Towards a New Agriculture for the Climate Change Era in West Asia, Iran

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1. Introduction

Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. It will potentially lead to such eventualities as drought and famine, which some of the CWANA countries have already experienced. The capacity of national governments and communities to mitigate disasters will be limited in the short to medium term, rendering them still vulnerable to the adversities of climate change. Climate change is a global issue with regional implications. Many multilateral environmental agreements address these issues, and some countries of the region have ratified some such agreements (CWANA, 2009). Effects of climate change on land use refers to both how land use might be altered by climate change and what land management strategies would mitigate the negative effects of climate change (Dale, 1997). Asia is the most populous continent, population in 2002 was reported to be about 3,902 million, of which almost 61% is rural and 38.5% lives within 100 km of the coast (Duedall & Maul, 2005). Asia is divided into seven sub-regions, namely North Asia, Central Asia, West Asia, Tibetan Plateau, East Asia, South Asia and South-East Asia. All of Asia is very likely to warm during this century; the warming is likely to be well above the global mean in central Asia, the Tibetan Plateau and northern Asia, above the global mean in East and South Asia, and similar to the global mean in Southeast Asia. Extreme weather events in Asia were reported to provide evidence of increases in the intensity or frequency on regional scales throughout the 20th century. More investigations predicted that the area-averaged annual mean warming would be about 3°C in the decade of the 2050s and about 5°C in the decade of the 2080s over the land regions of Asia as a result of future increases in atmospheric concentration of greenhouse gases (Lal et al., 2001). In addition rainfall will be altered too. Rainfall in the Philippines would continue to be highly variable, as influenced by seasonal changes and climate extremes and be of higher intensity (Perez, 2008). Also, Changes in annual precipitation for Singapore would range from –2 to +15% with a median of +7%. Extreme rainfall and winds associated with tropical cyclones are likely to increase (Ho, 2008). Other investigations for west Asia has reported that long-term climatic changes of annual surface air temperature, surface wind and rainfall of the State of Qatar, Sultanate of Oman and the United Arab Emirates revealed that significant climate warming is taking place in entire three countries. However, there is no notable trend observed in the rainfall series at any of these places. There is a significant decrease in the mean wind speed at many locations in the region of investigation. The moisture deficit and ecologically fragile land is likely to have further water stress conditions. There has been a steady increase in the total emissions of carbon dioxide over all the three states (Govinda Rao et al., 2003). Some studies (Rosenzweig et al., 2001; FAO, 2004) agree that higher temperatures and longer growth seasons could result in increased pest populations in temperate regions of Asia where central and west Asia include several countries of predominantly arid and semi-arid region which have not been dedicated by these problems. On contrary, the stresses of climate change are likely to disrupt the ecology of mountain and highland systems in west Asia. The anthropogenic release of CO_2 has increased greatly since the industrial age began and fossil fuels began being intensively used as an energy source. Currently, 61% of the anthropogenic greenhouse forcing can be attributed to CO_2 increases (Shine et al. 1990). Research and assessment carried out during the Climate Change Enabling Activity Project, under the UN Framework Convention on Climate Change, predicts that if the CO_2 concentration doubles by the year 2100, the average temperature in Iran will increase by 1.5 - 4.5°C. As well as it has been reported in Kazakhstan by Dolgikh Kazakh (2003) where air temperature and the sum of precipitation are expected to be 6.9°C and -12%, respectively, under double CO_2 conditions. Following CO_2 enrichment and changes in temperature may also affect ecology, the evolution of weed species over time and the competitiveness of C3 v. C4 weed species (Ziska, 2003). In arid central and west Asia, changes in climate and its variability continue to challenge the ability of countries in the arid and semi-arid region to meet the growth demands for water (Abu-Taleb, 2000; UNEP, 2002; Bou-Zeid & El-Fadel, 2002; Ragab & Prudhomme, 2002). Decreasing precipitation and increasing temperature commonly associated with ENSO have been reported to increase water shortage, particularly in parts of Asia where water resources are already under stress from growing water demands and inefficiencies in water use (Manton et al., 2001). Crop simulation modelling 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). Climate change can affect on land degradation risks in agricultural areas, soil erosion, and contamination corresponding to Mediterranean regions, too. Increased land degradation is one possible, and important, consequence of global climate change. Therefore the prediction of global environmental change impacts on these degradation risks is a priority (De la Rosa et al., 1996). Iran has located in desert belt where desertification, drought, water table reduction and flooding increment, vulnerability of land resources are the most relevant phenomena (Momeni, 2003). The impact of climate change in Iran includes changes in precipitation and temperature patterns and water resources, a rise in sea level, and an agricultural impact affecting food production, bioclimatic deficiency, land capability, agro-ecological field vulnerability and possibly more frequent droughts. The global demand for energy will increase in the coming decades, and this rising demand presents significant opportunities for our industry. As demand increases following population growth, however, the complexities of global climate change also pose serious questions for the energy industry and the broader society. During 1951 to 2003 several stations in different climatologically zones of Iran reported significant decrease in frost days due to rise in surface temperature. Also, some stations show a decreasing trend in precipitation (Anzali, Tabriz, Zahedan) while others (Mashad, Shiraz) have reported increasing trends (IRIMO, 2006 a & b; Rahimzadeh, 2006). Mean monthly weather data values from 1968 - 2000 for 12 major rainfed wheat production areas in north-west and western Iran have previously been used with a climate model, United Kingdom Meteorological Organization (UKMO), to predict the impact of climate change on rainfed wheat production for years 2025 and 2050. The crop simulation model, World Food Study (WOFOST, v 7.1), at CO_2 concentrations of 425 and 500 mg Kg^{-1} and rising air temperature of 2.7 - 4.7°C, projected a significant rainfed wheat yield reduction in 2025 and 2050. Average yield reduction was 18 and 24% for 2025 and 2050, respectively. The yield reduction was related to a rainfall deficit (8.3 - 17.7%) and shortening of the wheat growth period (8 - 36 d). Cultivated land used for rainfed wheat production under the climate change scenarios may be reduced by 15 - 40%. Potential improvements in wheat adaptation for climate change in Iran may include breeding new cultivars and changing agronomic practices like sowing dates (Nassiri et al., 2006). In a study conducted by the Office of Natural Resources & Environmental Policy and Planning (ONEP, 2008), negative impacts on corn productivity varied from 5–44%, depending on the location of production. The current research work for land evaluation therefore needs to be updated to reflect these newer concerns, some of which have been the focus of international conventions on climate change. The main objective is to introduce MicroLEIS, as a support system for agro-ecological land evaluations which can be used to assess soil quality and land use planning for selected time horizons.

2. MicroLEIS Agro-ecological Decision Support System

MicroLEIS, is an integrated system for land data transfer and agro-ecological land evaluation (De la Rosa et al., 1992). Decision support systems (DSS) are informatics systems that combine information from different sources; they help in the organization and analysis of information, and also, facilitate the evaluation (Sauter, 1997; Eom et al., 1998). MicroLEIS DSS provides a computer-based set of tools for an orderly arrangement and practical interpretation of land resources and agricultural management data. Its major components are: I) land evaluation using the following spatial units: place (climate), soil (site and soil), land (climate, site and soil) and field (climate, site, soil and management); II) data and knowledge engineering through the use of a variety of georeferenced database, computer programs, and boolean, statistical, expert system and neural network modelling techniques; III) monthly meteorological data and standard information as recorded in routine land surveys; IV) integrated agro-ecological approach, combining biophysical data with agricultural management experience; and V) generation of data output in a format readily accepted by GIS packages. Recently two components have been added in order to comply with rising environmental concerns (De la Rosa et al., 2001): prediction of global change impacts by creating hypothetical scenarios; and incorporating the land use sustainability concept through a set of tools to calculate current status; potentiality and risks; impacts; and responses. Thus, land evaluation requires information from different domains: soil, climate, crop and management. Soil surveys are the basic building blocks for developing the comprehensive data set needed to derive land evaluation which is normally based on data derived from soil survey, such as useful depth, soil texture, water capacity, drainage class, soil reaction or landscape (soil and site) attributes. The increasing pressure on natural resources leads to the erosion, physical degradation and chemical pollution of these resources, along with a reduction of their productive capacity. Computerized land evaluation techniques are a correct way to predict land productivity and land degradation, and to assess the consequences of changes such as climate. Therefore, other biophysical factors, mainly referred to monthly or daily climate parameters, are also considered as basic information or climate attributes (De la Rosa et al., 2004). There are various approaches to analyze the enormous complexity of land resource and its use and management from an agro-ecological perspective. It discusses the effectiveness of land evaluation for assessing land use changes in rural areas. Land evaluation analysis determines whether the requirements of land use and management are adequately met by the properties of the land. Within the new MicroLEIS DSS framework, land evaluation is considered as the only way to detect the environmental limits of land use sustainability (Shahbazi et al., 2010a). Today, MicroLEIS DSS is a set of useful tools for decision-making which in a wide range of agro-ecological schemes. The design philosophy follows a toolkit approach, integrating many software tools: databases, statistics, expert systems, neural networks, web and GIS applications, and other information technologies. It has divided to five packages: i) Inf & Kno; ii) Pro & Eco iii) Ero & Con; iv) Eng & Tec; and v) Imp & Res, while the packages related to climate observation and its perturbation were used to assessing the new agriculture for the climate change era in north-west of Iran. Diagrammatic scheme of the different packages and possibilities for using land evaluation models within the MicroLEIS framework and strategies supported by each model is presented in (Figure 1).

