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Climate Change Impact on Bioclimatic Deficiency, Using MicroLEIS DSS in Ahar Soils, Iran

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ABSTRACT

Regional impact studies of the future climate change effects are necessary because projected changes in meteorological variables differ from one region to another, and different climate systems can react in varied ways to the same changes. In this study, the effects of climate change on bioclimatic deficiency were compared in two cultivation methods (irrigated and rainfed) in a semi-arid region, Ahar (East Azarbaijan, IRAN). The agricultural land uses selected for evaluation were wheat (*Triticum aestivum*), alfalfa (*Medicago sativa*), sugar beet (*Beta vulgaris*), potato (*Solanum tuberosum*), and maize (*Zea mays*). In this way, Terraza model included in the land evaluation decision support system, called MicroLEIS DSS, was used. Terraza gives a quantitative prediction of a site bioclimatic deficiency. Soil morphological and analytical data were obtained from 44 sampling points based on a grid survey. Agro-climatic data, referred to temperature and precipitation, were collected from weather stations located in Ahar region, which benefits from more than 20 consecutive years of weather data. A future scenario of climate change was calculated according to the Intergovernmental Panel on Climate Change (IPCC) on regions of Asia under scenario A1FI (highest future emission) for 2080s. Although, increasing of precipitation being available by climate change in the future scenario, humidity index will be reduced because of high temperature. The results showed that climate change is likely to cause severe water stress in irrigated cultivation of alfalfa, sugar beet, potato, and maize, the use of irrigation methods being essential to maintain agricultural productivity. Although irrigation is indicated as very important in this regime of semi-arid agriculture, cultivation of rainfed wheat can be possible instead of the irrigated one. Also, it is revealed that climate perturbation effects on rainfed conditions are more serious than those on the irrigated conditions in the area.

Keywords: Bioclimatic deficiency, Climate change, MicroLEIS DSS, Semi-arid climate, Terraza model, Yield reduction.

INTRODUCTION

To date, there have been few bioclimatic classifications and systems proposed for global use. Among the best known, those of Koppen (1918), Thornthwaite (1931, 1933 and 1948), as well as Hargreaves (1985) could be mentioned.

In Ahar region, East Azarbaijan, IRAN, high technology on information and knowledge has almost never been used as a tool for bioclimatic deficiency evaluations. Additionally, information concerning possible climate change impacts in this part of Asia is rather scarce. However, land evaluation results from a complex interaction of physical, chemical and bioclimatic processes and evaluation models are tools reliable enough to accurately predict the behaviour of land. In

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this way, land evaluation analysis is considered an interface between land resources survey, and land use planning and management. The application of information and communication technology has exerted an impact on sustainable land use decision support. Since the early 1990s, and in this conceptual framework was developed the land evaluation decision support system MicroLEIS DSS (De la Rosa *et al.,* 2004). The MicroLEIS DSS system has been widely used over the last 20 years for many different purposes. As land evaluation focuses on global change, the methodology proposed by MicroLEIS DSS can be used to investigate the impact of new scenarios, like climate change, on potentialities and vulnerabilities of the land. This climate change will not occur without significant impacts upon various sectors of our environment and consequently of our society (Balabanis, 1995). Climate changes which appear in the semi-arid regions will have an important impact on soil productivity and more importantly on bioclimatic deficiency.

Land evaluation can be a formal, structured method to develop the capability to assess land degradation risks caused, for example, by long-term changes in climatic conditions and/or agricultural systems. Although increasing consideration is being given to agricultural diversification and to lower input agriculture, it is still important to identify optimum land use systems for resource sustainability and environmental quality as proportional to bioclimatic deficiency and climate change impact. Land evaluation makes it possible to use land according to its potential. During the last few years, increasing application of information technology to land evaluation procedures has led to the development of land evaluation information systems (De la Rosa *et al.*, 2004). Climate changes in the semi-arid regions will have an important impact on yield reduction. Crop simulation modeling studies based on future climate change scenarios indicate that substantial losses are likely in rainfed wheat in South and South-East Asia (Fischer *et al.,* 2002). For example, a 0.5°C rise in winter temperature would reduce wheat yield by 0.45 tons per hectare in India (Lal *et al.,* 1998; Kalra *et al.,* 2003). On the other hand, FAO Land and Water Development Division has played an active role during the past three decades in developing and promoting guidelines and methodologies on crop water management at field level that have become widely-used standards. This particularly applies to the methodologies for the calculation of crop water requirements and crop water productivity in irrigated and rainfed agriculture (Doorenbos and Pruitt, 1975).

