ASSESSING CLIMATE CHANGE IMPACT ON WATER PRODUCTIVITY (CASE STUDY: PAKDASHT, IRAN)

EVALUATION DE L'IMPACT DES CHANGEMENTS CLIMATIQUES SUR LA PRODUCTIVITE DE L'EAU (ETUDE DE CAS: PAKDASHT, IRAN)

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ABSTRACT

Achieving food security and and simultaneously sustaining the land and water productivity are the most important challenges in 21st century's agriculture. Many countries, especially those in arid or semi-arid regions, are attempting to achieve food security at national level. But the climate change impact on soil quality, water availability, variability of temperature and precipitations make achieving this goal difficult. As most of Iran's land, especially the central part, are arid or semi-arid, it is necessary to assess the impact of climate change on water productivity. The main objective of this study was to assess the impact of climate change on temperature and rainfall, simulating crop yield for 2010-2039 period using the AquaCrop model and determining the water productivity and the impact of climate change on it. The results would be useful in suggesting adaptation strategies and assessing their capability in future researches. Data collected from a maize farm in Pakdasht, south east of Tehran in 2009, were used to calibrate the AquaCrop model. Daily meteorological data (1971-2000) and of the base year of 2009 of the nearest station, Amin Abad were used in the study. There are many sources of uncertainties in climate change such as the emission scenarios; AOGCM (Atmosphere- Ocean General Circulation Model), downscaling methods, etc. Nine AOGCMs and A2 emission scenario were used in order to incorporate these uncertainties. Using the data from these AOGCMs and Bayesian method, weights were given to each AOGCM. Monte Carlo simulation method was used to generate CDF for 25, 50 and 75% probabilities. The outputs from the AOGCMs were downscaled using the change factor method. Temperatures and rainfall from downscaled data were used and ET0 was determined from Hargreaves-Samani method as input to AquaCrop model. Comparing results with base year (2009), the crop yield showed a future decreasing trend, most probably due to increment in temperature and rain variability and the consequent decrease in the water productivity. The appropriate solution was to test different quantities

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of irrigation water to find out the most efficient condition with the highest water productivity in coming years for better use of each drop of water.

Keywords: *Climate change, water productivity, AOGCM models, Iran*

RESUME

Fournir la nourriture nécessaire à la population croissante du monde et en même temps maintenir la productivité des terres et les sources d'eau est une tâche immense qui pose un gros défi à l'agriculture au 21ème siècle. De nombreux pays essaient de réaliser la sécurité alimentaire au niveau national, en particulier ceux qui sont situés dans les zones arides ou semi-arides, mais l'impact du changement climatique sur la qualité des sols, la disponibilité de l'eau, la température et les précipitations rendent cette tâche plus difficile. La plupart des terres en Iran étant situées dans les zones arides ou semi-arides, notamment la partie centrale, il semble nécessaire d'évaluer l'impact des changements climatiques sur la productivité de l'eau. L'objectif principal est l'étude, selon l'étape, de l'impact du Changement Climatique sur les température et les précipitations, en simulant le Rendement des cultures pendant la période de 2010-2039 par le Modèle AquaCrop en vue de déterminer la productivité de l'eau et l'impact du Changement Climatique sur la région. Ces données pourront être utilisées pour suggérer des stratégies d'adaptation et évaluer la capacité de recherches futures. Afin d'atteindre ces objectifs, les données recueillies à partir d'une plantation de maïs dans la région de Pakdasht au sud-est de Téhéran en 2009, ont été utilisées pour calibrer le modèle AquaCrop pour le maïs en ce lieu. Les données quotidiennes météorologiques de la station la plus proche (Amin Abad) de la période1971-2000 ont également été utilisées ainsi que l'année de référence (2009). Comme il existe de nombreuses sources d'incertitude dans le changement climatique telles que les incertitudes dans les scénarios d'émission, AOGCM (modèle de circulation générale atmosphère-océan), les méthodes de réduction d'échelle et beaucoup d'autres. Neuf modèles AOGCM et des scénarios d'émission A2 ont été utilisés afin d'intégrer ces incertitudes. En utilisant les données de ces modèles AOGCM et la méthode bayésienne, plus d'accent a été mis sur chaque AOGCM. La méthode de Monte Carlo a été utilisée pour générer des CDF pour les différents niveaux de probabilité variant de 25, 50 à 75%. Les données ont été constituées à la réalisation de AOGCM à l'échelle réduite par la méthode proportionnelle. Les températures et les précipitations à partir de données à échelle réduite, ont été utilisées, puis l'ET0 a été déterminée à partir de la méthode Hargreaves-Samani en tant qu'une entrée pour le modèle AquaCrop fut réalisé pour simuler le rendement des cultures pendant la période 2010-2039. Par rapport aux résultats de l'année de référence (2009), le rendement des cultures a montré des tendances à la baisse pour la période à venir. La solution appropriée est de tester différentes quantités d'eau d'irrigation, à savoir la condition la plus efficace avec la plus haute productivité de l'eau dans les prochaines années en vue d'une meilleure utilisation de chaque goutte d'eau.

