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Application of FAO-AquaCrop model in evaluating climate change impact on wheat productivity in the rainfed Zaer area

Oumaima Iben Halima(1), Hamza Iaaich(1), Abdelmajid Kerfati(2), Rachid Moussadek(1), Mazen Naaman(3) and Ihab Jnad(3

oumaima.ibenhalima@inra.ma

1: Regional Center of Agricultural Research, Rabat – Morocco
2: Hydro-Agricultural Experiment Center, Ministry of Agriculture, Rabat – Morocco
3: Arab Center for the Studies of Arid zones and Drylands, Damascus - Syria

Abstract

Accurate crop development modelling is important in planning rational use of water resources and crop management, along with evaluating the effects of climate change on crop productivity and predicting yields. This study aims at modelling winter wheat productivity under different climatic scenarios and models, in a Moroccan rainfed agriculture site using the FAO AquaCrop model. The study site was a one-hectare experiment plot located in the Marchouch plateau in the North-western Morocco. The model was calibrated using field parameters of the crop growing cycle, the soil characteristics, the crop management and the observed yield for a period covering three cropping cycles (from 2014/2015 to 2016/2017) using daily rainfall and temperature data. The calibrated model was then used to simulate wheat productivity in the study site for short-term (2020-2030) and medium-term periods (2040-2050) compared to a reference (1985-2005). Two Representative Concentration Pathway scenarios (RCP 4.5 and RCP 8.5) were considered for three General circulation models (CNRM, EC-EARTH, and GFDL) to derive the average model outputs with focus on the crop yield, crop growing cycle and evapotranspiration. The results showed a good model calibration, with coefficient of determination R^2 of 0.84, Nash-Sutcliffe indicator of 0.71 and Willmott index of 0.94. Simulations showed that under RCP 4.5 a short-term yield drop of 5.94%, a medium-term crop cycle decrease of 15 days and evapotranspiration reduction of 20mm. Meanwhile, the model predicted under RCP 8.5 a medium-term yield drop of 12.9%, a crop cycle decrease of 13 days and evapotranspiration reduction of 46mm. Overall, simulation results showed that AquaCrop model is suitable for simulating the effects of water and climatic stress on crop productivity in rainfed agricultural areas, which could help decision making in terms of water productivity and crop adaptation under future climate trends in the semiarid conditions.

Keywords: Crop Modelling, Climate change, Wheat, FAO-AquaCrop, Marchouch, Morocco.

Application du modèle FAO-AquaCrop à l'évaluation de l’impact des changements climatiques sur la productivité du blé dans la zone pluviale de Zaer

Résumé

Une modélisation précise de la croissance et du développement des cultures s’avère importante en vue de planifier l'utilisation rationnelle des ressources en eau et la gestion des cultures, ainsi que pour évaluer et prévenir les effets du changement climatique sur la productivité des cultures. Cette étude porte sur la modélisation de la productivité du blé tendre sous différents scénarios et modèles climatiques en agriculture pluviale à l'aide du modèle AquaCrop de FAO. Le site d'étude est une parcelle expérimentale d'un hectare située sur le plateau de Marchouch au nord-ouest du Maroc. Le modèle a été calibré en utilisant les données météorologiques, pédologiques, phénologiques et le rendement observé pour une période couvrant trois cycles allant de 2014/2015 à 2016/2017. Le modèle a été paramétré, calibré et validé pour la prévision des rendements en grain de blé et a été ensuite utilisé pour simuler la productivité du blé dans le site d'étude pour une période à court terme (2020-2030) et à moyen terme (2040-2050) par rapport à une période de référence (1985-2005). Trois modèles de circulation générale (CNRM, EC-EARTH et GFDL) ont été considérés pour les deux scénarios d’évolution de concentration de CO_2 (le scénario moyen RCP 4.5 et le scénario pessimiste RCP 8.5) pour dériver les sorties du logiciel en mettant l'accent sur le rendement des cultures, le cycle des cultures et l'évapotranspiration. Les résultats de calibration affichent un coefficient de corrélation R^2 de 0,84, un indicateur de Nash-Sutcliffe de 0,71 et un indice de Willmott de 0,94. Pour le scénario RCP 4.5, la simulation a montré une baisse de rendement à court terme de 5,94 %, et une diminution à moyen terme du cycle de culture de 15 jours et de l'évapotranspiration de 20 mm. Quant au scénario RCP 8.5, le modèle a prédit une baisse de rendement de 12,9%, une diminution à moyen terme du cycle de culture de 13 jours et une réduction de l'évapotranspiration de 46 mm. En général, les résultats de la simulation ont montré que le modèle AquaCrop est adapté pour simuler les effets du stress hydrique et climatique sur la productivité des cultures dans les zones agricoles pluviales, ce qui pourrait aider à la prise de décision en termes de productivité de l'eau et d'adaptation des cultures aux futures tendances climatiques sous les conditions semi-arides.