The main objective in this work is to estimate yield reduction in either rainfed or irrigation conditions in a semi-arid region and with special attention to the influence of climate change. By using Terraza model from MicroLEIS DSS (De la Rosa *et al.,* 2004); a land evaluation analysis was developed to calculate bioclimatic deficiency for two climate scenarios of: current and future. This research work also focuses on agricultural management changes, in rainfed and in irrigated conditions, to mitigate the negative climate impact and achieve sustainable agriculture in the long terms.

MATERIALS AND METHODS

The study was performed in Ahar region of East Azarbaijan, which benefits from different kinds of land use as associated with different parent materials such as: limestone, old alluvium, and volcano-sedimentary rocks. It covers about 9,000 ha, lying between $47^0 00' 00''$ to $47^0 07' 30''$ east and $38^0 24' 00''$ to $38^0 28' 30''$ north. The prevalent slopes range from level to 30%, and the elevation varies from 1,300 to 1,600 m above sea level. Flat, alluvial plain, hillside, and mountain are the main physiographical units in the study area. The location of the study area is shown in Figure 1.

Figure1. Location of the study area (East Azarbaijan, IRAN).

Climate Information

Climatic data such as mean, average, maximum, and minimum temperatures for each month and total annual precipitation for the last 20 consecutive years (1986-2006) were collected from Ahar meteorological station. These data were integrated into the CDBm database (De la Rosa *et al.,* 1986). Climate observation at a particular meteorological station is the essence of the CDBm database, a major component of MicroLEIS DSS (De la Rosa *et al.,* 2004). The mean values of such records for more than 10 days (20 consecutive years) are considered as climatic magnitudes. The basic data of CDBm are the mean values of daily data set for a particular month. Input parameters in CDBm data set are such climate data as mean, maximum, and minimum temperatures, as well as total annual precipitation. Potential evapotranspiration is calculated using two different methods of: Thornthwaite (Thornthwaite, 1948) and Hargreaves (Hargreaves, 1985). Humidity index (HUi), Aridity index (ARi), Growing season (GS), Modified Fournier index (MFi), and Arkley index (AKi) are output summarised calculations. Humidity index (HUi) is employed to estimate the overall available water for plant growth, and is commonly used to predict artificial drainage needs of a zone; Aridity index procedure attempts to estimate the general aridity of the climate as an annual index. Growing season denotes a procedure to calculate the length of the vegetative period (CEC, 1992); the modified Fournier index is frequently used to estimate the erosivity of rainfall (factor R) during the soil erosion process; and the Arkley index is used to estimate the effects of climate on the degree of soil leaching (Arkley, 1963).

Ahar climate data, including mean, maximum, and minimum temperatures, as well as total annual precipitation for the last 20 consecutive years (1986-2006), were procured. Results of CDBm program calculations are shown in Table 1.

Climate Perturbations

Climate change in IPCC (Intergovernmental Panel on Climate Change) usage refers to the climate that can be identified (e.g. using statistical tests) by changing in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Temperature increase is widespread over the globe, and is greater at higher northern

Table 1. Summary of agro-meteorological data from Ahar station, during the 1986-2006 period as generated by the CDBm database (MicroLEIS system).