Mots-clés: *Changement climatique, productivité de l'eau, modèles AOGCM, Iran*

1. INTRODUCTION

Currently, the anthropogenic greenhouse gas emission is considered as the main cause of temperature increment especially since mid-century (IPCC, 2007). Most of areas in the world will face increase in temperature, particularly minimum temperature, changes in precipitation and higher concentrations of carbon dioxide in the atmosphere, with some differences between regions (Meza et al., 2008).

The different aspects of Climate change such as higher atmospheric CO2 concentration, increasing temperature and changed rainfall all have different impacts on plant growth and crop yield. In combination, these effects can either increase or decrease plant growth. The final effect of climate change on crop yield depends on the interactions among these factors (Senthold et al., 2009) and local conditions. if temperature is the limiting factor, warmer conditions will be beneficial to crop yields, whereas temperature and succeeding evapotranspiration increase will cause yield reduction in places that already have warm spring and summer and even in some cases, these future climatic condition may worsen existing water stress, resulting crop failure (Challinor et al.,2007).

Today, agriculture is the predominant water consumer in the world especially in arid and semi-arid regions. Hence, food security without adversely affecting the land and water productivity is the most important challenge of the century and is one of the priorities of scientists. policy makers and goverments.

In developing countries where people's livelihood mostly depend on agriculture, more frequent hot extremes, droughts, floods and cyclones as consequences of climate change will aggravate the water deficiency and cause agriculture to suffer.

One of the most important processes that will be affected by climate change is photosynthesis. As in other C-4 plants, maize has the capability to fix carbon in mesophyll cells, separating RuBisCO from atmospheric oxygen. This characteristic has been regarded as an advantage over C-3 plants, especially under drought, carbon dioxide and nitrogen limitation conditions (Meza et al., 2008). Reducing maize growth may be one of temperature increment impact on photosynthesis. Increase in ambient temperature, within the range between 10 to 35 0C, allows the maize to complete its phonological stages in shorter period because of accelerated rate of development but in upper level (up to 41 0C) maize cultivars show negative responses to temperature increment (Yan and Hunt, 1999).

Water use efficiency increases under elevated CO2 concentrations due to stomata conductivity and consequent evaporation rate reductions (Leakey et al., 2006). Maize is one of the primary crops for which climate change impact assessment has been made, because of its relevance to sustenance and livelihood of several human systems. Acceleration of the rate of development, reduction of grain unit weight and grain number are some of the typical responses of this crop under climate change conditions (Parry, 1990). Globally, many impact assessment researches have been done under diverse climate condition and they indicated different per cents of yield reduction of maize: 5 -10% in Bulgaria (Alexandrov and Hoogenboom, 2000), and 10% in Romania (Cuculeanu et al., 1999), due to reduction of growing period. In the Pampas region in Argentina, maize growth was simulated under both current and year 2055 climate conditions. Even when the carbon dioxide effect was considered, the crop showed yield reductions of the order of 16%. The authors also showed that crop duration was cut down by 10 days and that unit grain weight was reduced by 10% (Magrin et al., 1997). 1.5 - 3.5 ton per hectare decrease in yield production until 2069 and also 10 days decrease in crop growth duration were reported in Pakdasht, Tehran. Field experiment was carried out to calibrate AquaCrop and in 4 different stages during crop growth period biomass were measured (Najjar et al.,2011)

Climate change impact assessment is subjected to many uncertainties due to both incomplete and unknown information. Incomplete knowledge, which can potentially be redressed in future, arises from inadequate information or understanding about biophysical processes or a lack of analytical resources available for impact assessment. Poorly understood climate physics and computing limitations, both of which limit the accuracy of general circulation model (GCM) is one of the uncertainties caused by incomplete knowledge (New and Hulme, 2000).

