ASSESSMENT OF IMPACTS, ADAPTATION, AND VULNERABILITY TO CLIMATE CHANGE IN NORTH AFRICA: FOOD PRODUCTION AND WATER RESOURCES

AIACC AF90 Semi-Annual Progress Report
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A. Summary of the project activities for the past six months

The focus of the work is the understanding of agriculture-climate interactions and the implications for water availability in North Africa. The work is developed by the project responsible investigators in Egypt, Tunisia, and Morocco, in close collaboration with Dr. Ana Iglesias from Spain.

The research focused on:
- Stakeholder engagement. We have defined the linkages of the projects with key stakeholders at different levels. A prototype survey to farmers' groups and extension agencies is being conducted and analysed in Tunisia and Egypt. The survey results define the strategies for agricultural adaptation to climate change based on the current and future vulnerability of the sector.
- Impact and vulnerability analysis. We have developed the database and GIS integration of climate, land use, and agricultural variables; the time series of variables and correlations are being analyzed. Future impacts on crop production and water use are being evaluated by using models.

Other activities during Feb 2003 to July 2003 included national and international field trips and participation in meetings linking International research in North Africa to the National project activities.

B. Tasks and outputs produced

B.1. Definition of adaptation strategies with the stakeholders in Egypt

The stakeholder engagement comprises a four step processes for each stakeholder group: identification of the key representatives; determination of the group's interests; evaluation of the group's power of influence; and formulation of the group's participation strategy.

Adaptation strategies of small-holder farmers, commercial farmers, and strategic resource managers were derived from the analysis of surveys and educational sessions carried out in El-Beheira, Khafr El-Sheikh, and El-Gharbia Governorates. The adaptation strategies are focused on optimising production and improving irrigation use efficiency.

The adaptation strategies included the production of both winter crops (wheat, sugar beet, and clover berseem) and summer crops (maize, cotton and rice). In each case the following parameters were evaluated form the farmers' point of view:
- Knowledge of the management technology for each crop;
- Attitudes towards practices of water management;
- adoption of water management practices;
- reasons for using too much water in irrigation; and
- farmers' suggestions for controlling the use of irrigation water.

The main conclusion is that adaptation is a process of "learning by doing". Farmers need and demand further guidance in relation to improved irrigation efficiency. In all cases, effective extension activities are the key to develop adaptation strategies at the farm level. The role of the resource managers and National scientists to enhance education and capacity building is essential. Further details are provided in Appendix H.1.

B.2. Definition of adaptation strategies with the stakeholders in Tunisia

In Tunisia, the project focuses in rainfed agriculture in the Center Region, the main agricultural area of the country. A survey to evaluate the capability of the farmers to adapt to changes in climate conditions is being conducted for both olive production (in Sfax) and wheat production (in Kairouan). Further details are provided in Appendix H.2.

B.3. Definition of adaptation strategies with the stakeholders in Morocco

In Morocco, interviews were conducted to identify the decision process of the National and Sub-National resource managers related to the agricultural decisions that are influenced by climate. All Institutions with responsibilities in the adaptation process are integrated in the Moroccan National Drought Observatory. The Observatory is developing a National Drought Policy Plan, with the close institutional collaboration of the Direction de la Meteorologie National, other institution in the Moroccan Government, and Universities. The aim of this effort is to develop an institutional structure/capacity that includes an early warning system and a delivery system for information to users. The goal here is adaptation and mitigation, moving away from reactive, crisis management. This effort represents recognition of the importance of carrying out some of the activities carried out in this project.

B.4. Impact, vulnerability, and adaptation analysis in Egypt

The climate change impact, vulnerability, and adaptation of the production of the major food crops and irrigation water requirements in Egypt are analyzed by evaluating the proposed stakeholders adaptation options with a range of modeling methodologies. The analysis includes both cereal and vegetable production. The stakeholders engaged in the project represent the small-holder farmers, commercial farmers, and strategic resource managers. An empirical statistical analysis is used to evaluate how agricultural cropping systems interact with intra and inter-annual climate variability. Simulation models are used to quantify some of the strategic adaptation options proposed by the stakeholders. The modeling studies consider on-farm adaptation techniques such as use of alternatives existing varieties and optimization of the timing of planting and other techniques can enhance sustainability under current conditions. The preliminary results show that there is an overall reduction in crop yields under climate change even when adaptation is taken into account. Further details are provided in Appendix H.1.

B.5. Vulnerability of dryland agricultural to current climate variability in the Center Region of Tunisia

The analysis is conducted in three steps: (1) Identification of the Tunisian agricultural land use; (2) Creation of a database of agricultural production and climate variables for the main production regions; and (3) Quantification of the production variability and correlation to the climate variability. The statistical analysis shows that the amount of rainfall and its distribution are important factors that determine yield and wheat production. A high significant linear relation (R_=0.51) has been found between rainfall during the growing season (from November to April) and wheat yield. Also, a significant linear relation (R_=0.39) has been found between March rainfall (critical growing phase) and yield. Each year, sown areas are not completely harvested due to crop failures, the ratio between harvested and total sown areas shows a high significant linear relation (R_=0.44) with rainfall during the growing season. Further details are provided in the first report of the AIACC AF90 Project.

B.6. Identification of current water deficit and stress for agricultural production in Kairouan (Tunisia)

The daily water balance (precipitation minus evapotranspiration) was calculated at the Kairouan station for the 1979-2000 period using the Penman Monteith equation for evapotranspiration. An important water deficit of over 200 mm form March to August, and of over 150 mm during September to February is manifested all years. These results in a high variation of areas cultivated in dryland conditions (as shown in the first report of the AIACC project) and are responsible for crop failures during the most severe drought years. Projected climate change will increase the water deficit and the stress for dryland crop production. Further details are provided in Appendix H.2.

B.7. Agro-ecological characterization and impact analysis in Morocco

At the country level climate is one of the components that may disrupt the agricultural sector. For example, cereal production in Morocco shows dramatic reductions during the severe climatologic and hydrologic drought of 1992-1994. This was a factor for the unbalance between the agricultural exports and imports in Morocco during the same period. Further details are provided in Appendix H.3.

At the case study level, the study region selected for the analysis is Chaouia that represents the major cereal production in the country. In this region, the following project components were developed during this reporting period:

(a) Agro-ecological characterization of la Chaouia. The time series of precipitation, evapotranspiration, and water balance was statistically correlated with the crop productivity during the same time period. The main result is that la Chaouia is affected by drought one every three years.

(b) Analysis of the potential wheat response. The method of analysis is integrated modeling in combination with decision support systems. The following models are used in the study:

- The SWG model is used to generate the time series of daily climate data needed for the agricultural study.

- The model Simtag is used to simulate wheat growth, production, and water balance under the climate scenarios. This model is used by the DMN for analysis of wheat conditions in the entire country.
- Phyto-pathologic models. A Decision Support System (DDS) that includes a phyto-pathologic model is used for rust and Cercospora, the main diseases that affect the wheat crop in Morocco that are directly related to climate conditions (high temperature and humidity).

The main results of the analysis are:

- Annual precipitation variability is responsible for about 35 percent of the variability of the wheat production.
- Early crop varieties show a smaller degree of variations. This has implications for adaptation strategies.

The Case Study of La Chaouia is conducted in collaboration with the project PAC, DMN-INRA-ICARDA with scientists of the National Institute for Agricultural Research (INRA, Dr. Karrou and Dr. Benaouda). Further details are provided in Appendix H.3.

B.8. Travel

- AIACC Africa Regional Open Meeting and Workshop. March 10-13, 2003. Hartebeespoortdam, South Africa.
- Tunisia Project Meeting. July 8-13, 2003. INRGREF, Tunis. Participation of R. Mougou and A. Iglesias.

C. Difficulties and lessons

The main difficulties encountered by all members of the project team were:

(a) Technical support in relation to the climate change scenarios. We would like to propose that the AIACC Newsletter includes the stage of development of the scenarios for the projects and provides datelines and deliverables to provide data for the projects.