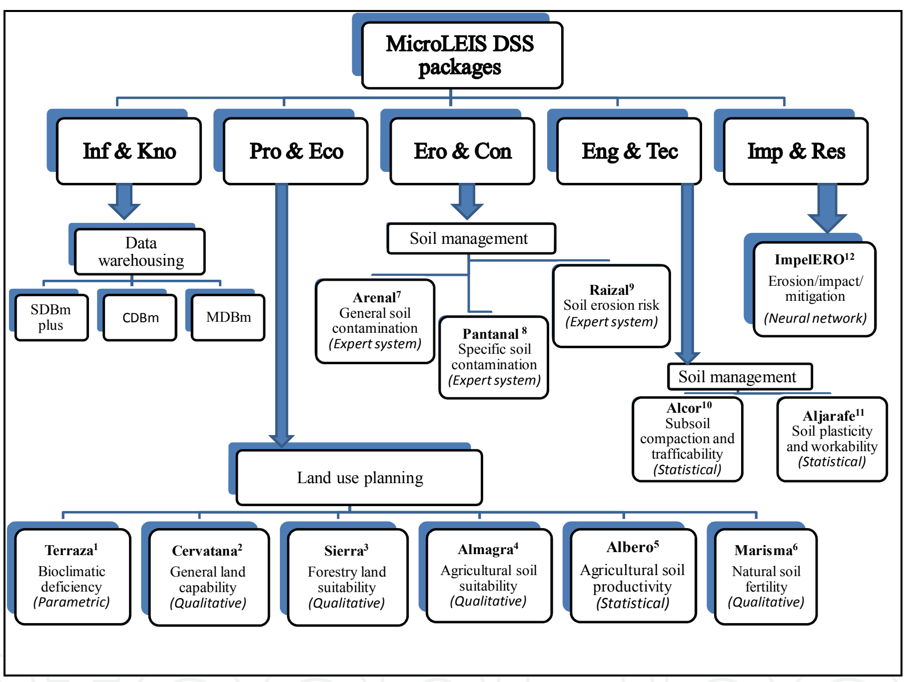

Fig. 1. General scheme of major components related to MicroLEIS DSS, modelling approach and supported strategies* (Shahbazi et al., 2010 a; Shahbazi & Jafarzadeh, 2010)

*Supported strategies by each model: [1]quantification of crop water supply and frost risk limitation; [2]segregation of best agricultural and marginal agricultural lands; [3]restoration of semi-natural habitats in marginal agricultural lands and selection of forest species; [4]diversification of crop rotation in best agricultural lands; [5]quantification of crop yields for wheat, maize and cotton; [6]identification of area with soil fertility problems and accommodation of fertilizer needs; [7]rationalization of total soil input application; [8]rationalization of specific soil input application such as N and P fertilizers, urban wastes, and pesticides; [9]identification of areas with soil erosion problems; [10]site-adjusted soil tillage machinery; [11]identification of soil workability timing; [12]formulating of management practices

3. GIS Spatialization

Geographic Information Systems have greatly improved spatial data handling (Burrough & McDonnell, 1998), broadened spatial data analysis (Bailey and Gatrell 1995) and enabled spatial modelling of terrain attributes through digital elevation models (Hutchinson 1989; Moore et al., 1991). The advent of GIS has brought about a whole set of new tools and enabled the use of methods that were not available at the time when the 1976 framework (FAO, 1976) was developed (FAO, 2006). Other systems, developed before the era of GIS, such as LESA, currently have been integrated with GIS (Hoobler et al., 2003). GIS and allows spatial monitoring and analyses where the knowledge of the stakeholders can be integrated. Tools related to environmental monitoring such as agroenvironmental indicators, soil-landscape relationships, land cover classification and analysis, land degradation assessment, estimation of agricultural biomass production potential and estimation of carbon sequestration all have their applications in land evaluation. Also risk assessment studies have grown in importance. The available GIS methods are usually combined with expert knowledge or production modelling to support studies such as land suitability assessment (Bouma et al., 1993; Bydekerke et al., 1998; Shahbazi et al., 2009a; Jafarzadeh et al., 2009) and risk analysis (Johnson & Cramb, 1996; Saunders et al., 1997; Shahbazi et al., 2009c).

4. Study Area

4.1. General Description

Iran, with an area of 1648000 km^2, is located between 25–40°N and 44–63 °E. The altitude varies from -40 to 5670 m, which has a pronounced influence on the diversity of the climate. Although, about 75% of total land area of Iran is dominated by an arid or semi-arid climate with annual precipitation rates from ~350 to less than 50 mm, Iran has a wide spectrum of climatic conditions. Lake sediments in western Iran and loess soil sequences in northern Iran have shown to be an excellent archive of climate change (Kehl, 2009). Total population inhabit 2004 was 69788000. Land area in 2002 was 163620000 ha where 17088000 ha and 15020000 ha were selected as permanent crops and arable land, respectively. Total forest area in 2005 was estimated 11075000 ha where 6.8% of them revealed as covered area (FAO, 2005). Natural renewable water resources in 2002 were 1900 m^3 capita^{-1}; Average production of cereals by 2005 was 21510000 T, while fish and fishery products in 2002 were estimated in average 5 Kg capita^{-1}. The average annual precipitation is 252 mm yr^{-1}. The northern and high altitude areas found in the west receive about 1600–2000 mm yr^{-1} (NCCO, 2003), while the central and eastern parts of the country receive less than 120 mm yr^{-1}. The per capita freshwater availability for the country was estimated at around 2000 m^3 capita^{-1} yr^{-1} in the year 2000 and expected to go below 1500 m^3 capita^{-1} yr^{-1} (the water scarcity threshold) by 2030 due to the population growth (Yang et al., 2003). Winter temperatures of -20 °C and below in high-altitude regions of much of the country and summer temperatures of more than 50 °C in the southern regions have been recorded (NCCO, 2003).
According to the national water planning report by the MOE (1998), Iran can be divided into eight main hydrologic regions (HR) comprising a total of 37 river basins where the case studied area included in this chapter are located in the north-west of Iran (Figure 2). As reported by MOE (1998), the second hydrologic region (HR_2) has covered a total of 131937 Km^2 where GRAS, SAVA, CRDY, CRWO, and SHRB are the most important land uses in the total of 54.22%, 17.53%, 14.2%, 11.3% and 2.61%, respectively. In HR_2, Urmia Lake is a

permanent salt lake receiving several permanent and ephemeral rivers and also Aras, as an international river, has located in this region. It originates in Turkey and flows along the Turkish–Armenian border, the Iranian–Armenian border and the Iranian–Azerbaijan border before it finally meet with the Kura River, which flows into the Caspian Sea. This hydrologic region is important for agricultural activities, as the water resource availability and climatic conditions are suitable.

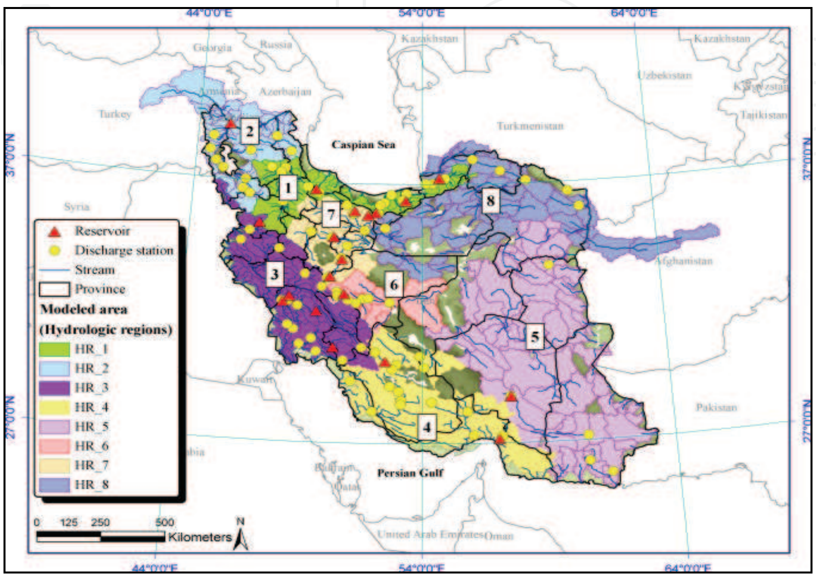

Fig. 2. Main hydrological divisions in Iran (Faramarzi et al., 2009)

4.2. Specific Description

Data required for this study were compiled from different sources belonged to the two major provinces, east and west Azerbaijan, where are located in the north-west of Iran. They include: Soil survey analyses for Ahar area where closed to Tabriz city in the east Azerbaijan province (Shahbazi et al., 2009a); Soil data extracted from the supported foundation by the university of Tabriz as an investigation for Souma area in the west Azerbaijan (Shahbazi et al., 2010 a); Climate data such as temperature for each month and total annual precipitation for last 20 consecutive years (1986-2006) from Ahar meteorological station and also 36 consecutive years (1966-2002) from Urmia meteorological station which is closed to Souma studied area according to Iran Meteorological Organization reports (IRIMO, 2006 b). IPCC refers to any change in climate over time, whether due to natural variability or as a result of human activity.

4.2.1. Site and Soil Information

Soil information is the engine of land evaluation process. Standard analyses, soluble salts and heavy metals, physical analyses, water content and hydraulic conductivity, and additional variables are the major laboratory works before land use planning or vulnerability assessment. Agriculture application is mainly related to site and soil information. Therefore, of course, only climate data will vary in this research work.