Months	T_m°C [a]	T_{max}°C [b]	T_{min}°C [c]	P (mm) [d]	ETo (mm) [e]	Hui [f]	Ari [g]	GS [h]	Mfi [i]	Aki [j]
Jan	0.1	4.1	-4	18.6	0.1	-----	-----	-----	-----	-----
Feb	0	3.3	-5.2	18	0	-----	-----	-----	-----	-----
Mar	3	7.9	-1.9	25.4	9.3	-----	-----	-----	-----	-----
Apr	8.3	14.2	2.6	38.2	35.5	-----	-----	-----	-----	-----
May	12.9	18.9	6.9	58.9	68.2	-----	-----	-----	-----	-----
Jun	17.8	24.7	10.9	27.1	102.2	-----	-----	-----	-----	-----
Jul	21	27.3	14.6	11.5	126.4	-----	-----	-----	-----	-----
Aug	22.3	28.6	15.9	8.9	127.7	-----	-----	-----	-----	-----
Sep	19.3	25.9	12.8	9.3	95.2	-----	-----	-----	-----	-----
Oct	14.5	20.9	8.2	23.7	61.7	-----	-----	-----	-----	-----
Nov	8.3	13.3	3.2	34.6	26.8	-----	-----	-----	-----	-----
Dec	2.9	7.2	-1.3	20.2	7.3	-----	-----	-----	-----	-----
Annual	10.8	16.3	5.3	294.4	660.3	0.45	6	8	32	76.1

[a] Average temperature; [b] Maximum temperature; [c] Minimum temperature; [d] Precipitation; [e] Evapotranspiration calculated through Thornthwaite method; [f] Humidity index; [g] Aridity index; [h] Growing season; [i] Modified Fournier index, [j] Arkley index.

latitudes. All of Asia is very likely to be warm during this century; the warming will probably be well above the global mean in west Asia (Christensen *et al.,* 2007). In order to apply the land evaluation approach, two climate change scenarios were constructed. The first was defined by the climate over the last 20 years during 1986-2006 periods (Table 2). The second scenario is based on projected changes in surface air temperature and precipitation for west Asia under the highest future emission trajectory (A1FI) for the 2080s (IPCC, 2007). Following the IPCC report, the mean temperature (ºC) will increase by 5.1, 5.6, 6.3 and 5.7 in winter, spring, summer and autumn respectively, in the future scenario and at the study area. On the other hand, total precipitation will decrease 11 and 25 percent in winter and spring, while it will increase by 32 and 52 percent in summer and autumn. It is estimated that the agricultural irrigation demand in arid and semi-arid regions of Asia will increase by at least 10% for an increase in temperature of 1°C (Fischer *et al.,* 2002; Liu, 2002). In the study area, climate change is likely to cause severe water stress in the 21st century because of the decreasing of precipitation during the growing season, water management becoming increasingly important.

Soils

The multilingual soil database SDBm plus (De la Rosa *et al.,* 2002) was used to store and manipulate the large amount of soil data extracted from 44 soil profiles. In this way, soil water retention capacity for all soils was calculated in the vertical control section of soils between 0.0 and 100 cm which is considered as a soil related factor in Terraza

Table 2. Changes in mean annual temperature and precipitation as compared to the present status in Ahar, and as predicted by IPCC (2007).

Scenario (years)	Annual temperature,°C				Annual precipitation, %			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Current scenario (1986-2006)	-1.4	-2.43	-1.37	+1.13	-33.6	+8.8	-70	+13.4
Future scenario (A1FI, 2080s)	+5.1	+5.6	+6.3	+5.7	-11	-25	+32	+52

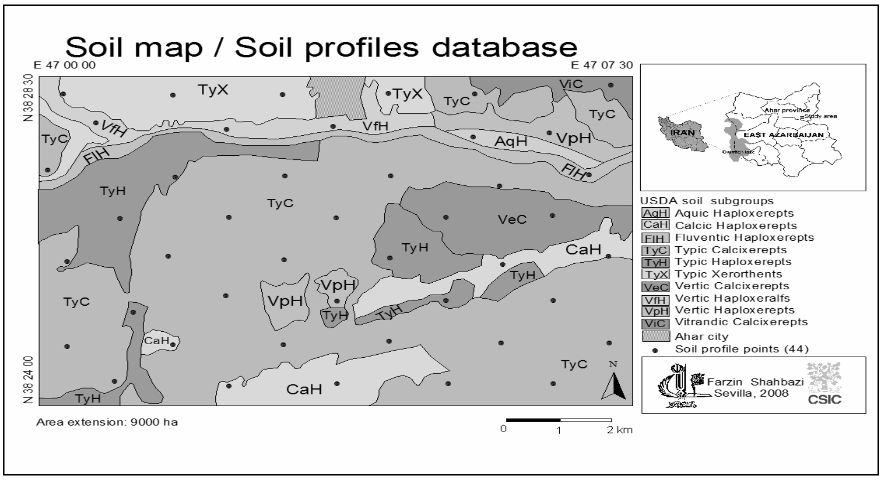


Figure 2. USDA soil subgroups map of the study area.

