Assessing the impact of climate change on land suitability for crops in El Hajeb province - Morocco

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Abstract

Climate change is recognized today as one of the main threats to the survival of species and the integrity of ecosystems around the world. Knowledge of the specific properties of these changes, which may have an impact on species distribution area, is a central element of adaptation strategies. In this perspective, the present study aims to evaluate the impact of these changes on the suitability of land for the main crops in El Hajeb area, by using the Ecocrop database integrated in the DIVA-GIS software and the current and future climate data by 2050. The results show that the expected fluctuations in precipitation and air temperature will lead to an increase in the land suitability for wheat, Chickpea, olive, almond and fig trees. The increase is mainly due to an increase in air temperature and a change in rainfall towards the optimal ranges for these crops. Consequently, the development and improvement strategies of these crops will not face the significant constraints linked to climate change, and should focus on improving agronomic management and strengthening the capacities of farmers.

Key words: climate change, land suitability, Morocco, adaptation.

Évaluation de l'impact du changement climatique sur l'aptitude des terres aux cultures à El Hajeb - Maroc

Résumé

Le changement climatique est aujourd'hui reconnu comme l'une des principales menaces à la survie des espèces et à l'intégrité des écosystèmes à travers le monde. La connaissance des propriétés spécifiques de ces changements, qui peuvent avoir un impact sur l'aire de répartition des espèces, est un élément central des stratégies d'adaptation. Dans cette perspective, la présente étude vise à évaluer l'impact de ces changements sur l'aptitude des terres aux principales cultures dans la zone d'El Hajeb, en utilisant la base de données Ecocrop intégrée dans le logiciel DIVA-GIS et les données climatiques actuelles et futures d'ici 2050. Les résultats montrent que les fluctuations attendues dans les précipitations et la température entraîneront une augmentation de l'aptitude des terres pour le blé, le pois chiche, l'olivier, l'amandier et le figuier. Par conséquent, les stratégies de développement et d'amélioration de ces cultures ne seront pas confrontées aux contraintes importantes liées au changement climatique, et devraient se concentrer sur l'amélioration de la gestion agronomique et le renforcement des capacités des agriculteurs.

Mots clés : changement climatique, aptitude des terres, Maroc, adaptation

تقييم تأثير تغير المناخ على ملائمة الأرض للمحاصيل في الحاجب - المغرب

لبعيوي أمال وبشوفي خديجة

ملخص

يعتبر تغير المناخ اليوم أحد التهديدات الرئيسية لبقاء الأنواع وسلامة النظم البيئية حول العالم. تعد معرفة الخصائص المحددة لهذه التغييرات، والتي قد يكون لها تأثير على منطقة توزيع الأنواع، عنصرًا أساسيًا في استراتيجيات التكيف. لهذا تهدف الدراسة الحالية إلى تقييم تأثير هذه التغييرات على ملائمة الأرض للمحاصيل الرئيسية في منطقة الحاجب، باستخدام قاعدة بيانات Ecocrop المدمجة في برنامج DIVA-GIS، والبيانات المناخية الحالية والمستقبلية بحلول عام 2050. أظهرت النتائج أن التقلبات المتوقعة في هطول الأمطار ودرجة الحرارة ستؤدي إلى زيادة ملائمة الأرض للقمح والحمص والزيتون واللوز والتين. لذلك، لن تواجه استراتيجيات التطوير والتحسين لهذه المحاصيل مشاكل كبيرة تتعلق بتغير المناخ، ويجب أن تركز على تحسين الإدارة الزراعية وبناء قدرات المزارعين.

الكلمات المفتاحية: تغير المناخ، ملائمة الأرض، المغرب، التكيف

Introduction

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), global average surface temperature, rainfall and extreme events such as heavy rainfall and droughts have significantly changed, and the changes are very likely to continue (IPCC, 2007b). Global average temperatures have increased by 0.2 °C per decade since the 1970s, and global average precipitation has increased by 2% over the past 100 years (IPCC, 2007a). It has increased by 5 to 10% in the northern hemisphere and has decreased in parts of the Mediterranean and Africa. Climate change is spatially heterogeneous. Some places, such as the Arctic, are undergoing much greater changes than global means, while others are exposed to side effects such as rising sea levels (IPCC, 2007a).

The observed evolution of the climate over the past decades, whatever its causes, has had an impact on the natural and human systems of all continents, reflecting the sensitivity of these systems to climate change (IPCC, 2014). Biodiversity and the geographic distribution of habitats favorable to species will be affected by these fluctuations in climatic variables (IPCC, 2007c). Climate change is recognized today as one of the main threats to the species survival and the integrity of ecosystems around the world and may have already given rise to several extinctions of recent species (McLaughlin et al., 2002; Pounds et al., 2006). Many ranges of plant and animal species have moved to new latitudes with more favorable climates in the last century (Parmesan and Yohe, 2003) and will certainly continue to do so (Pereira et al. 2010). It is, therefore, very likely that crops productive in an area will not be so in the future or inversely (Sthapit et al., 2012).

Agricultural crop production will certainly be hit by the expected increase in temperatures and change in rainfall patterns. This impact varies depending on location, climate change scenarios and crop (Tubiello et al., 2002). The effect of increased temperature will depend on the optimal temperature required for crop growth and development (Hatfield and al., 2014). In areas where temperatures are already near or above crop tolerance levels, higher temperatures may be very deleterious, inducing heat stress and water loss on crops and yields will decline. Conversely, some crops will benefit warming in location with lower average temperature currently (Gornall et al., 2010). In cooler regions, an increase in temperature up to 2.5°C, may promote increased agricultural production when in warmer regions, the production may decrease (Imtiaz et al., 2011). Shifting precipitation patterns are also expected to affect crop production negatively, the occurrence of drought periods or heavy rains can be harmful to crops.

The potential production of a crop depends on the appropriateness of a given type of land with crop growing conditions. Each crop will prosper within a specific climatic envelope but climate change will alter satisfaction of their requirements and the geography of crop suitability will shift (Chemura, 2020). Crops tend to migrate towards higher latitudes and production in areas already at the margin of production will push out (Anonym, 2011)." In the northern temperate region, agro-climatic zones are likely to move northwards as a result of climate change. In the southern areas, current crop areas may be abandoned due to low availability of water"(Clavo et al.). In sub-Sahara, Travis (2016) reported that while some crop cultivation may entirely

disappear, other current or substitute crops will remain suitable under climate change. The gain in suitable areas for some crops will occur in regions where these crops are not widely cultivated in the current period (Lane et al., 2007).

