin, James	CEEPA, University of Pretoria, PRETORIA, 0002; South Africa Tel: +27 12 420 5228 Fax: +27 12 420 4958	jbenhin@postino.up.ac.za	**CEEPA**	4 days
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6. Mahamadou, Ali	University of Niamey	cresa@intnet.ne	**NIGER**	AF 30 Apr PRS JNB 23:15 #09:40

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7. Mendelsohn, Robert	Yale School of Forestry and Environmental Studies, 360 Prospect Street, NEW HAVEN, CT 06511, Tel: +203 432 5128 Fax: +203 432 3809	robert.mendelsohn@yale.edu	**YALE UNIVERSITY**	SA 30Apr JFK JNB 17:55 #14:50 SA 15May JNB JFK 19:15 #07:10 6 days
8. Kurukulasuriya Pradeep	Yale School of Forestry & Environmental Studies; NEW HAVEN, CT 06511; Tel & Fax: +718 6230835 Mobile: +718 938 9965	pradeep.kurukulasuriya@yale.edu	YALE UNIVERSITY	SA 30Apr JFK JNB 17:55 #14:50 SA 07May JNB JFK 19:15 #07:10 6 days
9. Maddison, David	Institute of Economics, University of Southern Denmark, Campusvej 55; DK5230 Odense M, Denmark Tel: +45 6550 3270	dma@sam.sdu.dk	**UNIVERSITY OF SOUTHERN DENMARK**	BA 30Apr CPH LHR 16:10 17:05 BA 30Apr LHR JNB 19:10 #07:00 BA 07May JNB LHR 21:25 #07:40 BA 08May LHR CPH 09:55 12:45 7 days
10. Molua, Ernest	Dept. of Economics & Management, Faculty of Social & Management Sciences; University of Buea, Buea Southwest Province, Cameroon P.O. Box 63 Buea, Cameroon, West Africa Tel: +237 949 4393 Fax: +237 332 3014	elmolua@hotmail.com emolua@yahoo.com	**CAMEROON**	GN 30Apr DLA LBV 13:55 15:55 GN 30Apr LBV JNB 22:30 #04:05 GN 08May JNB LBV 05:35 09:25 GN 08May LBV DLA 11:20 12:15 8 days
11. Fosu, Yerfi	Univeristy of Ghana, Department of Agricultural Economics, P O Box LG323, Legon, ACCRA, Ghana Tel: +233 24 319665 Fax: +233 21 506842	duakon@yahoo.co.uk ari@africaonline.com.gh	GHANA	SA 30Apr ACC JNB 23:00 #07:00 SA 07May JNB ACC 13:20 17:20 6 days
12. Jain, Suman	Mathematics and Statistics Department, University of Zambia	sjain@natsci.unza.zm	**ZAMBIA**	SA 01May LUN JNB 14:30 16:35 SA 15May JNB LUN 13:45 11:05

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13. Diop, Mbaye	ISRA / LERG, Campus Universitaire de l'ESP, BP 25275, DAKAR-FANN Senegal, Tel: +221 8642317	mbaydiop@ucad.sn n_diop@yahoo.fr	**SENEGAL**	SA 29Apr DKR JNB 06:45 17:05 SA 07May JNB DKR 19:15 #01:50 8 days
14. Ouda, Samiha	Agricultural Research Centre CAIRO, Egypt	samiha_ouda@hotmail.com samihaouda@yahoo.com	EGYPT	MS 01May CAI JNB 04:00 11:00 MS 08May JNB CAI 20:00 05:00 7 days
15. Ouedraogo, Mathieu	INERA 01 BP 910 Bobo-Dioulasso 01 Burkina Faso Tel: +226 97 3378 / 98 2329 Fax: +226 97 0159	ouedmath@hotmail.com alsanou@fasonet.bf	BURKINA FASO	2J 27Apr OGD ABJ 08:00 10:25 SA 28Apr ABJ JNB 20:50 #07:00 SA 07May JNB ABJ 13:20 19:20 2J 08May ABJ OGD 11:50 15:25
16. Du Plessis, Dalène	CEEPA University of Pretoria	duplessisd@postino.up.ac.za	CEEPA	4 days
17. Burger, Lynette	CEEPA University of Pretoria	lynette.burger@postino.up.ac.za	CEEPA	**2 days**

Annex 3: Individuals and Institutions Participating in the GEF Climate and agriculture in Africa Project

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Dr. Cary Anne Cadman, Project Managers (August 2004 – July 2005), WBI, Washington DC WBI
Dr. Marian S. delos Angeles, Project Managers (August 2005 – end of project), WBI, Washington DC

Prof. Rashid M. Hassan, Project Leader, CEEPA, University of Pretoria, South Africa
Dr. James K.A. Benhin, Project Coordinator, CEEPA, University of Pretoria, South Africa
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Ms. Daléne du Plessis, Project Workshop Coordinator, CEEPA, University of Pretoria, South Africa

Regional Team: Economic Impact Assessment
Prof. Robert Mendelsohn, Yale University, USA
Dr. Pradeep Kurukulasuriya, Yale University, USA

Regional Team: Crop Response Simulation Modelling
Mr. Giovanni Munoz, FAO, Rome
Ms. Robina Wahaj, FAO, Rome
Mr. Martin Smith, FAO, Rome
Mr. Florent Maraux, FAO, Rome

Regional Team: River Basin Hydrology Modelling
Prof. Kenneth Strzpek (Univ. of Colorado, Boulder)
Ms. Alyssa McCluskey (Univ. of Colorado, Boulder)
Dr. Merrey Doug, IWMI, Pretoria
Dr. Matthew McCartney, IWMI, Pretoria
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Regional Team: Perception and Adaptation to Climate Change
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Annex 4. Summary Tables of Workshops Evaluations

See PDF Files attached at end

Annex 5. Monitoring and Evaluation Survey Questionnaires

GEF/WB REGIONAL CLIMATE, WATER AND AGRICULTURE:
IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA

Monitoring and Evaluation Survey I:
Sponsors and Implementing Agencies

1. Name and Organization

2. What was the nature of you and your organization's involvement in the project?

3. Please provide an evaluation of the project with respect to the following (**A** Strongly agree, **B** Agree, **C** Disagree, **D** Strongly disagree, **E** No opinion)

1.1 Project rationale was sensible for your organization to support [ ]

"Agriculture and agro-ecological systems are the most vulnerable and important sectors in African countries. They are especially vulnerable because the climates of many of these countries are already too hot. Further warming is consequently expected to reduce crop productivity adversely. Agriculture and agro-ecological systems are especially prominent in the economies of African countries, and therefore these countries have a special interest in the project. Using sample countries from the African continent, the targeted research will provide both national and regional understanding of the nature of the impact of climate change on the agricultural sector and possible adaptation."

2.2 Project goals and objectives (*listed in table below*) were consistent with your organisation interest and priorities [ ]

3.3 Project activities' design and implementation plans and modalities were sound [ ]

"(a) Collection and analyses of baseline climatic and agricultural production data for various regions in sample countries to produce quantitative estimates of the relationship between agricultural performance and various climatic variables by national research teams with the appropriate multidisciplinary mix
(b) Incorporate GCM results and hydrological models' output into the cross-section economic impact model to conduct analyses of future climate scenarios and effective adaptation measures at local, national and regional levels
(c) Organisation of training, research and dissemination workshops; provision of technical backstopping from international and regional experts; publication and networking activities (website and other) and management and sharing of a comprehensive continental database"

4.4 Project funding arrangements were adequate and satisfactory [ ]

4. Provide an evaluation of project performance in terms of achieving its stated objectives (**A** Fully achieved, **B** Partially achieved, **C** Not satisfactorily achieved, **D** Not achieved, **E** No opinion)

Project performance evaluation		
Objective	Indicators	Evaluation of Performance
(a) Conduct national level economic analyses of impact and adaptation.	*(a) National-level analyses of CC impact on the Agricultural sector and adaptation alternatives. Results presented in workshops and reports and based on sound analytical work.*	
(b) Conduct cross-national analysis and extrapolate results to countries not included in the sample.	*(b) Regional-level analysis of CC impact on the Agricultural sector and local and regional adaptation alternatives extrapolated to the sample countries and to countries outside the sample. Results presented in workshops and reports and based on sound analytical work.*	
(c) Include water supply in the analysis.	*(c) A working hydrological model provides input to economic analyses.*	
(d) Enhance the capacity of country experts.	*(d) All national-level work conducted by country teams. Graduate students (where applicable) complete their thesis research.*	
(e) Facilitate an intra-country exchange of findings and policy alternatives, among various levels of decision makers from each country.	*(e) Annual regional workshops, of the study teams and policy makers and government officials for exchange of results and deliberation over policy options.*	
(f) Develop inter-country exchanges between all the country teams participating in the project.	*(f) Full use of a Learning and Knowledge Sharing Network (LKSN) between teams' members, and involving scientists from countries other than the study sample. Full exchange of data, findings and methodologies among country teams.*	

5. Sustainability. Assess approach followed to influence continuation of project benefits after completion and likelihood of project sustainability and needs for that

6. Institutional capacity. Assess performance of implementing agencies and partners (CEEPA and World Bank)

7. In your opinion what was your organization’s most important contribution to this project?

8. Explain how this project supported your organization’s interest in climate change and adaptation?

9. In what way(s) have your organization’s interest been strengthened by this project?

10. Replicability / continuation: Would you like to support an extension of this work and what would be the nature and direction of such an extension?