The first case study was performed in Ahar area which has located in the east Azerbaijan, Iran. It has different kinds of land use associated with soils of different parent material, such as limestone, old alluvium, and volcano-sedimentary rocks and covers about 9000 ha, between 47°00' to 47°07'30" east and 38°24' to 38°28'30" north. Its slopes range from < 2% to 30%, and the elevation is from 1300 to 1600m above sea level. Flat, alluvial plain, hillside, and mountain are the main physiographical units in the study area. A total of 44 soil profiles were characterized in the field and the lab, determining standard morphological, physical and chemical variables. According to the USDA Soil Taxonomy (USDA, 2006), the dominant soils are classified as Inceptisols, Entisols, and Alfisols. Additionally, 10 soil subgroups and 23 soil family were obtained. Typic Calcixerepts is the major subgroup more than 53%of total area (figure 3).

Fig. 3. Site and soil profile described in the study area
For example: Clayey, mixed, mesic, semiactive Typic Calcixerepts with soil horizons A, Bk1, Bk2, C of a dark greyish brown colour on topsoil); Location: 38° 24´31˝ N and 47° 00´ 58˝ E (Shahbazi, 2008).

The second studied area covers about 4100 ha, and includes natural regions of Havarsin, Kharghoush, Aghsaghghal, Johney and Bardouk in the west Azerbaijan province of Iran. It has located between 44°35' to 44°40' east longitude and 37°50' to 37°55' north latitude. Altitude varies from 1200 to 1400m with a mean of about 1300m, and slope gradients vary from flat to more than 9%. Thirty-five representative soil profiles were described while the nine benchmark soil families were selected between them to present the land characteristics correspond to the soil factors. Fluventic Haploxerepts and Typic Calcixerepts are dominant soils in the central and north-east of study area, respectively (Figure 4). Soil surveys generate large quantities of data from field description and laboratory analysis for both study area (Shahbazi, 2008; Shahbazi et al, 2008; Shahbazi et al., 2010 b) which these huge data were stored in SDBm plus.

4.2.2. Agro-climatic Indexes

4.2.2.1. Climate Observations

The projected temperature increase is widespread over the globe, and is greater at higher northern latitudes. In order to apply the land evaluation approaches due to climate change and perturbation, two scenarios were constructed. The first is defined as current situation extracted from the climate observations during the last 20 and 36 years for Ahar and Souma areas, respectively while the second one will be calculated based on projected changes in surface air temperature and precipitation for west Asia under the highest future emission trajectory (A1FI) for the 2080s (Christensen & Hewitson, 2007). Following the IPCC report, the mean temperature in this part of Asia will increase 5.1, 5.6, 6.3 and 5.7 ºC in winter, spring, summer and autumn, respectively in the future scenario at the studied areas. On the other hand, total precipitation will decrease 11% and 25% in winter and spring, while it will be increased 32% and 52% in summer and autumn (Table 1).

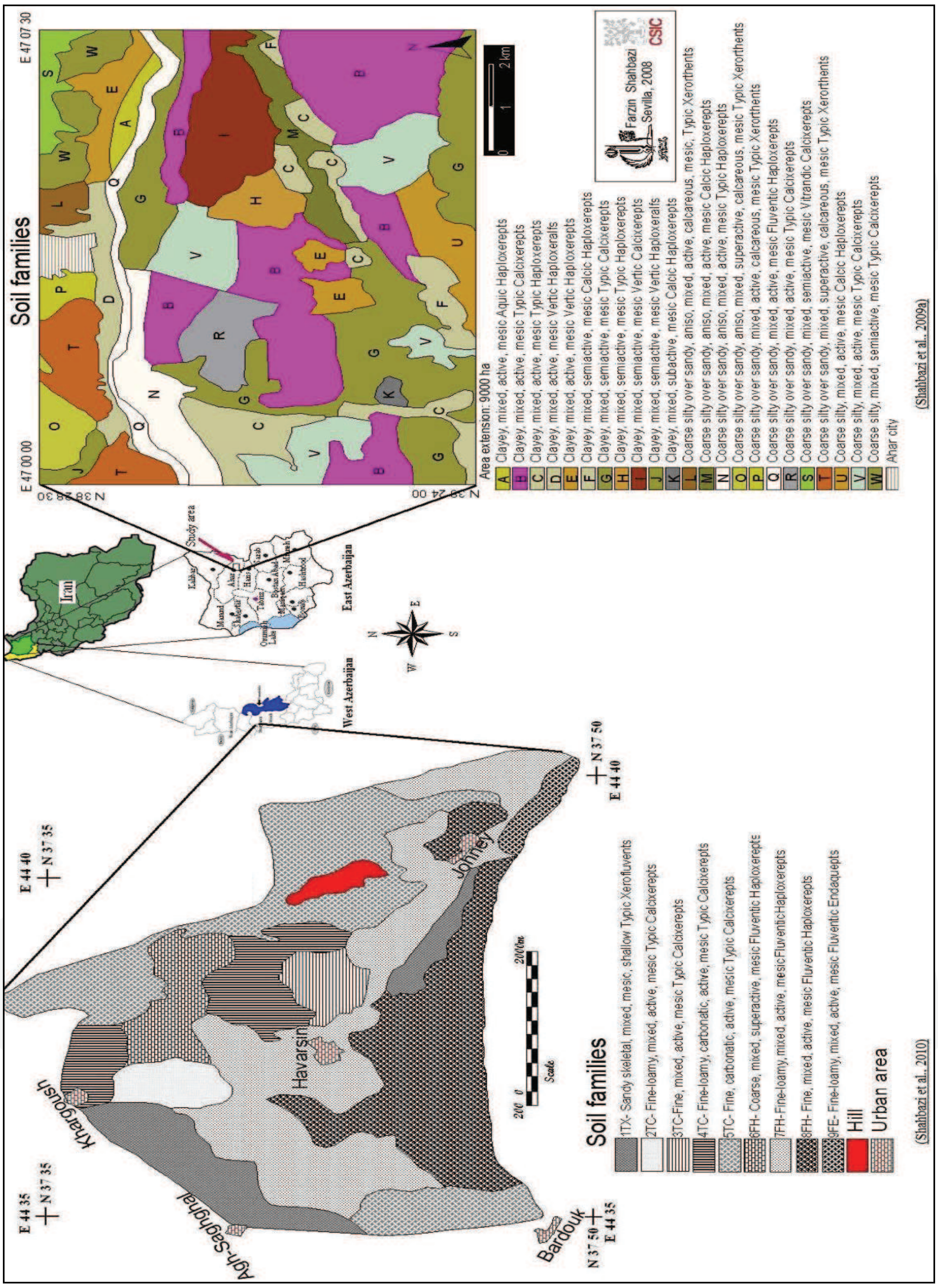

Fig. 4. Sites location and its soils covered in east and west Azerbaijan provinces, respectively (Shahbazi et al., 2009 a, 2010 a)

season	2010-2039				2040-2069				2070-2099			
	T(°C)		P (%)		T(°C)		P (%)		T(°C)		P (%)	
	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1	A1FI	B1
DJF	1.26	1.06	-3	-4	3.1	2	-3	-5	5.1	2.8	-11	-4
MAM	1.29	1.24	-2	-8	3.2	2.2	-8	-9	5.6	3	-25	-11
JJA	1.55	1.53	13	5	3.7	2.5	13	20	6.1	2.7	32	13
SON	1.48	1.35	18	13	3.6	2.2	27	29	5.7	3.2	52	25

Table 1. Projected changes in surface air temperature and precipitation for west Asia, (12N-42N; 26E-63E) pathways for three time slices, namely 2020s, 2050s and 2080s (IPCC, 2007).
DJF= Dec., Jan., Feb.; MAM= Mar., Apr., May; JJA= Jun, Jul., Aug.; SON= Sep., Oct., Nov.;
T (°C)= Temperature; P(%)= Precipitation; A1FI= Highest future emission trajectory;
B1= Lowest future emission trajectory

4.2.2.2. Climate Perturbation

Future scenario in this chapter is now defined as climate data extracted from the pathway for the time slice 2080s using highest future emission trajectory (A1FI) according to Table 1. With the gradual reduction in rainfall during the growing season for grass, aridity in west Asia has increased in recent years, reducing growth of grasslands and increasing bareness of the ground surface (Bou-Zeid & El-Fadel, 2002). Increasing bareness has led to increased reflection of solar radiation, such that more soil moisture is evaporated and the ground has become increasingly drier in a feedback process, thus adding to the acceleration of grassland degradation (Zhang et al., 2003). Also, 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). Paid attention to the literatures shows that towards a new agriculture for a climate change era in Iran (east and west Azerbaijan) will be visible in 2080s and must be attended. In this sense, estimated fresh climatic data are necessary to apply the land evaluation models for predicting coming events.