Assessing the impact of climate change on crops geographic distribution in coming decades is most important and it must be a central element of adaptation strategies to climate change in agricultural sector, to help in planning and diversification of agricultural production and conservation of species (Heller et al., 2009).

Morocco has not been spared from climate change and its effects. This change has influenced various natural phenomena, in particular the precipitation regime. Precipitation would tend towards a decrease in annual volumes while marking a concentration over time (Benaouda and Balaghi, 2002). Studies have shown that during the last forty-five years, the regions which were classified as humid and sub-humid climates regress in favor of regions with semi-arid and arid climates; This is evidenced by the increase in average annual temperature estimated at 0.16 ° C per decade and the decline in spring precipitation by 47% nationally (DMN 2007). These trends will undoubtedly affect the suitability of Moroccan lands for different crops. The pedo-climatic map of rainfed agricultural lands at the national level indicates that currently only 4% of the total area of the country has a very high suitability for durum wheat cultivation, 12% are moderately suitable, 25% with low aptitude, and 59% is considered unsuitable. Future climate projections according to the A1B scenario by 2050 show that Morocco will have 71% of its area unfit for this cultivation, 30% with low aptitude, 7% will have moderate aptitude and only 2% will remain very suitable (Benaouda and Balaghi, 2002). This increases the need for research in this direction by assessing land suitability for crops now and how it will be changed under future climatic conditions to help in designing and implementing adaptation strategies to mitigate the effects of climate change.

This study aims to assess the impact of projected climate change on land suitability for the main crops in El Hajeb province in Morocco. The results will constitute a decision support tool to promote climate resilient agriculture in this region.

Specifically, the study revolves around the following questions. From a climatic point of view, what is the extent of the areas favorable to these crops? With regard to climate projections, what is the potential effect of climate change on the extent of these areas and their geographical distribution by 2050? What are the implications of these results for the development of future crop policies?

Material and Methods

Study area

The study was conducted in the El Hajeb province (33°41'N, 5°22'W) located in central Morocco (Figure 1), at an altitude of 1000 m and characterized by a temperate climate. Annual rainfall varies between 400 mm and 600 mm and the annual mean temperature is around 20.5 ° C, with a minimum of 2.8 °C and a maximum of 39 °C. It is bordered to the east by the province of Sefrou, to the west by the province of Khemissate, to the north by the province of Meknes, and to the south by the provinces of Ifrane and Khenifra. With a population of 247,016 inhabitants (RGPH, 2014) and a surface area of 2193.41 km^2, the province is organized into 16 communes. The province has a useful agricultural area (UAA) of 150000 ha. Agriculture is the greatest wealth of the region. The main crops grown are: viticulture, arboriculture, cereals and legumes, while livestock occupies a modest place. Land use remains dominated by cereals which represent 45% of the UAA, followed by fruit growing with 28%, market gardening 9% and fodder crops with more than 8%. Crop production is characterized by significant inter-annual variability mainly linked to climatic conditions, in particular drought which has become a structural constraint. El Hajeb province is classified as a favorable rainfed area and thus has a diversified agricultural vocation allowing the development of several agricultural sectors (El Hajeb monograph).

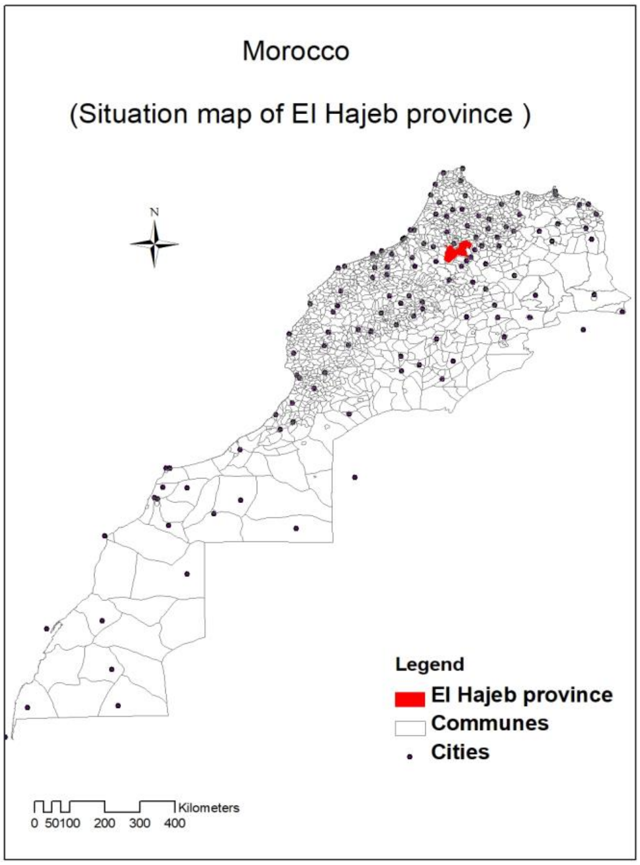

Figure 1: The geographical location of study area

Climate suitability model

Ecocrop (EC), originally developed by Hijmans et al. (2001) and implemented in DIVA-GIS software (Hijmans et al., 2005b), is a crop niche prediction model. It provides a simple method to assess the impacts of climate change on a wide range of crops, including the least studied crops. This model uses environmental ranges as input data, to determine the main niche of a crop, to then produce an overall harvestability as a percentage, and separate suitability values related to temperature and precipitation, as output data. Ecocrop predicts climate / crop compliance, using the following parameters: temperature killing plants, minimum, optimum minimum, optimum maximum, and maximum temperature, minimum, optimum minimum, optimum maximum and maximum required rainwater, and the length of the growing season. The EC model is a relevant general modeling approach, if only temperature and rainfall are considered as determining elements of crop adaptation. Information on soil data and crop management is not included in the model. In addition, the accuracy of the models depends directly on the quality of the expertise used to define the culture parameters (Eitzinger et al., 2013a).

In the EC model, there are two ecological ranges for a given crop, each defined by a pair of parameters for each variable (temperature and precipitation). First, the absolute range, defined by Tmin and Tmax (absolute minimum and maximum temperatures at which the crop can grow) for temperature, and by Rmin and Rmax (minimum and maximum absolute precipitation at which the crop grows) for precipitation, and then the optimum range over which the crop will grow optimally, defined by TOPmin and TOPmax (minimum optimum temperature and maximum optimum temperature), and ROPmin and ROPmax (optimum maximum precipitation and optimum minimum precipitation) (**Table 1**) . An additional temperature parameter is used (Tkill) to illustrate the effect of the minimum temperature of a month.