11. Any other comments on aspects not covered above

GEF/WB REGIONAL CLIMATE, WATER AND AGRICULTURE:
IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA

Monitoring and Evaluation Survey II: Participating African country research teams

1. Name and Organization

2. What was the nature of your involvement in the project?

3. Please provide an evaluation of the project with respect to the following (**A** Strongly agree, **B** Agree, **C** Disagree, **D** Strongly disagree, **E** No opinion)

3.1 Project rationale was sensible for your organization to participate in

"Agriculture and agro-ecological systems are the most vulnerable and important sectors in African countries. They are especially vulnerable because the climates of many of these countries are already too hot. Further warming is consequently expected to reduce crop productivity adversely. Agriculture and agro-ecological systems are especially prominent in the economies of African countries, and therefore these countries have a special interest in the project. Using sample countries from the African continent, the targeted research will provide both national and regional understanding of the nature of the impact of climate change on the agricultural sector and possible adaptation."

3.2 Project goals and objectives (*listed in table below*) were consistent with your organization interest and priorities

3.3 Project activities' design and implementation plans and modalities were sound

"(a) Collection and analyses of baseline climatic and agricultural production data for various regions in sample countries to produce quantitative estimates of the relationship between agricultural performance and various climatic variables by national research teams with the appropriate multidisciplinary mix
(b) Incorporate GCM results and hydrological models' output into the cross-section economic impact model to conduct analyses of future climate scenarios and effective adaptation measures at local, national and regional levels
(c) Organisation of training, research and dissemination workshops; provision of technical backstopping from international and regional experts; publication and networking activities (website and other) and management and sharing of a comprehensive continental database"

3.4 Project funding arrangements were adequate and satisfactory

4. Evaluate performance of implementing agency and partners/collaborators with respect to the following (**A** Excellent, **B** Very good, **C** Good, **D** Satisfactory, **E** Not satisfactory, **F** Poor)

4.1. Planning and coordination of project activities

i. Planning of activities ______________________________ [ ]

ii. Communication and provision of information _________ [ ]

iii. Provision of technical guidance and assistance ________ [ ]

iv. Contractual arrangements ___________________________ [ ]

4.2. Organisation and facilitation of workshops

i. Program and contents of workshops _________________ [ ]

ii. Facilitation of workshop sessions ___________________ [ ]

iii. Achievement of workshop objectives ________________ [ ]

iv. Logistical support (travel, etc.) _____________________ [ ]

4.3. Technical guidance and backstopping in design and implementation of data collection activities [ ]

4.4. Provision of the necessary equipment and software for data analyses and report writing [ ]

4.5. Technical guidance, training and backstopping in data analyses and report writing activities [ ]

4.6. Review of produced research reports and guidance for revision [ ]

5. Provide an evaluation of project performance in terms of achieving its stated objectives of relevance to your country/organisation (**A** Fully achieved, **B** Partially achieved, **C** Not satisfactorily achieved, **D** Not achieved, **E** Not applicable, **F** No opinion)

Project performance evaluation		
Objective	Indicators	Evaluation of Performance
(a) Conduct national level economic analyses of impact and adaptation.	*(a) National-level analyses of CC impact on the Agricultural sector and adaptation alternatives. Results presented in workshops and reports and*	

Project performance evaluation		
Objective	Indicators	Evaluation of Performance
	based on sound analytical work.	
(b) Conduct cross-national analysis and extrapolate results to countries not included in the sample.	*(b) Regional-level analysis of CC impact on the Agricultural sector and local and regional adaptation alternatives extrapolated to the sample countries and to countries outside the sample. Results presented in workshops and reports and based on sound analytical work.*	
(c) Include water supply in the analysis.	*(c) A working hydrological model provides input to economic analyses.*	
(d) Enhance the capacity of country experts.	*(d) All national-level work conducted by country teams. Graduate students (where applicable) complete their thesis research.*	
(e) Facilitate an intra-country exchange of findings and policy alternatives, among various levels of decision makers from each country.	*(e) Annual regional workshops, of the study teams and policy makers and government officials for exchange of results and deliberation over policy options.*	
(f) Develop inter-country exchanges between all the country teams participating in the project.	*(f) Full use of a Learning and Knowledge Sharing Network (LKSN) between teams' members, and involving scientists from countries other than the study sample. Full exchange of data, findings and methodologies among country teams.*	

6. Project benefits to your country/organization (**A** Significant, **B** Good, **C** Fair, **D** Low, **E** No benefit, **F** No opinion)

6.1 Enhanced research capacity and analytical skills

6.2 Improved knowledge and information on impacts of and adaptation to climate change

6.3 Technical research outputs produced

6.4 Policy value of project findings

7. How do you plan to use the capacity gained and results to inform policy in your country and future research

8. Replicability/continuation. Assess likelihood of replication and/or extension of project activities in your country

9. Any other comments on aspects not covered above

GEF/WB REGIONAL CLIMATE, WATER AND AGRICULTURE:
IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA

Monitoring and Evaluation Survey III: Collaborating regional research teams

1. Name and Organization

2. What was the nature of your involvement in the project?

3. Please provide an evaluation of the project with respect to the following (**A** Strongly agree, **B** Agree, **C** Disagree, **D** Strongly disagree, **E** No opinion)

   3.1. Project rationale was sensible for your organization to participate in

"Agriculture and agro-ecological systems are the most vulnerable and important sectors in African countries. They are especially vulnerable because the climates of many of these countries are already too hot. Further warming is consequently expected to reduce crop productivity adversely. Agriculture and agro-ecological systems are especially prominent in the economies of African countries, and therefore these countries have a special interest in the project. Using sample countries from the African continent, the targeted research will provide both national and regional understanding of the nature of the impact of climate change on the agricultural sector and possible adaptation."

   3.2. Project goals and objectives (*listed in table below*) were consistent with your organisation interest and Priorities

   3.3. Project activities' design and implementation plans and modalities were sound

"(a) Collection and analyses of baseline climatic and agricultural production data for various regions in sample countries to produce quantitative estimates of the relationship between agricultural performance and various climatic variables by national research teams with the appropriate multidisciplinary mix
(b) Incorporate GCM results and hydrological models' output into the cross-section economic impact model to conduct analyses of future climate scenarios and effective adaptation measures at local, national and regional levels
(c) Organisation of training, research and dissemination workshops; provision of technical backstopping from international and regional experts; publication and networking activities (website and other) and management and sharing of a comprehensive continental database"

   3.4. Project funding arrangements were adequate and satisfactory

4. Evaluate performance of implementing agency and partners/collaborators with respect to the following (**A** Excellent, **B** Very good, **C** Good, **D** Satisfactory, **E** Not satisfactory, **F** Poor)

4.1. Planning and coordination of project activities

i. Planning of activities ___________________________ [ ]

ii. Communication and provision of information _______ [ ]

iii. Provision of technical guidance and assistance _______ [ ]

iv. Contractual arrangements ________________________ [ ]

4.2. Organisation and facilitation of workshops

i. Program and contents of workshops _______________ [ ]

ii. Facilitation of workshop sessions _________________ [ ]

iii. Achievement of workshop objectives ______________ [ ]

iv. Logistical support (travel, etc.) ___________________ [ ]

4.3. Technical guidance and backstopping in design and implementation of data collection activities [ ]

4.4. Technical guidance, training and backstopping in data analyses and report writing
activities [ ]

4.5. Review of produced research reports and guidance for revision [ ]

5. Provide an evaluation of project performance in terms of achieving its stated objectives of relevance to your country/organisation (**A** Fully achieved, **B** Partially achieved, **C** Not satisfactorily achieved, **D** Not achieved, **E** Not applicable, **F** No opinion)