4.2.2.3. Calculated Climate Variables

Mean monthly values of a set of temperature and precipitation variables can be stored in a microcomputer-based tool named CDBm which includes software subroutines for calculating climate variables for use in agricultural land evaluation, organization, storage and manipulation of agro-climatic data. These interpretative procedures require large quantities of input data related to site, soil, climate, land use and management. The CDBm module has been developed mainly to help in the application of land use models, via their mechanization (e.g., De la Rosa and Crompvoets, 1998; De la Rosa et al., 1996; Shahbazi, 2008). Such models normally use monthly data from long periods of time. It is thus necessary to draw up climate summaries for such long periods. For periods longer than a year, the monthly data are mean values of the monthly dataset for the years under consideration. In this sense, evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. The evapotranspiration rate is normally expressed in millimeters (mm) per unit time which it expresses the amount of water lost from a cropped surface in units of water depth. Two main formula were considered within the CDBm to calculate it: By Thornthwaite (1948) and Hargreaves (Hargreaves et al., 1985) methods. The second one appears to give very good results in Mediterranean regions, and particularly in the Guadalquivir valley (Orgaz et al. 1996). For the Andalucian stations included in CDBm, the differences in results between this method and that of Thornthwaite are quite significant, above all for winter months. Calculated results taken by climatic observations from both station reports shows that total annual calculated evapotranspiration by using Hargreaves are higher than Thornthwaite method while it is going to increase for the climate change era (Table 2).

Season (months)		Current situation				Future scenario			
		EAT	**EAH**	**WAT**	**WAH**	**EAT**	**EAH**	**WAT**	**WAH**
winter	Dec.	2.5	46.7	5.3	46	9.3	59.2	13.1	57.9
	Jan.	0	43.7	0	42.1	2.8	52	6.2	53
	Feb.	0	47.6	0	46.3	5.2	61.2	6.7	59.6
spring	Mar.	16.1	64.9	14.6	61.4	25.3	80.7	24.2	77
	Apr.	42.4	83.3	43.2	82.9	55.8	99.5	55.9	99.3
	May	70	96.7	65.9	91.6	92.4	112.9	84.8	107.5
summer	Jun	95.1	111.5	89.2	104.4	134	129.4	121.7	121.9
	Jul.	122.5	123.9	109.7	109.1	158	142.1	139.5	125.9
	Aug.	119.8	132.1	110.4	115.7	155.4	151.6	139.5	133.5
Autumn	Sep.	89.5	126.1	84.5	112.8	121.7	145.5	111.4	130.7
	Oct.	57.3	98.3	56.9	91.3	75.8	116.3	73.8	108.3
	Nov.	22.3	67.6	24.2	63.9	32	82.3	32.2	73.5
Annual		**637.7**	**1042.5**	**603.9**	**967.5**	**868**	**1232.6**	**809**	**1148.1**

Table 2. Calculated potential evapotranspiration for two hypothetical scenarios
Calculated potential evapotranspiration for: EAT= East Azerbaijan using Thornthwaite method; EAH= East Azerbaijan using Hargreaves method; WAT= West Azerbaijan using Thornthwaite method; WAH= West Azerbaijan using Hargreaves method

Earlier investigations showed that there are the same differences in results for Ahar area (Shahbazi, 2008). Although, annual precipitation in east and west Azerbaijan during this era will be +3.4% and -3.6%, but total annual evapotranspiration will excess 230.3 and 205.1 mm, respectively. This emphasizes that before choosing one method or the other, it is essential to compare, in each case, with experimental measurements or those calculated using other, more exact procedures. However, all of other calculations for east and west Azerbaijan were performed according to Thornthwaite method. As crop evapotranspiration is directly affected by potential evapotranspiration, it seems that Humidity, Aridity, Precipitation concentration, Modified Fournier, and Arkley indexes will change which are dependant variables to potential evapotranspiratioin (Table 3). According to the results, Humidity and Precipitation concentration indexes will increase in both studied are. On contrary, Aridity and Arkley indexes will decrease. Therefore, effect of climate on degree of soil leaching will be monitored while it must carefully be paid attention to west Azerbaijan (Souma area) compared to east Azerbaijan (Ahar area). On the other hand irrigation effect and new methods can be assessed in east Azerbaijan. Although increment of growing seasons during this climate change era is certain, irrigation will be key role in this part of Asia. Graphical presentation for both studied area and climate change impact is shown in (Figure 5).

Variables	East Azerbaijan (Ahar station)		West Azerbaijan (Urmia station)	
	Current situation	Future scenario	Current situation	Future scenario
HUi	0.46	0.35	0.56	0.41
Ari	6	7	6	7
PCi	11	10	12	11
MFi	31	31	41	37
Aki	79.8	44.2	160	100
GS	9	11	8	11

Table 3. Calculated agro-climatic variables and climate change impact using CDBm

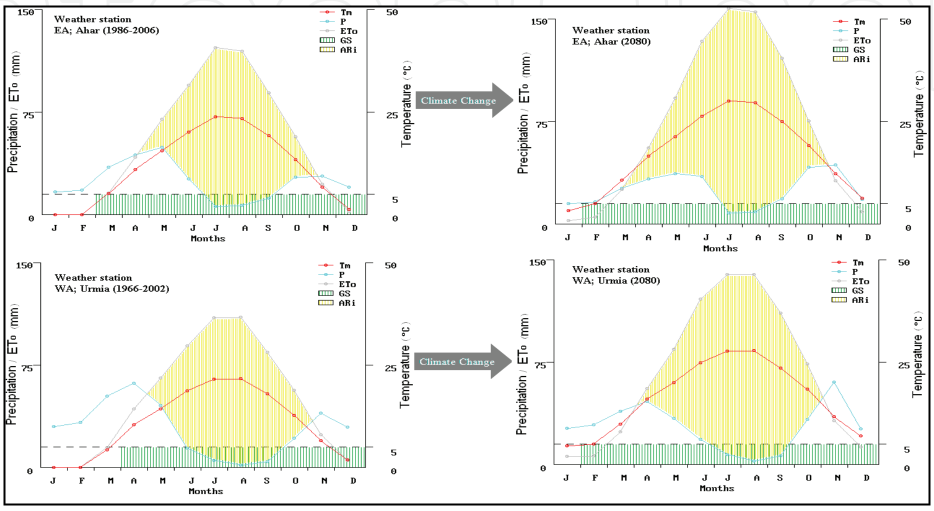

Fig. 5. Graphical presentation of some calculated parameters using CDBm
Tm = mean temperature; P = precipitation; Gs = growing period; ETo = potential evapotranspiration calculated by Thornthwaite method; Ari = aridity index; EA= East Azerbaijan; WA= West Azerbaijan

4.2.3. Agricultural Knowledge

The MDB database gives special attention to management/technological aspects at the field level combined with land characteristics. This database contains management information, which is described exclusively in technical terms and divided into two categories: crop properties and cultivation practices. It was used to capture, store, process, and transfer agricultural crop and management information obtained through interviews with farmers of Havarsin, Khargoush, Aghsaghghal, Johney and Bardouk natural regions related to Souma area. Also, water irrigation management for Ahar area where it is characterized by the seasonal distribution of precipitation, with summers more or less dry. This situation is not very suitable for crop growth. Therefore, most agricultural production systems depend basically on irrigation water as available water resource. The amount of water for irrigation of the selected crops in Ahar area varies between 3100 and 6800 m^3ha^{-1}, with 35% water use efficiency where The number of irrigations is 4-8 times in a growth period (Farshi et al., 1997). According to these extracted site, soil, climate and management data, bioclimatic deficiency and land capability evaluation in east Azerbaijan was being considered. In addition, land vulnerability evaluation due to water and wind erosion and contamination arising phosphorous, nitrogen, pesticides and heavy metals for the climate change era was examined.

5. Land Evaluation in Climate Change Scenarios

Bioclimatic deficiency, land capability, land vulnerability and finally in summary, land evaluation or land use planning will vary following the climate change impacts on the indexes. Thus, management will have an important role to achieve the sustainability.

5.1. Land Productivity Impact

5.1.1. Bioclimatic Deficiency in East Azerbaijan

While temperature conditions may be favorable for growing new types of crops, moisture deficits may preclude these new crops as an adaptation option. However, in order to adopt these new crops moisture deficits could be overcome through the use of irrigation (also an adaptive strategy). Decreasing availability of water for all users will lead to conflicts as producers compete with re-creationists, household users, electrical utilities, and the manufacturing and other industry for water for irrigation (Rosenberg, 1992; Wittrock & Wheaton, 1992). Moisture stress as affected by rainfed and irrigated conditions and impacts on yield reduction of production for wheat, alfalfa, sugar beet, potato, and maize as major crops in Ahar area was calculated applying the Terraza model (Figure 6).

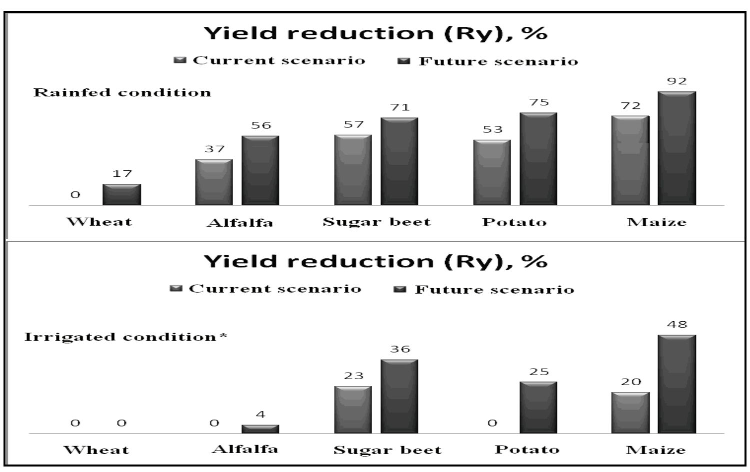

Fig. 6. Annual yield reduction for cultivation of irrigated and rainfed; comparing two scenarios (Shahbazi et al., 2009 a)

* Water irrigation supplement based on usual amount in the study area (see Table 6)

Bioclimatic classification; H1, 0-20%; H2, 20-40%; H3, 40-60%; H4, >60%

In the current situation, the Terraza modelling approach predicts that wheat has 0% (H1 class) of yield reduction in both rainfed and irrigated cultivations. The usual irrigation in the study area for potato and alfalfa is sufficient, increasing their bioclimatic classes from H3 and H2 to H1. Sugar beet and maize currently have 57% and 72% yield reduction of production, while this reduction will decrease to 23% and 20% respectively for the selected crops. Results reveal that usual irrigation, the amount of water is sufficient for wheat, alfalfa and sugar beet, but for potato and especially for maize is inadequate (Shahbazi et al., 2009 a; 2010 b). The Terraza model approach predicts that the currently high water deficit in Ahar area will be increased for the climate change era by the 2080s for all the crops except wheat. Although irrigation is indicated as very important in this semi-arid agriculture, results show that is possible cultivation of rainfed wheat in order to reduce the tillage operation costs.