Table 1: Ecological requirements of crops studied according to the Ecocrop database
(For wheat and chickpea, the data are calibrated according to Moroccan conditions).

Culture/Paramètre	Wheat	Chickpea	Olive Tree	Almond Tree	Fig Tree
T_{min}	5	7	5	10	4
$Topt_{min}$	15	15	20	12	16
$Topt_{max}$	25	29	34	35	26
T_{max}	30	35	40	40	38
R_{min}	250	300	200	250	300
$Ropt_{min}$	450	400	400	600	700
$Ropt_{max}$	600	600	700	900	1500
R_{max}	850	1800	1200	1500	2700

The temperature suitability is assessed for each month of the growing season using the temperature parameters. The total suitability for a crop, for one location as well as temperature, for the entire growing season, is the lowest skill score of the months

needed to complete the growing season. Suitability for precipitation is assessed for the entire growing season and not for each month, in the same way as for temperature.

When climate conditions during the growing season (temperature and precipitation) at a particular location, are beyond absolute thresholds, there are no suitable conditions for growing (white area in Figure 2.A.), and when they are between the absolute and optimum thresholds (dark gray area in Figure 2.A), there is a range of suitability conditions (from 1 to 99), and when they are in the optimum condition area (area in light gray), the conditions are very suitable for the crop and the aptitude score is equal to 100%. The model performs two different calculations separately, one for precipitation and the other for temperature, and then calculates the interaction by multiplying the two scores to give the final suitability index (Figure 2.B).

Final aptitude = Aptitude (Temp.) * Aptitude (prec.)

Finally, according to this index, land suitability is classified into six crop suitability classes (**Table 2)**

Table 2: Definition of the suitability classes according to the calculated final suitability.

Suitability classes	Suitability (%)
Inapt	0
Very marginal	0 à 20
Marginal	20 à 40
Suitable	40 à 60
Very suitable	60 à 80
Excellent	80 à 100

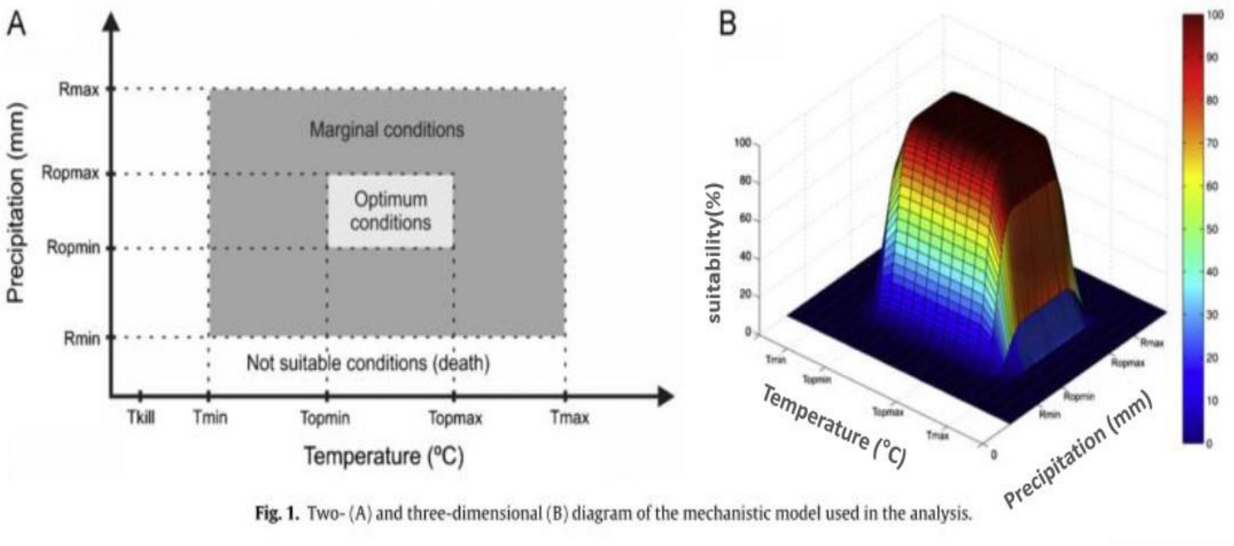

Figure 2: Diagram of the mechanistic model used in the analysis of land suitability (Eitzinger et al., 2013b)

The changes in suitability are obtained by subtracting the suitability of land by 2050 from the suitability of land for the current period.

Climatic data

In order to predict future climate changes, it was necessary for us to establish a baseline, in order to compare the results of the Global Circulation Model (GCM) with the current climatic conditions.

For the current climate (Reference Line), we used monthly data from the Worlclim (WC) database (publicly and free of charge available at http://www.worldclim.org). WC provides information on interpolated global climate surfaces, using latitude, longitude, and elevation, as independent variables, as well as maximum, minimum, and average temperatures and total rainfall over the period (1950 2000). The input data for the WC database came from weather stations around the world, including ~ 47,000 weather stations with monthly rainfall information, ~ 23,000 stations with average temperature data, and ~ 13,000 locations. By going through a quality control algorithm, the input data was finally interpolated to a spatial resolution of 30 arc seconds, commonly referred to as "1-km" resolution (Eitzinger et al., 2013).

The projections of the future climate are the outputs of the Miroc-ESM model. We downloaded monthly time series of maximum, minimum, and average temperature and total precipitation from the site: www.ccafs-climate.org, at 30 arc seconds resolution, for the 2050 horizon and for RCP4.5 5 and RCP8.5 scenarios. The Miroc-ESM model is based on the global climate model MIROC (Interdisciplinary Model for Climate Research) developed in cooperation between the University of Tokyo and the Japanese Agency for Earth Sciences and Marine Technologies.

Results and discussion

Projected climate changes

Changes in rainfall and temperature were assessed by comparing the projected future (2041–2060) and current climate. The maps in figure 3 and figure 4 illustrate the predicted changes in air temperature and precipitation according to the two scenarios RCP4.5 and RCP8.5 compared to the current climate. Miroc-ESM climatic model used in this study projected a decline in annual precipitation all over the province for the two considred climatic scenarios, with the highest decrease in the North and North West of the province, which corresponds to areas at low latitudes. The scenario RCP8.5 records the biggest decrease compared to the RCP4.5 scenario (Figure 4).