Mots clés : Modélisation des cultures, Changement climatique, Blé, AquaCrop- FAO, Marchouch, Maroc.

تأثيرالتغيرات المناخية على إنتاجية القمح في منطقة زعير البعلية

ابن حليمة أميمة، إعيش حمزة، كرفاتي عبد المجيد، مصدق رشيد، مازن نعمان وايهاب جناد

ملخص

تلعب النمذجة الدقيقة دورا مهما في التخطيط المعقلن لاستخدام الموارد المائية وإدارة المزروعات، وكذا تقييم آثار التغيرات المناخية على إنتاجية المزروعات بالإضافة إلى التنبؤ بالمردودية.

تهدف هذه الدراسة إلى نمذجة إنتاجية القمح عبر وضع عدة سيناريوهات ونماذج مناخية في منطقة بورية بالمغرب، وذلك باستخدام نموذج (AquaCrop) المطور من طرف منظمة الأغذية والزراعة للأمم المتحدة.

يقع موقع الدراسة في منطقة مرشوش بهضبة الشمال الغربي للمغرب ويمتد على مساحة واحد هكتار.

تمت معايرة النموذج باستخدام المعطيات الحقلية للدورة النباتية وخصائص التربة وإدارة الحقل وكذا الإنتاجية المحصل عليها خلال ثلاثة مواسم فلاحية (2015/2014 و2016/2015 و2017/2016) وكذا بالاعتماد على البيانات اليومية للتساقطات المطرية ودرجة الحرارة.

بعد ذلك، تم استخدام هذ النموذج لمحاكاة إنتاجية القمح في موقع الدراسة للمدى القصير (2020-2030) والمدى المتوسط (2040-2050) مقارنةً بالفترة المرجعية (1985-2005).

و من أجل رصد مدى تأثير التغيرات المناخية على الإنتاجية وطول موسم النمو وكذا التبخر-نتح، قمنا بالاعتماد على ثلاثة نماذج مناخية (**CNRM, GFDL, EC-EARTH**)، و سيناريوهين (**RCP8.5 , RCP4.5**).

ولقد كانت نتائج هذه المحاكاة جيدة، حيث تم الحصول على 0،84 كمعامل ارتباط (R^2) و0،71 كمؤشر (Nash-Sutcliffe) و0،94 كمؤشر (Willmott).

كما أظهرت النتائج أنه بالنسبة للسيناريو (RCP 4.5) ، سُجِّل انخفاضًا في الإنتاجية بنسبة 5.94٪على المدى القصير، وانخفاضًا في طول موسم النمو لمدة 15 يومًا وكذا انخفاضًا في التبخر-نتح بمقدار 20 مم على المدى المتوسط.

في حين توقع النموذج في حالة السيناريو (RCP 8.5) ، انخفاضًا في الإنتاجية بنسبة 12.9٪ وانخفاضًا في طول موسم النمو لمدة 13 يوم وفي وكذا انخفاضًا في التبخر-نتح بمقدار 46 مم على المدى المتوسط.

عموما ، أكدت نتائج المحاكاة أن نموذج (AquaCrop) مناسب لتقييم تأثيرات الإجهاد المائي والتغيرات المناخية على إنتاجية المزروعات في المناطق البورية، مما قد يساعد في اتخاذ القرارات المتعلقة بتخطيط استخدام الموارد المائية وتكييف الزراعات، خصوصا في ظل التغيرات المناخية المستقبلية في المناطق الشبه الجافة.

الكلمات المفتاحية: نمذجة المحاصيل، التغيرات المناخية، القمح اللين، **Aquacrop**، مرشوش، المغرب

Introduction

Almost 60% of global arid and semi-arid regions are in developing countries where agricultural production is mostly dependent on rainfall (Parr et al., 1990). Morocco is not an exception as 85% of cultivated areas are in rainfed agriculture. The cereal farming occupies an important socio-economic position in Morocco, forming the basic human and animal foodstuffs. It represents 52% of the cultivated area, of which 29% (of total production) is wheat (MAPM, 2015).

According to IPCC experts, droughts, floods, soil erosion, extended periods of drought/intensive rainfall are among the extreme manifestations of global warming expected in the 21st century (IPCC, 2007, 2018). Since climate is one of the driving factors for crop production, changes in temperature, CO_2 concentration, and extreme events frequency (drought, heat), it would significantly affect crop yields and fields operation. Global warming has a big impact on the phenological development during the vegetative and reproductive phases of a crop (Field et al., 2012; Mrabet et al., 2020).