(b) Budget. Lack of funds for engagement of the stakeholders in the design of adaptation strategies and project coordination and synthesis.

D. Connections or interactions with the UNFCCC

- Egypt National Communication: Prof. Abou-Hadid and Dr. Medany assisted in first National Communication as President and CEO and Minister's Bureau Manager, Ministry of State for Environmental Affairs, respectively. Both remain Steering Committee Members and will participate in further National Communications.

- Linkages between the Egypt National Communications and the AIACC project: The results of the AIACC North Africa Project will be included in the National Communications of

Egypt. Prof. Abou-Hadid provides updated information to H.E. Dr. Riad, Minister of Ministry of State for Environmental Affairs, Dr. El-Hamady, Dean of Environmental Research and Studies Institute, Ain-Shams University and Dr. Eissa, General Manager of Information Dept., Egyptian Meteorology Authority (EMA). Also Prof. Abou-Hadid is the General Manager of Arid Land Agricultural Research Unit (ALARU).

- In Tunisia the Focal Point of Climate Change consults the work of INRGREF to include it in the Official National Communications.

- Dr. Mougou also participates in national and international activities related to the project, such as: (1) International Workshop 'Les Mécanismes de Développement propre. Enjeux et barrière', Tunis, décembre 2002; (2) International seminar 'Le Climat de demain', Institut National de la Météorologie de Tunisie, March 2003; (3) National forum 'L'évaluation et les perspectives en matière de changement climatique', Ministry of Agriculture, l'Environment and Hydraulic Resources. May 2003; and (4) First International Conference 'Les Changements Climatiques et le tourisme', Oganisation Mondiale du Tourisme, April 2003.

- In Morocco, Dr. Mokssit a permanent representative in the World Meteorological Organization activities related to climate change. He is also a member of the Moroccan National commissions related to climate change and drought.

E. Tasks in the next eight-month period

- The main research objective for the coming eight-month period is to evaluate adaptation methods to current and projected climate stress. The set of adaptation strategies will be derived form the survey results and the analysis of the responses in the past. The evaluation will take place at two temporal scales (current and future) and two spatial scales (local farm-level) and regional North Africa level. Future climate and socio-economic scenarios will be derived from the HadCM3 climate model under the A1 and B2 SRES socio-economic scenarios.

- Education and capacity building activities in each country will include scientific lectures and participation in meetings and workshops with the extension services.

F. Anticipated difficulties

- Lack of funds for engagement of the stakeholders in the design of adaptation strategies and project coordination and synthesis. We would like to explore the opportunity for additional funds for:
  (a) Conducting surveys and interviews to the main stakeholders;
  (b) Field trips for the project partners to the other countries to coordinate the methods used for the analysis and synthesize the project results, and for writing scientific papers;
  (c) Local country trips to coordinate the project activities with related efforts at the National level; and

(d) Workshops to communicate the project results to the main groups of stakeholders and to incorporate their comments.

- Possible delay in developing the climate scenarios needed to complete the study of impacts and adaptation successfully due to lack of technical support providing the GCM data necessary for the project. This will imply a delay in the analysis of the adaptation options developed with the stakeholders.

G. Draft or final papers

Abdel Hafez, S. A., N. G. Ainer and H. M. Eid. 2003. Climate change impacts on Delta crop productivity, water and agricultural land. J. Agric.Sci. Mansoura Univ. Special Issue, Scientific Symposium on "Problems of Soils and Water in Dakahlia and Damietta Governorates". ISSN 1110-0346 Pp. 15-26 March 18, 2003.

Iglesias, A. 2003. Climate, drought, and prediction in the Mediterranean: Opportunities for agricultural adaptation. Revista de Ingenieria Civil, in press.

Iglesias, A. M.N. Ward, M. Menendez, and C. Rosenzweig. 2003. Water Availability for Agriculture Under Climate Change: Understanding Adaptation Strategies in the Mediterranean. In: Giupponi, C. ans M. Shechter (eds.). Climate Change and the Mediterranean: Socioeconomic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar Publishers.

Mougou, R. and Ben Slaem, M. 2003. Meteorological conditions in arid regions and effects of climate change in dryland crops. Training on Agricultural Techniques for Rainfed Agriculture and Communication to Farmers, Arab Center for Studies in Dryland Agriculture (ACSAD), Tunis.

An oral presentation of the project by A. Iglesias has been invited for the 2003 World Water Congress (October, Spain), the full text will be included in the Congress Proceedings.

An oral presentation was presented by R. Mougou, Le changement climatique et l'agriculture. In: 'International seminar on *Le Climat de demain,* Institut National de la Météorologie de Tunisie, March 2003.

In Egypt, Dr. Abou-Hadid and Dr. Medany are preparing for new research papers and supervising more than 7 Ph.D. and M.Sc. thesis. The research focuses on climate change impact evaluation in Egyptian agriculture and can be viewed as future input to the AIACC project.

In Spain, Dr. Iglesias is directing two Ph.D. thesis related to the AIACC research.

H. Appendices

H. 1. Assessment of impacts, vulnerability, and adaptation to climate change in agriculture and ware needs in Egypt

H.2. Tunisian Report: (1) Vulnerability of dryland agricultural to current climate variability in the Center Region; (2) Identification of current water deficit and stress for agricultural production in Kairouan; and (3) Questionnaire to the stakeholders in Tunisia

H.3. Climate Change: Potential and Limitations for Agriculture in the La Chaouia Region of Morocco

APPENDIX H.1.

ASSESSMENT OF IMPACTS, VULNERABILITY, AND ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE AND WATER NEEDS IN EGYPT

Progress Report of the Egyptian Case Study of the AIACC AF90 Project
15 July 2003

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SUMMARY

The climate change impact, vulnerability, and adaptation of the production of the major food crops and irrigation water requirements in Egypt are analyzed by evaluating the proposed stakeholders adaptation options with a range of modeling methodologies. The analysis includes both cereal and vegetable production. The stakeholders engaged in the project represent the small-holder farmers, commercial farmers, and strategic resource managers. An empirical statistical analysis is used to evaluate how agricultural cropping systems interact with intra and inter-annual climate variability. Simulation models are used to quantify some of the strategic adaptation options proposed by the stakeholders. The modeling studies consider on-farm adaptation techniques such as use of alternatives existing varieties and optimization of the timing of planting and other techniques can enhance sustainability under current conditions. The preliminary results show that there is an overall reduction in crop yields under climate change even when adaptation is taken into account.

STAKEHOLDERS ANALYSIS

The stakeholder engagement was conducted through four steps processes as follows:
- Identifying Key Stakeholders,
- Determining Stakeholders' Interests,
- Determining Stakeholder Power and Influence, and
- Formulating a Stakeholder Participation Strategy.

The stakeholders in Egypt did field-based studies of the adaptation choices of small-holder farmers, commercial farmers and strategic resource managers. The methodology is based on survey analysis and communication with stakeholders by local training. The training includes the educational effect of the extension and field demonstration for growing winter crops (wheat and others) and summer crops (maize and others) at El-Beheira, Khafr El-Sheikh Governorates and also national workshops. A list of farmers from El-Beheira, Khafr El-Sheikh, and El-Gharbia Governorates was prepared representing stakeholders of the Delta region and will be included in the annual report.

With the goal of increasing agricultural production and achieving the best possible use of water resources, the study demonstrates the value of application of improved agricultural technologies in Behiera and Khafr El-Sheikh Governorates. The study depends on effective extension activities which provide the farmers with the knowledge needed and teach them how to apply this knowledge's. Extension efforts have been exerted to convince farmers that it is necessary to follow the agricultural practices which guide the use of water in irrigation. Among such activities were paying attention to the demonstration aggregates and fields to cultivate various crops where technologies are applied in order to increase production and guide to the use of water through the use of precession land leveling, long furrows, long borders, and planting dry berseem (as alternative to the traditional wet method), etc. In addition, to increase the educational effectiveness of the field demonstration, the analysis included meetings, and field visits made by researchers and extension workers.