The temperature projection shows an increase by about 3 to 4 °C in all parts of the province for both scenarios but more markedly for the RCP8.5 scenario (Figure 3). The temperature increase at the East is more than at the West. This change in climatic variables will affect the climatic suitability of crops in our study area.

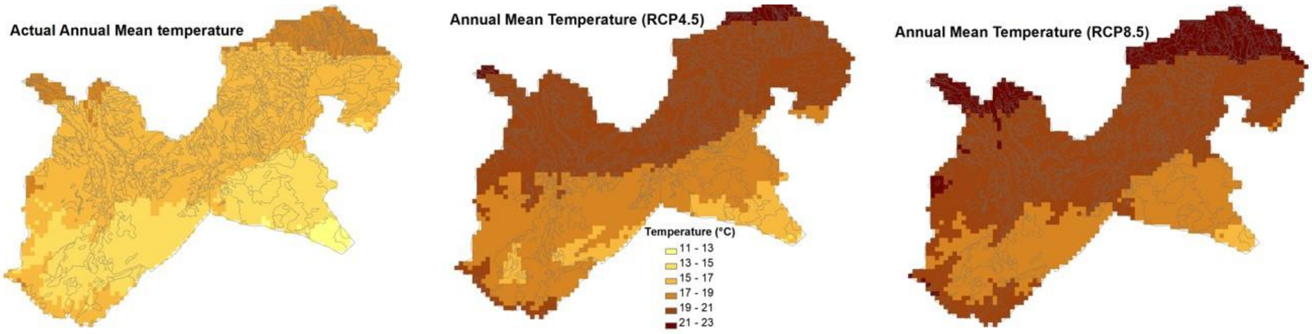

Figure 3: Changes projected in temperature in El Hajeb province by 2050

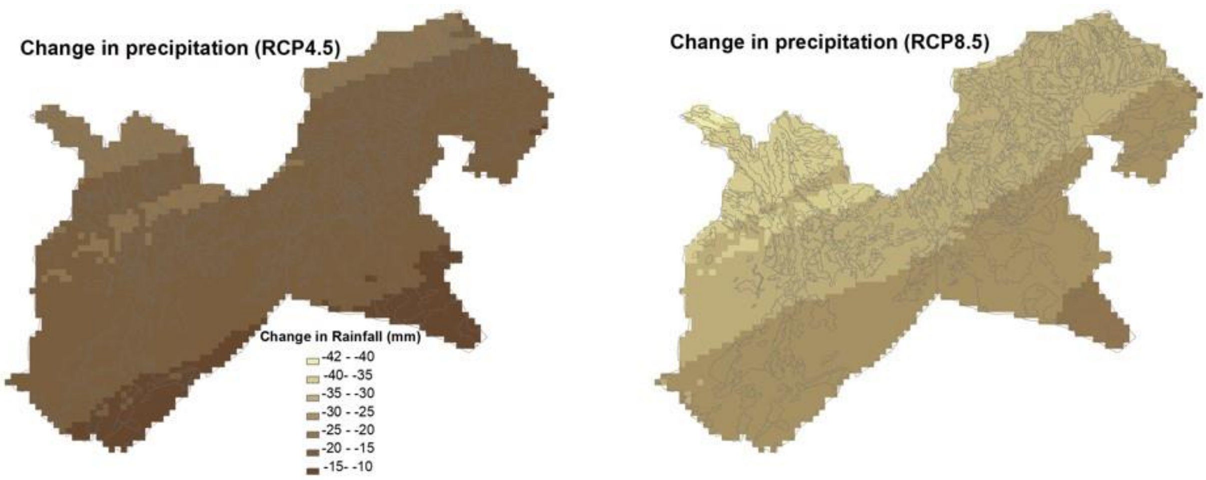

Figure 4: Changes projected in rainfall in El Hajeb province by 2050

The decrease in rainfall is generally moderate according to the two scenarios compared to the falls in rainfall projected in other parts of Morocco. Balaghi (2016) reported that climate change will cause a decrease in rainfall up to -80% in southern part of Morocco. However, when this decline is associated with an increase in minimum, mean and maximum temperatures, it could cause a plants higher evapotranspiration rate, which would trigger heat stress and water deficit in the soils. Increased stresses due to temperature, and drought conditions, have substantial effects on biomass production and the reproductive stages of many plants and crops. The impact depends on initial climatic conditions in the locality subject to the assessment and on the crops requirements.

Climate change impact on Crop land suitability

To develop the suitability maps for El Hajeb province, the principle consists of comparing the climatic conditions; rainfall and temperature in the province with the climatic requirements of crops during the growing season. We note that the climatic requirements of wheat and chickpeas have been adjusted according to Moroccan conditions, the olive, almond and fig trees are evaluated based on the Ecocrop database (see table 1). It is the combination of the two aptitudes: aptitude towards temperature and towards precipitation, which determine the final climatic aptitude of a unit of land for a given crop. To assess the impact of climate change on crop suitability, the maps of current suitability are compared with maps of future suitability in terms of suitability classes surface.

Changes in climatic variables according to the Miroc-ESM model will have an influence on crops suitability. The percentage distributions of the current and future aptitude classes of the five crops considered are shown in Table 3.

Table 3: Percentage distribution of current and future climatic suitability classes according to the two scenarios RCP4.5 and RCP8.5, of the considered crops.

Suitability	Wheat			Olive tree			Almond tree			Fig tree			Chickpea		
	AA (%)	FA (%) Rcp4.5	FA (%) Rcp8.5	AA (%)	FA (%) Rcp4.5	FA (%) Rcp8.5	AA (%)	FA (%) Rcp4.5	FA (%) Rcp8.5	AA (%)	FA (%) Rcp4.5	FA (%) Rcp8.5	AA (%)	FA (%) Rcp4.5	FA (%) Rcp8.5
Inapt	1	0	0	23	4	1	0	0	0	0	0	0	2	1	7
Very marginal	29	0	4	0	0	0	66	1	0	1	0	0	58	34	39
Marginal	38	10	30	12	1	0	31	50	33	68	26	22	40	65	53
Suitable	30	52	13	59	38	16	3	35	49	31	74	74	0	0	2
Very suitable	2	33	44	5	56	83	1	14	18	0	0	3	0	0	0
Excellent	0	5	9	0	0	0	0	0	0	0	0	0	0	0	0

***AA**: Actual area* ***FA**: Future area*

Wheat

The suitable and very suitable areas for wheat represent only 32% of the total area of El Hajeb according to the current scenario, climatic changes under Rcp4.5 scenario will increase the wheat suitability and the areas able to very able will occupy 90% of the total. For the Rcp8.5 scenario, the suitable areas will reach 67% of agricultural land (Figure 5). The climatically suitable land units will be mainly downgraded because of the slope, coarse elements and erosion (Chikh, 2009).