The rainfed agriculture is particularly vulnerable to climate change negative impact. Several authors report various degrees of sensitivity under different agro-ecological regions (Porter et al., 2014; Mbow et al., 2019; MedECC, 2020). The impacts of drought and heat stress occurring in critical phenological phases can induce serious crop yield losses and quality reduction. In fact, the entire agriculture sector in the Mediterranean region is heavily affected by drought events (Mrabet et al., 2020). Valverde et al (2015) study in Mediterranean Southern Portugal showed that winter wheat, sunflower and other herbaceous crops were the most susceptible to yield losses under climate change, with yield drops of 13.6% and 18.5% respectively. In the Middle East Region, Al-Bakri et al (2011) study in the North-western rainfed area of Jordan showed a potential yield decrease by 10–20% for wheat and 4–8% for barley for a 10–20% rainfall reduction. Also, the authors report that the increase of air temperature by 1°C resulted in deviation from expected yield by −17% for wheat and −14% for barley. For the Southern African Region, Mongi et al (2010) study in semiarid Tanzania concluded that there is strong evidence demonstrating the vulnerability of rainfed agriculture to negative impacts of climate change and variability in the study area.

Morocco is also sensitive to the effects of climate change due to its geographical location and to the variability of the Mediterranean climate. Studies on climate projections point out Morocco as one of the most vulnerable countries in the world to global warming (Niang et al., 2014; Bouras et al., 2020). It will be threatened by climate change (Driouech, 2010) particularly due to the expected increase in temperature, between 1.4 to 5.8 °C, by 2100 (Benaouda and Balaghi, 2009). The use of various models also predict a decrease in annual precipitation volumes, though with high rainfall intensity being concentrated in a shorter time period.

With growing water demand to produce more food and increasing competition across water-using sectors, Morocco faces a challenge to produce more food with less water. This goal will be met only if appropriate strategies are sought for water savings and for more efficient water uses in agriculture. One important strategy is to better manage the water and increase its productivity. In spite of all the efforts to mitigate the issue of water scarcity, reasonable management and rational utilization of available water still needs plans and actions (MAPM, 2015).

Several sophisticated crop-growth models, based on physiological processes, have been developed and applied in crop water management with varying degrees of success. The crop simulation model AquaCrop, developed by FAO (Steduto et al., 2009; Raes et al., 2009), simulates daily biomass production and final crop yield in relation to water supply and consumption and agronomic management, based on current plant physiological. Details of the simulated processes are provided in a set of three papers which were published at the model's release (Raes et al., 2009). AquaCrop has been applied in various regions around the world to characterize the crop response to water stress and can be used specifically in situations where water is a key limiting factor in crop production. It is used to characterize the crop response to water stress (Araya et al., 2010), to develop deficit irrigation schedules (Geerts et al., 2010), to improve farm irrigation management (García-Vila and Fereres, 2012), to assess the potential increase in production by crop and field management (Abrha et al., 2012; Mhizha et al., 2014; Shrestha et al., 2013; Tsegay et al., 2012; Zinyengere et al., 2011), to assess the impact of climate change on crop production (Vanuytrecht et al., 2014) and to develop decision support tools for farm operations (Cusicanqui et al., 2013).

The main objective of the present study is modelling winter wheat productivity under different future climatic scenarios and models in a Moroccan rainfed agriculture site using the FAO AquaCrop model. Specific objectives are the model calibration and wheat growth and yield simulation for a short-term (2020-2030) and a medium-term period (2040-2050) by considering two Representative Concentration Pathway scenarios (RCP 4.5 and RCP 8.5) through three General circulation models (GCM) : CNRM, EC-EARTH, and GFDL, in order to derive average model outputs, with focus on the crop yield, crop cycle and evapotranspiration.

Materials and methods

Study area

The study was conducted at the Marchouch plateau in Northwestern Morocco. The experimental field, of one hectare, is located in Marchouch experiment station (Y1= 33°36'24.4" N and Y2= 33°37' 17.6"N; X1= 6°43'15.9"W and X2= 6°42’26.1’’W; Z = 425m) (Figure 1). The soils are vertisols (Chromoxerert) and the climate is a typical Mediterranean as for the Central Morocco. Weather records used for AquaCrop model calibration for the three growing seasons (2014-2017) were acquired from the meteorological station located at the study site. Daily values of rainfall and maximum and minimum air temperatures were available and used.