Arid and semi-arid regions are more vulnerable to the consequences of climate such as increasing temperature, changing rainfall variability and increment in frequency of extreme events. Most of Iran's lands especially those in the central part, are classified as arid, and it is necessary to assess the impact of climate change on meteorological parameters and also on water producticvity. The purpose of this study was to assess the impact of climate change on daily rainfall and temperature, exploring its impact on maize production and water productivity and also risk analysis in order to use the results in future investigations to permit developing appropriate adaptation strategies.

2. MATERIALS AND METHODS

2.1. Study Area Description

The research site of this investigation was Pakdasht (350 28" N; 510 45' E) in south east of Tehran. It has arid climate with low annual precipitation (200mm) concentrated in late autumn and winter and a wide maximum temperature range (-1 to 440C). Maize is grown during spring-summer season (June to November) under irrigated condition and normally, long maturity or mid maturity hybrids are chosen because of their high yield potentials. The soil is loamy of approximately 1.0 m depth and is well-drained.

The data recorded in an automatic meteorological station located in Abureyhan Campus in Pakdasht were used to calculate evapotranspiration with both Penman-Monteith and Hargreaves-Samani methods in 2009. Historical daily climate data (maximum temperature, minimum temperature and rainfall) for 1971–2000 period were taken from the nearest climatological station, Amin Abad.

2.2. Model description

AquaCrop is a Windows-based software developed in 2007 by FAO (Food and Agriculture organization of the United Nations), to simulate biomass and yield responses of field crops to various degrees of water availability. It is applicable for rain fed as well as supplementary, deficit and full irrigation. It is based on a water-driven growth-engine that uses biomass water productivity (or biomass water use efficiency) as key growth parameter. The model runs on daily time-steps using either calendar time or thermal time. It accounts for three levels of water-stress responses (canopy expansion rate, stomatal closure and senescence acceleration), for salinity build-up in the root zone and for fertility status. In brief, AquaCrop is a tool for:

1. Predicting crop production under different water-management conditions (including rain fed and supplementary, deficit and full irrigation) under present and future climate change conditions;
2. Investigating different management strategies, under present and future climate change conditions.

2.3. Model calibration

Required data for model calibration were taken from Najjar et al., 2011 field experiment, which was carried out in experimental station of the Abureyhan College of agriculture, Tehran University, located in Pakdasht.

Model performance were evaluated through data collected from four stages during crop growth periods of 14, 49, 74 and 125 days after planting in full irrigation treatment and 14, 52, 75 and 125 days after planting in deficit irrigation treatment, which were used for comparing simulation results of calibrated AquaCrop with measured data by means of two statistical measures. One of these measures was root mean square errors (RMSE) as follow:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - M_i)^2} \quad (1)$$

Where *Si* and *Mi* are the simulated and measured values, respectively, and n is the number of observations. The unit for *RMSE* is the same as that for *Si* and *Mi*; and a model's fit improves as *RMSE* approaches zero. The other measure was the index of agreement (*d*) of Willmott (1982) as follow:

$$d = 1 - \frac{\sum_{i=1}^{n}(S_i - M_i)^2}{\sum_{i=1}^{n}(|S_i - \overline{M}| + |M_i - \overline{M}|)^2} \quad (2)$$

Where $\overline{M}$ is the mean of the *n* measured values. The value of d ranges from –∞ to 1.0; and the model's fit improves as d approaches unity. Both analyses were applied to the sequential data points collected over the season for a given treatment, so "*n*" is the number of measurements taken from the same treatment on different dates over the season.