Wheat is a suitable crop for temperate climates and high temperatures can affect the crop at different development stages. Above 30 °C, heat can mainly damage the leaves and the photosynthesis mechanisms, which accelerates the aging process of wheat (Wilcox et al., 2014). The expected climate changes could strongly affect the wheat production worldwide (Kajla et al., 2015). The higher temperatures may negatively affect the wheat growth process and decrease its production (Pervez and al., 2010). High temperatures can accelerate ripening; allowing less time to accumulate dry matter during the grain filling period, thereby reducing yields (Wheeler et al. 1996). In addition, heat stress during flowering can also reduce crop yields (Semenov and Shewry, 2011). However, rising temperatures may be beneficial for crop yields at higher latitudes where the growing season length is currently limited. Changes in precipitation can also have both positive and negative effects. Higher precipitation can increase production in areas with water scarcity, but in areas that already have high precipitation; a further increase can lead to water saturation of soils and leaching of nutrients (Ludwig and Asseng, 2006).

Previous studies have showed an important yield loss when the temperature increase is above 2.3 °C. However, high CO_2 content, greater than 640 ppm (for comparison, the concentration of CO_2 in the atmosphere was of 396 ppm in 2013) can compensate for the negative effect of a temperature increase of + 2 ° C and a decrease in precipitation of -20% (Wilcox and al., 2014).

The climate change is thus likely to have an effect on wheat yields, but it is not easy to predict whether this effect will be positive or negative. This uncertainty is mainly due to the opposite effects between temperature, precipitation and CO_2 content on wheat yield. Numerous studies have been carried out in recent years to study, using crop models, the effect of different climate scenarios in different regions of the world. They have given rise to the publications revealing variable, sometimes even contradictory, effects (Wilcox and al., 2014). The land's wheat suitability will decrease by 18% over the world (Lane and al., 2007). Benaouda and Balaghi, 2002, showed that Morocco would have 71% of its area unfit to durum wheat cultivation by 2050 according to the AB1 climate scenario.

The increase in land suitability for wheat in our study site is mainly due to the increase in air temperatures to more favorable values than at present and to the decrease in precipitation. Wheat requires between 450 and 600 mm of water for optimal growth and development. These conditions exist currently on 37% of El Hajeb lands and climate change will increase these proportions, which will reach 44% under the RCP4.5 scenario and 48% under RCP8.5 (Figure 6). For the temperature, 67 % of El Hajeb land has currently between 15 and 20°C, in the future 96% will have

as mean temperature between 15 et 23 °C which corresponds to the optimal temperature required by wheat for best growing.

On areas when the climate does not present a constraint, the final suitability is essentially based on the soil characteristics like slope, which downgraded 17 % of the total areas in El Hajeb (Chikh, 2009).

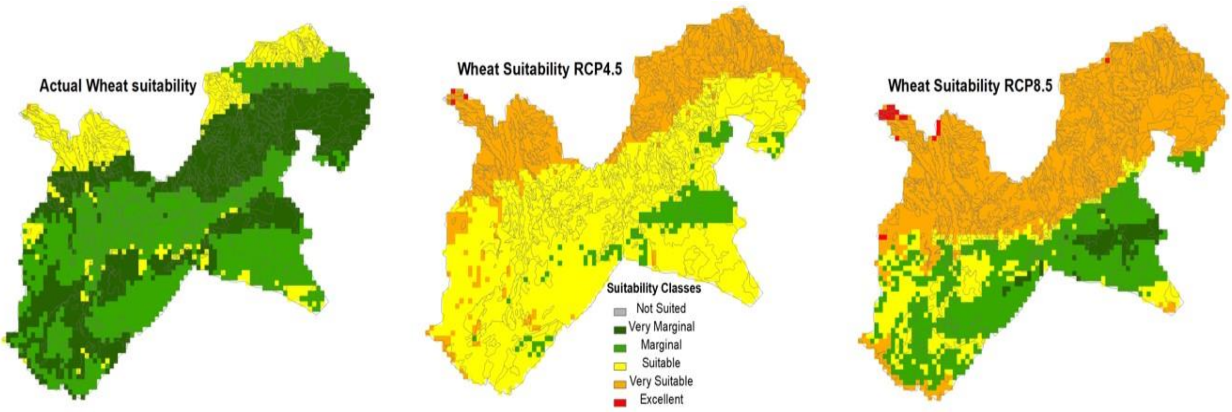

Figure 5: Wheat suitability according to the tree scenarios: Actual, RCP4.5 and RCP8.5