Using new and classic irrigation methods can be recommended to increase the water use efficiency and decrease the yield reduction of production.

5.1.2. Bioclimatic Deficiency in West Azerbaijan

The predicted results of applying the Terraza model constituents of MicroLEIS DSS in Souma area showed that the annual yield reduction of maize is the highest amounts (74%) between the selected crops (Shahbazi et al., 2009 b) while it will increase up to 86% for the climate change era at rainfed condition in 2080s. Also, these annual reduction for wheat, alfalfa, potato and sugar beet is now calculated 0%, 39%, 55% and 60%, respectively where they are going to recalculated as 0%, 50% 61% and 70%. It means that in the current situation, west Azerbaijan has fewer limitations for wheat production and also it can be suggested as a rainfed cultivation because of its low stress.

5.1.3. Land Capability

Land comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the results of past and present human activity, e.g. reclamation from the sea, vegetation clearance, and also adverse results, e.g. soil salinization. The term "land capability" is used in a number of land classification systems notably that of the Soil Conservation Service of the U.S. Department of Agriculture (Klingebiel & Montgomery, 1961). In the USDA system, soil mapping units are grouped primarily on the basis of their capability to produce common cultivated crops and pasture plants without deterioration over a long period of time. Capability is viewed by some as the inherent capacity of land to perform at a given level for a general use, and suitability as a statement of the adaptability of a given area for a specific kind of land use; others see capability as a classification of land primarily in relation to degradation hazards, whilst some regard the terms "suitability" and "capability" as interchangeable. Capability units are soil groups within a subclass. The soils in a capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity. According to this preface, as climate observations have been included as a part of land characteristics, its change will impact on land capability and productivity. Given the potential changes in production variables, it is estimated that the average potential yields may fall by 10-30% (Williams et al., 1988). Across the prairies, crops yields will vary. For example, all crops in Manitoba may decrease by 1%, Alberta wheat, barley and canola may decrease by 7% and Saskatchewan wheat, barley and canola may increase by 2-8% (Arthur, 1988). Considering the type of soil loss impact in terms of productivity changes with time horizon (2020, 2050 and 2100) in southern Spain showed that the maximum impact according to the long-term productivity reduction (97%) for the 2100 time horizon (De la Rosa et al., 2000). The evaluation is based on the degree of limitation imposed on that land by a variety of physical factors which include erosion, soils, wetness and climate. Land is evaluated on the basis of the range of potential crops, productivity, and ease of management and risk of degradation. Therefore, the first step for land use planning to achieve sustainability is arable land identifications. Marginal agricultural land under any kind of farming system used to be the ideal scenario for soil erosion (De la Rosa & Sobral, 2008). For example, applying Terraza (bioclimatic deficiency) and Cervatana (land capability) models in the selected nine benchmark sites in Sevilla province of Spain showed that seven application sites are classified as arable or best agricultural lands, and another two as marginal or unsuitable lands. The Vega site (Typic Xerofluvent) and the Alcores site (Calcic Haploxeralf soil) present the highest capability for most agricultural crops; in contrast, the Sierra Norte site (Palexerult) and the Sierra Sur site (Vertic Xerorthent) show the most-unfavorable conditions (De la Rosa et al., 2009). Changes in land use from natural habitat to intensively tilled agricultural cultivation are one of the primary reasons for soil degradation. Deforestation for agricultural needs and overgrazing has led to severe erosion in the past. Usually, increasing agricultural land capability correlates with a decrease in the soil erosion process. In summary, a positive correlation between current land use and potential land capability would be necessary (De la Rosa & van Diepen, 2002).

Land use capability for a broad series of possible agricultural uses can be predicted by Cervatana model, as a component of MicroLEIS DSS (De la Rosa et al., 2004). The data requirements can be grouped in the following biophysical factors: relief, soil, climate, and current use or vegetation. This qualitative model works interactively, through different gradation matrixes, comparing the values of the input characteristics of the land unit to be evaluated with the generalisation levels established for each capability class. The first three classes – S1, S2, and S3 – include land considered able to support continuing, intensive agricultural use, while land of Class N is more appropriate for natural or forestry use. Studies in Suma area revealed that 80.49% of the total area was good capable for agricultural uses and 19.51% must be reforested and not dedicated to agriculture. Also, Sois of Typic Xerofluvents, Typic Calcixerepts with high carbonate percent and Fluventic Endaquepts with 812ha extension are not suitable for agricultural uses, while uses and must be reforested, while Typic Calcixerepts , Fluventic Haploxerepts with 3344 ha are mainly high suitable and in some cases optimum and moderately suitable (Jafarzadeh et al., 2009; Shahbazi & Jafarzadeh 2010). Following identification of agricultural land according to their limitations and ecological potentialities, prediction of land suitability for a specific crop or crop diversification (e.g. Figure 7; Shahbazi et al., 2009 d) over a long period of time is the subsequent option. In contrast, simplification of crop rotation as a relevant element of arable intensification has led to soil deterioration and other negative environmental impacts.

5.1.3.1. Case Study for the Climate Change Era

Agriculture has always been dependent on the variability of the climate for the growing season and the state of the land at the start of the growing season. The key for adaptation for crop production to climate change is the predictability of the conditions. What is required is an understanding of the effect on the changing climate on land, water and temperature. For instance, land evaluation analysis was developed for the current and future climate scenarios and for rainfed and irrigated conditions in east Azerbaijan province of Iran as follows: **I)** The land capability classification for irrigated cultivation using the normal water amount associated with 35% water use efficiency is divided in two sets: Dense cover (wheat and alfalfa) and moderate cover (sugar beet, potato, and maize). The first group presents similar capability classes to that for rainfed cultivation of wheat. Sugar beet cultivation showed no response to climate change concerning to constant bioclimatic deficiency class (H2), so 87.3% was good agricultural land but the rest was moderate agricultural land. The major limitation factors in classifying the capability of the area were bioclimatic and erosion risks, which were constant with climate change. The results showed that bioclimatic deficiency is the main agent in decreasing the capability classes in irrigated cultivation of potato and maize. **II)** For rainfed cultivation in both hypothetical scenarios (the current situation and the 2080s), model illustrated that wheat in all the simulated conditions has the same land capability classification. In summary, 41.7%, 45.6%, and 11.7% of the total area presents excellent (S1), well (S2), and moderate (S3) capability classes, respectively. Soil texture limitation was the main factor for converting the capability class from excellent to good. The bioclimatic limitation factor (b) was not determined in the cultivation of wheat. Therefore, the capability classes will not be changed in the long-term scenario. With climate change, 45.6% of the total area for alfalfa has been changed from good- to moderate-capability land. The same area for potato and sugar beet has been changed from good- to moderate-capability land. The whole area was not suitable in either the current situation or the 2080s for maize. Bioclimatic deficiency was the most-limiting factor. Concerning soil evaluation, eight application soil subgroups are classified as arable or best agricultural lands, and another two as moderate lands.

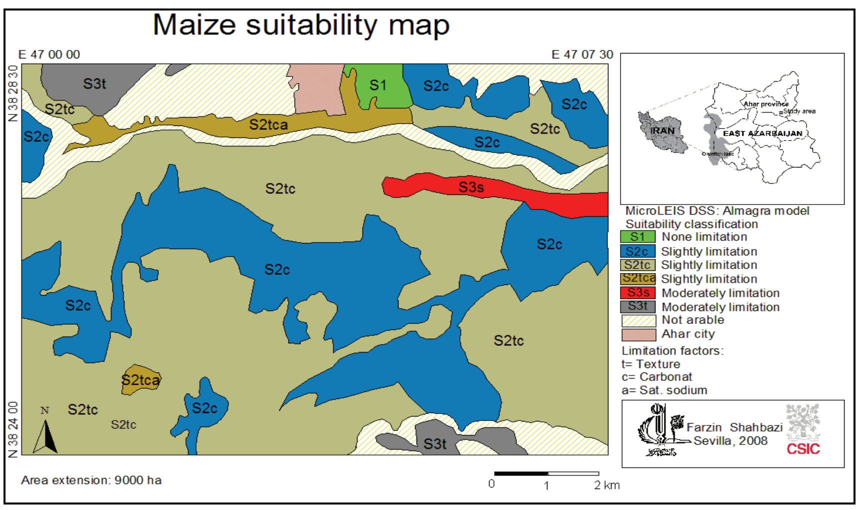

Fig. 7. Suitability of Maize in Ahar area (Shahbazi et al., 2009 d)

Typic Calcixerepts, Typic Haploxerepts, Vertic Calcixerepts, Vertic Haploxeralfs, Calcic Haploxerepts, and Vertic Haploxerepts present an extension of 22.8%, 7%, 5.6%, 3.1%, 1.83%, and 1.43%, respectively of S1 class for most of the crops. Soil and topography limitation are the two basic factors in classifying the Fluventic Haploxerept and Vitrandic Calcixerept subgroups as moderate lands that are currently dedicated to agricultural use. The change in these last two soil subgroups from natural habitat to intensively tilled agricultural cultivation is one of the primary reasons for soil degradation. Land use will be taken as optimum when considering the moderate arable lands as a natural habitat cultivation area. However, 45% of the study area is classified by the soil limitation factor as good-capability land (Shahbazi et al., 2009 a; Figure 8).