Much attention has been devoted to evaluate the educational effect for such field demonstration during the winter season, including wheat, sugar beet, and clover (berseem) crops, and summer season crops, including cotton and rice to know the extent of the farmers knowledge of the technologies used for each crop, find out the growers attitudes towards practices of water management, farmers adoption of water management practices, farmers reasons for using too much water in irrigation, and their suggestions for controlling the use of irrigation water. It is here the process of learning by doing.

The analysis focused on the following headings in the field based studies:

- Characteristics of the growers.
- Educational effects of the field demonstration related to: (1) Growers knowledge about wheat, cotton and rice practices; and (2) Growers knowledge about water management practices.
- Adoption of water management practices.
- Growers information resources about water management.
- Growers attitudes towards practices of water management.
- Growers reasons for using excessive water for irrigation and their suggestions as to how to manage it.

With regard to Gharbia Governorate, a short questionnaire was used to detect the farmer's experiences with the wheat growing practices and evaluate the level of awareness with regard to the influence of climate variability as well as the adoption options for wheat and vegetables grown in the cropping pattern. The analysis of the Gharbia Governorate farmer's results will be explained in the annual report.

EVALUATION OF IMPACTS AND ADAPTATION OF WHEAT AND TOMATO PRODUCTION UNDER CLIMATE CHANGE

Regression analysis

Empirical models are defined as models directly describing observational data, while containing no information beyond the original data (Thornley and Johnson, 1990). One form of empirical model is prediction equations resulted from regression analysis. Regression analysis (Drapper and Smith, 1987) is a technique utilized to fit a line through a set of observations, and test how a single dependent variable is affected by the value of one or more independent variables. As a result, a prediction equation is developed and used to predict the performance of those dependent variables, when values of these independent variables vary.

The aim of the use of models in this project is to predict wheat and tomatoes productivity under current temperature and with a raise in temperature by 1.5° C and by 3.6° C.

Data for mean temperature and wheat productivity were collected for twenty five years (1975-1999) for Sakha, Kafer El-Sheakh Governorate, Egypt (as a representative of Delta region). Sowing was assumed to be done at November, 20. Wheat season length for each year was determined and mean temperature was summed throughout the growing season. Mean temperature was used to predict wheat productivity, where a straight line was fitted to wheat yield as a function of temperature. This assumption was examined by testing for lack of fit. The developed equation was used to assess the impact of high temperature by predicting wheat yield (kg/ha) under current temperature, current temperature + 1.5° C, and current temperature +3.6° C. The impact of high temperature on wheat yield in that case is the percent reduction in yield. The developed equation can be stated as follows:

[1] $Y' = 14205.25 - 610.85 * Mtemp$
Mean = 4673 ± 229.1

Predicted yield using equation [1] was graphed with measured yield. For graphing purposes and to reduce yield inter-annual variation, data was customized and then graphed with predicted yield.

To overcome the adverse impact of high temperature on yield and reduce vulnerability, different adaptation techniques were examined e.g. delay sowing, and altering irrigation amounts. Three sowing dates (November, 30; December, 10; December, 20), and/or four irrigation amounts (300, 350, 400, 450 mm/season) were included in the prediction and new prediction equations was developed. The percent of yield quantity improvement as a result of these adaptation techniques is then determined.

- Effect of sowing date. Prediction equations that include different sowing dates could be stated as follows:
  - Sowing at November, 20: [2] $Y' = 13856.32 - 588.32 * Mtemp$

- Sowing at December, 10: [3] Y` = 14565.38 - 647.06 * Mtemp
- Sowing at December, 20: [4] Y` = 14620.89 - 658.04 * Mtemp

- Effect of irrigation amounts. Prediction equation that includes different irrigation amounts (Irr) could be stated as follows:

  [5] Y` = 14043.10 - 611.55 * Mtemp +0.86 * Irr

- Interaction between sowing dates and irrigation amounts. When both delay sowing and irrigation amounts were considered in the predication, prediction equations could be stated as follows:

  - Sowing at November, 30 with irrigation amounts included
  [6] Y` = 13703.85 - 588.94 * Mtemp +0.73 * Irr
  - Sowing at December, 10 with irrigation amounts included
  [7] Y` = 14408.01 - 647.72 * Mtemp +0.95 * Irr
  - Sowing at December, 20 with irrigation amounts included
  [8] Y` = 14771.53 – 658.75 * Mtemp +0.63 * Irr

Wheat yield was predicted using equation [1] under current temperature, current temperature + 1.5° C, and current temperature +3.6° C. The vulnerability of wheat to high temperature increased by 20.93% when temperature increased from + 1.5° C to + 3.6° C is shown in Table 1.

Table 1. Predicted wheat yield under current temperature, and with a raise in temperature.

Temperature	Predicted yield (kg/ha)	Impact (%)
Current temperature	6129.81	--
Current temperature + 1.5° C	5299.08	-14.95
Current temperature + 3.6° C	3930.75	-35.87

Reduction in yield as a result of heat stress could be attributed to low biomass accumulation as a result of reduction in the growth duration (Ritchie and Nesmith, 1991). Predicted wheat yield using equation [1] under current temperature conditions was validated against observed yield.

Using regression models to evaluate the effect of adaptation strategies

Effect of sowing date

Although delay sowing reduces season length and consequently reduces yield, it could be useful to overcome the impact of high temperature on wheat yield, and reduce vulnerability. As it shown in Table 2, wheat yield was predicted using equations [2], [3], and [4]. The differences in yield as a result of a raise in temperature were found to be decreasing, when sowing was delayed. Results in Table 3 showed that sowing wheat at December, 20 reduced vulnerability by 1.61, 1.64 % under a raise in temperature by 1.5° C and 3.6° C, respectively.

Table 2. Predicted wheat yield using different sowing dates under current temperature, and with a raise in temperature.

Sowing Date	Predicted yield under current temperature (kg/ha)	Predicted yield under current temperature + 1.5° C (kg/ha)		Predicted yield under current temperature + 3.6° C (kg/ha)	
		Yield	Yield $_{current}$ - Yield $_{+1.5^{\circ}C}$	Yield	Yield $_{current}$ - Yield $_{+3.6^{\circ}C}$
Nov, 20	6129.8	5213.5	- 916.3	3930.8	-2199.0
Nov, 30	6078.7	5196.2	-882.5	3915.7	-2163.0
Dec, 10	6011.3	5170.1	-841.2	3940.7	-2070.6
Dec, 20	5921.6	5132.0	-789.6	3894.8	-2027.4

Table 3. Effect of delay sowing on wheat yield and vulnerability to high temperature.

Sowing dates	+ 1.5° C			+ 3.6° C		
	Impact	Adaptation	Vulnerability	Impact	Adaptation	Vulnerability
November, 20	-14.95	0	-14.95	-35.87	0	-35.87
November, 30	-14.95	+0.43	-14.52	-35.87	+0.29	-35.58
December, 10	-14.95	+0.96	-13.99	-35.87	+1.42	-34.45
December, 20	-14.95	+1.61	-13.34	-35.87	+1.64	-34.23

Effect of irrigation amounts

As a result of heat stress, the atmospheric demand increases, which in turn, increases evapotanspiration (Gardner et al., 1985). Therefore, increasing irrigation amounts could reduce the impact of heat stress. Wheat yield was predicted using equation [5]. The differences in wheat yield as a result of a raise in temperature were found to be decreasing with the increase of irrigation amount per season Table 4. Results in Table 5 show that increasing irrigation amount could serve as a relief factor to overcome heat stress. Irrigation with 450 mm/season reduced wheat yield vulnerability by 3.51 and 3.46 % when a raise in temperature by +1.5° C and 3.6° C occurs, respectively.