2.4. Climate scenarios & risk analysis

In order to assess the uncertainties caused by AOGCMs (Atmosphere - Ocean General Circulation Models), nine AOGCM, running under A2 emission scenario, were chosen from 4th Assessment Report (AR4) of IPCC (Intergovernmental panel of climate change) which was released in 2007. These models were employed for climate change impact assessment in 2010-2039. The characteristics of these nine models are indicated in Table 1.

Weights were given to each AOGCM model via MTOP method (mean observed temperature precipitation method) basing on mean deviation of monthly observed and simulated (by AOGCMs) temperature and rainfall using equations 3 and 4.

$$\begin{cases} B_{x,i} = T_{obs} - T_{sim} \\ B_{x,i} = P_{obs} - P_{sim} \end{cases} \quad (3)$$

T_{obs} corresponds to monthly mean observed (historical) temperature and P_{obs} corresponds to monthly mean observed precipitation for base period (1971-2000). T_{sim} represents monthly mean of simulated temperature and P_{sim} represents monthly mean of precipitation simulated by each AOGCM in base period (1971-2000).

$$R_i = \frac{\frac{1}{B_{x,i}}}{\sum_{i=1}^{N} \frac{1}{B_{x,i}}} \quad (4)$$

N is number of AOGCMs, *X* corresponds to months and R_i is the weight given to each AOGCM. In order to analyze the risk and incorporate uncertainties originated from AOGCMs, Monte Carlo simulation method and Simlab software (Giglioli and Saltelli, 2003) were used, and according to calculated weights, 2000 sample of ΔT and ΔP were made which actually was a CDF (Cumulative Distribution Function) for each AOGCM. Probability levels of 25, 50 and 75% were chosen in this study because it was not possible to use continuous data as input file of AquaCrop.

2.5. Downscaling

Lack of climate change scenario data at appropriate scales for regional impacts modeling is a constraint in revealing climate change impact. The General Circulation Models (GCMs) provide only a general view of how variables, such as temperature and rainfall patterns, might change in the future because of greenhouse gases increment. GCMs cannot resolve many of the regional- and local-scale processes that are often required for impact studies. Hence, downscaling is done to produce scenarios of higher spatial resolutions (Diaz-Nieto and. Wilby, 2005)

A relatively simple and popular downscaling procedure for rapid impact assessment involves the use of "change factors" (CFs) methodology whereby future changes in climate, projected by General Circulation Models (GCMs) are applied to a baseline climatology (Equations 5 and 6).

$$T = T_{obs,base} + (\overline{T}_{GCM,fut} - \overline{T}_{GCM,base}) \quad (5)$$

$$P = P_{obs,base} \times (\frac{\overline{P}_{GCM,fut}}{\overline{P}_{GCM,base}}) \quad (6)$$

$T_{obs,base}$ and $P_{obs,base}$ correspond to time series of observed baseline (1961-1990 or 1971-

2000) temperature and precipitation, respectively. $\overline{T}_{GCM,fut}$ and $\overline{T}_{GCM,base}$ represent monthly mean projected temperature by GCMs in future and baseline period, respectively. $\overline{P}_{GCM,fut}$ and $\overline{P}_{GCM,base}$ are monthly average of projected precipitation by GCMs. T and P would be temperature and rainfall series.

Downscaled data along with other observed parameters in field were used as input for AquaCrop, biomass and yield were computed in desire years (2010-2039) and then consequently water productivity was estimated.

Table 1. Characteristics of 9 AOGCM models from IPCC-AR4 (Caractéristiques des modèles AOGCM 9 de IPCC-AR4)

Global Climate Model	Centre acronym	Scenarios	Grid resolution		Refrences
			Atmospheric	oceanic	
CCSM3	NCAR (USA)	A2, B1	1.4° . 1.4°	0.46° · 1.125°	Collins et al. (2006)
CGCM3	CCCMA (Canada)	A2, B1	3.75° · 3.75°	1.875° · 1.875°	Kim et al. (2002, 2003)
CSIRO Mk3	ABM (Australia)	A2, B1	1.875° · 1.875°	0.95° · 1.875°	Gordon et al. (2002)
GFDL CM2.1	NOAA/GFDL (USA)	A1FI, A2, B1	2° · 2.5°	0.9° · 1.0°	Delworth et al. (2006)
GISS E-R	NASA/GISS (USA)	A2, B1	4° · 5°	4°· 5°	Schmidt et al. (2006)
HadCM3	UKMO (UK)	A1FI, A2, B1	2.5° · 3.75°	1.25° · 1.25°	Pope et al. (2000)
ECHAM5	MPI (Germany)	A2, B1	1.875° · 1.875°	1.0°· 1.0°	Roeckner et al. (2003)
MIROC-med	CCSR (Japan)	A2, B1	2.81° · 2.81°	0.9° · 1.4°	Hasumi and Emori (2004)
PCM	NCAR (USA)	A1FI, A2, B1	2.81° · 2.81°	1.0° · 1.0°	Washington et al. (2000)

