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Predicting the Impact of Global Warming on the Middle East Region: Case Study on Hashemite Kingdom of Jordan Using the Application of Geographical Information System

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Abstract: This study intends to analyze the metrological data like rain fall, temperature and humidity obtained from Jordanian metrological department, covering the period of 1955-2002. These obtained data were analyzed using the Geographic Information System (GIS) and converted into geographical maps. Three different parameters were investigated temperatures annual mean maximum and annual mean minimum, the average annual rainfall and the average annual relative humidity. The results show that no change in the average annual rainfall in both northern and eastern part of the kingdom, while it has been increases in the middle region of the kingdom. Although local temperatures fluctuates naturally, but over the past 50 years the average local temperature in Jordan has increased at very rapid rate since 1990 and it reached an elevation in temperature up to about 1.5-2°C. It is noticed that the global warming impact on Jordan weather has been started after the 1991, in which the phenomena of the global warming was noticed to have its impacts worldwide since that date. Due to the predicted increase in both maximum and minimum temperatures in some regions, the rate of evaporation will also tends to increase and hence higher relative humidity will be expected in that regions. The application of GIS in this analytical study was successfully used to analyze the data and to produce maps easy to understand the impact of global warming. GIS also helps to calculate the exact area where region experienced a change in temperature and or rain falls. This application will be the first in its application in Jordan at country level. The result will be in a great help for those in decision making in the field of environment.

Key words: Climate change, global warming, GIS, Jordan, environmental change, impact of global warming, Middle East region, environmental management engineering, global warming predication, arid region

INTRODUCTION

Among the regional challenges confronting the Middle East in the recent century, is the climate change which may have significant impacts on precipitation, soil erosion and decertification. These climate change related factors will have a significant impact on agricultural prospects on the availability of arable land and on yields. In addition three human trends have to be taken into account: population growth, urbanization and the growing demand for water and food. As many Intergovernmental Panel on Climate Change (1996) studies have indicated these factors of the survival cannot be separated nor can the impacts of climate change on future security policy be analyzed in isolation. Within the Middle East region there are common features: climate change and weather extremities (droughts, floods), water scarcity and soil erosion and decertification. But there are major differences on demography, food scarcity and surplus and on urbanization and pollution.

Due to the urban population growth in most Arab countries is high, especially in the Gulf area, the increase in future demands for modern energy services are expected to accelerate proportionately (ESCWA, 2005). In addition, in Arab rural areas, where the rural population accounts for about 46% of the total population, traditional energy use, mainly in the form of unprocessed biomass, dominates the energy sector. This low consumption of commercial energy and high dependence on traditional fuels thus became a measure of poverty levels in some parts of the Arab Countries. Therefore, access to clean; reliable and sustainable energy is vital to socio-economic development and poverty eradication in the Arab world. Per capita energy consumption varies greatly between oil producing countries and non-oil producers. For example Qatar has the highest per capita consumption. On the other hand, the per capita consumption of 12 Arab countries is lower than the world average (ESCWA, 2005)

CO_2 is the primary Green House Gas (GHG) for almost all Arab countries. Both CH_4 and N_2O were not as important contributors to the total GHG emissions. The energy sector was the largest source of GHG emissions for all Arab countries. Agriculture was the second largest emitters for almost all countries. The level of emissions varied widely among reporting Arab countries reflecting disparities in energy consumption and levels of development. In 1998, three countries (Saudi Arabia, Egypt and Algeria) have CO_2 emissions higher than 100,000 Gg, the rest have lower CO_2 emission levels (ESCWA, 2005). Among the Arab countries, that have the highest levels of gas emission is Qatar. This is due to the high levels of precipitate income, accelerated rate of industrialization and energy use. Eight countries (Bahrain, Kuwait, Lebanon, Libya, Oman, Qatar, Saudi Arabia and UAE) have precipitate CO_2 emissions greater than the world's average in 1998, which was 4.1 Gg per person (UNEP, 2006).