Project performance evaluation		
Objective	Indicators	Evaluation of Performance
(a) Conduct national level economic analyses of impact and adaptation.	*(a) National-level analyses of CC impact on the Agricultural sector and adaptation alternatives. Results presented in workshops and reports and based on sound analytical work.*	
(b) Conduct cross-national analysis and extrapolate results to countries not included in the	*(b) Regional-level analysis of CC impact on the Agricultural sector and local and regional*	

Project performance evaluation		
Objective	Indicators	Evaluation of Performance
sample.	*adaptation alternatives extrapolated to the sample countries and to countries outside the sample. Results presented in workshops and reports and based on sound analytical work.*	
(c) Include water supply in the analysis.	*(c) A working hydrological model provides input to economic analyses.*	
(d) Enhance the capacity of country experts.	*(d) All national-level work conducted by country teams. Graduate students (where applicable) complete their thesis research.*	
(e) Facilitate an intra-country exchange of findings and policy alternatives, among various levels of decision makers from each country.	*(e) Annual regional workshops, of the study teams and policy makers and government officials for exchange of results and deliberation over policy options.*	
(f) Develop inter-country exchanges between all the country teams participating in the project.	*(f) Full use of a Learning and Knowledge Sharing Network (LKSN) between teams' members, and involving scientists from countries other than the study sample. Full exchange of data, findings and methodologies among country teams.*	

6. Project benefits to your organization (**A** Significant, **B** Good, **C** Fair, **D** Low, **E** No benefit, **F** No opinion)

6.1 Enhanced research capacity and analytical skills

6.2 Improved knowledge and information on impacts of and adaptation to climate change

6.3 Technical research outputs produced

6.4 Policy value of project findings

7. Replicability/continuation. Assess likelihood of replication and/or extension of project activities.

8. Any other comments on aspects not covered above

GEF/WB REGIONAL CLIMATE, WATER AND AGRICULTURE: IMPACTS ON AND ADAPTATION OF AGRO-ECOLOGICAL SYSTEMS IN AFRICA

Monitoring and Evaluation Survey

ANNEX: PROJECT ACTIVITIES AND OUTPUTS

(A) Workshops

(1) Launching and training workshop on unified methodologies and data collection needs. **Date:** December 4 – 7, 2002. **Venue:** Cape Town, South Africa
Participants: (i) Three each from universities, research and government institutions in the eleven participating countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe; (ii) Other institutions: Agricultural and Rural Development Department and the Africa Region of the World Bank, World Bank Institute, CEEPA, Yale University, FAO, UNDP, IWMI, University of Minnesota, Institutes Rabat in Morocco, University of Southern Denmark, and the University of Cape Town.
Objectives: (i) provide and standardized data needs and analyses for all country studies; (ii) enhance the capacity of the research teams responsible for conducting country studies in the application of the proposed methodological approaches; (iii) define the nature and scope of planned regional economic and hydrological analyses; (iii) develop standardized format and plans for an integrated regional database.

(2) Technical training workshop on crop response simulation and river basin hydrological modelling. **Date:** June 23 – 26, 2003. **Venue:** Accra, Ghana
Participants: (i) Two each from the eleven participating countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe; (ii) Other institutions: IWMI, FAO, CEEPA, and Yale University.
Objectives: (i) provide further training to country teams on two of the study methodologies and data needs; (ii) further harmonize the technical capacity of the national teams to ensure quality of the country analyses and reports with respect to the use of the two methodologies; (iii) allow transfer of experience between the international experts and African experts; (iv) exchange information on data potential-problems and discuss possible solutions to the problems.

(3) Training workshop on quality control for country level and regional analyses and reporting. **Date:** November 10 – 13, 2003. **Venue:** Cairo, Egypt
Participants: (i) Two each from the eleven participating countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe; (ii) Other institutions: Agricultural and Rural Development Department and the Africa Region of the World Bank, CEEPA, Yale University, IWMI, FAO.
Objectives: (i) improve consistency of data and uniformity of analytical frameworks to be followed for completion of the country case studies and regional research; (ii) make decisions on the best design and operation of an African-wide integrated digital database for this study.

(4) Technical training workshop on the implementation of the Ricardian analysis. **Date:** May 3 – 6, 2004. **Venue:** KwaZulu-Natal, South Africa
Participants: (i) One each from the eleven participating countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe; (ii)

Other institutions: Agricultural and Rural Development Department and the Africa Region of the World Bank, CEEPA, Yale University.
Objectives: (i) discuss and finalize the country level data for the Ricardian analysis (ii) provide further training to country teams on the statistical package to undertake the Ricardian analysis (iii) decide on the functional forms of the country level Ricardian model and run initial country level Ricardian regressions; and (iv) provide guidance on how to undertake the microeconomic analysis.

(5) Understanding and adapting to climate change: what can the world learn from Africa's experience. **Date:** December 13 – 16, 2004. **Venue:** Zaragoza, Spain
Participants: (i) Two each from the eleven participating countries (Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Zambia and Zimbabwe; (ii) Other institutions: Agricultural and Rural Development Department, and the Climate Change Team (ENV) both of the World Bank, World Bank Institute, Yale University, FAO, University of Colorado-Boulder, University College, London (UCL), Hebrew University of Jerusalem, Israel, and seven Latin American countries – Brazil, Chile, Argentina, Ecuador, Venezuela and Uruguay.
Objectives: (i) rigorous review and critical evaluation of the preliminary empirical results of the national studies and provide suggestions for improving the analyses and interpretation of study results and findings and their policy implications; (ii) review and evaluation of the results of the regional assessment studies on the potential economic and hydrological impacts and crop responses of climate change on agro-ecosystems in Africa and the various adaptation options. These complemented by presentations of similar studies in Latin America and Israel, as well as adaptation studies by the Environment Department of the World Bank.

(6) Proposed final workshop: International conference for African policy makers: impacts of climate change on agro-ecological systems in Africa, and adaptation options. **Proposed date:** 2006. **Venue:** Cape Town, South Africa.
Participants: Country teams (up to three per country from the eleven African countries, regional experts from CEEPA, international experts, and policy makers, and politicians associated with relevant policies from various African countries.
Objectives: (i) disseminate lessons learned from GEF project to policy makers and professionals in the climate change field at the regional and international levels, and to build on that momentum in order to make a policy change; (ii) be informed about results of two adaptation studies in Africa, funded by the GEF: the UNDP regional project-Coping with drought and climate change, and the AIACC project by START; (iii) a special outreach workshop for senior officials in Africa to raise awareness among policymakers about climate change, impacts on Africa, various policy interventions, and their relative effectiveness and associated costs; (iv) Country teams to present plans for an outreach program that will be undertaken to inform local farmers following the completion of the national studies; (v) use the policy relevant results from the GEF project to create a momentum for future activities that would include: training, education, dialogue and exchange of information.

(B) Research output
(1) Project reports (31 reports in 2006) on: regional economic impacts assessment of climate change on crops and livestock, country level economic impact assessment of climate change on crops and adaptation option; regional and country level CROPWAT analysis of crop water requirements as a result of climate change; regional and country level WATBAL analysis of impact of climate change on water resource and water availability; Regional level analysis of

perception and adaptation to climate change country level analysis on crop response simulation; regional analysis of the sensitivity cropping patterns to climate change
(2) World Bank Working Papers produced from suitable project reports (25 in 2006)
(3) Policy Briefs: Regional and country level policy messages extracted from the project reports
(4) Edited book synthesizing key methods, findings and policy messages of the research carried under the project (2007)
(5) Synthesis Report by Dinar et al. (2006). The Policy Nexus Between Agriculture And Climate Change In Africa. Prepared for a World Bank Publication
(6) Kurukulasuriya et al. (2006). Will African agriculture survive climate change? Submitted to the World Bank Economic Review (WBER)
(7) Several other manuscripts written from project outputs and data under review by various journals

(C) Capacity Building
(1) Training workshops on CROPWAT (for crop response simulation modelling) and WATBAL (for hydrology modelling) models, Ricardian approach, STATA statistical and econometric software.
(2) Postgraduates degree completed using project support and data
- (i) Yale University: 2 PhD's completed
- (ii) University of Colorado: 1 PhD completed
- (iii) South Africa: 2 MSc's completed and 2 PhD's in progress
- (iv) University College, London (UCL): One MSc completed
- (v) Burkina Faso: One PhD in progress

(3) Other: country participants at the several workshops training students in their home universities and institutions on application of STATA in several courses. For example, Zambia for statistics course, and South Africa for courses in Natural and Resource economics for students from South and Eastern Africa universities participating in CEEPA's "regional master specialization course in environmental economics."