model. Therefore, mean value of soil water retention capacity was applied in the total area. Following USDA Soil Taxonomy (USDA, 2006) and FAO Soil classifications (FAO, 1976) the dominant soils were classified as Inceptisols (Cambisols), Entisols (Regosols) and Alfisols (Luvisols) where Typic Calcixerepts is the most considerable subgroup (> 53% area) among them. Soil map of the studied area as based on subgroup category is shown in Figure 2.

Irrigation Water Management

In any semi-arid region, the seasonal distribution of precipitation, with more or less dry summers, is not enough for crop growth. Therefore, most agricultural production systems depend basically on available water resources (irrigation water). Water irrigation amount for the selected crops in Ahar region varied between 3,100 to 6,800 m^3 ha^{-1}, with a 35% water use efficiency (Farshi *et al.,* 1997). Number of irrigations in the growing period, were 4-8 times. Water management conditions in the present study area are summarized in Table 3.

Terraza Model Constituent of MicroLEIS DSS

MicroLEIS DSS (De la Rosa *et al.,* 2004) is a decision support system for scaling-up of process knowledge from the micro-scale to the landscape-scale. At present, Socio-economic attributes are not considered. MicroLEIS DSS has evolved significantly towards a user-friendly agro-ecological decision support system for sustainable land use and management. Using its land evaluation sub- model, Terraza, the model has the capacity to analyze the influence of climate on bioclimatic deficiency of selected

Table 3. Water irrigation supplements for the crops in the present climate conditions (Farshi *et al.,* 1997).

Crop	Irrigation m^3ha^{-1}	No. of Irrigations	Irrigation months	Sowing date
Wheat	3100	4-6	Oct., Nov., May, June, July	Oct
Alfalfa	6800	7-8	Oct., May, June, July, Aug., Sep.	May
Sugar beet	6300	5-7	May, June, July, Aug., Sep.	Nov
Potato	5500	4-5	May, June, July, Aug., Sep.	May
Maize	5500	4-6	May, June, July, Aug., Sep.	May

crops. The Terraza model is a parametric model that uses a single procedure to simulate the influence of bioclimatic deficiency on a traditional crop, through an adaptation of the AEZ bioclimatic scheme (Antoine, 1994) which gives an empirical prediction of the bioclimatic deficiency of a site for crops growth. It is based on general criteria established in earlier versions of the Cervatana model of MicroLEIS (De la Rosa *et al.,* 1992). Besides the typical radiation and temperature of the site, the water balance is considered as a main climatic deficiency that can be repaired by the water irrigation supplements in an area. The site, soil, climate, latitude, soil water retention capacity, rainfall, monthly maximum and minimum temperatures, coefficient of photosynthetic efficacy and coefficient of efficiency are input variables to run the Terraza model. The calculation of this bioclimatic classification and percentage of yield reduction begins by determining the monthly potential evapotranspiration (ETo), using the method of Thornthwaite. Soil water retention capacity for all soil types varied from 7.3 to 17 cm; the mean value of which was applied to run the Terraza model. Crop coefficient and yield response factor of the crops were taken from FAO (FAO, 1986). Within the model it is possible to define any arbitrary set of climate perturbation(s) as the hypothetical climate change. For example, maximum and minimum temperature (°C) and precipitation (%) are climate related factors which can be manipulated as climate change by adding to the previous figures. Irrigation water (cm) can be considered as a precipitation factor. Reduction in yield of wheat, alfalfa, sugar beet, potato and Maize in either case of rainfed or irrigated conditions were estimated.

Calculations

The calculation of this bioclimatic classification and percentage yield reduction begins by determining the monthly potential evapotranspiration (ETo), using Thornthwaite method (1948). Equation (1) presents the way crop monthly potential evapotranspiration is calculated (ETc).

$ETc = ETo \times Kc$ (1

where, *Kc* is monthly crop coefficient; *ETo,* monthly potential evapotranspiration.