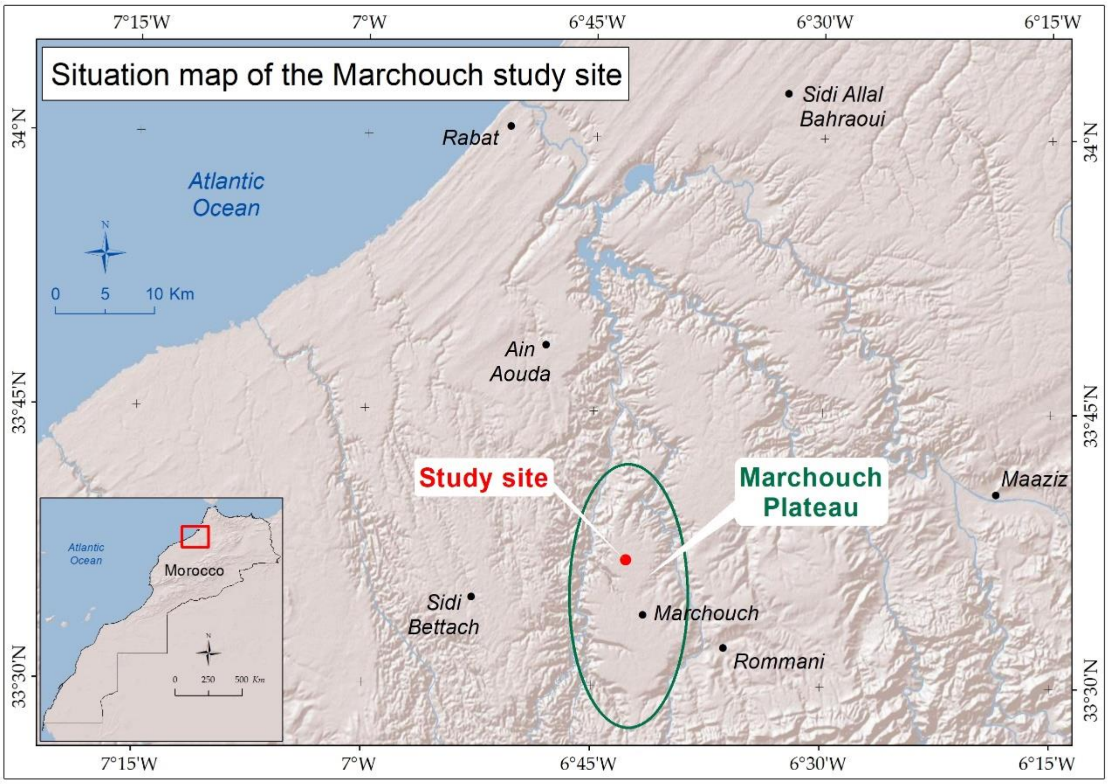
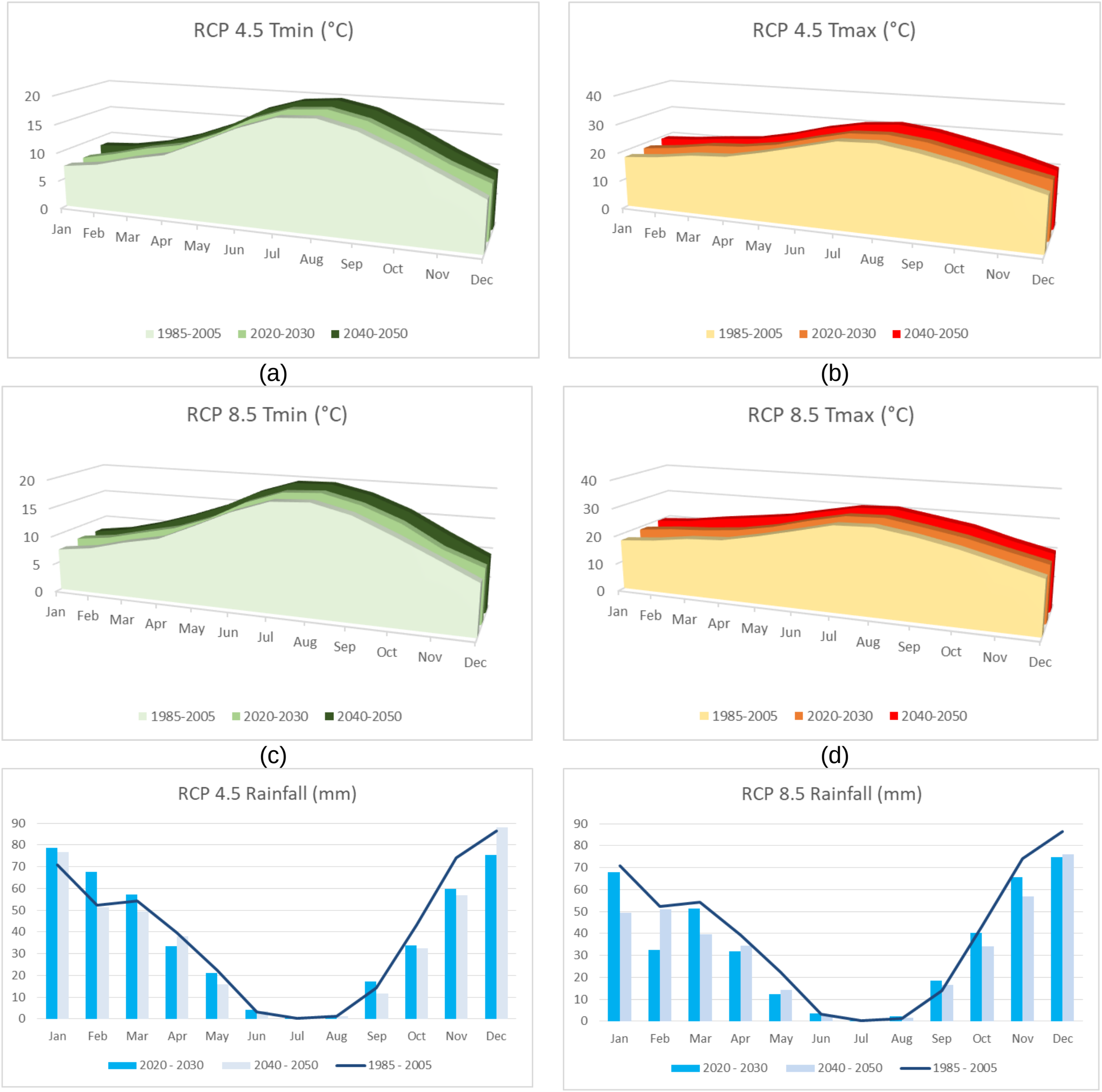