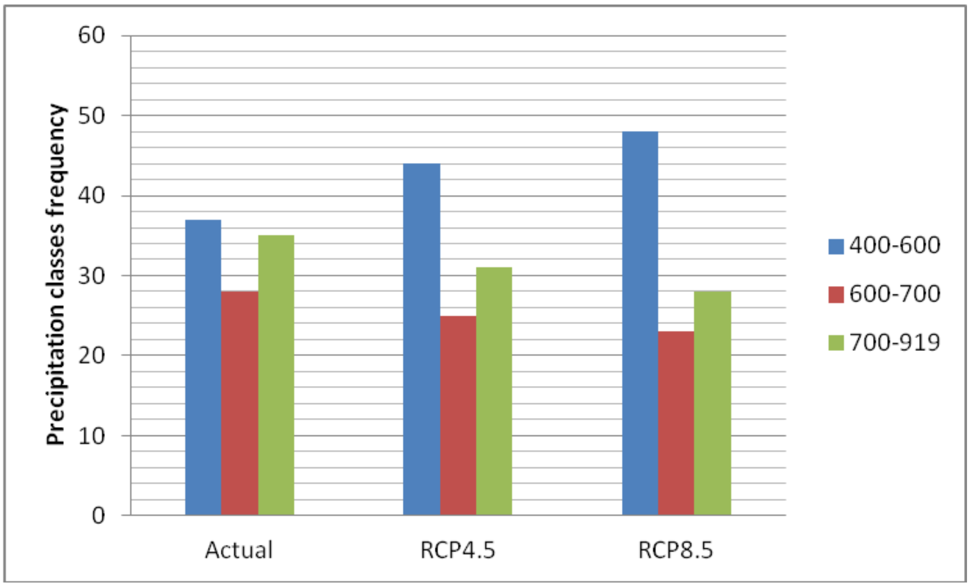

Figure 6: Precipitation classes frequency according to the three Scenarios

Chickpea

Chickpea (Cicer arietinum L.) is a marginal crop on 67% of the land in the study area (marginal and very marginal) and only 33% of the total area is currently suitable (Figure 7). This is explained by the prevailing temperature in the study area which are low (between 9 and 20 ° C as annual average) compared to the chickpea heat requirements which are between 15 to 29 °C during its growth cycle. This low aptitude is also due to the short cycle of this crop, which is placed, between the end of the winter season and spring season. The increase in the projected temperature will improve the chickpea suitability in the province. 90% of the land will be suitable and very suitable under RCP4.5 and RCP8.5 scenarios (Table 3). The change in the rainfall regime in El Hajeb is also in favor of chickpea cultivation that demands from 400 to 600 mm to best grow and develop (Figure 6). This result is in agreement with other studies carried out in Morocco, which confirmed a shift in the distribution area of some species towards the north and the high-altitude areas more favorable climatically in the future, despite the increase in temperature and the decrease in expected precipitation (Balaghi et al, 2016).

Chickpea is best grown in areas between 400 and 600 mm rainfall and their temperature requirements vary with developmental stages, it ranges from 15 °C to 29°C (Imtiaz et al., 2011). Generally, chickpea is adapted to high temperatures; however, heat stress during reproductive phase can cause significant yield loss (Berger et al., 2011). The productivity of most chickpea genotypes decreases dramatically when the temperature reaches 35°C (Basu et al., 2009). Increasing temperature in some chickpea growing area due to climate change may cause chickpea production to expand to cooler locations (Berger et al., 2011). Planting chickpea in winter season led to higher seed yield by taking advantage in water availability and a long growing season (singh, 2008). In this case, the crop becomes more sensitive to cold damage at the end of the vegetative stage (Singh et al., 1995).

Drought is the second most important limiting factor of chickpea production (Singh et al., 2014). Repeated droughts throughout the season have resulted in zero yields of food legumes for consecutive years in Morocco (Fathi, 2016). The yield losses can reach 50% as a result of climate change (Wilding, 2019), more particularly in area with water scarcity. The impact of climate change on chickpea is different from one region to other, and in Ethiopia, projected climate change will imply an increase in productivity by an increase in harvest index, biomass and yield (Ibrahim et al., 2016). The same result has also been reported by Koocheki et al., (2016) in Iran. On the other hand, Bhadauria and al., 2009 reported that chickpea yield in rainfed ecosystem, will be impacted negatively under rising temperature in India.

Others studies carried out in different sites in south Asia and East Africa, conclude that the impact of climate change on chickpea yield could be negative or positive, since the impact’s magnitudes can be quite different from one site to the other, however, the main factor affecting chickpea yields at the site, was the temperature (Singh et al., 2014). Grain yield of chickpea will increase in 2050s by about 17% to 25% at the cooler sites but at the warmer sites, yield will decrease by 7% to 16% as compared to the yields under baseline climate of the sites (Singh et al. 2014). In Morocco, the land suitability for spring crops such as chickpeas will reduce greatly,

except in northern part of the country where future climatic conditions will be more favorable for chickpea production (Balaghi, 2016). According to Imtiaz et al., (2011) Chickpea will be benefit from temperature increase. Global warming may allow chickpea, which is a warm-season plant, to be better adapted to cooler regions at high latitude (Gan et al. 2009**)**.

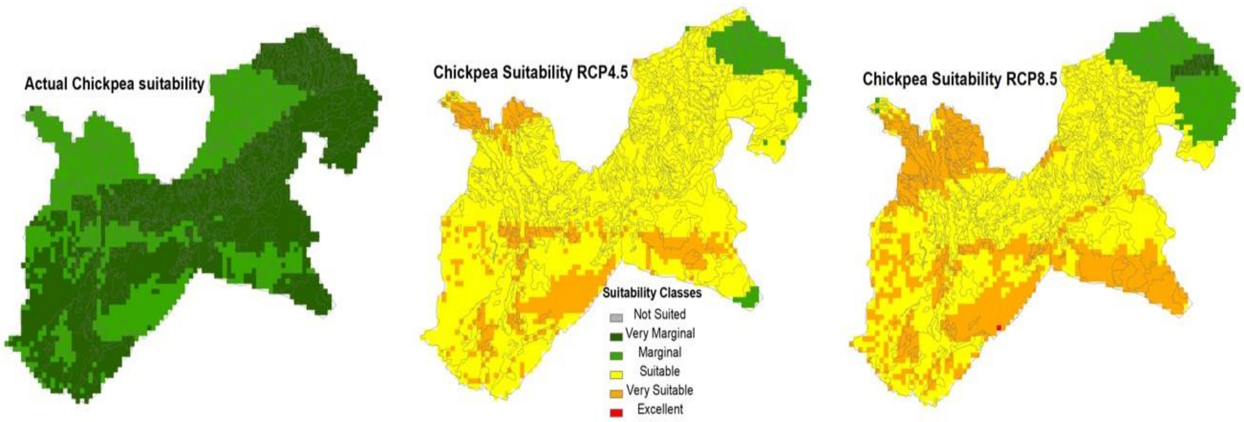

Figure 7: Chickpea suitability according to the tree scenarios: Actual, RCP4.5 and RCP8.5

Olive tree

The olive tree is currently unsuitable on only 23% of the land of El Hajeb province. Changes in temperature and precipitation patterns will cause an improvement in the climatic suitability for olive trees making the province almost suitable to very suitable for this crop according to the two climatic scenarios (Figure 8). The change in the two climatic variables is towards the optimal ranges for olive tree development. The final suitability for this crop in the future will be determined mainly by soil parameters such as slope, coarse element load and depth (Chikh, 2009).