Equation (2) is monthly actual evapotranspiration (ETa).

$ETa = ETc – D$ (2

where, D is monthly water deficit at the site.

Difference between monthly potential evapotranspiration and the precipitation at a site can be either positive or negative. In case positive, there is a surplus or excess (S) of water, otherwise, there would be a deficit or lack of (D).

Equations (3-5) show the calculation procedure for monthly reduction in crop production (Ry)

$Ya/Ym = Ky(1-ETa/ETc)$ (3

Substituting: $Ry = 1-Ya/Ym$ (4

$Ry\% = Ky(1-ETa/ETc)\times 100$ (5

where, *Ya, Ym* and *Ky* are actual crop production, potential crop production and coefficient of crop efficiency, respectively. *Kc* and *Ky* for wheat, alfalfa, sugar beet, potato, maize and soybean were derived from FAO information (FAO, 1986).

Finally, Equation (6) produces the annual reduction in crop production (Rys)

$Rys\% = Kys(1-\Sigma ETa/\Sigma ETc)\times 100$ (6

Where, *Kys, ΣETa* and *ΣETc* are the coefficient of seasonal reduction, sum of the monthly actual and potential evapotranspiration during the phenological period of the crops, respectively.

RESULTS AND DISCUSSION

Impact of Climate Perturbation

Using the A1FI scenario (highest future emission) for 2080s, the basic necessary data of CDBm program such as mean, maximum and minimum temperatures, as well as total annual precipitation were calculated. Results

Table 4. Summary of agro-meteorological data from Ahar station, considering the climate change perturbation for 2080s, as generated by the CDBm database (MicroLEIS system).

Months	T_m (°C) [a]	T_{max} (°C) [b]	T_{min} (°C) [c]	P (mm)[d]	ETo (mm) [e]	Hui [f]	Ari [g]	GS [h]	Mfi [i]	Aki [j]
Jan	5.1	9.2	1.1	16.6	6	-----	-----	-----	-----	-----
Feb	4.7	8.4	1.9	16	5.1	-----	-----	-----	-----	-----
Mar	8.6	13.5	3.7	19.1	18.5	-----	-----	-----	-----	-----
Apr	14	19.8	8.2	28.7	47.3	-----	-----	-----	-----	-----
May	18.5	24.5	12.5	44.2	87.1	-----	-----	-----	-----	-----
Jun	24.1	31	17.2	35.8	140.8	-----	-----	-----	-----	-----
Jul	27.2	33.6	20.9	15.2	139.5	-----	-----	-----	-----	-----
Aug	28.6	34.9	22.2	11.7	147.8	-----	-----	-----	-----	-----
Sep	25	31.6	18.5	13.5	126.1	-----	-----	-----	-----	-----
Oct	20.2	26.6	13.9	36	79.5	-----	-----	-----	-----	-----
Nov	13.9	19	8.9	52.6	35.7	-----	-----	-----	-----	-----
Dec	8.1	12.3	4	18	13.4	-----	-----	-----	-----	-----
Annual	16.5	22	11.1	307.4	846.9	0.36	7	11	32	52.6

[a] Average temperature; [b] Maximum temperature; [c] Minimum temperature; [d] Precipitation; [e] Evapotranspiration calculated through Thornthwaite method; [f] Humidity index; [g] Aridity index; [h] Growing season; [i] Modified Fournier index, [j] Arkley index.