On the other hand another factor may be contributed to enhance the global warming in the Middle East and Arab Region particularly, is the urbanization. Several researchers have presented evidence to demonstrate that increase in temperatures have resulted from the daily minimum temperature increasing at a faster rate or decreasing at a slower rate than the daily maximum which results in a decrease in the Diurnal Temperature Range (DTR) (Easterling *et al*., 1997). In the United States, large-area trends showed that maximum temperatures have increased slightly but the minimum temperatures increased at a faster rate (Karl *et al*., 1990). A study carried out on climatic data in Kuwait showed that urban warming appeared to be both at daytime and night-time phenomenon (Al-Fahed *et al*., 1997). In another study done in Turkey by Türkes *et al*. (2002) concluded that significant night-time warming trends could be likely related to urbanization with considerable increase over a period of three decades. Similar studies in other regions showed seasonal variations in long-term maximum and minimum temperatures (Philandras *et al*., 1999; Chung *et al*., 2004). Another study on four large cities of Turkey by Tayanc and Toros (1997), seasonal analysis of individual 21.00 h temperature series suggested that the regional warming is strongest in spring and weakest in autumn and winter. Urban warming was also detected to be more or less equally distributed over the year with a slight increase in the autumn months

In 1992, Jordan along with 189 other countries became party to the United Nations Framework Convention on Climate Change (UNFCCC), which seeks to come up with plans to reduce global warming and to cope with whatever temperature increases are inevitable. This would correspond to an estimated annual mitigation potential of <0.5% of Jordan's CO_2-C emissions from fossil fuels and land use change for 1990, the baseline year for Kyoto Protocol reporting (Niels, 2006).

Jordan is one of the countries in the Middle East to be highly affected with climate change impacts. Although Jordan's emissions of greenhouse gases are very low, climate change is a big threat to Jordan since the ecosystem productivity and water resources are highly dependent on the hydrological cycle. Climatic changes have a very significant impact on irrigation requirements. A change in precipitation of 10% gave a change of approximately 5% in irrigation demand, while an increase of evaporation of 10% (corresponding in an increase of temperature of around +2°C) will increase irrigation demand by about 18%. When the precipitation decreases by 10 and 20%, the production of wheat in Jordan will decrease by about 8.5 thousand and 15 thousand tons respectively (MOE, 2006).

This study will focus on the actual and real data exist in National Jordanian Meteorological Department, such as rain fall, temperature with maximum and minimum and humidity obtained covering the period of 1955-2002. These obtained data will be analyzed using the GIS and converted into geographical maps. The generated data will be analyzed in two different methods: one is to produce a digital maps in which the country will divided into regions according to its topographical change where the specified temperatures, humidity and rain falls will be produced inside these maps. The second part will depend on the produced maps to calculate the area of each region in which the climate change impact will be analyzed to compare its current and previous area in order to predict the changes due to the global warming.

MATERIALS AND METHODS

The data used for analysis were obtained form National Jordanian Meteorological Department and consisted of monthly average and seasonal average including daily minimum and maximum temperatures, rainfall and relative humidity. These data covered the three decades from 1982 to 2005. Mean monthly and annual maximum and minimum temperatures were derived from daily maximum and minimum temperatures. The annual mean temperatures were calculated by averaging the monthly mean maximum and temperatures over the year. These obtained data for some selected metrological stations were fixed on the Kingdom digital map, with its exact coordination. Figure 1 represents the whole region