(D) Integrated digital databases
(1) More than ten thousand surveys of farm households in the eleven study countries on their farming activities in the 2002 – 2004 farming seasons
(2) District level climate attributes' database
(3) Soil database at the district level
(4) Runoff and flow for all districts in Africa
(5) Climate scenarios for all districts in Africa for 2010 – 2100.

(E) Project website

Contains information on project activities: workshop reports; information on participating teams from the eleven countries, Yale University, FAO, IWMI and the University of Colorado; database (to be made available to the public soon) and; Research reports.

Annex 6. Monitoring and Evaluation Survey: Responses to Open Ended Questions

(a) Funders

Question 5: Sustainability. Assess approach followed to influence continuation of project benefits after completion and likelihood of project sustainability and needs for that

WBI: Networking conducted by researchers will enable them to continue the work using other funding sources; WB has also initiated subsequent activities that would enable uptake by various stakeholders of the results generated by the studies

Question 6: Institutional capacity. Assess performance of implementing agencies and partners (CEEPA and World Bank)

WBI: Long processes for meeting the WB administrative requirements put some strain on the relationship although these had been smoothened out recently

Question 7: In your opinion what was your organization's most important contribution to this project?

WBI: Providing the opportunity for faster uptake of the studies findings and recommendations: but this is yet to be realized in the next six months since the reports were finalized only recently

Question 8: Explain how this project supported your organization's interest in climate change and adaptation?

WBI: The low level interest in the Bank in climate change adaptation at the start of the project meant lost opportunities for making the studies more adapted to Bank clients' needs. Nonetheless, the recent upsurge of Bank interest in the topic means greater demand for the work conducted under this initiative.

Question 9: In what way(s) has your organization's interest been strengthened by this project?

WBI: This is one of two important entry points for the WBI Environment and Natural Resources Management Program in Africa. Since WBI's work is now more intensive in select focus countries, it is likely that the future work will emphasize information sharing and training for these focus countries.

Question 10: Replicability / continuation: Would you like to support an extension of this work and what would be the nature and direction of such an extension?

WBI: We would be interested in supporting extension of this work to enable the researchers disseminate results for a selected set of countries, perform more scenario analysis that would be needed for specific analytical, investment planning, and project development work by the Bank, and disseminate the results to economic policy makers.

Question 11: Any other comments on aspects not covered above

WBI: WBI is more interested in component C of the project; thus, the potential for collaboration with the researchers is yet to be maximized. We look forward to forthcoming opportunities to realize this potential.

(b) Regional teams

Question 7: Replicability/continuation. Assess likelihood of replication and/or extension of project activities

Yale University: The project is being replicated as we speak in Latin America. There is every reason to expect that a similar project in Asia would also be quite successful. This would give the world a good grasp of some of the most important impacts of climate change in the low latitudes. It would also provide valuable information about adaptation to climate change.

Yale University: It is strongly recommended that the group is kept together to further analyse the dataset and prepare lessons learnt on adaptation to climate change. This aspect has not been sufficiently addressed in the research due to lack of funding. This should be expanded on and CEEPA should lead this effort, together with Yale University.

Hydrology – Colorado University: The work completed by the hydrological team could easily be extended to other areas of the globe. The water resources aspect could be extended to include training on more water resource planning type models (i.e., WEAP.)

International Experts – University College London: Difficult to assess

Question 8: Any other comments on aspects not covered above

Ricardian - Yale University: GEF should definitely repeat this experiment in other regions. There was an enormous amount of African capacity building as part of this project. Further, the research from this project has provided the first quantitative evidence of the economic impacts of climate change to Africa. Finally, the research has revealed that African farmers have engaged in a lot of activities to adapt to climate. Understanding adaptation is very important right now as international agencies try to build adaptation programs in the field.

Hydrology –IWMI: IWMI was only involved in the first year of this study. IWMI participated in the development of the hydrological model used (WATBAL) and developed runoff estimates into the districts for which the Ricardian Analysis was conducted. We also assisted with training of the country teams in the use of WATBAL. Unfortunately project financial resources were insufficient to enable us to participate in other years of the study. Since we have not been involved since the first year we are unable to comment on the final project outputs or the overall project performance.

International Experts – University College London: Main problem encountered was in the sharing of the data. Unless the data is made publicly available a large potential benefit of the project will be lost. Plans must be put in place for visitors to download the data and supporting materials.

(c) National teams

Question 7: How do you plan to use the capacity gained and results to inform policy in your country and future research?

Ricardian –Cameroon: Paper Presentations in Seminars/Conferences

Ricardian –Senegal: Publication and presentation on national climate change workshop.

Ricardian –Egypt: (Submit a copy of the Ricardian analysis report to the head of Agricultural Research Centre and to the Minister of Agriculture, meet with them and present the results to them)

Ricardian –Zimbabwe: By continuing to undertake research on climate change issues

Cropwat- South Africa: Through attendance and involvement in other CC projects currently being run and planed in South Africa

Cropwat-Ethiopia: The skills gained through the short term trainings on Recardian analysis, Cropwat model and Stata softwares are very useful for making further research . Results found will also be presented in workshops.

Cropwat- Kenya: Through presentation of results in Invited national workshops and circulation of an executive summary in Government ministries and research institutions.

Cropwat-Burkina Faso: Reports

Question 8: Replicability/continuation. Assess likelihood of replication and/or extension of project activities in your country?

Ricardian – Cameroon: I have developed some research projects on similar lines. I am currently seeking funding for the research projects, for studies to be undertaken in Cameroon. In the new research projects, I have included younger researchers who were not involved in the GEF/World Bank Project. This is a continuation of the capacity building effort.

Ricardian –Senegal: With the experiences gain on the project, we can do simular works on local level (villages or department) to see what will was the result in small scale. We can also organize courses on climate changes impact using the ricardian method on school foresteries and university (by studing the possibilities to do that and what will was the implications). It will be good to take the project contacts for the technical needs. We also can extend the project to others countries

Ricardian – Kenya: I intend to extend the analysis to livestock

Ricardian – Egypt: Yes, extension of the project, or even replicating it could be easily done in Egypt. Particularly, with the profound results obtained from the current project.

Ricardian – Zambia: Less likelihood for continuation activities without seeking outside support or collaboration for financial and technical needs

Ricardian – Zimbabwe: (1) Country level extension – Two proposals have been submitted by members of Zimbabwe team to extend the research; (2) Region level extension: GECAF proposal by SADC team will extend the research at the regional level. However, I believe more could be done under the auspices of CEEPA and willing partners.

Cropwat – Egypt: I hope replication and/ or extension of project activities in my country and more concentration on the studies of the impact of climate change on the yield production and water needs for the main crops in Egypt. Because there are more crops are more vulnerable to increasing temperature and others like it

Cropwat – South Africa: Would be interested to repeat the project using the same methodologies CROPWAT and DSSAT-CERES to determine the future water use of maize using different CC scenarios at regional scale using data from UCT. (time and funding)

Cropwat - Ethiopia: Research made so far on climate change impact and vulnerability and adaptation in Ethiopia is limited. Further research on climate change issues has to be done to develop adaptation polices. Therefore extension is likely.

Cropwat- Kenya: A proposal to include other districts that were not involved in the study will be written for future funding. The main problem is the lack of funds.

Cropwat – Burkina Faso: I think the research activities need to be done again for two or three years to be confirmed before extension.

Cropwat - Senegal: Activities started with the project will allow us to train students in this field. One student is completing his thesis and will defend it by the end of 2006. This is the commencing of capacity building in the thematic of the imapct of climate change and adaptation of farmers. The training aspect will be the main continuation of the activities developped by the project.

Question 9: Any other comments on aspects not covered above

Ricardian – Senegal: Develop the capacities of team researcher member in courses organized on specific school's (Environment, Economy, Modeling, Statistics...). It will be good for their knowledge and will permit them to teach to others.

Ricardian – Egypt: No.

Finally, I want to thank all the team of CEEPA for their greet help and support during the project duration. Thank you all

Ricardian – Jain (Zam) – Team Leader: We could have included evaluation of data on physical parameters like climate, soil etc which was provided by external sources

Ricardian – Zimbabwe: Policy advocacy work to sensitize policy makers around the theme at the national and regional levels is one of the major gaps I noted. However I still believe that national and regional workshop with stakeholders can still be hosted funding permitted to promote the research findings especially at the regional level.