3. RESULTS AND DISCUSSION

3.1. AquaCrop calibration

In four different stages of maize growth, biomass was measured in field and these data were used for calibration by help of RMSE and d (index of agreement of Willmott). Full and deficit irrigation treatments were used for calibration and verification processes, respectively, and data are shown in Table 2.

Table 2. Observed (obs) and predicted (pred) biomass by AquaCrop for full and deficit irrigation treatment in four different stages (Enregistrées (obs.) et prédites (Pred.) de la biomasse par le modèle AquaCrop pour le traitement d' irrigation complet et le déficit en quatre étapes différentes).

Full irrigation			Deficit irrigation		
Day	**Obs. biomass**	**Pred. biomass**	**Day**	**Obs. biomass**	**Pred. biomass**
14	0.161	0.091	14	0.177	0.075
49	4.86	7.516	52	3.407	7.582
74	14.129	15.6	75	5.618	10.77
125	22.05	21.599	125	13.217	13.139
RMSE *d*	1.54 0.996			1.91 0.985	

The normal planting date of maize in Pakdasht area is about first of June but unfortunately, in the study carried out by Najjar et al. (2011), planting date was postponed to 29th of July because of seed problem. As results show, there was no significant difference between treatments of with and without nitrogen fertilizers (most probably because of no need to fertilizer in that farm or improper fertilizer using time). Therefore, it was not possible to calibrate fertility stress of AquaCrop. Data related to full irrigation treatment were used for calibration and deficit irrigation treatment data were used for verification. As seen from Table 2, in calibration and verification treatments, agreement index of Willmott (d) were more than 0.98 and RMSE was less than 2. These values are acceptable according to previous studies. Based on the model performance statistics, the model performs at acceptable level. It was also notable that these RMSE and d values related to four stages of measuring during crop period and the values for final biomass would be much less.

3.2. Risk analysis and climate change impact

Climate change assessment needs more than 30 years of historical data. Since Pakdasht climatological weather station was established in 1986, therefore, historical daily climate data (maximum and minimum temperatures and rainfall) for 1971–2000 period were taken from the nearest climatological station (Amin Abad)

Using the MTOP method, weights were given to each GCM according to their monthly mean projection efficiency in baseline (1971-2000) so that the GCMs with higher weights would have better performance. Results are shown in Tables 3 and 4.

Table 5 gives the ΔT and ΔP that were results of risk analysis in three different probability levels (25, 50 and 75%). These data were used in the downscaling procedure in order to produce three time series of temperature and precipitation.

Number of months in a year which were susceptible to precipitation decline was different in various probability levels. It was 8 out of 12 months (Feb-Oct) in 25%, 6 months in 50% and 4 months in 75% probability level. The highest decrease rate was in September in all levels of likelihood according to Table 4.

Table 3. GCMs weights according to MOTP method for monthly mean temperature (poids selon la methode MOTP pour la temperature moyen mensuelle).