Figure 1: Location of Marchouch study site.

Historical and future climate data

To estimate the change in agricultural productivity in a future climate, the FAO model AquaCrop (version 4, 2013) (Raes, 2012) was used. Once the model was calibrated for three cropping seasons (2014-2017), it was run to simulate the wheat yield, growth cycle length and evapotranspiration for a short-term (2020-2030) and a medium-term (2040-2050) periods compared to a reference period (1985-2005).

In this work, the AquaCrop crop growth simulation model was used for the projection of climatic changes. The climatic variables used from each model were, on a daily basis, the maximum and minimum of air temperature (°C), precipitation ($mm.day^{-1}$), reference evapotranspiration (ETo) and CO_2 concentration. The data were derived from the outputs of the RICCAR (*Regional Initiative for the Assessment of Climate Change Impact in the Arab Region*) project (ESCWA, 2017). Daily temperature and precipitation data of two Representative Concentration Pathway scenarios (RCP 4.5 and RCP 8.5) were considered and three climatic models (CNRM, EC-EARTH, and GFDL) were used to force AquaCrop to derive the average crop yield, crop cycle length and evapotranspiration.



(a) (b)

(c) (d)

(e) (f)

Figure 2: Future trends of minimum temperature (a & c), maximum temperature (b & d) and rainfall (e & f)

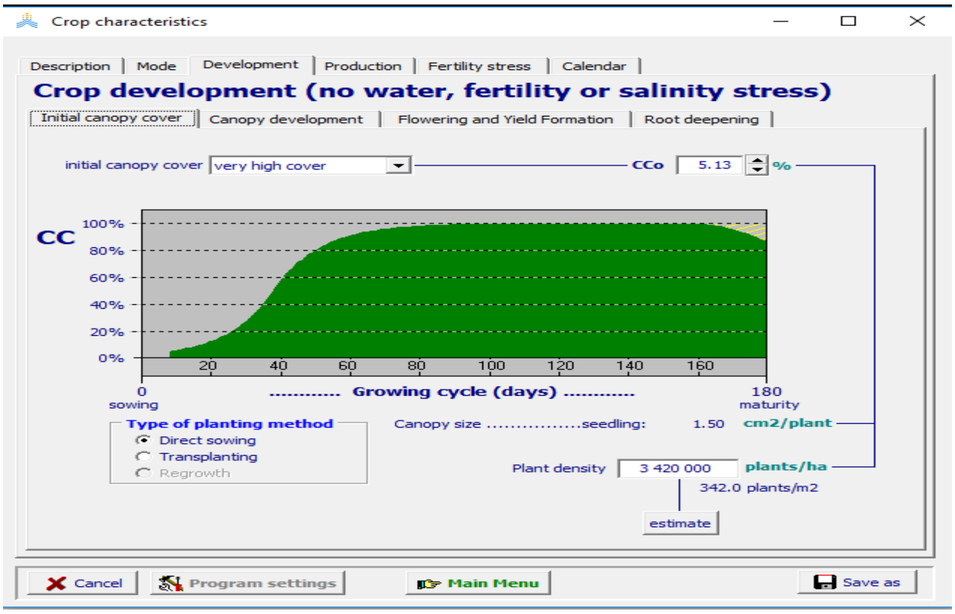
The analysis of the daily climatic data from the three General circulation models of the two scenarios for the three considered periods (Figure 2), showed for the RCP 4.5 scenario an average increase in the minimum temperature by 0.36°C for the period 2020-2030 compared to the reference period and an average increase in the maximum temperature by 0.58°C, in addition to an average 12mm decrease in precipitation, with a more significant precipitation decrease (24.3 mm) during the wheat cropping development stages. Whereas, the scenario for the period 2040-2050 indicates an average increase in the minimum temperature by 0.77°C for the period 2020-2030 compared to the reference period and an average increase in the maximum temperature by 1.23°C, in addition to a higher average 36mm decrease in precipitation, with a more significant precipitation decrease (30.1 mm) during the wheat cropping season.