Cropwat – Egypt: CropWat: I sent more reports about CropWat under current and climate change conditions, and i did not receivie any comments on it.
IWMI or WATBAL: We didn't know how we can use this model?

Cropwat – South Africa: It was/is a very interesting project to work on and my first one with such a large international involvement which I thoroughly enjoyed. The networking and the introduction to other research organizations, which exist was an eye opener. The workshops were very professionally planed; the hotels, food and programs were excellent. With this I would like to congratulate the team at CEEPA, Dr J Benin, Dr R Hassan and Ms D du Plessis on a very good effort. I would also like to thank them for their and their friendliness and encouragement to stay involved in agricultural research and the opportunities they presented.

Cropwat -Ethiopia: CEEPA should be appreciated for coordinating the project and coming to the completion. I think CEEPA should continue coordinating research projects building on the experience it gained and on the expert/institutional network already established under the project. I would like to comment that CEEPA should emphasize more on capacity building in terms of short and long term (MSC, PhD) training and tools/facilities/models needed for climate change research

Cropwat - Kenya: This was a good chance to interact and create contacts with researchers in other countries in Africa and internationally, especially during the annual workshops.

Cropwat – Burkina Faso: We did not have money to go back to our partners to give them a feed back of the results in order to confirm them.

Cropwat - Senegal: It will be very important to continue such training activities, to have all the tools available in the different countries, after the end of the project.

Annex 7. Manual for project website

GEF Climate Change and Agriculture in Africa

http://www.ceepa.co.za/Climate_Change/index.html

A Brief Guide to the Discussion Board

Prepared by

Paul Schalkwyk
Website Coordinator

February, 2003

One of the Objectives of this project is the use of a Learning Knowledge Sharing Network (LKSN) to develop exchanges between and among country- and regional teams, international experts and all other participants on the project. The "Climate Change and Agriculture in Africa" website (http://www.ceepa.co.za/Climate_Change/index.html), more specifically the "discussion board" on the site is one of the important tools for achieving this objective. This manual intends to provide a brief introduction to the operation of the discussion board.

1 The Discussion Board

The discussion board is a virtual forum, which allows all participants on the project to interact with each other. It involves participants posting and responding to topics in the form of questions, opinions, observations, etc on various issues, with respect to the project in particular

2. Operation of the Discussion Board

2.1 Registering

Registration is not required to view current topics on the forum; however, if you wish to post a new topic or reply to an existing topic registration is required. Registration is free and only takes a few minutes. Your registration will be reviewed by an Administrator who will grant/deny your registration, either way you will be notified by email.

2.2 Users

The forum users are divided into three main groups according to the privileges given to the user by an *Administrator*:

i. *Regular users*: This group can participate by reading and posting messages, editing and deleting only those messages they have created or written. They cannot delete topics even they were the ones who created them.
ii. *Moderators*: Moderators control individual forums. They may edit, delete, or prune any posts in their forums. If users have any questions about a particular forum, they should direct them to the forum moderator.
iii. *Administrators*: This group has all the privileges of the regular users and moderators. In addition they can control group forums. They can also add or delete a forum or a group of forums.

2.3 Forum Moderation

Moderation: This feature allows the Administrator or the Moderator to "approve", "hold" or "delete" a users post before it is shown to the public.

Approve: Only the administrators or the moderators will be able to approve a post made to a moderated forum. When the post is approved, it will be made viewable to the public.

Hold: When a user posts a message to a moderated forum, the message is automatically put on hold until a moderator or an administrator approves of the post. No one will be able to view the post while it is put on hold. *Note: Authors of the post will be able to edit their post during this mode.*

Delete: If the administrator or moderator chooses this option, the post will be deleted and an email will be sent to the poster of the message, informing them that their post was not approved. The administrator/moderator will be able to give their reason for not approving the post in the email.

2.4 Authorization Type

This feature allows the Administrator to place restrictions on who is allowed to access which forums. A description of each type is outlined below:

- **All Visitors:** This allows all members (including unregistered members) to access the forum. This is selected by default.

- **Members Only:** This allows only registered members to access the forum. Unregistered members are not allowed access.

- **Members Only (Hidden):** This allows only registered members to access the forum. The forum will be hidden to unregistered members and they are not allowed access.

- **Password Protected:** This allows the Administrator to set a password on the forum. All members (including unregistered members) will be asked for a password before they are given access. Once they provide the correct password, they won't be asked for the password again.

- **Members Only & Password Protected:** This allows all registered members to access the forum **OR** if they are not registered members, they will be asked for their password. Once they enter the correct password, they won't be asked for the password again.

- **Allowed Member List & Password Protected:** This allows the members selected from the Available Members' List, to access the forum **OR** if they are not in the Selected Members List, they will be asked for the password set for the forum. Once they enter the correct password, they won't be asked for the password again.

- **Allowed Member List:** This allows only selected members from the Available Members List, to access the forum. All other members (including unregistered members) are not granted access.

- **Allowed Member List (Hidden):** This allows only selected members from the Available Members List, to access the forum. The forum is hidden from all other members (including unregistered members) who are not on the Selected Members List.

2.5 Cookies:

The forum uses cookies to store the following information: the last time you logged in, your username and password, if you set them in preferences. These cookies are stored on your hard drive. Cookies are not used to track your movement or perform any function other than to enhance your use of these forums. If you have not enabled cookies in your browser, many of these time-saving features will not work properly. Also, you need to have cookies enabled if you want to enter the private forum or post a topic/reply. You may delete all cookies set by these forums in selecting the "logout" button at the top of any page.

2.6 Discussion Periods:

Forums with their topics and replies can be on the site as long as an Administrator or Moderator wants the discussions to carry on.

2.7 Active Topics:

Cookies track active topics. When you click on the "active topics" link, a page is generated listing all topics that have been posted since your last visit to these forums (or approximately 20 minutes). This allows the user to easily join in the discussions.

2.8 Attaching Files:

You may not attach files to any posts. However, you may cut and paste text into your post.

2.9 Searching For Specific Posts:

You may search for specific posts based on a word or words found in the posts, user name, date, and particular forum(s). This is can be done by clicking on the "search" link at the top of most pages.

2.10 Censoring Posts

The forum censors certain words that may be posted for one of many reasons. Words that are censored are replaced with asterisks.

3 Using and Participating in the Discussion Forums

The discussion forums are constructed of several levels. Each level is a sub-level of the higher one. It is very important that you know on which level you are to make for your easy participation in the discussions. The following screen shots give a visual idea and describe all the links to each level.