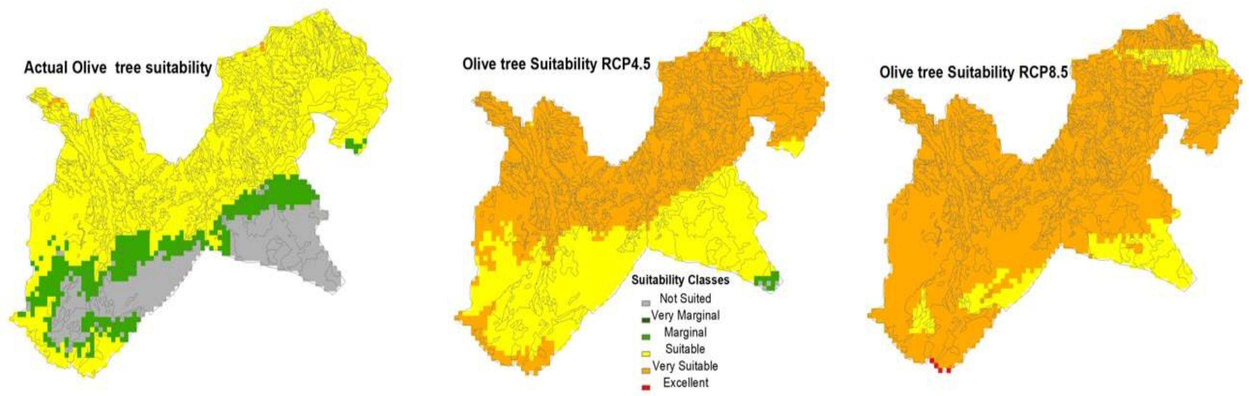

Figure 8: Olive tree suitability according to the tree scenarios: Actual, RCP4.5 and RCP8.5

The temperature conditions have various physiological processes on olive tree growth and development. This is one of the most important criteria for adapting to environmental conditions. At 35-38 °C, vegetative growth stops at 40 ° C and above, burns and damages the leaf apparatus and can cause fruit drop, especially if water is insufficient (Wallali et al., 2003). Rainfall between 400 and 700 mm that is well distributed, the olive tree vegetates and produces normally. Between 200 and 400 mm, the production is possible if the soil's water retention capacities are sufficient (deep clay-loam soils). With a rainfall less than 200 mm, olive growing is economically unprofitable. The tree olive cultivation is very sensitive to winter temperatures below 0°C, and even below 10°C, which contributes to stop the fertilization process during the flowering period. The province of El Hajeb is currently recording between 9 and 20 °C as an annual average, which will increase to vary between 13 and 24 °C under RCP8.5 Scenario. Thus, it is temperature changes that will cause the suitability improvement for tree olive in the study area.

According to other studies, the expected increase in temperature can negatively affect several physiological processes of the olive tree and consequently decrease its production (Fraga et al. 2019). The predicted water stress will also result in negative impacts on the olive tree (Arampatzis et al. 2018). Tanasijevic et al. (2014) and Rodríguez et al. (2020), agreed that the suitability of olive farms in the Mediterranean will decrease under the effect of heat and water stress with a possible expansion of olive orchards in northern Europe by 2100 (Moriondon et al., 2013). On the other hand, Orlandi et al. (2020) reported that some olive-growing areas in the Mediterranean are projected to have an increase in productivity in the future. The climate change impact on the olive tree is heterogeneous way and it depends on the climatic conditions of each region and their compatibility with the olive tree requirements. This requires studying the impact at the local level (Farga et al., 2021).

Almond tree

Almond tree is predicted to increase its suitability in the studied area; suitable to very suitable land will represent 49% (under Rcp4.5 scenario) and 67% (under Rcp8.5 scenario) of the total area instead of 4% for the current period (Figure 9). This increase is due to the interaction between temperature and precipitation and their evolution during the growth season.

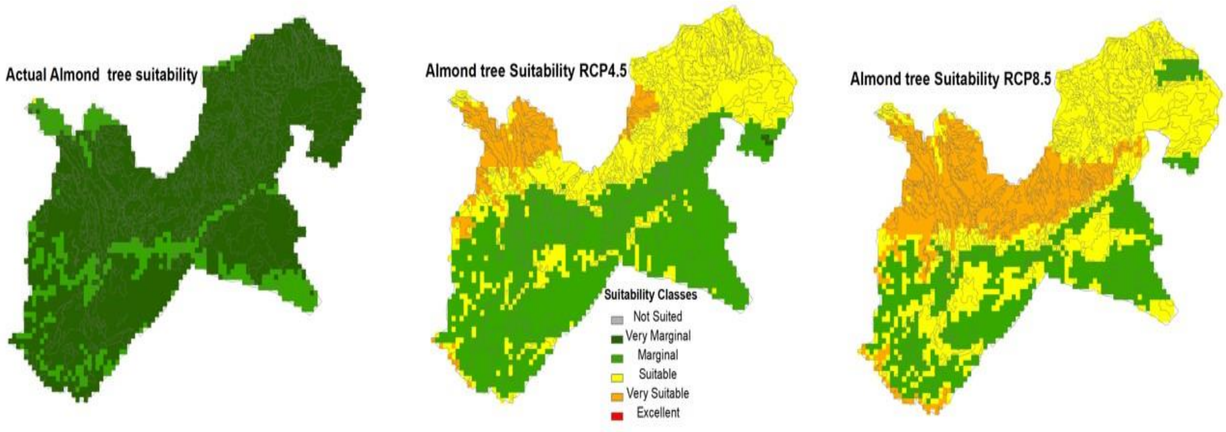

Figure 9: Almond tree suitability according to the tree scenarios: Actual, RCP4.5 and RCP8.5

Almond tree is known as a cold tolerate species. It requires low winter temperatures to break dormancy (200 to 400 hours below 7.2 °C). Its flowering is early (December to March) thus frost zones should be avoided (Wallali et al*., 2003)*. It is more demanding in light and heat during the fruit growth phase. The optimum temperature range for almond photosynthetic activity is between 25-30 ºC, giving a strong reduction with temperatures below 15 ºC or above 35 ºC. High temperature above 35 °C enters the tree in summer vegetative stop (especially in dry conditions) and temperature above 40°C can cause zero production (Arquero, 2013). Rain gauge is one of the main productive limitations for almond tree, which has optimal water needs ranging between 600 and 900 mm (Ecocrop database). It will tolerate dry conditions, but in areas under prolonged periods of drought, yields are drastically reduced unless crops are irrigated (Beaulieu, 2020)

The impact of the climate on the almond tree is perceived mainly on its phenology mainly under the impact of temperature shift, which affects the yield in different ways (Lorite et al., 2020). We are witnessing a shortening of vegetative rest period, an advance in flowering and fruit maturity. Areas suitable for this crop will be affected. Di Lena (2018) reported losses in almond land suitability in northern Italy over the past six decades, due to loss of chilling units. On the other hand, an opportunity to expand suitable areas for almond trees is foreseen in the middle of the 21st century in western Oregon which is currently limited by insufficient heat (Parker et al. 2018).