In the other hand, the RCP 8.5 trends indicate higher impacts of temperature and rainfall changes on the wheat cropping cycle, with an average increase in the minimum temperature by 0.4°C for the period 2020-2030 compared to the reference period and an average increase in the maximum temperature by 0.9°C, in addition to an average 37.8mm decrease in precipitation, with a more significant precipitation decrease (26.3 mm) during the wheat cropping development stages. Whereas, the scenario for the period 2040-2050 indicates an average increase in the minimum temperature by 0.9°C for the period 2020-2030 compared to the reference period and an average increase in the maximum temperature by 1.6°C, in addition to a higher average 103.8mm decrease in precipitation, with a more significant precipitation decrease (75.7 mm) during the wheat cropping season.

Agronomic practices and data collection

AquaCrop model requires inputs including climatic parameters, crop, soil and field and irrigation management data. The model contains a complete set of input parameters that can be selected and adjusted for different soil or crop types.

Crop data: The crop data were of *Arrihane* winter wheat cultivar which is widely cultivated in the study area. The average seeding rate was 340 seeds m^{-2}. Fertilizer applications made before sowing and during the stem elongation stage were sufficient to meet nutrient requirements. Weed and disease control were led using herbicides and a preventive fungicide. No disease infections or pests were detected. Observations of phenological development stages and senescence of wheat were made and the dates of emergence, maximum canopy cover (CC), duration of flowering, start of senescence, anthesis and maturity were recorded. The crop file was created from the reference file "WheatGDD" using the parameters (Figures 3 and 4).



Crop development (no water, fertility or salinity stress)

initial canopy cover: very high cover

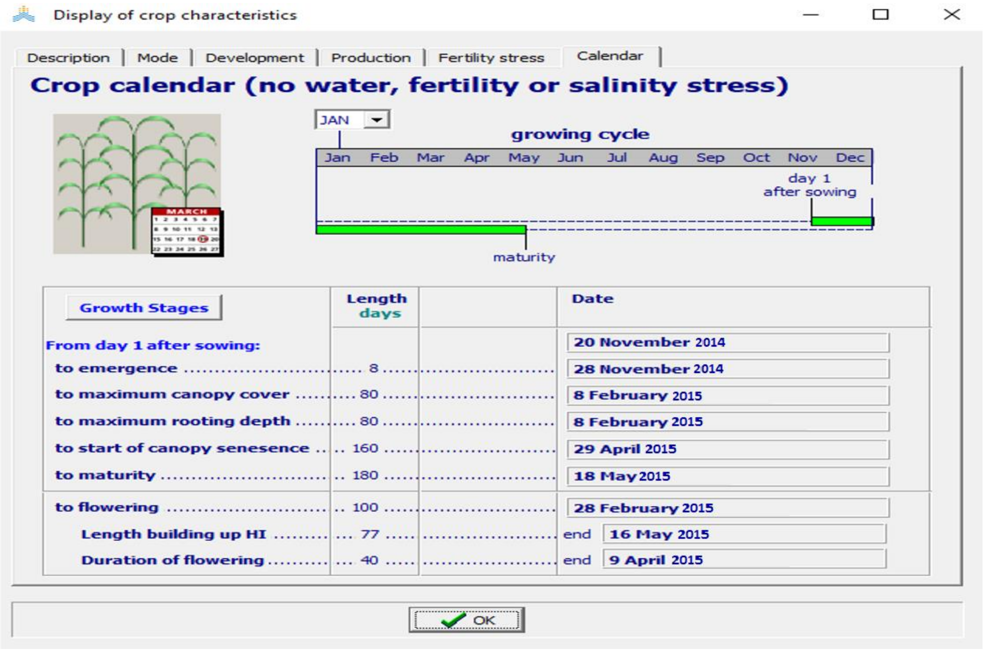
CCo: 5.13 %

Type of planting method
● Direct sowing
○ Transplanting
○ Regrowth

Canopy size ....seedling: 1.50 cm2/plant

Plant density: 3 420 000 plants/ha
342.0 plants/m2

Figure 3: Screenshot of AquaCrop model canopy cover (CC) development graph



Crop calendar (no water, fertility or salinity stress)

Growth Stages	Length days		Date
From day 1 after sowing:			20 November 2014
to emergence	8		28 November 2014
to maximum canopy cover	80		8 February 2015
to maximum rooting depth	80		8 February 2015
to start of canopy senesence	160		29 April 2015
to maturity	180		18 May 2015
to flowering	100		28 February 2015
Length building up HI	77		end 16 May 2015
Duration of flowering	40		end 9 April 2015

Figure 4 : Screenshot of AquaCrop model crop development calendar

Soil parameters: The soil file was created on the basis of field measurements and laboratory analyses of physical and chemical properties of the soil of Marchouch study field (Table 1). No impervious or restrictive underlying soil layer occurs in the experimental site to obstruct the root expansion.