Table 4. Predicted wheat yield using different irrigation amounts under current temperature and with temperature increase.

Irrigation amounts	Predicted yield under current temperature (kg/ha)	Predicted yield under current temperature + 1.5° C (kg/ha)		Predicted yield under current temperature + 3.6° C (kg/ha)	
		Yield	Yield$_{current}$ - Yield$_{+1.5^{\circ}C}$	Yield	Yield$_{current}$ - Yield$_{+3.6^{\circ}C}$
300 mm/season	6129.81	5299.08	-830.73	4014.82	-2114.99
350 mm/season	6078.73	5342.08	-736.65	4057.82	-2020.91
400 mm/season	6011.25	5385.08	-626.17	4100.82	-1910.43
450 mm/season	5921.60	5428.08	-493.52	4143.82	-1777.78

Table 5. Effect of irrigation amounts on wheat yield and vulnerability to increased temperature.

Irrigation amounts	Current temperature + 1.5° C			Current temperature + 3.6° C		
	Impact	Adaptation	Vulnerability	Impact	Adaptation	Vulnerability
300 mm/season	-14.95	+0.92	-14.03	-35.87	+1.37	-34.50
350 mm/season	-14.95	+2.01	-12.85	-35.87	+2.05	-33.82
400 mm/season	-14.95	+2.81	-12.14	-35.87	+2.77	-33.10
450 mm/season	-14.95	+3.51	-11.44	-35.87	+3.46	-32.41

Interaction between sowing dates and irrigation amounts

Both the effect of delay sowing and increasing irrigation amounts were included in the prediction to reduce vulnerability of wheat yield to heat stress (Tables 6 and 7). Results in Table 6 show that under the condition of temperature increased by + 1.5° C, planting wheat at December, 20 reduced yield vulnerability was by 2.2, 2.7, 3.3, 3.8 %, when the four irrigation amounts were used, respectively.

Furthermore, results in Table 7 show that under the condition of temperature increased by + 3.6° C, planting wheat at December, 20 reduced yield vulnerability was by 1.1, 1.6, 3.1, 3.6 %, when the four irrigation amounts were used, respectively.

Table 6. Effect on wheat yield of the interaction between the delay in sowing date and irrigation amounts under current temperature and + 1.5° C temperature increase.

Treatments	300 mm/season			350 mm/season			400 mm/season			450 mm/season		
	I	A	V	I	A	V	I	A	V	I	A	V
Nov, 20	-15.0	+1.4	13.6	-15.0	+2.1	-13.	-15.0	+2.9	-12.1	-15.0	+3.6	-11.4
Nov, 30	-14.5	+1.4	13.1	-14.5	+2.0	-12.	-14.5	+2.6	-11.9	-14.5	+3.2	-11.3
Dec, 10	-14.0	+1.1	12.9	-14.0	+1.9	-12.	-14.0	+2.7	-11.3	-14.0	+3.5	-10.5
Dec, 20	-13.3	+2.2	11.1	-13.3	+2.7	-10.	-13.3	+3.3	-10.0	-13.3	+3.8	- 9.5

I = impact A = adaptation V = vulnerability

Table 7. Effect on wheat yield of the interaction between the delay in sowing date and irrigation amounts under current temperature and + 3.6° C temperature increase.

Treatments	300 mm/season			350 mm/season			400 mm/season			450 mm/season		
	I	A	V	I	A	V	I	A	V	I	A	V
Nov, 20	-35.9	+1.4	-34.5	-35.9	+2.1	-33.	-35.9	+2.8	-33.1	-35.9	+2.5	-32.4
Nov, 30	-35.5	+1.7	-33.8	-35.5	+2.2	-33.	-35.5	+2.8	-32.7	-35.5	+3.4	-32.1
Dec, 10	-34.5	+1.1	-33.4	-34.5	+1.9	-32.	-34.5	+2.7	-31.8	-34.5	+3.5	-31.0
Dec, 20	-34.2	+1.1	-33.1	-34.2	+1.6	-32.	-34.2	+3.1	-31.1	-34.2	+3.6	-30.6

I = impact A = adaptation V = vulnerability

Evaluation of the inter and intra-annual variability of wheat yield

Riebsame (1989) stated that the simplest climate impact assessment is to compare yields during climate fluctuations to more normal years. Typically, "normal" yields are defined as an average over several years. In our study, wheat yields were compared through the studied twenty-five years to determine normal and abnormal yields. Results presented in Table 8 show that there is no significant difference in wheat yield, between years having the same letter. Similarly, there is a significant difference between years having the different letter. Yield variability in high latitudes is usually caused by temperature variations (Riebsame, 1989).

Table 8. Inter- annual variability for wheat yield from 1975-1999.

Wheat yield (kg/ha)	Year
3528.0^{B}	1974/75
0342.0^{AB}	1975/76
3405.6^{AB}	1976/77
3531.6^{AB}	1977/78
3322.8^{B}	1978/79
3398.4^{AB}	1979/80
3567.6^{AB}	1980/81
3772.8^{AB}	1981/82
3880.8^{AB}	1982/83
3913.2^{AB}	1983/84
3963.6^{AB}	1984/85
3945.6^{AB}	1985/86
4032.0^{AB}	1986/87
4748.4^{AB}	1987/88
5004.0^{AB}	1988/89
$5637.\ 6^{AB}$	1989/90
5389.2^{AB}	1990/91
5828.4^{AB}	1991/92
5976.0^{AB}	1992/93
5698.8^{AB}	1993/94
5929.2^{AB}	1994/95
6130.8^{AB}	1995/96
5731.2^{AB}	1996/97
6336.0^{AB}	1997/98
6757.2^{A}	1998/99

For Egyptian wheat varieties, tillering occurs about 45 days after planting, booting takes about 35-40 after ward. Anthesis takes about 5-10 days and grain filling period takes about 45-60 days. For each growth stage, one prediction equation was developed and used to predict wheat yield under normal temperature and with a raise in the temperature as follows.

Tillering: Y`=18259.2 - 835.2 * Mtemp
Booting: Y`=109411.2 – 993.6 * Mtemp
Anthesis: Y`= 16578.0 – 817.2 * Mtemp

Grain filling Y`= 14205.3 - 610.9 * Mtemp
Mean = 4673 ± 229.1

Results in Table 9 show that booting is the most sensitive stage to heat stress, where reduction in yield was 23.74 and 56.99 % when temperature increased by + 1.5° C and + 3.6° C, respectively.

Table 9. Intra-annual variation in wheat yield under current conditions and with temperature increase.

Stage	Predicted yield under current temperature (kg/ha)	Predicted yield under current temperature + 1.5° C (kg/ha)			Predicted yield under current temperature + 3.6° C (kg/ha)		
		Yield	$Yield_{current}$ - $Yield_{+1.5°C}$	Impact	Yield	$Yield_{current}$ - $Yield_{+3.6°C}$	Impact
Tillering	7217.9	5965.1	-1252.8	-17.35	4211.1	-3006.8	-41.65
Booting	6275.8	4785.4	-1490.4	-23.74	2698.8	-3577.0	-56.99
Anthesis	5774.6	4548.8	-1225.8	-21.22	2832.7	-2941.9	-50.94
Grain Filling	6129.8	5215.5	-916.3	-14.95	3930.8	-2199.0	-35.87

Process-based crop agricultural models and decision support systems

Simulation models mainly DSSAT was the main tool for analysis and databases of historical climatic data, soils and crop management variables for Egypt, which were used in the impacts assessment. Projected impacts on crop productivity in the Nile Delta will be assessed according to future conditions derived form the scenarios formulation (Eid et al., 1994) and (GCMs/ MAGICC/SCENGEN) (Eid et al., 2001). New climate scenarios will be developed and used instead of the mentioned ones. Results on climate change will be included in the annual report.