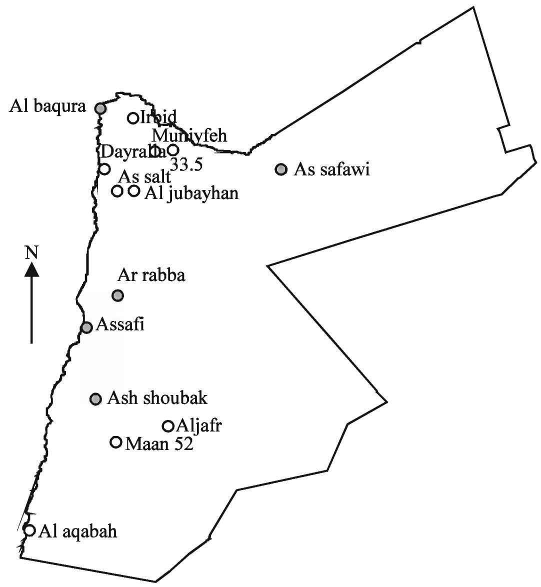

Fig. 1: Digital location for the metrological station in Jordan (map is not to scale)

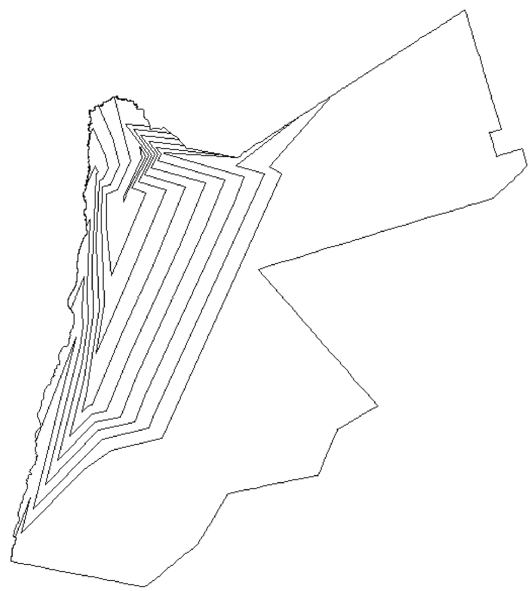

Fig. 2: Preparing the contour line for the study parameters (map is not to scale)

of the Kingdom and the selected metrological stations for this study.

GIS methodology: ARC GIS version 9.2 is employed to predict the impact of global warming and climate change on the Kingdom of Jordan. The Arc GIS consists of the followings; Arc catalog, Arc map, Arc tool box, Arc scene, Arc global, Work station, Desktop administration, Arc reader. Arc catalog used to prepare the coordinate system and entering the spatial data and arc map used to make layers and editing to produce the map. Created layers or feature class (Geodata set), was fixed in the map after choosing the suitable geometry shape (line, point, polygon), for example four layers for temperature, rainfall, wind and humidity were created in this study. The digital map for the Kingdom inserts into arc map software and all selected metrological station located on its position. All data entered here under the aim of creating layers and zones in geographical maps for analysis.

The final shape after data have been entered into layers by GIS software for one parameter like rainfall, temperature and relative humidity for only one year. The contour lines are demonstrated by Fig. 2 all these lines are simulated by 3D analysis. Then these lines were analyzed and connected according to its regional zone values, for recognition purpose, each contour line can be assign by certain color to generate different zones or regions.

Data analysis: In this study we are focusing on three parameters to be investigated mainly; annual means minimum and maximum temperatures, annual relative humidity and annual average rainfall. All data were entered to GIS software and retrieved for producing zones for each parameter in different time periods.

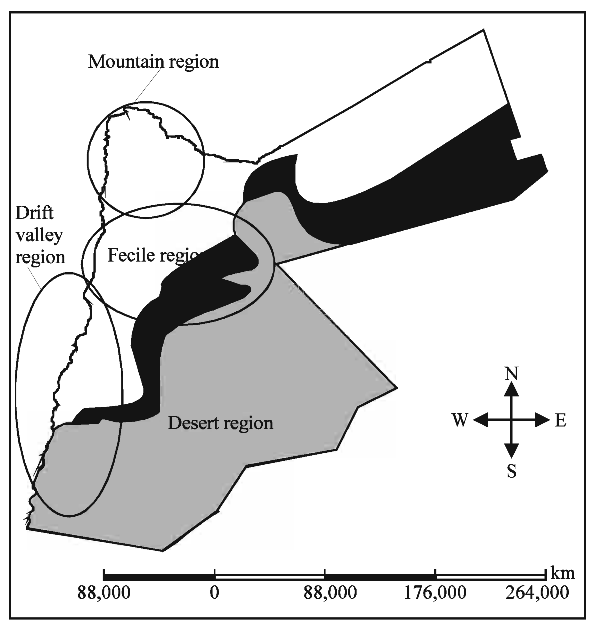

Fig. 3: Jordan regional distribution for analysis purpose

For making analysis easier to the reader, Jordan territory is divided into four parts distributed as demonstrated by Fig. 3:

- **Drift valley:** It occupies about 8.5% of Jordan area and consists from Dead Sea and going South down till Aqaba.
- **The mountain region:** it occupies around 4.8% from overall Jordan area mainly at the middle and north of Jordan.
- **Facile region:** It forms 11.3% of Jordan overall area.
- **The desert:** It occupies most east and south region, about 75.4% of overall Jordan area.

Based on these categories the analyzed data will be discussed and classified according to these regions and cover the period of 1982-2002.

RESULTS

Annual average minimum and maximum temperatures data analysis: The average annual mean minimum temperature for the years 1982, 1987, 1992, 1998 and 2002 are demonstrated in Fig. 4.

According to results shown in both Fig. 4 and 5, it is clear that the annual mean minimum and maximum temperature in the east and south (which is mainly the desert zone) region of the Kingdom has increased to about (1.5°C), at same time the annual mean minimum temperature for same period 1982-2002 has also increased by (1.5°C). Figure 6 data indicates that between the periods of 1982-1998 the changes in annual mean maximum temperature has increased from 28.5°C, up to 31.5°C. While the annual mean minimum temperature has also increased from 16.5 to 18°C, with the same period. In order to give a clear idea about the temperature changes during the same period, each area for the desert region, the whole zone as area was calculated using GIS techniques. The area is calculated in square kilometers for the desert region at different time periods. As it can be seen, in 1982, the maximum temperature was 28.5°C and has an area equal to about 68,000 km^2. However, the area has shrinkaged to 25,000 km^2, in 2002 and the maximum temperature has also risen to 31.5°C. This means that the