Table 1: Soil data of Marchouch experiment site

Soil properties	Value
Sand (%)	13
Silt (%)	35
Clay (%)	50
FC (%)	40
PWP (%)	25
Ks (mm.day-1)	151. 2
EC (mS/cm)	0.24
pH	7.8
Bd (g.cm^{-3})	1.45

FC: field capacity; PWP: permanent wilting point; Ks: saturated hydraulic conductivity; EC: electrical conductivity; Bd: bulk density.

Management practice data: Management practices were divided into two categories: plot management and management of the land. In our case, the fertilization was optimal and the agricultural practices plots do not affect soil evaporation or runoff. As for the management of irrigation, the rainfed cropping system was considered.

Initial conditions file: The soil electrical conductivity was 0.24 mS cm^{-1} and the Total Available Water was 10% of the usable reserve at the start of the simulation.

Model calibration and validation: Validation and fine tuning processes of the AquaCrop model for winter wheat was done by using the collected data from the field experiment during the cropping season from 2014 to 2017 as compared to the model simulation in terms of grain yield. Subsequently, the goodness of fit between the predicted output and observed values was assessed by using the prediction error statistics. The coefficient of determination (R^2), Pearson's R, Nash-Sutcliffe and Willmott indicators were the main statistical indicators used.

Simulation of climate change effect

After calibration, the model was run to simulate the wheat productivity, the crop growth length and the evapotranspiration for three periods: reference (1986-2005), short-term (2020-2030) and medium-term (2040-2050) periods, by using the corresponding climatic data to each time period. In order to evaluate the impact of climate change on the study site and on wheat, we used three General circulation models: CNRM, EC-EARTH, and GFDL for the two scenarios of CO_2 concentration evolution RCP 4.5 and RCP 8.5. The crop fertility and management strategies were kept as those adopted in the calibration.

Results and Discussion

Calibrating AquaCrop model

Table 2 and figure 5 show the relationship between observed and simulated wheat grain yields. The simulated and measured yields show a good correlation with an R^2 value of 0.84. Andarzian et al. (2011) and Mkhabela and Bullock (2012) reported that the difference between the predicted and observed grain yield of wheat was 0.14 t ha^{-1} and 0.12 t ha^{-1} respectively, indicating that AquaCrop overestimated the yield by 2.7% and 3% respectively. Benabdelouahab et al. (2016) reported the average difference between simulated and observed biomass of durum wheat was 0.08 t ha^{-1}, indicating that the model slightly underestimated this parameter by 0.6%.

Table 2: Measured and simulated winter wheat production at Marchouch site

Cropping season	Simulated yield (T ha-1)	Measured yield (T ha-1)
2014-2015	3,452	3,45
2015-2016	0	0,57
2016-2017	2,766	1,82

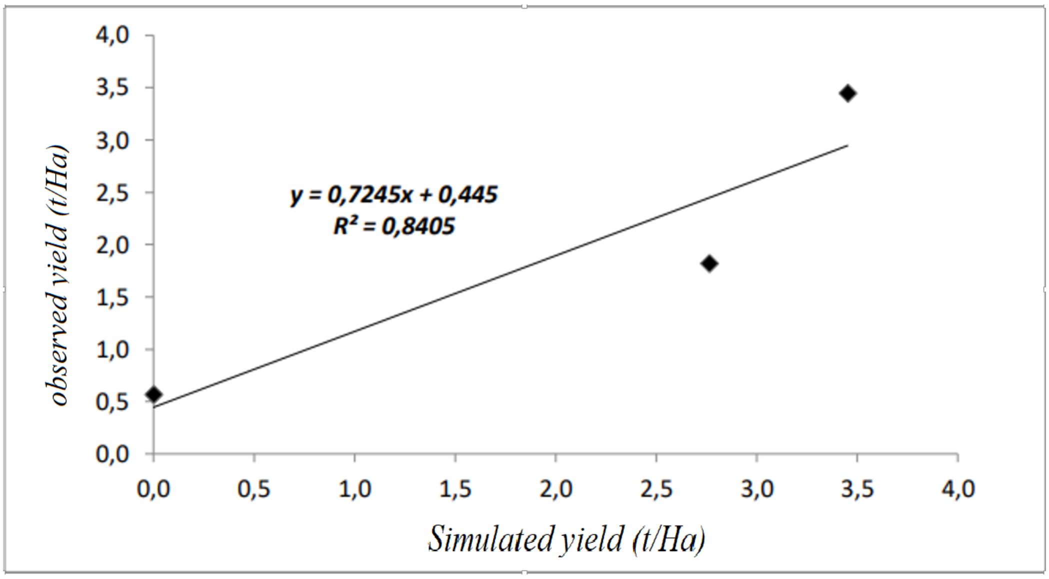


Figure 5: Relationship between observed and simulated wheat grain yield (t ha^{-1}) for three cropping season

The AquaCrop results were evaluated using three additional statistical indicators (Table 3). The indicator values all showed good to very good correlation.