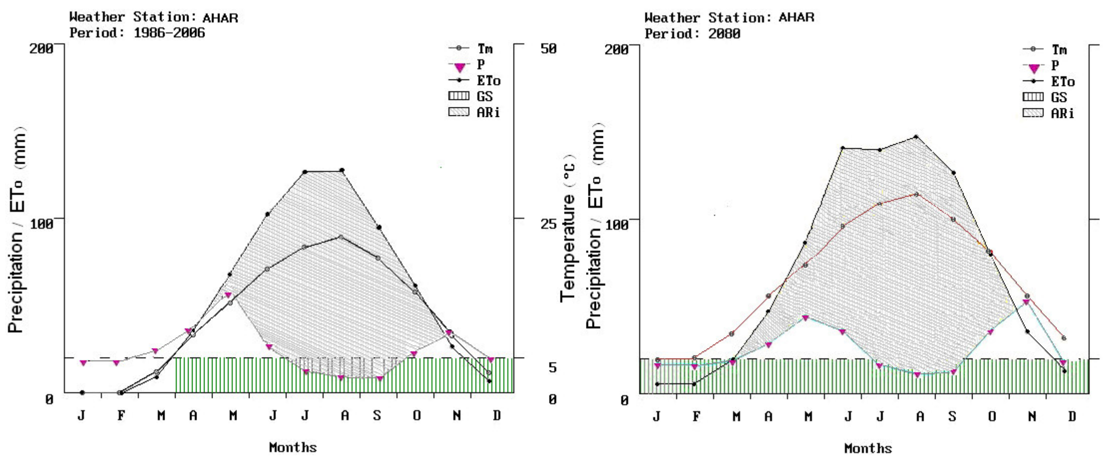
pertaining to CDBm program calculations are shown in Table 4.

Summaries of water balance components calculated through CDBm program of MicroLEIS for either of current or future scenarios for Ahar synoptic station are graphically shown in Figure 3.

Through climate change in the long term; temperature, precipitation, evapotranspiration, aridity index and duration of growing season will increase, while humidity and Arkley indexes decreasing. This means that in the distant future, in despite of increase in rainfall; the main problem confronting agricultural land use will be draught.

Bioclimatic Deficiency

From the range of annual reduction in crop production (Rys) calculated through model (De la Rosa *et al.,* 2004), four classes of water deficiency have been established (H1



Tm= Mean temperature; P= Precipitation; Gs= Growing season; ETo= Potential evapotranspiration, Ari= Aridity index.

Figure 3. Climate graphically representation of the study area, (current and future scenarios).

to H4). In the present work the variable "*frost risk*" was not taken into consideration and the reduction in yield was estimated based only upon water stress values.

Rainfed Conditions

Comparing humidity loss with aridity index increment, it is seems that in the future scenario the rainfed cultivation will be seriously affected by water stress.

The prediction of Terraza modeling approach for wheat yield reduction in both the current and future scenarios was H1 class. By climate change, the bioclimatic class of sugar beet, potato and maize will increase from H3 to H4. Also, for alfalfa, this parameter will be changed from H2 to H3. In other words, 17, 19, 14, 22 and 20% changes were evaluated for cultivation of wheat, alfalfa, sugar beet, potato and maize respectively.

Irrigated Conditions

Water supplement in Ahar area (Table 3) is sufficient for cultivation of all crops, except for sugarbeet. Wheat, alfalfa and potato show varied reductions in yield (class H1), while sugar beet and maize indicating 23% and 20% (H2 and H1) reduction, respectively. Through climate change model application wheat and alfalfa stood in H1; sugar beet and potato in H2 and maize in H3 classes. New and classic irrigation methods would be recommended to increase water use efficiency and decrease yield reduction in crop production.

Results of model application for either of the rainfed or irrigated conditions, comparing the current and future scenarios are summarized in Table 5. Through Terraza model approach it is predicted that not only currently study area but also predicted climate change by 2080s is at increased water deficit for all the crops except for wheat. Although irrigation is pointed out as very important in this semi-arid agriculture, cultivation of rainfed wheat can be recommended to replace the cultivation of irrigated wheat.

Validation Analysis

Testing involves a comparison of outputs of MicroLEIS DSS models with factual information and a determination of DSS suitability for an intended purpose. Factual information is represented by field data on the aspects for which the models are being tested. During the modeling development phase, each model was validated through the generally applied calculations of

Table 5. Terraza model (MicroLEIS system) results for the study area: prediction of yield reduction (%) [a] either rainfed or irrigated conditions.