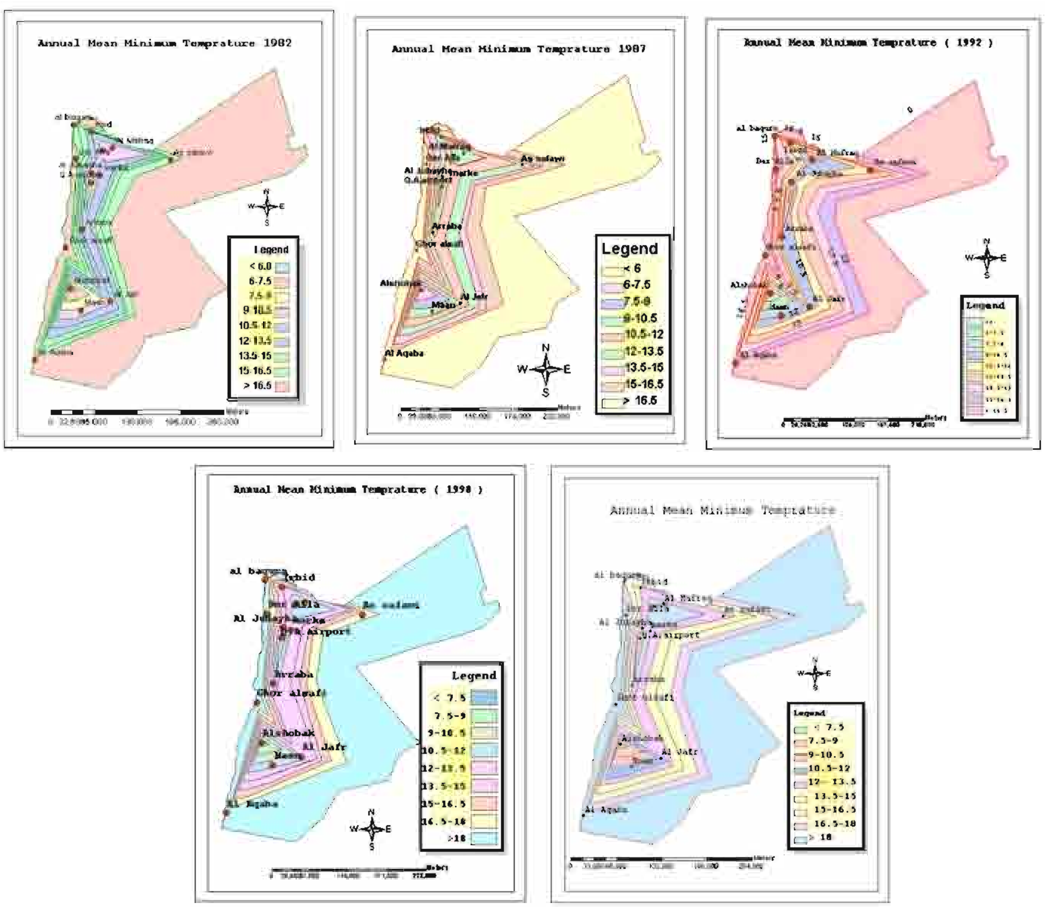

Fig. 4: The annual mean minimum temperature distribution over the Kingdom in 1982, 1987, 1992, 1998 and 2002

Fig. 5: The Average annual mean maximum temperature distribution over the Kingdom in 1982, 1987, 1992, 1998 and 2002

desert area region felt down in a higher temperature zone compared to the 1982.

The same procedure was repeated for the northern region and temperature zones areas were calculated. It is clear the area for the northern region has been increased from 5000 to 40000 km^2 (Fig. 7). This will give a strong indication that the northern part of the Kingdom for maximum temperature zones has increased eight times from 1982 till 2002.

The facile region data where capital of Jordan (Amman) is located, has calculated for annual mean maximum and minimum temperatures from Fig. 4 and 5, the results are given Fig. 8. The data demonstrates an increase in annual mean temperature by 3°C over the period of 1982-2002 and the annual mean minimum temperature had also the same behavior of increasing by 1.5°C over the period of 1982-1998.

In the northern part of the Kingdom the maximum and minimum temperature calculated from Fig. 4 and 5, are given in Fig. 8. This figure indicates clear increases in annual mean temperature over the period of 1982-2002. In addition, to that the annual mean maximum increased by

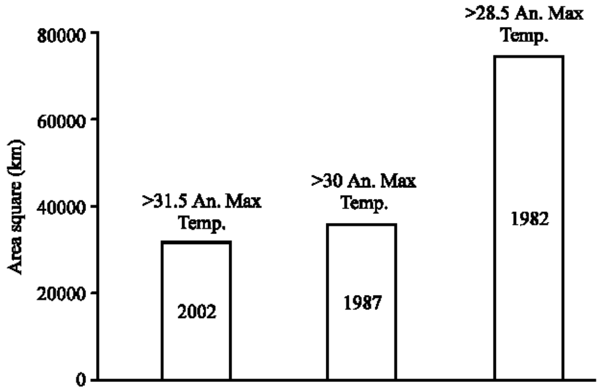

Fig. 6: Calculated area in square kilometers by GIS for desert region for annual mean maximum temperature during the period of 1982-2002