Methodology and data requirements

Crop yields and demand for irrigation water were estimated with the CERES-Wheat model included in the DSSAT 3.5 (1998) developed by the International Benchmark Sites Network for Agrotechnology Transfer. Daily maximum and minimum temperatures, precipitation, and solar radiation data were obtained for Sakha from 1975 to 1999. Typical soils at Sakha (clay loam soils) are montmorillonitic, thermic, slightly calcareous, and deep (Abdel-Wahed 1983). The texture, albedo, and water-related specific characteristics of these soils are adequately represented by the generic soil (Medium silty clay) provided for the study.

Wheat is grown using flood irrigation. Data of one experiment at the site (Sakha) were used in the present study (Eid, 1994). For the simulations, the field schedule irrigation option was chosen to provide the crop with water as field schedule; the model includes an option that simulates flooding. Wheat is fertilized in the region in this study, and therefore the simulation considered water and nitrogen balances.

The CERES- Wheat model was validated by comparing observed data on biomass, yield, and maturity date to simulated values (Table 10). The results of the validation experiment indicate that the CERES-Wheat crop model can be used successfully at the selected site in Egypt. The observed data on grain yield and season length were very close to the corresponding simulated values. The observed total biomass was slightly smaller than the simulated one. According to these results, the model was considered validated for the conditions of the study.

Table 10. Calibration and validation test for wheat (Sakha-8 CV) at Sakha region.

Variable	MEASURED	PREDICTED
Flowering Date (dap)	124	122
Physiological Maturity (dap)	165	163
Grain Yield (kg/ ha; dry)	4769	4754
Wt. per Grain (g; dry)	0.03	0.038
Grain Number (grain/ m^2)	12400	12229
Maximum LAI (m^2/ m^2)	5.6	5.02
Biomass (kg/ ha) at Harvest Mat.	14229	16942

Adaptation to Climate Variability

Studies of adaptation strategy evaluation to climate variability were carried out using the following method: Simulation runs on different cultivars and sowing dates through DSSAT 3.5 model on wheat. Adaptation of the wheat crop productivity to the climate change was studied through DSSAT 3.5 model. Future adaptation strategies to climate change may involve the development of new, more heat-tolerant cultivars, and/ or changing practice (optimum sowing dates, water amount and cultivars for suitable agroclimatological region (Tables 11-14).

Table 11. Simulated of grain yield under different sowing dates for wheat.

Year	Sowing dates			
	Nov. 20	**Nov. 30**	**Dec. 10**	**Dec. 20**
1975	4804	4694	4824	4722
1976	4554	4511	4545	4408
1977	4456	4426	4340	4394
1978	4225	4485	4475	4573
1979	4567	4540	4650	4728
1980	4632	4630	4651	4624
1981	4778	4861	4819	4601
1982	4990	5005	5026	5101
1983	4896	4854	4713	4711
1984	4700	4826	4783	4729
1985	4630	4605	4630	4543
1986	5136	5114	4940	4984
1987	4783	4759	4767	4678
1988	4629	4498	4397	4200
1989	5388	5371	5425	5375
1990	4806	4746	4967	5210
1991	4690	4518	4375	4578
1992	4268	4408	3374	3332
1993	4234	4085	4112	3755
1994	4640	4785	5025	5027
1995	4930	4890	5010	4975
1996	5249	5255	5033	5032
1997	5036	4964	4760	4917
1998	4796	4689	4893	5164
1999	4921	4873	4934	4852
Average	4750	4736	4699	4689

Table 12. Simulated of skipping irrigation at different physiological stages for wheat grain yield.

Year	Skipping Irrigation				
	2nd irri.	**3rd irri.**	**4th irri.**	**5th irri.**	**6th irri.**
1975	4398	4427	4709	4709	4709
1976	4117	4188	4482	4484	4484
1977	3538	3758	4022	4285	4285
1978	4302	4367	4360	4074	4212
1979	4276	4403	4671	4665	4665
1980	3543	4007	4226	4590	4590
1981	4619	4660	4770	4654	4788
1982	4570	4696	4987	4971	4987
1983	4154	4254	4301	4677	4677
1984	4325	4439	4580	4760	4760
1985	4391	4332	4320	4628	4628
1986	4188	4363	4643	4897	4897
1987	4204	4519	4684	4684	4684
1988	3677	3855	4022	4394	4394
1989	4989	5036	4378	5410	5410
1990	3964	4466	4776	4776	4776
1991	4365	4417	4417	4417	4417
1992	3295	3318	4347	4357	4357
1993	3648	3672	4115	4115	4115
1994	4263	4722	5077	5077	5077
1995	4857	4881	5042	5042	5042
1996	4621	4807	5056	5056	5056
1997	3808	4370	4853	4853	4853
1998	3866	4184	4493	4697	4697
1999	4386	4517	4801	4955	4955
Average	4175	4346	4565	4689	4701

Table 13. Simulated of grain yield at different irrigation amounts for wheat at Sakha region.

Year	Irrigation amounts			
	300 mm/ season	400 mm/ season	500 mm/ season	600 mm/ season
1975	3969	4648	4709	4718
1976	3803	4328	4484	4520
1977	3407	4049	4285	4344
1978	2299	4256	4486	4496
1979	3863	4530	4671	4670
1980	2876	4205	4590	4662
1981	2752	4736	4788	4790
1982	4276	4879	4987	4988
1983	3588	4485	4677	4737
1984	3548	4551	4760	4795
1985	3094	4519	4628	4646
1986	3577	4604	4897	4966
1987	4062	4548	4684	4689
1988	3372	4133	4394	4457
1989	4023	5222	5410	5429
1990	3552	4412	4776	4837
1991	4298	4412	4417	4417
1992	3263	3342	4357	4358
1993	3187	3880	4115	4166
1994	3881	4824	5077	5103
1995	4663	4988	5042	5042
1996	4145	4874	5056	5088
1997	3283	4451	4853	4895
1998	3407	4372	4697	4774
1999	3801	4733	4955	5022
Average	3600	4479	4712	4744

Table 14. Simulated grain yield under different cultivars for wheat at Sakha region.

Year	Cultivars		
	Sakha-8	Giza-164	Sakha-69
1975	4709	7052	9003
1976	4484	7838	8605
1977	4285	6774	8828
1978	4486	5735	6037
1979	4671	7861	9194
1980	4590	6431	8491
1981	4788	6639	7121
1982	4987	7263	9888
1983	4677	6753	7492
1984	4760	7502	7694
1985	4628	7566	7793
1986	4897	7178	8959
1987	4684	7085	8730
1988	4394	6032	8266
1989	5410	7051	9330
1990	4776	7879	10118
1991	4417	10496	10330
1992	4357	6203	6982
1993	4115	6977	7472
1994	5077	8431	10379
1995	5042	9277	9666
1996	5056	7190	8504
1997	4853	7619	9564
1998	4697	7563	9008
1999	4955	6346	9100
Average	4712	7310	8662

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APPENDIX H.2.

TUNISIAN REPORT

1. Vulnerability of dryland agricultural to current climate variability in the Center Region

2. Identification of current water deficit and stress for agricultural production in Kairouan

3. Questionnaire to the stakeholders in Tunisia

Progress Report of the Tunisian Case Study of the AIACC AF90 Project
15 July 2003

R. Mougou
Institut National de Recherche en Génie Rural, Eaux et Forêts (INRGRF)
(National coordination of the Tunisian AIACC Project)

1. VULNERABILITY OF DRYLAND AGRICULTURAL TO CURRENT CLIMATE VARIABILITY IN THE CENTER REGION

Tunisia belongs to the hydraulic poor countries. In Tunisia rainfall is characterized by its scarcity and spatial and temporal variability. The average of total annual rainfall varies from 1500 mm in the North to 100 mm in the South. Temperatures and solar radiation are rather high, that leads to a higher evaporation and lower water resources. Currently, water demand is about 2.5 Billons m3. Irrigation uses 83% of the available resources, industry consumes about 5 %, potable consumption represents 11% and tourism 1%.