Crops	Rainfed cultivation			Irrigated cultivation		
	Current scenario	Future scenario	Changes	Current scenario	Future scenario	Changes
Wheat	0	17	+17	0	0	0
Alfalfa	37	56	+19	0	4	+4
Sugar beet	57	71	+14	23	36	+13
Potato	53	75	+22	0	25	+25
Maize	72	92	+20	20	48	+28

[a] H= <20%; H2= 20-40%; H3= 40-60%, H4= >60%.

standard error, root mean square error, slope and intercept of regression, and correlation of observed *vs.* predicted results (De la Rosa *et al.,* 2004). Other scientists have also tested the model over diverse semi-arid regions by exposing the models to new and different environments to test for the model robustness (Machin and Navas, 2007). The predicted land capability values were simulated by extrapolation from benchmark site results while applying the Terraza model to the corresponding natural environmental region. The relationship between predicted and current bioclimatic deficiency statistical records is found out as clearly unbalanced. Similar situations are very frequent in the Mediterranean regional environments.

CONCLUSIONS

Bioclimatic deficiency is the most sensitive area to be affected by climate change. For rainfed conditions, yield reduction increases with climate change for all the studied crops, ranking as follows: maize> potato> sugar beet> alfalfa> wheat. However, under irrigation conditions yield reduction would be ranked as: maize> sugar beet> potato> alfalfa. Although, irrigation is pointed out as very important in this semi-arid agricultural environment, rainfed wheat cultivation can be more recommended then irrigated wheat. Climate perturbation effects in rainfed conditions are more serious than in the irrigated conditions. Irrigated maize and potato will be more influenced than the other mentioned crops in a future scenario. As climate change is likely to bring about severe water stress in the 21st century; therefore, water management priorities can be felt more and more. However, more practical modern irrigation methods are a must to be recommended for Ahar area in the coming future.

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تأثیر تغییرات اقلیمی در محدودیت بیواقلیمی با استفاده از سیستم تصمیم گیری میکرولیز در خاکهای اهر(ایران)

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چکیده

مطالعات ناحیه ای تأثیر تغییرات اقلیمی آینده بنا به دلایلی مانند متغیر بودن داده های اندازه گیری از منطقه ای به منطقه دیگر ضروری است و سیستمهای اقلیمی مختلف نسبت به تغییرات یکسان ممکن است واکنش

های متفاوتی نشان دهند. در این تحقیق، اثرات تغییرات اقلیمی روی محدودیت بیو- اقلیمی در دو حالت کشت دیم و آبی برای اراضی شهرستان اهر (استان آذربایجان شرقی) مقایسه شده است. تیپ های بهره وری مورد مطاله شامل گندم، یونجه، چغندرقند، سیب زمینی و ذرت بوده است. هدف عمده ارزیابی اراضی رسیدن به کشاورزی پایدار بوده که اولین قدم تعیین استرس ها و محدودیت های رطوبتی می باشد. در این میان، مدل Terraza به عنوان زیر مجموعه ای از سیستم تصمیم گیری میکرولیز(Micro LEIS DSS) استفاده شده است. داده های مرفولوژیکی و نتایج تجزیه ۴۴ نقطه نمونه برداری بر اساس روش شبکه بندی بدست آمده و فقط یک پارامتر مکش آب توسط خاک در نظر گرفته شد. آلفی سل، انتی سل و اینسپتی سل بعنوان رده های خاک همراه با ۱۰ زیر رده متعلق به این رده ها رده بندی شدند. از طرف دیگر، اطلاعات اقلیمی نظیر بارندگی و درجه حرارت توسط ایستگاه سینوپتیک شهرستان اهر برای یک دوره ۲۰ ساله اخیر جمع آوری گردید. جهت پیشگوئی وضعیت اقلیمی آینده برای سال ۲۰۸۰ میلادی از داده های تخمینی IPCC مربوط به غرب آسیا استفاده گردیدو نتایج نشان داد که علیرغم افزایش بارندگی در دهه های اخیر، رطوبت نسبی بدلیل افزایش متقابل دما کاهش خواهد یافت. همچنین استرس شدید کم آبی در قرن ۲۱ تخمین زده شده است که این مسئله باعث افزایش نقش مدیریت آب آبیاری مثل استفاده از روشهای نوین آبیاری در سالهای آینده مخصوصا برای کشت سیب زمینی و چغندرقند خواهد بود. لذا، علیرغم مهم بودن آبیاری برای کشاورزی مناطق نیمه خشک، کشت دیم گندم بجای کشت آبی این محصول می تواند قابل توصیه باشد.