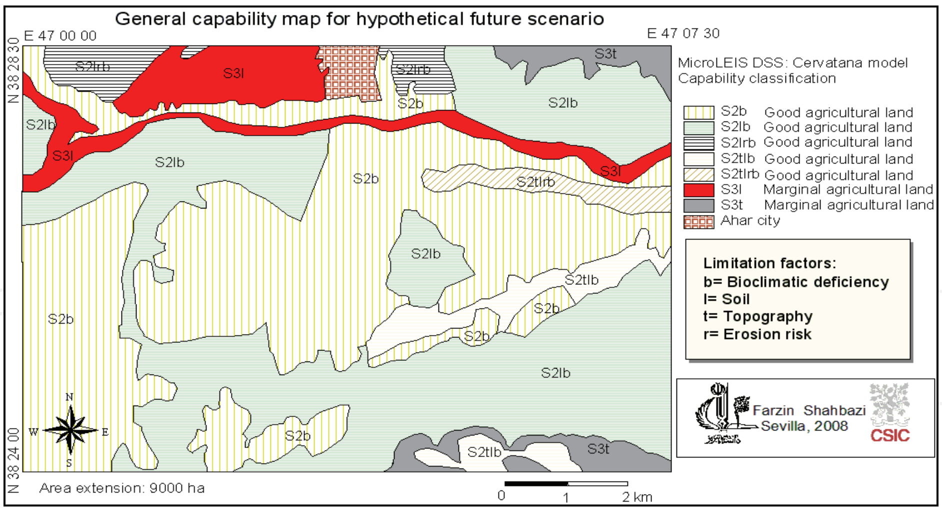

Fig. 8. General capability map for the climate change era in EA (Shahbazi et al., 2009 a)

5.2. Land Vulnerability Impact

The effects of agricultural and climate changes on the degradation of land resources are characterized not only by long-term perspectives, but also by diffuse incidence and large geographic areas impacted. The protection of these resources depends on the correct prediction of such effects (De la Rosa & Crompvoets, 1998). Land degradation is a global problem which involves climate, soil, vegetation, economic, and population conditions. It can be lifted by water and wind erosion or contaminants such as phosphorous, nitrogen, heavy metals and pesticides consumptions. When vulnerability is defined as the degree to which production and livelihood systems are susceptible to, or unable to cope with, adverse effect of climate change, including climate variability and extremes (IPCC, 2001), it is evident that rural poor will be the most vulnerable to these changes both in terms of risks to their production systems and infrastructures (e.g., houses and roads) because they have less assets to call upon in order to cope with extreme events such as prolonged droughts, intense storms and subsequent flooding (Thomas, 2008). Attempts to help the rural poor adapt to climate change must build on existing "coping strategies" that generally involve three elements: preparing for harsh climates by developing various types of insurances, actually coping with the stress when it happens and thirdly, adapting and recovering from the stress (Dietz & Verhagen, 2004). The third way in sustainable developing is the main goal which is completely related to management procedures versus natural variation and coming events. In Mediterranean Europe climatic variability and human pressure combine to produce soil sealing, erosion, salinization, fire risk, and landscape fragmentation, all regarded as important factors to start LD (Salvati & Zitti, 2009). Land vulnerability to degradation, environmental quality and management are all dynamic entities. Developing decision support systems appears as a promising tool to define trends and predict changes in land vulnerability and to promote efficient management of land degradation (Rubio & Bochet, 1998; Basso et al., 2000). It had been demonstrated that these systems could be used to predict for the climate change era. As reported by De la Rosa et al., (1996), two of the main desertification indices or land degradation risks in agricultural areas are soil erosion and contamination. Soil erosion by water is one of today's most important problems, in great part due to changes in agricultural land use and management (De la Rosa et al., 1999). Increased land degradation is one possible, and important, consequence of global climate change. Therefore, it is a priority to predict global environmental change impacts on these degradation risks. For this purpose, The Andalucia Region of Spain was used as the test region for applying Raizal and Pantanal models, based on the current climate and two climate change scenarios. The evaluation results show that 16% and 27% of the studied area is at elevated risk of soil rainfall erosion and contamination, respectively; and a further 58% and 33% at medium risk. For the present drought scenario, the modelling approach predicts that in 59% of land the erosion risk decreases, while for 24% of land this vulnerability increases. These values are 40% and 60%, respectively, for soil contamination vulnerability. The second scenario assumes the predicted climate change for 2050s for the Mediterranean area. This evaluation predicts that in 18% of land the erosion risk decreases, and increases in 47% of land. For the contamination vulnerability the predicted values are similar to those of the first scenario. Thus, change in rainfall amount affected erosion risks strongly, but this change proved to have little direct influence on contamination vulnerability. Pantanal model focuses on diffuse soil agro-contamination from agricultural substances. Tested case for hydrological change scenario in the province of Sevilla, 1 400 000 ha, within the Andalucia region correspond to six current agricultural change scenarios defined by the combination of several intensification production steps with three representative soil types, and with the major traditional crops showed that spatial variability in relation to soil and crop implies significant differences in vulnerability to the four types of soil contaminants considered. Ero&Con models evaluate the vulnerability risks of an agricultural field to land degradation, considering separately three types of vulnerability: attainable, management and actual; and for each degradation factor: water and wind erosion; and nitrogen, phosphorus, heavy metals (Cu, Zn, Cd, Hg, Pb) and pesticides (general, hydrophilic and hydrophobic) contamination. The attainable vulnerability considers the biophysical risk of the capability of the soil being harmed in one or more of its ecological functions. The management vulnerability considers the risk of a particular Field Utilization Type to land degradation. The actual vulnerability considers simultaneously the biophysical and management risk factors of a particular field unit.

5.2.1. Water and Wind Erosion

Ten soil erosion vulnerability classes established by Raizal for the attainable and actual Vulnerability risks (V1-V10). Increasing the number of classes equal with vulnerability risks increments and effect of management change on the vulnerability classes could be important. When class V10 (extreme) field units present an extremely high vulnerability to water or wind erosion. The field will erode until it has an intricate pattern of moderately deep or deep gullies. Soil profiles will be destroyed except in small areas between gullies. Such fields will not be useful for crops in this condition. Reclamation for crop production or for improved pasture is very difficult but will be practical if the other characteristics of the soil are favorable and erosion is controlled by soil conservation techniques, for example by construction of terraces. The assessment of the soil erosion management vulnerability is classified into four classes: V1-V4; very low, moderately low, moderately high, and very high. Three available states of risk types (attainable, management, and actual) for two hypothetical scenarios using Raizal model as point by point view in the whole studied area located in east Azerbaijan are completely summarized in (Table 4).

Natural regions	Current situation (1986-2006)						Future scenario (2008)					
	VAW	VAD	VMW	VMD	VCW	VCD	VAW	VAD	VMW	VMD	VCW	VCD
1-Kord Ahmad	V10	V6	V4u	V3o	V10e	V4	V10	V6	V4u	V3o	V10e	V4
4-Central Ahar	V9	V6	V3u	V4z	V10e	V2k	V9	V6	V3u	V4z	V10e	V2k
5-Dizaj Chalou	V10	V7	V4u	V3o	V10e	V5k	V10	V7	V4u	V3o	V10e	V5k
7-Kord Ahmad	V8	V3	V3u	V4z	V8e	V1	V9	V3	V3u	V4z	V9e	V1
8-Central Ahar	V8	V3	V3u	V4z	V8e	V1	V9	V3	V3u	V4z	V8e	V1
9-Central Ahar	V8	V3	V3u	V4z	V8e	V1	V9	V3	V3u	V4z	V9e	V1
10-Central	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
11-Central	V10	V4	V4u	V3o	V9e	V2	V10	V4	V4u	V3o	V10e	V2
12-KordAhmad	V8	V8	V3u	V4z	V8e	V4	V9	V8	V3u	V4z	V9e	V4
13-Dizbin	V10	V6	V4u	V3o	V8e	V4	V10	V6	V4u	V3o	V9e	V4
14-Dizbin	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
15-Mardehkatan	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
16-Garangah	V10	V8	V4u	V3o	V9e	V6	V10	V8	V4u	V3o	V10e	V6
18-Dizbin	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
19-Dehestan	V9	V6	V3u	V4z	V9e	V2	V9	V6	V3u	V4z	V10e	V2
20-Dizaj Talkhaj	V8	V3	V3u	V4z	V8e	V1	V9	V3	V3u	V4z	V9e	V1
21-Garangah	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
22-Garangah	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
23-Khonyagh	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
24-Dizbin	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
25-Dehestan	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
26-Mardehkatan	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
27-Garangah	V10	V8	V4u	V3o	V9e	V6	V10	V8	V4u	V3o	V10e	V6
28-Garangah	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
29-Khonyagh	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
30-kalhor	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
31-Dizaj Talkhaj	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
32-Mardehkatan	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
33-Garangah	V10	V6	V4u	V3o	V9e	V4	V10	V6	V4u	V3o	V10e	V4
34-Cheshmezan	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2
35-kalhor	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
36-Dehestan	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
37-Kordlar	V10	V6	V4u	V3o	V8e	V4	V10	V6	V4u	V3o	V9e	V4
38-Kordlar	V9	V8	V3u	V4z	V8e	V4	V9	V8	V3u	V4z	V10e	V4
39-Garangah	V10	V6	V4u	V3o	V8e	V4	V10	V6	V4u	V3o	V9e	V4
40-Gorchi	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
41-Kalhor	V8	V3	V3u	V4z	V8e	V1	V8	V3	V3u	V4z	V8e	V1
42-Kordlar	V10	V2	V4u	V3o	V8e	V1	V10	V2	V4u	V3o	V9e	V1
43-Dehestan	V10	V4	V4u	V3o	V8e	V2	V10	V4	V4u	V3o	V9e	V2