	CGCM3	ECHAM5	GFDLCM	GISS	HadCM3	MIRCO	PCM	CCSM3	SCIRO
Jan	0.02	0.11	0.13	0.05	0.03	0.40	0.02	0.12	0.12
Feb	0.03	0.11	0.19	0.09	0.07	0.30	0.02	0.09	0.09
Mar	0.04	0.16	0.13	0.09	0.09	0.26	0.03	0.07	0.13
Apr	0.02	0.37	0.04	0.03	0.04	0.20	0.02	0.04	0.24
May	0.02	0.69	0.02	0.02	0.03	0.08	0.01	0.03	0.10
Jun	0.07	0.15	0.04	0.07	0.06	0.38	0.02	0.05	0.16
Jul	0.65	0.10	0.03	0.05	0.02	0.06	0.01	0.03	0.05
Aug	0.18	0.41	0.05	0.08	0.04	0.11	0.02	0.05	0.06
Sep	0.02	0.08	0.01	0.46	0.01	0.39	0.01	0.01	0.01
Oct	0.06	0.43	0.07	0.07	0.05	0.17	0.03	0.06	0.07
Nov	0.01	0.89	0.01	0.01	0.01	0.03	0.01	0.01	0.02
Dec	0.02	0.48	0.05	0.03	0.03	0.15	0.01	0.07	0.16

Table 4. GCMs weights according to MOTP method for monthly mean precipitation (GCM poids selon la méthode MOTP pour les précipitations moyennes mensuelles).

	CGCM3	ECHAM5	GFDLCM	GISS	HadCM3	MIRCO	PCM	CCSM3	SCIRO
Jan	0.44	0.07	0.13	0.06	0.06	0.11	0.03	0.03	0.05
Feb	0.38	0.05	0.14	0.12	0.07	0.06	0.03	0.09	0.05
Mar	0.04	0.07	0.06	0.04	0.46	0.19	0.05	0.05	0.05
Apr	0.02	0.49	0.03	0.03	0.08	0.05	0.13	0.07	0.11
May	0.01	0.50	0.04	0.02	0.06	0.02	0.11	0.11	0.12
Jun	0.01	0.12	0.17	0.02	0.05	0.04	0.09	0.05	0.45
Jul	0.14	0.02	0.01	0.01	0.46	0.08	0.01	0.26	0.01
Aug	0.75	0.12	0.01	0.01	0.04	0.00	0.02	0.00	0.04
Sep	0.05	0.07	0.20	0.30	0.04	0.03	0.21	0.01	0.09
Oct	0.21	0.22	0.08	0.03	0.06	0.11	0.06	0.04	0.19
Nov	0.02	0.18	0.08	0.03	0.19	0.25	0.05	0.03	0.16
Dec	0.41	0.08	0.08	0.15	0.04	0.09	0.05	0.05	0.06

Table 5. Rainfall and temperature variation in 25, 50 and 75% probability (Les précipitations et les écarts de température dans les 25, 50 et 75% de probabilité).

	Precipitation			Temperature		
	25%	50%	75%	25%	50%	75%
Jan	1.01	1.08	1.08	0.77	1.06	1.1
Feb	0.96	1.01	1.01	0.51	0.84	1.34
Mar	0.86	1.02	1.02	0.93	1.03	1.34
Apr	0.93	1.05	1.05	0.71	0.86	1.19
May	0.85	0.85	1.04	0.92	0.92	1.47
Jun	0.86	0.86	0.90	1.26	1.68	1.87
Jul	0.60	0.81	0.81	1.41	1.41	1.41
Aug	0.95	0.95	0.95	1.06	1.26	1.74
Sep	0.24	0.70	0.78	1.21	1.21	1.57
Oct	0.93	0.99	1.04	1.19	1.19	1.42
Nov	1.07	1.19	1.33	0.71	0.71	0.71
Dec	1.06	1.12	1.19	0.98	1.05	1.05

Although there were some months with temperature reduction in next 30 years but the dominant trend was upward with maximum temperature increment belonged to 75 percent probability level in June which was equal to 1.860 C. generally, the higher the probability level, the more the number of susceptible months to temperature increment would be.

Projected climate data along with crop data which were achieved in calibration procedure were employed in AquaCrop model to compute biomass and yield for planting date of June 1st which was the common regional planting date. It was perceptible from diagrams that maize biomass under full and deficit irrigation treatment would be decreased during next 30 years about 8 and 17 percent, respectively. The main cause of biomass reduction was evapotraspiration improvement as consequence of higher temperature which is harmful in condition of non-availability of enough water (Figures 3 and 4).