Expected climatic change, population increase, urbanization and industrial development as well as irrigation intensification constantly increase water demand and can worsen the situation.
At present, the volume of available water (underground and surface water) per year and per habitant is estimated about 450m3. This value will reach 315m3/year/habitant in 2030.

Agriculture is the most sensitive and vulnerable field regarding climate change. Although 93% of cultivated areas are under rainwater agriculture, irrigated areas are the biggest consumers of water. Variability and scarcity of water resources and high temperatures affect negatively the production in rainfed agriculture and mainly cereal production. In Tunisia, 97% of cereals are cultivated under rainfed conditions. Cereals represent one of the most important sectors in Tunisia economy. Areas cultivated in cereals cover 30% of the total cultivated areas.

The Tunisian component of the AIACC project is evaluating the impact of the current climate variability on wheat production in a semi arid region of Tunisia. As a first step, the results of Tunisian studies on the assessment of cultivated areas and production variability according to climate variability have been considered. Then, a statistical study was used considering monthly rainfall data over 50 years, yield data and wheat production data over 20 years. This has permitted to quantify the effect of rainfall variability on yield. Also monthly air temperatures data from 1950 to 2001 were analysed. The statistical analysis confirms that the amount of rainfall and its distribution are important factors that determine yield and wheat production. A high significant linear relation (R_=0.51) has been found between rainfall during the growing season (from November to April) and wheat yield. Also, a significant linear relation (R_=0.39) has been found between March rainfall (critical growing phase) and yield. Yearly sown areas are not totally harvested, the ratio between harvested and total sown areas shows a high significant linear relation (R_=0.44) with rainfall during growing season.

2. IDENTIFICATION OF CURRENT WATER DEFICIT AND STRESS FOR AGRICULTURAL PRODUCTION IN KAIROUAN

An analysis of rainfall and evapotranspiration data has been used to evaluate the water balance and to show the sheer scale of water deficit for Kairouan station. Using daily evapotranspiration (Penman Monteith formula), we evaluated monthly evapotranspiration data from Kairouan, in order to calculate the water balance (Figure 1).

The Water balance date related to Kairouan station from 1979 to 2000 show an important water deficit. From Mars to August, the water balance is always negative. The water deficit can reach 200 mm during the summer. During the start of agricultural season until February, the water balance is also negative during almost all months with however less raised values. However the monthly deficit value can reach about 150 mm.

The water deficit during the start of agricultural season lead on high variation of cereals cultivated areas as it was shown in the first report to the AIACC project. The water deficit can also affect the harvested areas if it occurs when the cereal water needs are higher. These results concerning the water balance confirm that the amount and the distribution of rainfall and the high evapotranspiration are important factors that determine yield and cereal production.

The predicted climate change will increase the water deficit by increasing temperature and rainfall variability and consequently can worsen the situation. Therefore, due to the variability of rainfall, the high evapotranspirarion increase the need of new adaptation methods as a selection of new cultivars, change of planting date, increasing of agriculture area and use of new agronomic practices.

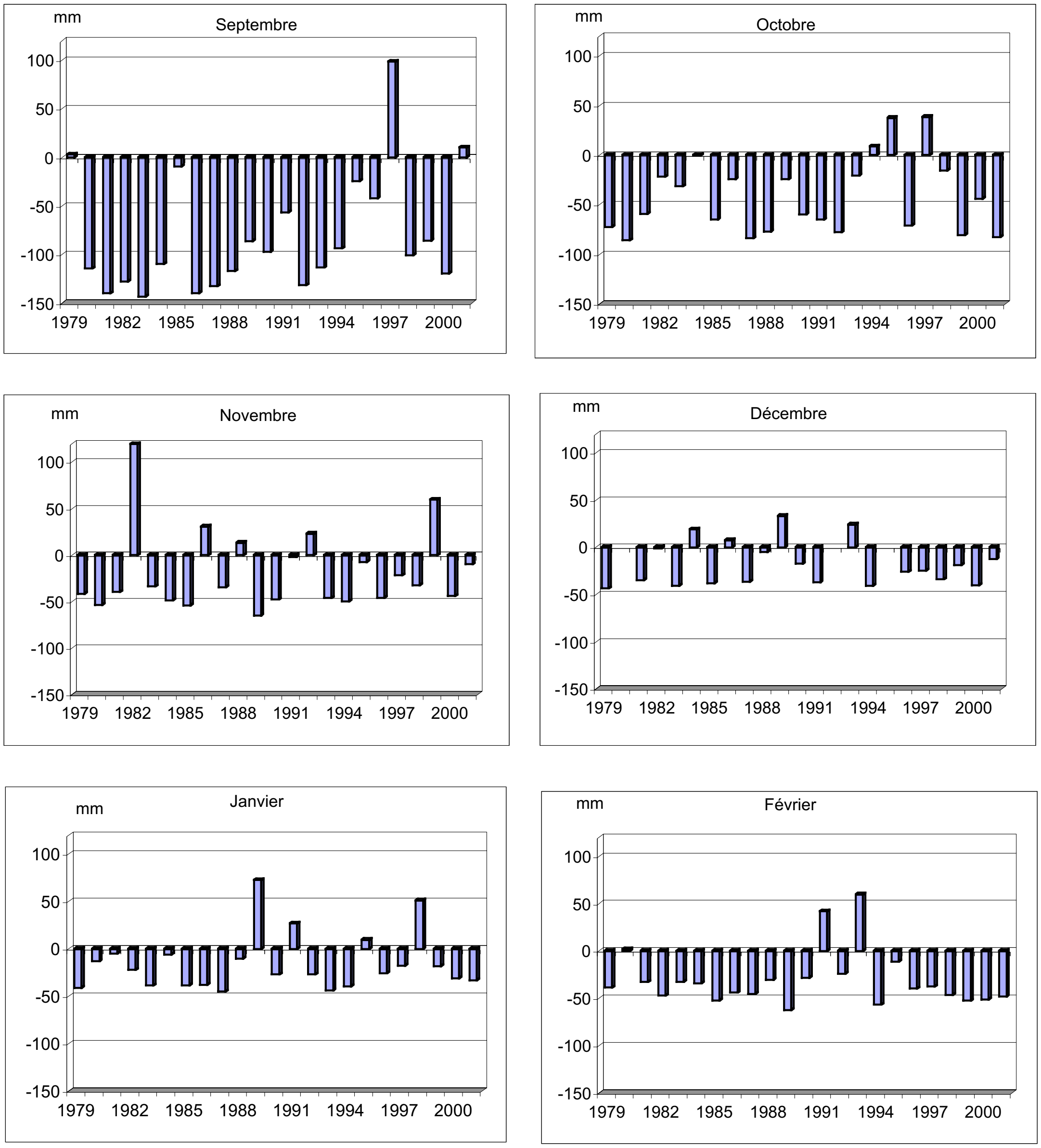

Figure 1a. Monthly agrometeorological water balance (P- PET) for Kairouan station (1979/2000) during September to February