Table 4. Summary of vulnerability classes due to water and wind erosion for the climate change era in east Azerbaijan using Raizal model (Shahbazi, 2008)

Natural regions (2, 3, 6, 17 and 44) were identified as marginal and not arable lands (12% of total area) by Cervatana model (see Figure 8);
Water erosion: VAW= attainable risk; VMW= Management risk; VCW= actual risk;
Wind erosion: VAD= attainable risk; VMD= Management risk; VCD= actual risk;
Vulnerability class: V1= none; V2= very low; V3= low; V4= moderately low; V5= slightly low;
V6= slightly high; V7= moderately high; V8= high; V9= very high; V10= extreme;
Land qualities: t= relief; k= soil erodibility; r= rainfall erosivity; e= wind erosion erodibility; Management qualities: o= crop properties to water erosion; z= cultivation practices to water erosion;
c= crop properties to wind erosion; u= cultivation practices to wind erosion

Area extension for all mapping units and natural regions were calculated. According to the results, management vulnerability caused by current cultivation will be constant for the climate change era where wheat, alfalfa and apple garden were relevant land uses. In this sense, 73% and 15% of total area were distinguished as low and moderately low (V3&V4) vulnerable risk caused by water erosion while 9% and 79% of those areas rose with wind erosion. In summary attainable water erosion risk will not be affected by climate change (Figure 9), on contrary, attainable wind erosion is abruptly being increased.

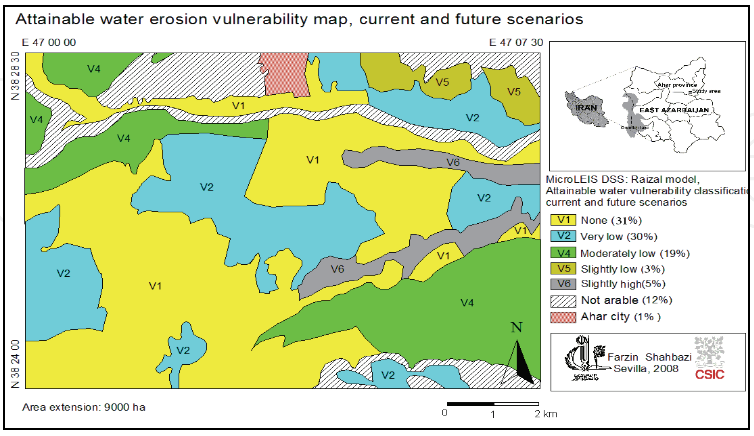

Fig. 9. Water erosion impact on land vulnerability for two hypothetical scenarios (Shahbazi, 2008)

5.2.2. Agricultural Management

Ero&Con models can also make hypothetical evaluations considering climate and management changes simultaneously. This option combines two of the changes: climate factors and management characteristics. Intensive cultivation of wheat, barley, alfalfa, maize, potato, and sugar beet as crop properties effect on water and wind erosions were examined. The order of these intensive cultivation impacts on decreasing land vulnerability raised by water erosion as follows: Sugar beet> alfalfa> wheat>. But there are not significant differences between other selected crops to reduce water erosion and vulnerability. Potato are now identified as the best land use to reduce wind erosion while wheat and maize are the worth one. Alfalfa, Barley and sugar beet have the same results versus wind erosion.

On the other hand, as reclamation for crop production or for improved pasture is very difficult but will be practical if the other characteristics of the soil are favorable and erosion is controlled by soil conservation techniques, for example by construction of terraces. Therefore, it is interested to assume cultivation practices (e.g., contouring and terraces) impact to control the movement of water over the soil surface and those effects on land vulnerability classes for the climate change era. The differences between two practices are shown in (Figure 10a & 10b) which will be achieved in the far future (Shahbazi, 2008). According to these results, terrace application without attention to economical condition and financial costs could be better than contouring to reduce risk of vulnerabilities. Also, the area covered with none level risk in the first examined item is 38% more than the second chosen one where 5% of a total are scattered near the Garangah and Mardekatan natural regions previously distinguished as low level risk will be altered to high level risk by selecting contouring practice instead of terrace procedure.

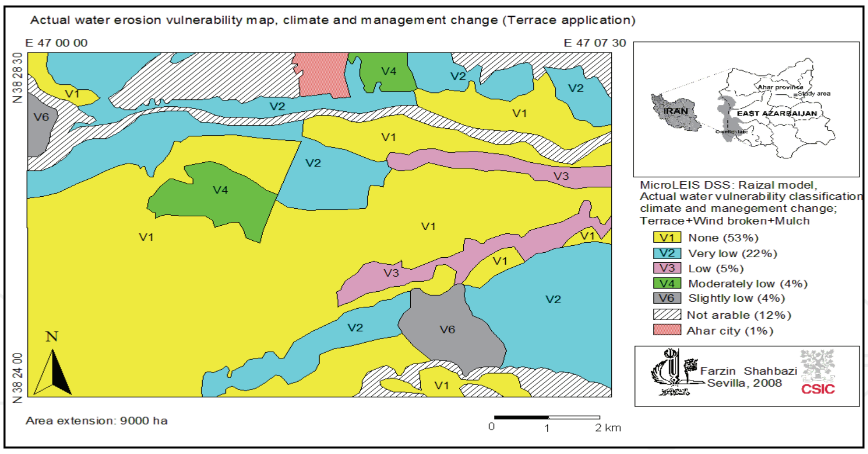

Fig. 10a. Terrace practice and climate change impact on land vulnerability caused by actual water erosion (Shahbazi, 2008)

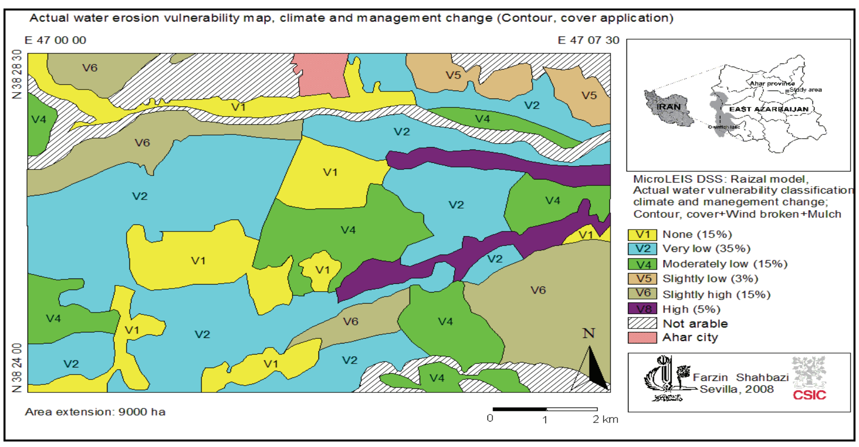

Fig. 10b. Contouring practice and climate change impact on land vulnerability caused by actual water erosion (Shahbazi, 2008)

5.2.3. Contaminants Risks

In general terms, the agrocontamination risk is considered to be directly related to the capacity of soils to store and immobilize toxic chemicals. The surface runoff transports high amounts of substances, such as phosphates in over-fertilized soils. Many biophysical and management factors control substance release from the soil to the water. The leaching of agricultural chemicals results from a complex interaction of physical, chemical and biological processes and attempts have been made to model these by equations based on classical mechanistic physics, and on a statistical or stochastic framework (De la Rosa & Crompvoets, 1998). However, models are not yet reliable enough to predict accurately the behavior of agrochemicals in the field. Soils are heterogeneous, climate and management factors vary, both in the short and long-terms. The development of land evaluation models is thus justified in terms of providing a tool with which to assess large amounts of soil information, such as that obtained from soil surveys, in order to yield the most practicable strategy for environmental protection (De la Rosa et al., 1993). The excesses of mineral nutrients and organic pesticides seem to be the most significant potential contaminants. However, impurities in fertilizers, manure and wastes can also be an important source of pollution especially with heavy metals. Therefore, the studied vulnerability types in west

Asia are: phosphorus, nitrogen, heavy metals and pesticides same as Mediterranean region. For Pantanal model establishment main following witticisms have been considered:
Phosphate substances are basically transported by runoff and constitute a possible source of eutrophication of waters. However, the phosphate fixation on clay minerals, along with its interaction with other soil components, was also estimated although the mobility of phosphate is usually very low in relation to other mineral nutrients. The amount of phosphate adsorbed by soil depends greatly on pH values, and also on particle size distribution and organic matter. Nitrate is the major nitrogen derived pollutant and the main source of groundwater contamination because of its high mobility. Along with land qualities associated with the rainfall partitioning, cation adsorption and denitrification are expected to predict this contamination risk. Retention of the heavy metals: copper, zinc and cadmium, by soils is analyzed considering the pH, as indicative of soil carbonate content, the main land characteristic controlling the different reactions. Organic matter content strongly affects adsorption–desorption and biodegradation of many pesticides, although other soil properties such as particle size distribution and CEC are also considered decision factors (De la Rosa & Crompvoets, 1998).