Table 3 : Statistical indicator of the calibrated AquaCrop model

Indicator	Value
Pearson’s R	0,92
Nash-Sutcliffe	0,708
Willmott	0,94

Simulation under the two scenarios of CO_2 concentration trends (RCP 4.5, RCP 8.5)

There were separate runs of AquaCrop for each climate model over each future time period and for two scenarios of CO_2 concentration in the Growing Degree-Days mode. The results of the simulation of the impact of climate change on yield, growth cycle length and evapotranspiration (ET) for wheat are presented in Tables 4, 5,6, 7,8 and 9.

Several conclusions can be drawn from Tables 4 and 5. The RCP 4.5 scenario indicates a decrease in the yield by 5.94% over the 2020-2030 short term period and a stabilization of yield in the 2040-2050 medium term period, compared to the reference period of 1985-2005. This stability in yield reflects the adaptation to the new climatic conditions in the medium term (2040-2050), which corresponds with the beginning of the stabilization of the CO_2 concentration for this scenario. According to the changes in temperature, there is a high decrease in the growth cycle length, from 147 days to 129 days for the short-term period and to 132 days for the medium term period. This trend is due to the accumulation of heat at certain critical stages, which accelerates the development of the crop which in turn leads to the reduction of the growing cycle. The consequences of these temperatures also affect the yield in terms of the number of grains per ear of wheat and the average weight of grains. However, the effects can be very different depending on the stage and the water supply. The projections show that the actual evapotranspiration will decrease in both periods compared to the reference period (Table 5). This decrease is mainly due to the decrease in cycle length and the increase of high atmospheric evaporative demand in concentrated periods.

Table 4: Grain yield evolution under the RCP 4.5 scenario

Parameter	Mean difference in 2020-2030	Mean difference in 2040-2050
Reference yield (t ha^{-1})	2,78	
Absolute difference (t ha^{-1})	-0,16	+0,04
Relative difference (%)	-5,94%	+1,34%

Table 5: Evapotranspiration evolution under the RCP 4.5 scenario

Parameter	1986-2005	2020-2030	2040-2050
Actual Evapotranspiration (mm)	240	210	220

The same conclusions could be drawn from Table 6, 7 and 8. The pessimistic scenario of RCP 8.5 highlighted higher decreases in various parameters. This is due to the exponential increase of the CO_2 concentration for this scenario. The yield is decreasing for the short and medium-term periods. It would decrease by 7.1 % in 2020- 2030 and would continue to decrease during the 2040- 2050 period by 12.9 %, compared to the reference period (Table 6). Forthe cycle length, the model predicts a decrease from 145 days in the reference period to 143 in 2020-2030 and 132 in the 2040- 2050 periods (Table7). For Evapotranspiration, it decreases for both periods compared to the reference period (Table 8).

Table 6: Grain yield evolution under the RCP 8.5 scenario

Parameter	Mean difference in 2020-2030	Mean difference in 2040-2050
Reference yield (t ha-1)	2.81	
Absolute difference (t ha-1)	-0,2	-0,36
Relative difference (%)	-7,1%	-12,9%

Table 7: Crop cycle evolution under the RCP 8.5 scenario

Parameter	1986-2005	2020-2030	2040-2050
Cycle length(days)	145	143	132

Table 8: Evapotranspiration evolution under the RCP 8.5 scenario

Parameter	1986-2005	2020-2030	2040-2050
Actual Evapotranspiration (mm)	295	285	239

Irrespective of the climate models, the results detailed in the previous tables, suggest that under climatic change in both periods there are similar trends of decrease to those reported by the IPCC (4th report) about the impact of climate change on agriculture. The impact of climate change on crop productivity is noted for the most widespread grain crops: wheat, corn, sunflower, soybeans (Olsen and Bindi, 2002; Porter et al., 2014; Mrabet et al., 2020; IPCC, 2007).

Conclusions

In this study, AquaCrop model was used to simulate wheat yield in rainfed condition at Marchouch site, Northwestern Morocco under two future climate scenarios. A field experiment was conducted for three crop growing seasons (2014-2017) to calibrate AquaCrop model. The simulations result for wheat yield were in agreement with the measured values over the calibration period.

The impact of two CO_2 scenarios using three climatic models on the future wheat’s growing period and yield was studied. The prediction by AquaCrop revealed negative impacts of climate change on winter wheat yields. Moreover, the model showed a clear trend towards a shortening in the mean values of the growing cycle in the medium-term period 2040-2050. However, the highest decrease was predicted by the RCP 4.5 in the short-term period. For both scenarios, we can assumpt that evapotranspiration decreases due to negative effects of climatic variability and significant temperature increase.

Overall, AquaCrop model seems to be a suitable tool for simulating the effects of water stress on crop productivity, which can help in setting strategies in order to optimize water productivity under semiarid conditions.

Conflicts of Interest

The authors declare no conflicts of interest.

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