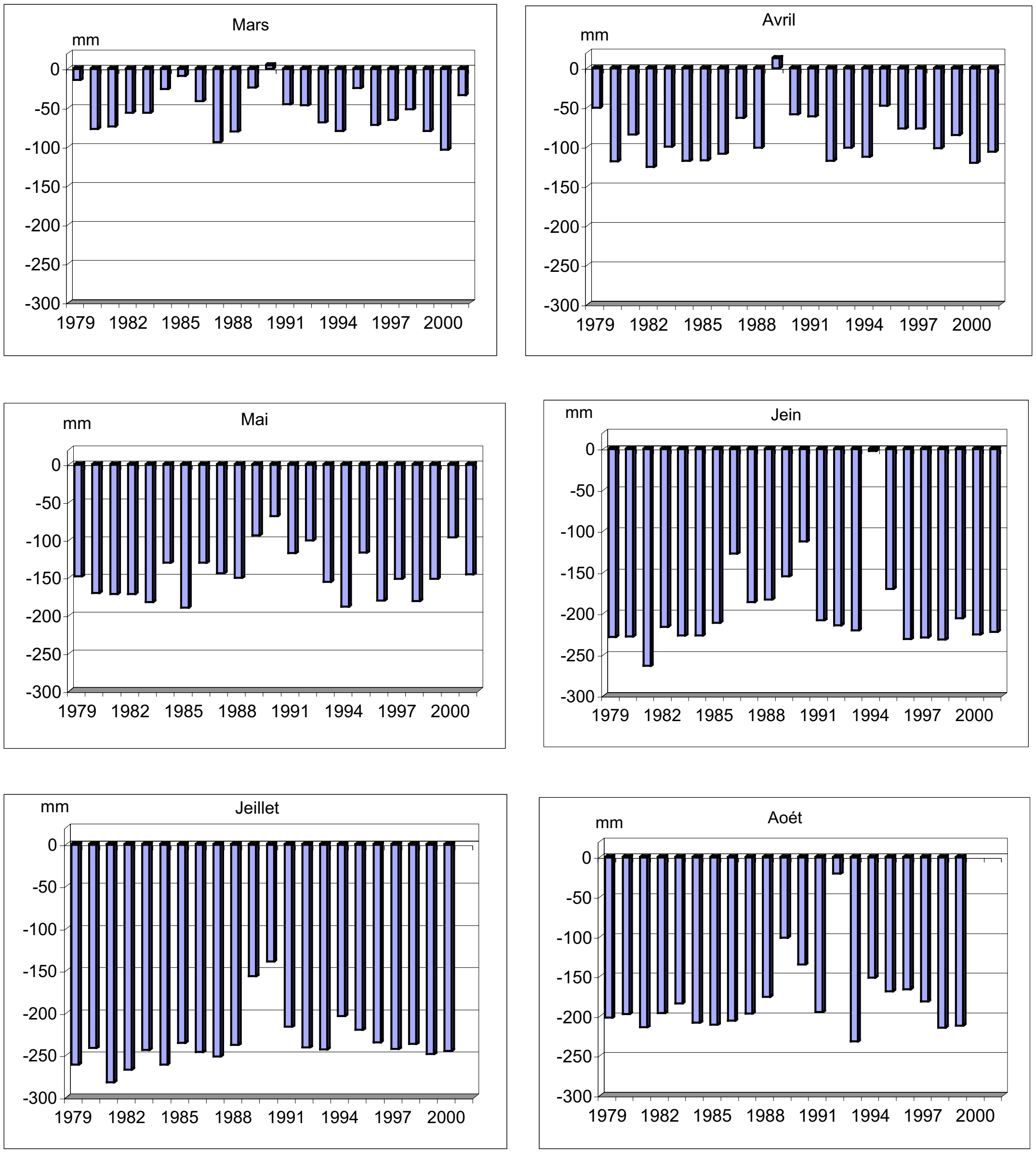

Figure 1b. Monthly agrometeorological water balance (P- PET) for Kairouan station (1979/2000) during March to August.

Ministère de l'Agriculture, de l'Environnement et des Ressources Hydrauliques

IRESA

INRGREF

Questionnaire destiné aux agriculteurs et aux agents de vulgarisation

Cadre de l'enquête :
Projet sur "l'Evaluation de l'Impact et Adaptation au Changement Climatique"

Gouvernorat:

Kasserine ☐

Kairouan ☐

Sfax ☐

Sidi Bouzid ☐

Enquête N° :…………………

Menée par : …………………………………

Date :……………………………………….

Année 2003

1- Localisation de l'exploitation

Gouvernorat	Région	Localité

2- Identification de l'agriculteur

Nom et Prénom : (Facultatif)
Niveau de formation :
Situation Familiale :
Nombre d'enfants non mariés :

Scolarisés	Ayant un travail	En chômage

- Propriétaire ☐
- Locataire ☐

Avez-vous une source d'argent autre que l'agriculture ? oui ☐ Non ☐

Si oui laquelle

3- Systèmes de cultures et modes de conduite

Année en cours	Localisation	Superficie (mentionner unités)	Culture	Mode de conduite <u>Pluvial</u> ou <u>Irrigué</u>
Parcelle 1				
Parcelle 2				
Parcelle 3				
Parcelle 4				
Parcelle 5				
Parcelle 6				
Parcelle 7				
Parcelle 8				

- Provenance de l'eau d'irrigation :
  - Public ☐
  - Privée ☐
- Disponibilité :

Toujours ☐ Moyennement ☐ Rarement ☐

4- Occupation des parcelles

	Années			**Observations**
	Année 2000	Année 2001	Année 2002	
Parcelle 1				

Parcelle 2				
Parcelle 3				
Parcelle 4				
Parcelle 5				
Parcelle 6				
Parcelle 7				

5- Techniques utilisées

	Cultures	Système d'irrigation	Type de fertilisation	Autres
Cultures maraîchères				
Arboriculture				
Oliviers				
Blé				
Orge				

6- Variation des rendements

Cultures	R^{dt} max	Année	R^{dt} min	Année	Comment est gérée la production (gestion du surplus)

7- Causes des variations des rendements

cultures	Disponibilité en eau	Choix des variétés	Changement des systèmes de cultures	Autres (climatiques)

Commentaires
(Céréales pluviales pour région de Kairouan et oliviers pluvial pour région de Sfax)

8- Causes des variations de la production

cultures	Disponibilité en eau	Variation des superficies emblavées	Variation des superficies récoltées	Variation des techniques de production

Commentaires
(Céréales en pluvial pour région de Kairouan et oliviers en pluvial pour région de Sfax)

9- Climat et production

-Pensez vous que les conditions climatiques ont un effet sur la production agricole ?

oui ☐ Non ☐

Si oui, comment ?

Dans votre cas	Chez vos voisins

- Le climat, par son effet sur la production, a-t-il un effet sur le revenu ?

Oui ☐ Non ☐

- Quel est d'après vous le facteur qui a le plus d'effets sur la production et dont vous aimeriez être plus informé ?
  - Pluviométrie ☐ Température ☐ Autres facteurs ☐

(Mettre une croix dans la case correspondante)
si autres lesquelles
Pouvez-vous donner des exemples concrets :

Facteurs	**Années**	**Cultures**	**Effets**

- Avez- vous à l'esprit des années typiques de sécheresse ? Si oui, lesquelles ?
-
-
-

10- Etat des connaissances des agriculteurs sur le changement climatique

- Avez – vous remarqué un changement climatique au cours des dernières années ? oui ☐ non ☐
  - Si oui Comment ?

- Etes vous informé du changement climatique prévus ?

oui ☐ Non ☐

Si oui, par qui ?

- Ce changement a-t-il eu un effet sur la production ?

Dans votre exploitation ☐	Les rendements ☐ La qualité… ☐	
Dans celles des voisins ☐	Les rendements……☐ La qualité………… ☐	
Chez d'autres agriculteurs ☐	Les rendements……☐ La qualité………… ☐	

(Mettre une croix devant la ligne correspondante)

- Ce changement a-t-il eu un effet sur le niveau de vie du ménage ?

oui ☐ Non ☐

- Quel est d'après vous le facteur qui a le plus d'effet sur la production ?

Température élevée ☐

Faible précipitation ☐

Variation de la pluviométrie ☐

Autres ☐

11- Mesures d'adaptation

- Prenez vous des mesures d'adaptation au changement climatique ?

oui ☐ Non ☐

Si oui lesquelles ?
-
-
-
-
- Essayez vous de vous adapter à la variabilité actuelle du climat ?
oui ☐ Non ☐
Si oui comment:
-
-
-
-
-
-
-
-

-Etes vous aidé par quelqu'un ?