5.2.3.1. Case Study in East Azerbaijan

General contamination assessing in Ahar area revealed that only soil profiles under using of apple garden between the 44 studied profiles because of having artificial drainage has classified as moderate level risk (V2). Therefore, a total of 1560 ha (17.3%) are susceptible to contamination effect. In the current situation and without any climate and management changes risks of vulnerability raised by nitrogen and phosphorous (28% and 23% of studied area, respectively) are many times more than pesticides and heavy metals. It can be described as false management practices for using nitrogen fertilizers which are now presented in the whole are (88% area except not investigated lands where had been identified as marginal area by Cervatana model). Besides of that 57% area are distinguished as susceptible correspond to pesticides, correct management practices caused to be reduced the actual vulnerability compared with attainable one. Attainable and actual vulnerability classes for two hypothetical scenarios are summarized in (Table 5).

Vulnerability classes		Current and future scenarios (% of total area)			
		Phosphorous	Nitrogen	Heavy metals	Pesticides
V1	Attainable	32	55	57	1
V2		25	32	----	2
V3		4	1	31	49
V4		27	----	----	36
V5		----	----	----	----
V1	Actual	10	----	15	3
V2		29	----	47	11→12
V3		----	55	----	26→41
V4		26	32	26	48→32
V5		23	1	----	----

Table 5. Summary of Pantanal model application as a point by point view in Ahar area
* V1= none; V2= low; V3= moderate; V4= high; V5= extreme; → (impact of climate change)

According to the results, climate change will not effect on contamination vulnerabilities as well as water or wind erosion in part of Asia. The most important management practices accompany with climate change was examined as follows: Intensive wheat, barley, alfalfa, maize, potato, and sugar beet. Following orders present the best practice to decrease land vulnerability raised by: I) phosphorous; II) nitrogen; III) pesticides and IV) heavy metals, respectively.

I. Maize> Sugar beet> Barley> Wheat> Alfalfa> Potato
II. Alfalfa> Maize- Sugar beet- Wheat- Alfalfa- Potato
III. Potato> Maize> Barley> Sugar beet> Alfalfa> Wheat
IV. Maize> Barley- Sugar beet- Potato> Wheat

5.2.3.2. Case Study in West Azerbaijan for the Climate Change Era

Agro-ecological field vulnerability evaluation was compiled in Souma area where is closed to Urmia. Raizal model application resulted that for rainfall erosion, 72% of Souma lands are at none level of risk (ClassV1), and a further 28% at a very low and medium level. The medium risk area is more scattered in the north of study area which has established on plateau unit and characterised by a medium soil texture. In the simulated hypothetical scenario by long-term these results will be constant. Also, the study area is susceptible for wind vulnerability erosion and will increase in the future by climate change. The highest risk areas (V10) are located at the north-west and south-east of study area and refer to shallow Entisols. Soils No 2 and 6 areas will be altering from very high to extreme vulnerable land by climate change. Besides 10% extreme vulnerable land, 70% of the total area will be susceptible to vulnerability risks. A point-to-point application of Pantanal model results were summarized in (Table 6).

Soil No	Phosphate		Nitrogen		Heavy metals		Pesticides	
	current	future	current	future	current	future	current	future
1	V4	V4	V3	V3	V3	V3	V4	V4
2	V2	V2	V2	V1	V1	V1	V3	V3
3	V1	V1	V2	V1	V1	V1	V3	V2
4	V2	V2	V2	V1	V1	V1	V4	V3
5	V1	V1	V2	V1	V1	V1	V4	V3
6	V2	V2	V2	V1	V1	V1	V4	V3
7	V2	V2	V2	V1	V1	V1	V3	V3
8	V1	V1	V2	V1	V1	V1	V3	V3
9	V2	V2	V2	V1	V1	V1	V4	V3
Vulnerability classes*								
V1	18.63** (45%)	18.63 (45%)	0	37.53 (90%)	37.53 (90%)	37.53 (90%)	0	0
V2	18.9 (45%)	18.9 (45%)	37.53 (90%)	0	0	0	0	1.25 (3%)
V3	0	0	4.03 (10%)	4.03 (10%)	4.03 (10%)	4.03 (10%)	22.05 (53%)	36.28 (87%)
V4	4.03 (10%)	4.03 (10%)	0	0	0	0	19.51 (47%)	4.03 (10%)

Table 6. Summary of contamination vulnerability risk evaluation assessment in Souma (Shahbazi et al., 2009c)

* V1 = None; V2 = Low; V3 = Moderate; V4 = High, ** Area extention = km^2

According to obtained results, 10% of Souma area is at a high risk (Class V4) by phosphate while more than 45% is at a low level risk, and also 45% of the area presents no risk (ClassV1) of contamination. Reaction from local staff to the quality of the evaluation results for the current situation in Souma area was positive, although additional work on sensitivity and validation testing are needed in order to improve the prediction capacity of the risk evaluation approach (Shahbazi et al., 2009c).

6. Conclusion Remarks

Agro-ecological land evaluation appears to be a useful way to predict the potential index and/or general capability to distinguish the best agricultural land resulting from interactive changes in land use and climate. Due to bioclimatic deficiency is the most-sensitive factor affected by climate change; irrigation is indicated as very important in this semi-arid agriculture. However, the cultivation of rainfed wheat can be recommended instead of irrigated wheat in order to reduce the tillage operation costs. Also, the use of modern irrigation methods is recommended for the studied area in the future. Determining the impacts of climate change on land use systems involves also biophysical effects on agricultural management practices. Climate change might constrain or mandate particular land management strategies (e.g., irrigation); however, these options will be different for each particular site. In summary, the application of the land evaluation decision support system MicroLEIS DSS for planning the use and management of sustainable agriculture is suggested in west Asia region, for present and future climate conditions.

7. Abbreviations and Acronyms

AKi: Arkley index; **ARi:** Aridity index; **CDBm:** Monthly Climate database; **CRDY:** Dry land, Cropland, Pasture; **CRWO:** Cropland-Woodland mosaic; **CWANA:** Central and West Asia and North Africa; **ENSO:** El Niño-Southern Oscillation; **Eng & Tec:** Engineering and Technology Prediction; **Ero & Con:** Erosion and contamination modelling; **ETo:** Potential evapotranspiration; **GIS:** Geographic Information System; **GRAS:** Grassland; **GS:** Growth season; **HUi:** Humidity index; **ICCD:** Impacts of Climate Changes on Drylands; **Imp & Res:** Impact and Response simulation; **ImpelERO:** Integrated Model to Predict European Land use for erosion; **Inf & Kno:** Information and Knowledge databases; **IPCC:** Intergovernmental Panel on Climate Change; **LES:** Land Evaluation Systems; **LESA:** Land evaluation and site assessment; **LD:** Land degradation; **LUP:** Land use planning; **MDBm:** Management database; **MicroLEIS:** Mediterranean land evaluation information system; **MFi:** Modified Fournier index; **ONEP:** Office of Natural Resources & Environmental Policy and Planning; **p:** Monthly precipitation; **P:** Annual precipitation; **PCi:** precipitation concentration index; **Pro & Eco:** Production and Ecosystem modelling; **SAVA:** Savanna; **SDBm plus:** The multilingual soil database software; **SHRB:** Shrub land

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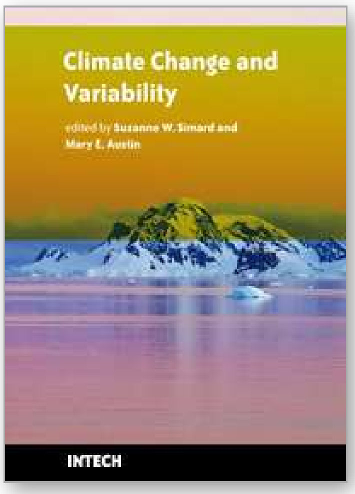

Climate Change and Variability
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Climate change is emerging as one of the most important issues of our time, with the potential to cause profound cascading effects on ecosystems and society. However, these effects are poorly understood and our projections for climate change trends and effects have thus far proven to be inaccurate. In this collection of 24 chapters, we present a cross-section of some of the most challenging issues related to oceans, lakes, forests, and agricultural systems under a changing climate. The authors present evidence for changes and variability in climatic and atmospheric conditions, investigate some the impacts that climate change is having on the Earth's ecological and social systems, and provide novel ideas, advances and applications for mitigation and adaptation of our socio-ecological systems to climate change. Difficult questions are asked. What have been some of the impacts of climate change on our natural and managed ecosystems? How do we manage for resilient socio-ecological systems? How do we predict the future? What are relevant climatic change and management scenarios? How can we shape management regimes to increase our adaptive capacity to climate change? These themes are visited across broad spatial and temporal scales, touch on important and relevant ecological patterns and processes, and represent broad geographic regions, from the tropics, to temperate and boreal regions, to the Arctic.