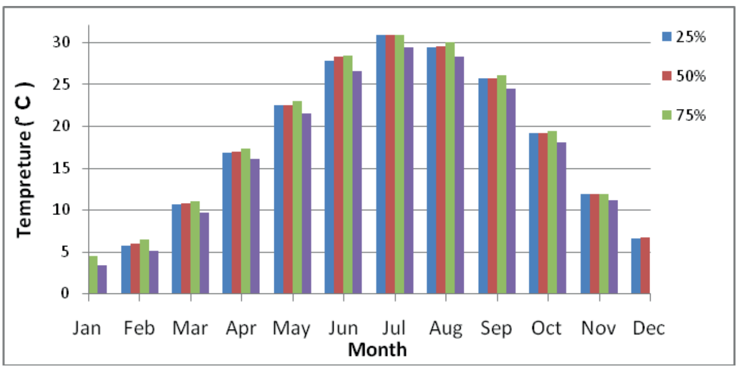

Figure 1. Mean monthly temperature in next 30 years (2010-2039) in three different probability levels (Des températures moyennes mensuelles dans les 30 prochaines années (2010-2039) dans trois différents niveaux de probabilité).

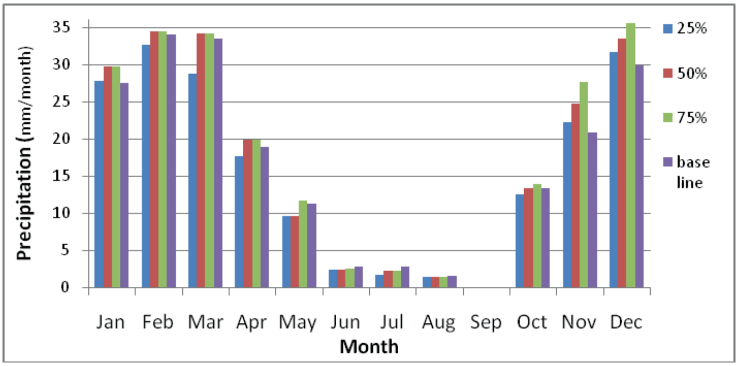

Figure 2. Mean monthly precipitation in next 30 years (2010-2039) in three different probability levels (Précipitations Moyennes Mensuelles Dans les 30 prochaines années (2010-2039) dans trois différents niveaux de probabilité).

There were some years in data that biomass values didn't follow the trend (i. e., 2015). The reason might be in either climatological characteristics of the historical data (1971-2000) which were used or downscaling method reflecting the properties of historical data.

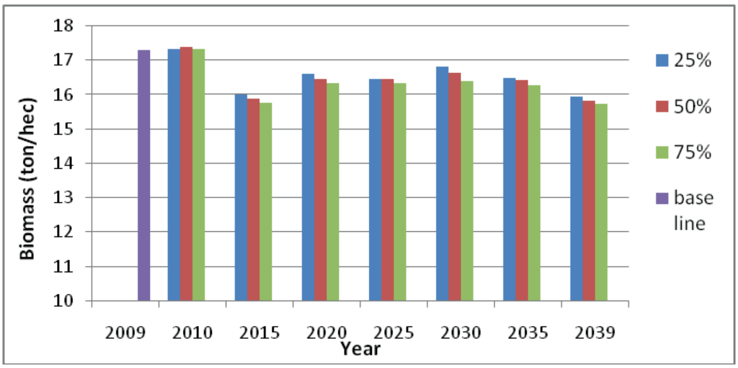

Figure 3. Biomass values of full irrigation treatment in base year (2009) and next 30 years for common planting date in Pakdasht (June 1st) (Les valeurs de la biomasse de traitement complet de l'irrigation dans l' année de référence (2009) et les 30 prochaines années pour la date de semis commune dans Pakdasht (1er Juin)).