Par qui le message vous parvient- il	Comment le message vous parvient-il ?	Observations
Des membres de la famille		
Des voisins agriculteurs		
Des voisins non agriculteurs		
Des vulgarisateurs agricoles		
Des brochures de vulgarisations		
Des journées d'information		
Autres moyens		

- Prenez- vous des décisions, qui soient en rapport avec le climat, pour la préparation et le suivi de la campagne agricole ?

Oui chaque année ☐ Oui parfois ☐ Non jamais ☐

(Mettre une croix dans la case correspondante)

- Pensez- vous qu'il y a d'autres mesures d'adaptation au changement climatique que vous êtes actuellement incapable de suivre par manque de moyens ?

Mesures d'adaptation	Raisons qui empêchent leurs suivis

APPENDIX H.3.

CHANGEMENT DE CLIMAT, POTENTIALITES ET LIMITES DES STRATEGIES AGRICOLES DAN LA REGION DE LA CHAOUIA (MAROC)

CLIMATE CHANGE: POTENTIAL AND LIMITATIONS FOR AGRICULTURE IN THE LA CHAOUIA REGION OF MOROCCO

Progress Report of the Moroccan Case Study of the AIACC AF90 Project
15 July 2003

A. Mokssit

Résumé

Ce travail souligne la nécessité de la prise en considération des changements climatiques dans divers programmes de recherches agronomiques. Ce besoin est d'autant plus marqué lorsqu'il s'agit d'environnements arides et semi-arides. Dans de tels contextes, les agriculteurs et les décideurs sont soumis aux risques des rendements et des marchés. Quelles nouvelles technologies et quelles procédures à adopter, quelles recherches agronomiques conséquentes à introduire, quelles pratiques agricoles à inclure, etc. ? Un ensemble de questions auxquels différents types de modèles de décision pourraient être envisagées pour les agriculteurs et les décideurs des zones pluviales arides et semis arides.

Introduction

Les variabilités inter et intra annuelles des conditions climatiques (pluies, températures, radiation solaire, etc.) ainsi que l'hétérogénéité des autres composantes de l'environnement physique (fertilité, topographie et profondeur des sols, faible teneur en matière organique des sols, etc.) constituent d'importants facteurs qui influencent la production agricole pluviale au Maroc. Les zones dites arides et semi-arides (isohyètes < 300 mm) connaissent des fluctuations de production et donc de revenu, plus élevées que celle des régions pluviales favorables. Au niveau de ces zones, le cycle de production est souvent décalé par rapport au cycle des pluies, à cause de la variabilité de celles-ci (Watts et El Mourid, 1988).

En effet, la sécheresse récurrente conjuguée à des hausses subites des températures dans ces zones, qui peuvent intervenir à n'importe quel moment de l'année agricole, font chuter les rendements agricoles. La faible capacité de stockage d'eau des sols et les variétés et techniques culturales non adaptées pratiquées par les agriculteurs constituent les autres paramètres affectant les rendements (Benaouda et Karrou, 1993). Un autre spectre se profile à l'horizon et qui constitue un facteur perturbateur de l'économie agricole de ces zones, est celui des changements climatiques. C’est un nouvel élément vis à vis duquel beaucoup d’efforts sont à consentir pour permettre le maintien durable des ressources agricoles de ces zones.

L’agriculteur de la plaine de la Chouia qui est l’une des régions à forte production agricole céréalière du pays, se trouve de plus en plus confrontée à une multitude de termes qui sont synonymes de contraintes environnementales. Il s’agit dans cette présente note, après un survol de la caractérisation agro-écologique de la Chaouia, d’introduire le débat sur le management de la stratégie agricole confrontée aux variations climatiques probables qui risquent de se manifester au niveau de cette région.

Méthodes

La forte variabilité des disponibilités hydriques due au manque d’eau et des sécheresses a amené la recherche agrometeorologique a développer des outils méthodologiques pour appréhender cette diversité.

(a) Etudes statistiques. Le premier pas est de bien connaître l’environnement physique; sa variabilité et ses effets sur l’agriculture. Cette approche s’est concrétisée par des études fréquentielles des précipitations de l évapotranspiration et du déficit climatique. En plus des relations climat /rendements sur plusieurs cultures et dans plusieurs régions du Maroc.

(b) Modèles développes pour la caractérisation agro-écologique. Pour pallier aux manques des données, on utilise le modèle SWG qui génère de longues séries de données climatiques indispensables a la caractérisation a la caractérisation de la production agricole. On utilise ses résultats directement dans Simtag.

Le modèle de croissance du blé Simtag simule la croissance, le développement, le rendement et ses composantes du blé tendre ainsi que l évolution des réserves hydriques et leur utilisation par les plantes. Les résultats sont présentes sous différentes formats: des cartes, des tableaux, etc. Il a été appliqué sur différentes régions du Maroc.

Les modèles phytopathologiques. Le modèle DSS (Decision Support System) est prévu pour la protection du blé et de la betterave à sucre. Il simule l’épidémiologie et les apparitions des maladies de rouille de blé et le Cercopriose de betterave de sucre. Le modèle Plasmo simule l’évolution du mildiou de la vigne. Il utilise l’ensemble des équations qui décrivent l’enchaînement des cycles de base du champignon dont le résultat est cette maladie. Ces modèles assistent l’agriculteur en matière de protection des cultures et lutte contre les phytopathologies.

Caractérisation agro-écologique de la Chaouia

L’application des modèles SWG et Simtag ont montré que la Chaouia connaît une année sur trois considérée comme sèche. La simulation faite sur les précipitations a confirmé que la région connaît des fluctuations inter-annuelle avec des coefficients de variation 33% et 35%. Les simulations du blé ont montré une grande variabilité des rendements potentiels entre les régions et les années. A Chaouia, le rendement atteint 60qx /ha avec meilleurs résultats en cas d’ utilisation des variétés précoces.

Etude en cours (simple mise à jour des résultats acquis lors du projet PAC, DMN-INRA-ICARDA) en coordination avec les chercheurs de l'INRA (Dr Karrou et Benaouda).

Conclusion et recommandations: Gestion des risques de changement climatique et modèle de décision

L'essentiel des risques de la production agricole est d'origine climatique. En effet,
Les changement climatiques ont limite les ressources hydriques, et créent une grande variabilité pluviométriques avec probabilité de périodes sèches.
Face a ces changements, les agriculteurs ont développé des stratégies pour minimiser leurs impacts sur la production et stabiliser le revenu de la production.

Les études sur le comportement des agriculteurs ont porté sur ses implications des préférences des agriculteurs sur le choix des systèmes de production agricoles, sur le choix et l'adoption des technologies. Il est établi que la prise en compte des préférences des agriculteurs permet d'identifier les options techniques, les systèmes de productions et les options de politiques agricoles adéquates aux régions arides.

En ce qui concerne les changements climatiques, deux questions clef se posent. La première question est de savoir si les agriculteurs ont intégré les changements climatiques et comment. En effet, il est démontré que les agriculteurs ont une représentation claire des distributions des rendements possibles. Une enquête rapide auprès des agriculteurs portant sur les rendements et les probabilités liées a leurs différents niveaux possibles a permis d'établir une distribution des rendements qui s'est avéré être identique a celle établie sur la base des observations historiques. Cette question est primordiale, car les choix des agriculteurs étant faits sur la base de leur connaissance de l'environnement de production, s'ils pensent que celui ci a changé, ils vont prendre des mesures stratégiques et effectuer des modifications structurelles dans leur système de production.

La seconde question est d'identifier de façon ex ante, les modifications et les directions dans lesquelles vont évoluer les systèmes de productions. Dans ce cadre, la DMN essais d'assister l'agriculteur en matière de décision et de choix de stratégie agricole via les modèles culturaux et phytopathologistes qui prévoient les dates de semi et les quantités d'irrigation pour obtenir les meilleurs rendements ainsi que les risques phytopathologiques et les dates optimales pour commencer la lutte contre elles.