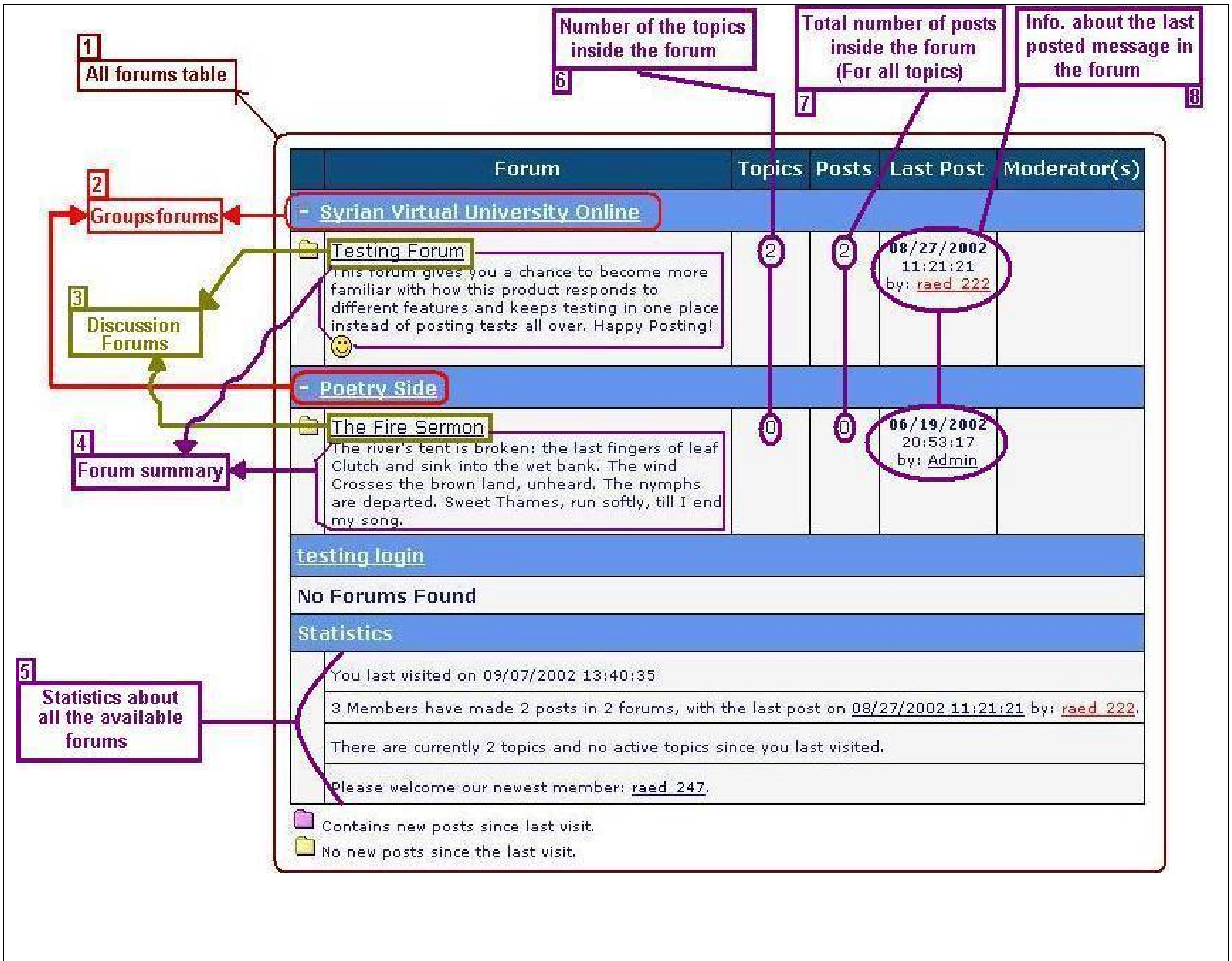

Figure (2-1)

3.1 All Forums table:

When you first log on to the forums, you will be directed to the main forums' page, which should look similar to **Figure (2-1)**. This table contains all the necessary information about the available groups of forums and the discussion forums up to date. This information should give a general idea about each group of forums.

3.2 Group of forums:

The forums are divided into groups, which are categorized by the Administrator. Each group can contain several discussion forums. You can select a group of forums by clicking on it; this will take you to a page that only contains the discussion forums of the selected group (**Figure (2-2)**)

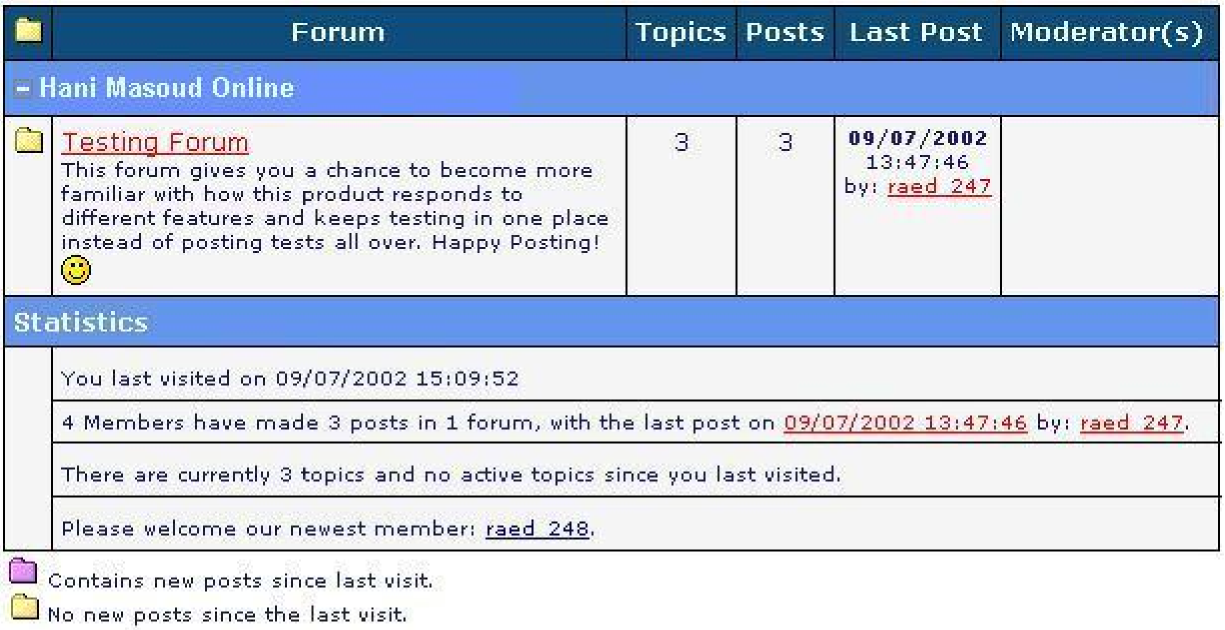

Figure (2-2)

3.3 Discussion forums:

Once a discussion forum is selected by clicking on it, whether from the "All forums page" or from the "Group forums page", you will get a list of forum's topics' titles with some information about each topic (who the author of the topic is, how many replies the topic have received, how many users have read the topic and statistics about the last posted message in this topic). In this part, you can select any topic in the forum that you might find interesting to read or participate in the discussions.

Moderators only can make revisions to the forums. The "ordinary user" can only add new topics to an existing forum, but not create a new discussion forum. **Figure (2-3)**.

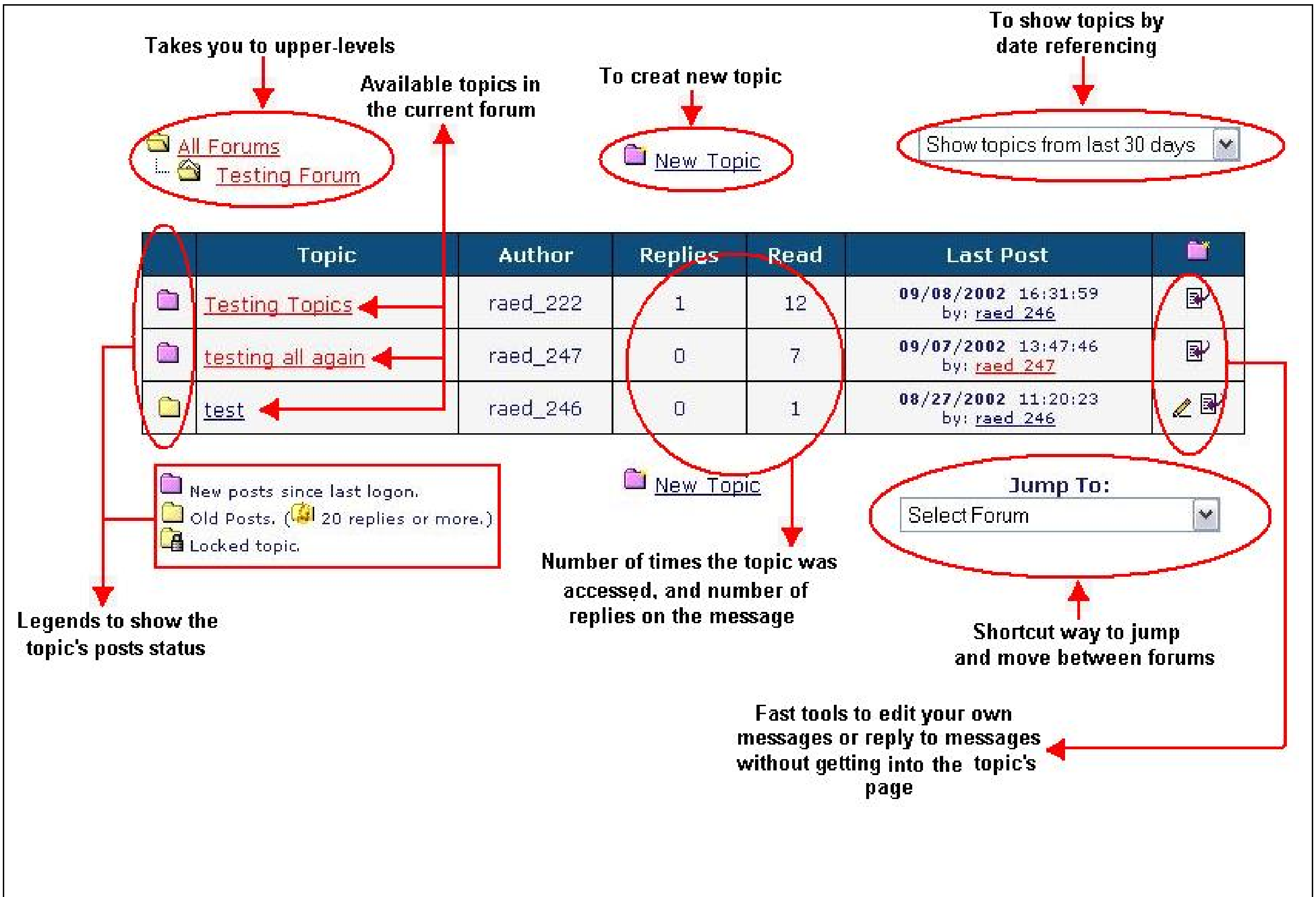

Figure (2-3)

Topics in the forums are organized in a chronological order. This allows users to easily identify the latest post in the forum.