Fig tree

Although the fig tree is not widespread in the study area, the results show that 31% of the assessed area is currently suitable for this crop (Table 3). The projected climate changes in El Hajeb will increase climatic suitability for fig tree (Figure 10), suitable areas will reach 74% of the total surface according to the two future scenarios, hence the interest of encouraging this speculation on land that does not present any pedological limitation such as depth and coarse elements load, two heavy constraints in the allocation of the final suitability for fig in the study area. The suitability will increase at high altitudes which will arbitrate the favorable conditions to the fig tree.

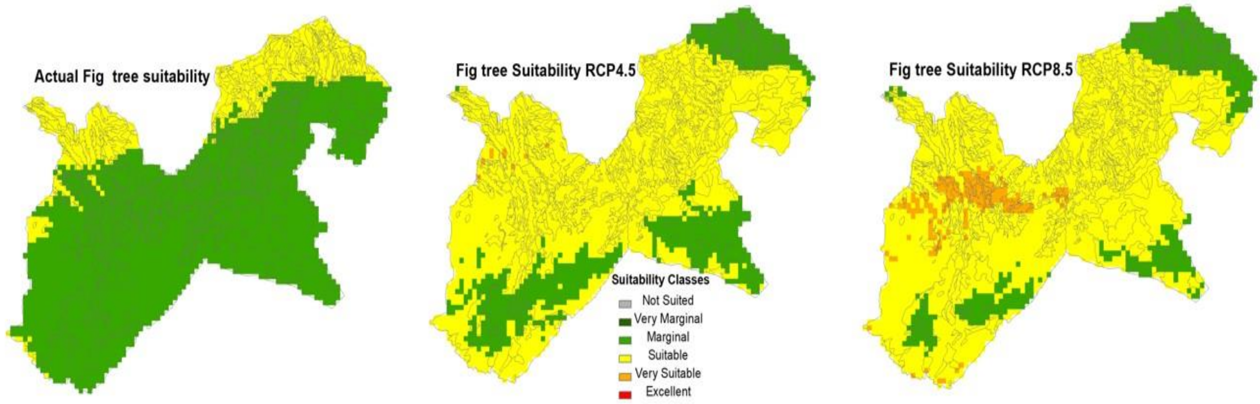

Figure 10: Fig tree suitability according to the tree scenarios: Actual, RCP4.5 and RCP8.5

The fig tree is a hardy species that adapts almost to all climates and to all ecosystems, but it has affinities with hot climates (Mkedder, 2018). Native to arid, semi desert region, figs best under intense solar radiance, high summer temperatures, soft winter and low relative humidity (Botti et al., 2003). This species doesn't resist to intense winter cold. For this tree, -17 ° C is the limit temperature for resistance to cold. Below, we see destruction of its root system and the death of the tree. Spring frosts can destroy the potential production of flowering figs, especially when temperatures are -4 ° C. Temperatures of 32 to 37 ° C are very favorable to the development and maturity of the fruits (Vidaud, 1997). The high summer temperatures are particularly favorable for drying figs (Oukabli et al., 2003). But most excellent table figs may grow where the heat is moderate (Botti et al., 2003). Despite being considered as a suitable crop for dry areas, intense drought conditions affect seriously fig growth and development (Tapia et al., 2003). There is little information about fig water requirements. Goldhammer and Salinas (1999) studied the effect of irrigation on fig fruit production and concluded that a supply of 914 mm of water by season must be applied to reach the highest fruit yield. Even if the fig tree is less demanding than the olive tree as regards climatic conditions, it requires some climatic peculiarities to attain perfection that few localities can offer (Botti et al., 2003).

In our study, and given the requirements of the fig tree, this tree will benefit above all from the expected change in temperatures, since the change in rain does not impact greatly the fig suitability in the study area.

There are no studies showing the impact of climate change on fig production but like all fruit trees, the fig tree will suffer the impacts of climate shift. The increase in temperature has been reported to affect the phenology of perennial trees (Dinesh and al., 2012). In areas with already high temperatures, future increases in temperature will affect the yield and quality of fruits adversely. While, in areas where cold temperatures are the major constraint limiting crop production, increases in temperature will be beneficial (Dinesh and al., 2012).

In the main, the climate of the province of El Hajeb will evolve in the positive direction for all the crops evaluated, according to the two climatic scenarios. The impacts of climate change are not always predicted as negative (Mathur and al., 2012), they are likely to be variable in different regions and for different crops. Some regions and crops may be negatively affected while others may benefit from a changing climate (Lobell and Burke, 2008). Our study area will be among ones in which will benefit from the increase in air temperature and the change in rainfall to expand suitable areas for evaluated crops.

Conclusion

Climate projections according to the Miroc-ESM model used in this study, showed that El Hajeb province will experience an increase in the land suitability for the crops assessed (namely: wheat, chickpeas, olive tree, almond tree and the fig tree) under the two climatic scenarios Rcp4.5 and Rcp8.5 by 2050. This is due to the projected changes in air temperature and rainfall and the interaction between these two climatic variables to provide a favorable climate for optimal growth and development of these crops in the studied area. Consequently, the development and improvement strategies of these crops will not face the significant constraints linked to climatic conditions, and should focus on the organizational aspects and marketing channels. In addition, much can be done by improving agronomic management and strengthening the capacities of farmers, including pest and disease control techniques and improved plantation systems.

These maps will also be used by various operators in the agricultural sector as a tool to guide investments, optimize the use of existing soil resources and guide rural development in the context of climate change.

Our results are based on a single Miroc-ESM climate model, the use of several models is necessary to allow comparison and for greater relevance of decision-making because bad management options can turn out to be even more dramatic than climatic changes. The variations in the results obtained by different models provide a better idea of the uncertainties and they should be taken into account in planning. We should also note that the results we have presented are based only on the average values of climatic variables (temperature and precipitation). The possibility of extreme events and, more broadly, taking into account the variability of these factors could lead to different impacts of this change by exceeding threshold values that are still poorly understood. Indeed, if the scenarios predict mild temperatures on average, the probability of cold episodes or devastating heat waves cannot be ruled out. This is also evident for rainfall where periods of drought or heavy rains can be harmful to crops. Also, the effect on physiology during particular periods in growing season has not been explored; we analyzed only the impact over the whole growing season.

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