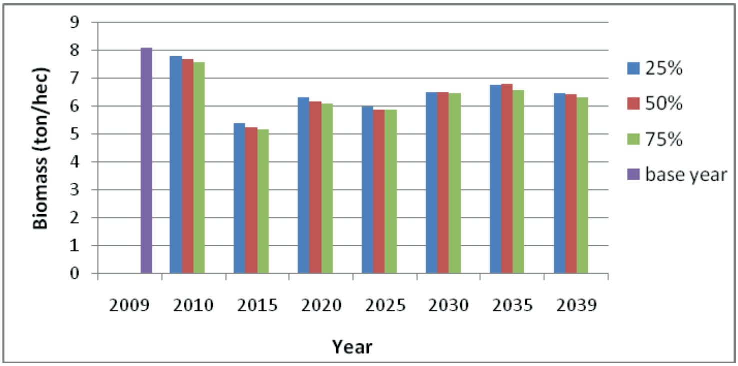

Figure 4. Biomass values of deficit irrigation treatment in base year (2009) and next 30 years under limited irrigation for common planting date in Pakdasht (June 1st) (Valeurs de la biomasse de traitement irrigation déficitaire en année de base (2009) et les 30 prochaines années pour la date de semis commune dans Pakdasht (1er Juin)).

Previous results were related to common maize planting date in Pakdasht. There is no doubt that biomass and yield amounts would be different from previous ones if planting date was modified. Another date (July 29th, planting date in field experiment) was used to investigate either the effect of planting time on maize biomass or the climate change impact on it in next 30 years (Fig. 5). AquaCrop outcomes were significantly different with first trial and an ascending trend was detectable in biomass data which was most probably due to higher temperature in late season (autumn), presenting required degree days for efficient growth of maize. Beside, different trend of these two tests, quantities of biomass were not at all similar since high temperature would reduce or stop crop productivity (maximum temperature reached 440C in July and August in Pakdasht).

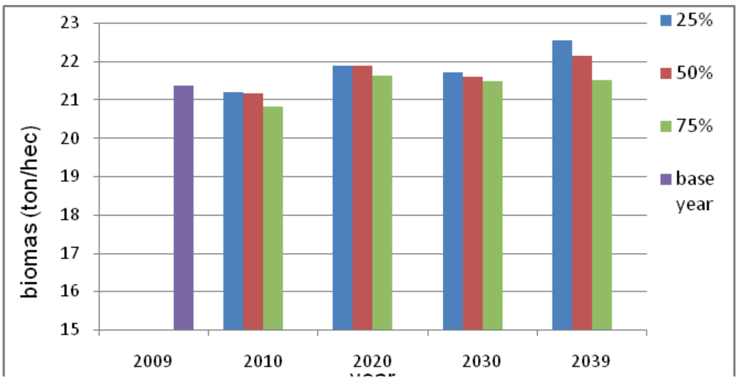

Figure 5. Biomass values in base year (2009) and next 30 years under full irrigation for planting date (June 29th) (Les valeurs de la biomass dans l'année de référence (2009) et les 30 prochaines années pour la date de semis (29 Juin)).

Water productivity and biomass modification would have the same trend in case of fixed irrigation schedule. Water productivity magnitudes for different years were indicated in Table 6 which had upward trend when planting date was July 29th and downward in June 1st planting time.

Table 6. Water productivity (Kg/m3) values in two planting dates (June 1st and July 29th) for different years (Productivité de l'eau (kg/m3) valeurs de deux dates de semis (1er Juin et Juillet 29) pour différentes années).

	June 1st		July 29th
	FI[1]	DI[2]	DI
2009	2.58	1.21	3.19
2010	2.58	1.17	3.16
2015	2.39	0.81	2.82
2020	2.48	0.95	3.27
2025	2.46	0.89	3.23
2030	2.51	0.97	3.24
2035	2.46	1.01	3.28
2039	2.38	0.97	3.37

1. Full Irrigation treatment and 2.Deficit Irrigation

(1. Traitement complet d' irrigation et 2. Déficit d' irrigation)

4. CONCLUSIONS

Nine AOGCM and A2 emission scenario were incorporated in this study to assess one part of uncertainties originating from these models and observe climate change impact on temperature, precipitation, maize production and water productivity in next 30 years. Mont Carlo method as well as Bayesian was used for weighting and producing CDFs in different probability levels of 25, 50 and 75%. Downscaling was done by change factor method and final meteorological data were used in AquaCrop model to simulate maize production in coming years.

It was found that temperature increment range was between 1.87-0.51 oC in different months and probability levels and rainfall might decrease in summer or increase in winter. Maize production might have ascending or descending trend according to plant date, so that common planting date in the region might cause yield and biomass reduction and late planting date might result in biomass increase as well as crop productivity growth.

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