As the number of forums and groups of forums increase, a user can have a fast access to all available forums by the use of drop down menu indicated at the right-bottom corner of the current window (**Figure (2-3a)**).

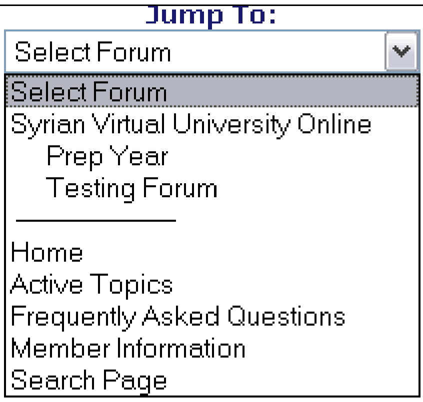

Figure (2-3a)

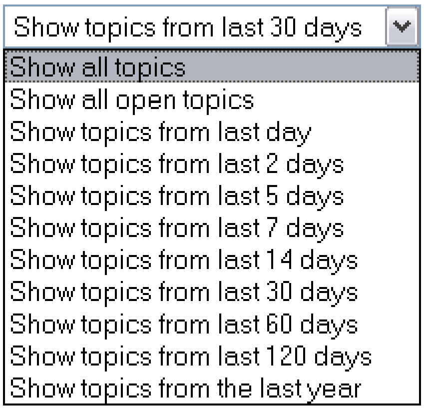

Figure (2-3-b)

More over, you can limit the size of the shown topics of a certain forum. By clicking the drop down menu to the right-top corner, you can specify a period of time within which you want to check the topics that have been created. **Figure (2-3b)**.

Creating a new topic in that discussion forum can also be done from this window by clicking the new topic pink icon ( ) or by clicking at "New Topic".

As a quick access option, you may reply to a topic, without having to get inside it. This can be done by clicking the reply icon ( ) to the right-hand most field in the topic's row. Note that you can also edit any topics you have created before; change the subject, starting message, or any other details in this topic. You can start editing a topic you started by clicking the edit icon ( ) which only appears next to those topics, which you have started.

Deleting an existing topic, even if it was created by you, can't be done but by only the Administrator(s) or the Moderator(s).

3.4 Discussion forum's topics: (**Figure (2-4)**)

When you select a topic of a certain discussion forum by clicking at the topic itself, you will be directed to a page that holds all the posted messages in this topic. You can also see who posted the message, when it was posted and the user ranking in the forums community.
In this window, apart from reading the messages, you can also view the participants' profiles ( ) and post a reply by e-mail ( ). Sending a reply to a message and quoting it within the reply can be done by clicking the reply icon ( ), which appears above the message among the other icons. Also a regular (general) reply to the topic can be done by clicking the reply icon ( ) at the top or bottom of the topic messages page. With respect to the messages that you have already posted, you can edit ( ) or delete ( ) them from the topic.

Creating a new topic in the discussion forum can also be done from this window by clicking the new topic pink icon ( ) or by clicking at "New Topic".

When you get into a topic page, you can directly go to the next topic, without going up-one-level; that is by clicking at the icon at the top row of the table, which will take you directly to the next topic ( ).

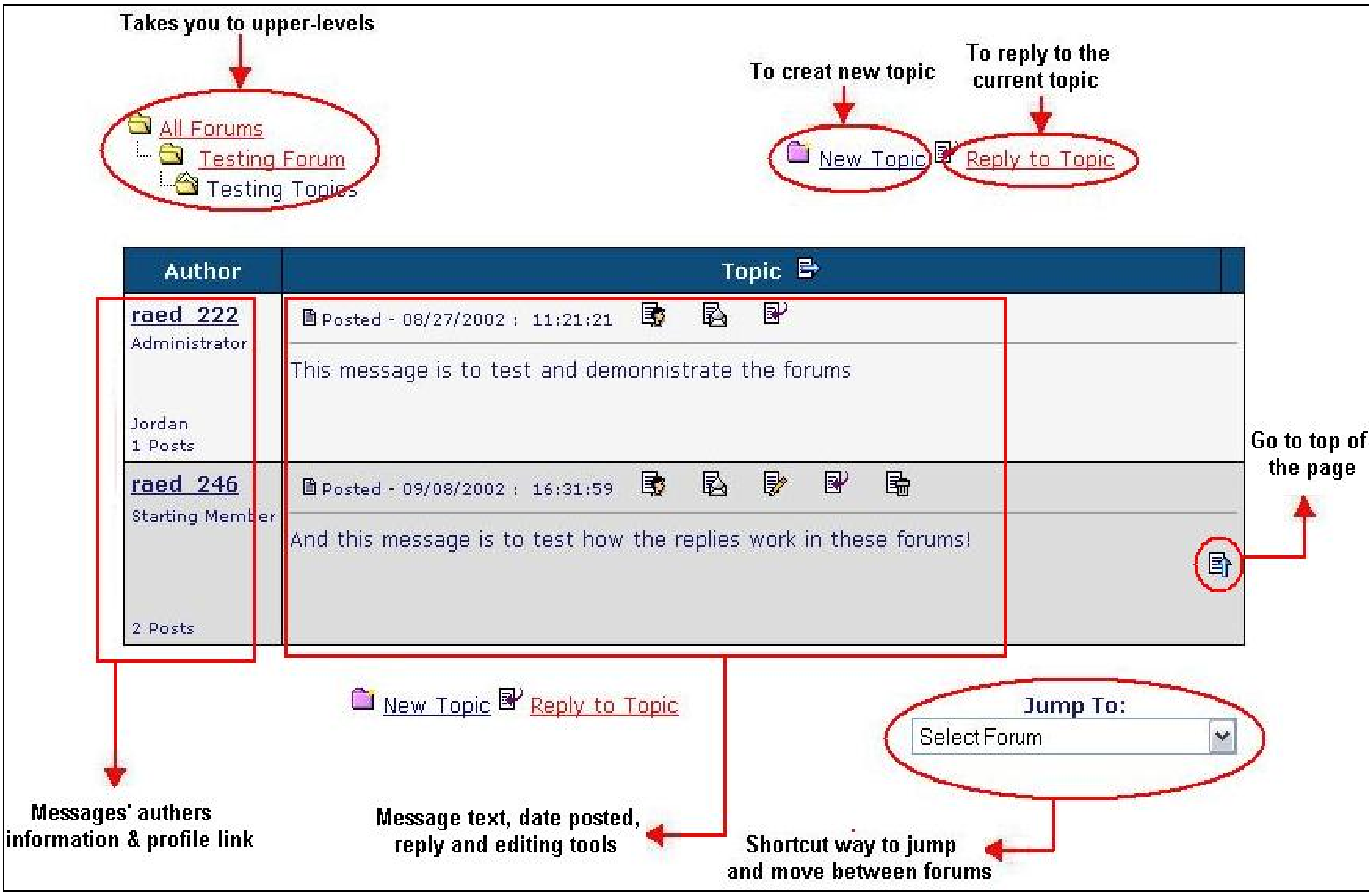

Figure (2-4)

3.5 Replying to a topic:

When you choose to reply to a certain topic you will get a window similar to the one shown in (**Figure (2-5)**. In this window you can format your message the way you want it to be viewed. Changing the "Screen size" gives you options to design your message. The formatting tools used in this window, are the common formatting tools that are available in all word processing applications. You can also add a hyperlink; insert e-mail address, programming codes and more.

There are three main modes in which you can compose your message:

1st mode: The Basic Mode:

Clicking on any formatting tool while in this mode inserts an opening and a closing tag into the writing pad. All you have to do then is to insert your text between the two newly added tags.

2nd mode: The Help Mode:

By clicking on any formatting tool while in this mode, a pop-up window will appear. This window will show you how you should write the selected formatting tags by showing you an example. You can then go back to the writing pad and type your message following the given example.

3rd Mode: The Prompt Mode:

If you click on a formatting tool while in the prompt mode, a popup window with a text box inside will appear on your screen. This window will prompt you to write, and it will guide you step by step through the composition of your message. You will have to write your text in the small text box in the pop-up window. By clicking OK on the pop-up window, the text you have typed in the text box will be moved to the writing pad, and the needed tags will be added to it automatically.

You can switch between the three modes by selecting the targeted mode from the drop down menu at the bottom of the message text box.

Including your signature to the message is optional. You can add your profile signature by checking the box at the bottom of the writing pad, or you can remove the signature by clearing the check box.

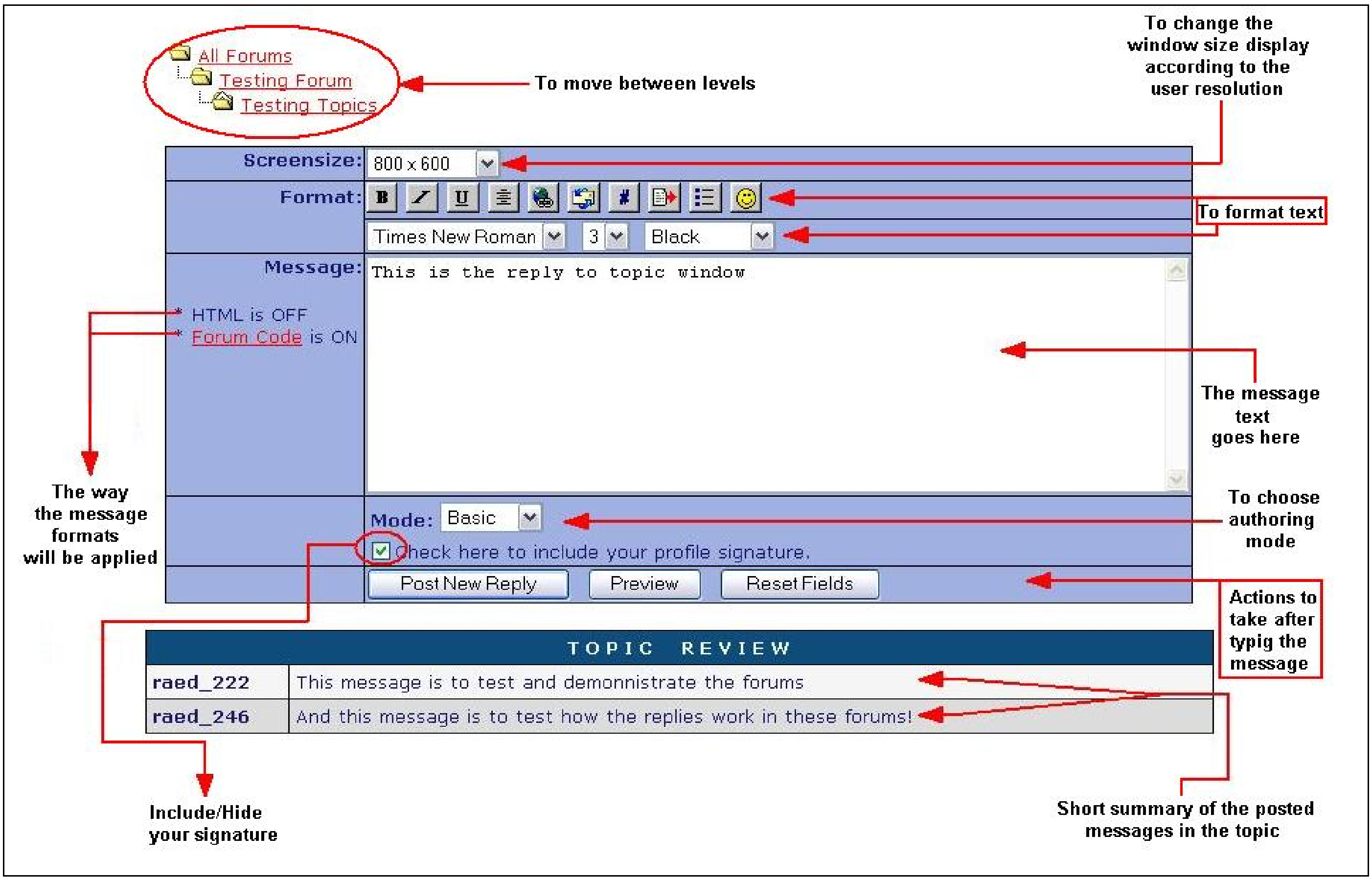

Figure (2-5)

There are three buttons at the bottom of the pad:

1. 

To post your message to the topic you are in.
2. 

To preview your message before posting.
3. 

To reset all the fields of the message to start typing it again.

When you click on "Post New Reply" your reply will be posted and added to the topic messages. After you add a reply, the topic will appear at the top of the Forum Page, and anyone with access to the forum can read your message.

If you choose to create a new topic, you will have a window similar to the reply window, but there will be one more field to specify the subject of the new topic.

Below is a list of some formatting tags that can be used in formatting a message:

Bold: enclose your text with [b] and [/b] . *Example:* This is **[b]**bold**[/b]** text. = This is **bold** text.

Italic: enclose your text with [i] and [/i] . *Example:* This is **[i]**italic**[/i]** text. = This is *italic* text.

<u>Underline:</u> enclose your text with [u] and [/u]. *Example:* This is **[u]**underline**[/u]** text. = This is <u>underline</u> text.

Aligning Text Left: Enclose your text with [left] and [/left]

Aligning Text Center: Enclose your text with [center] and [/center]

Aligning Text Right: Enclose your text with [right] and [/right]

Striking Text: Enclose your text with [s] and [/s] Example: **[s]**mistake**[/s]** = ~~mistake~~

Font Colors: Enclose your text with [*fontcolor*] and [/*fontcolor*]
Example: **[red]**Text**[/red]** = Text
Example: **[blue]**Text**[/blue]** = Text
Example: **[pink]**Text**[/pink]** = Text
Example: **[brown]**Text**[/brown]** = Text

Font Sizes:
Example: **[size=1]**text**[/size=1]** = Text
Example: **[size=2]**text**[/size=2]** = Text
Example: **[size=3]**text**[/size=3]** = Text
Example: **[size=4]**text**[/size=4]** = Text
Example: **[size=5]**text**[/size=5]** = Text
Example: **[size=6]**text**[/size=6]** = Text

Bulleted List: **[list]** and **[/list]**, and items in list with **[*]** and **[/*]**.

Ordered Alpha List: **[list=a]** and **[/list=1]**, and items in list with **[*]** and **[/*]**.

Ordered Number List: **[list=1]** and **[/list=1]**, and items in list with **[*]** and **[/*]**.

Code: enclose your text with **[code]** and **[/code]**.

Quote: enclose your text with **[quote]** and **[/quote]**.

Example: **[black]**Text**[/black]** = Text
Example: **[orange]**Text**[/orange]** = Text
Example: **[violet]**Text**[/violet]** = Text
Example: **[yellow]**Text**[/yellow]** = Text
Example: **[green]**Text**[/green]** = Text
Example: **[gold]**Text**[/gold]** = Text
Example: **[white]**Text**[/white]** =
Example: **[purple]**Text**[/purple]** = Text

Headings:
Enclose your text with [h*number*] and [/h*n*]
Example: **[h1]**Text**[/h1]** =

Text

Example: **[h2]**Text**[/h2]** =

Text

Example: **[h3]**Text**[/h3]** =

Text

Example: **[h4]**Text**[/h4]** =

Text

Example: **[h5]**Text**[/h5]** =

Text

Example: **[h6]**Text**[/h6]** =

Text

smile	[:)]	frown	[:(]
big smile	[:D]	shy	[8)]
cool	[8D]	shocked	[:O]
blush	[:I]	angry	[:(!]
tongue	[:P]	dead	[xx(]
evil	[}:)]		
wink	[;)]	sleepy	[|)]
clown	[:o)]	kisses	[:X]
black eye	[B)]	approve	[^]
		disapprove	[V]
eightball	[8]	question	[?]

Problems and Queries about this site?
Please e-mail Paul Schalkwyk <paul@webdhm.co.za>

Annex 8: Financial Management Status

See PDF Files attached at end