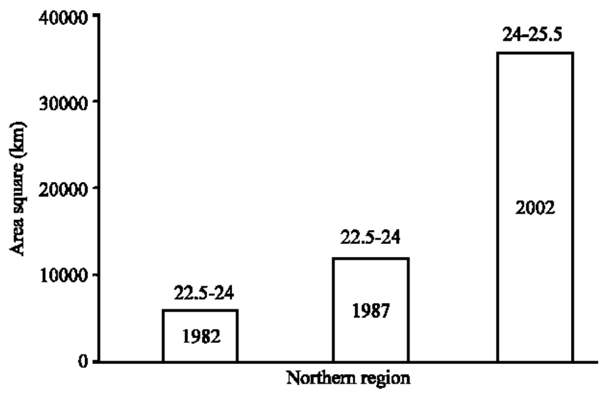

Fig. 7: Extracted data from GIS for northern region area calculation for annual mean maximum temperature during the period of 1982-2002

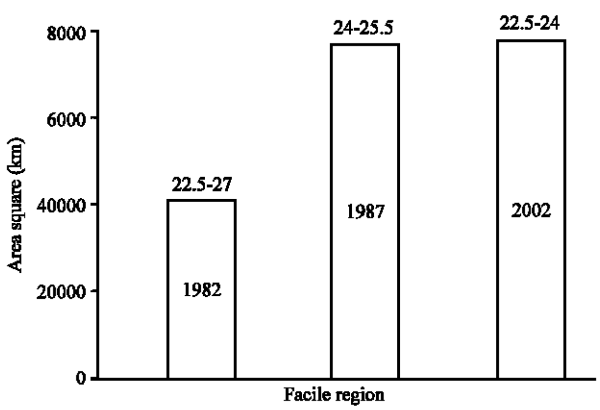

Fig. 8: Extracted data from GIS for facile (capital) region area calculation for annual mean maximum temperature during the period of 1982-2002

about of 1.5°C, from 22.5 to 24°C. While, the annual mean minimum temperature has also increased from 12 to 13.5°C, within the same period from 1982-2002.

Table 1: Annual average relative Humidity during 1982-1995

Year	1982	1987	1990	1995
Northern region (%)	58.5-60	56-57.5	52.5-54	>62
Facile region (%)	61.5-63	54.5-56	57-58.5	60-62
Desert (%)	46.5	<40.5	<42	<50

Table 2: Annual rainfall (mm) in different regions during (1985-2005)

Year	1985	1996	2000	2005
Desert	>50	>50	>50	>50
Northern	350-400	350-400	350-400	350-400
Middle	400-450	400-450	450-500	450-500

The area for temperature zones for the facile region at different time periods was extracted from Fig. 4 and 5 and calculated. It is clear that the area has been increased from 3000 km^2 in 1982 to 8000 km^2 in 2002 (Fig. 8). This will give an indication that a hotter region will be noticed if the same pattern of temperature rise will continue to increase with time. This what is recently has been noticed by local residence at this region. In addition to that, the increasing in area will give a tangible notice of temperature change by normal people who used to be living in this region to feel hotter weather before 2002 in comparison with 1982. Another factor contributes to this increase in temperature may be attributed to the very rapid expansion in urban development after 1993, which witnessed the Gulf crisis era.

Annual relative humidity distribution data analysis: To study the effect of climate changes on the relative humidity data for the period of 1982-1990 (These are the only available data from Jordan metrological department), collected and treated by GIS (Fig. 9). Table 1 demonstrates that the desert area in southern and eastern part of Jordan, has shown an increase in the relative humidity from 46.5-50%. While in the facile region, its relative humidity was fluctuated from high value during 1982 which was around 60%, to lower average value of 55% in 1987-1990 and then to a higher value of 61% in 1995. Knowing that there is a strong indication between the relative humidity and rain fall when it has high value this means high rain fall possibility and when it is low its mean that no rain fall. It is said when relative humidity value reaches 10%, it is a very dry season.

Data analysis for rainfall: Rain fall annual average calculated data for the period of 1980, 1985, 1990, 1996, 2000 and 2005, in the Kingdom are demonstrated in Fig. 10.

The obtained results for the annual average rainfall in the desert region are given in Table 2. It is interesting to notice from Table 2, that the average annual rainfall value keep on constant value over the period of 1985-2005, which is greater than 50 mm. Therefore the amount of rainfall in this region was kept on its minimum, but the

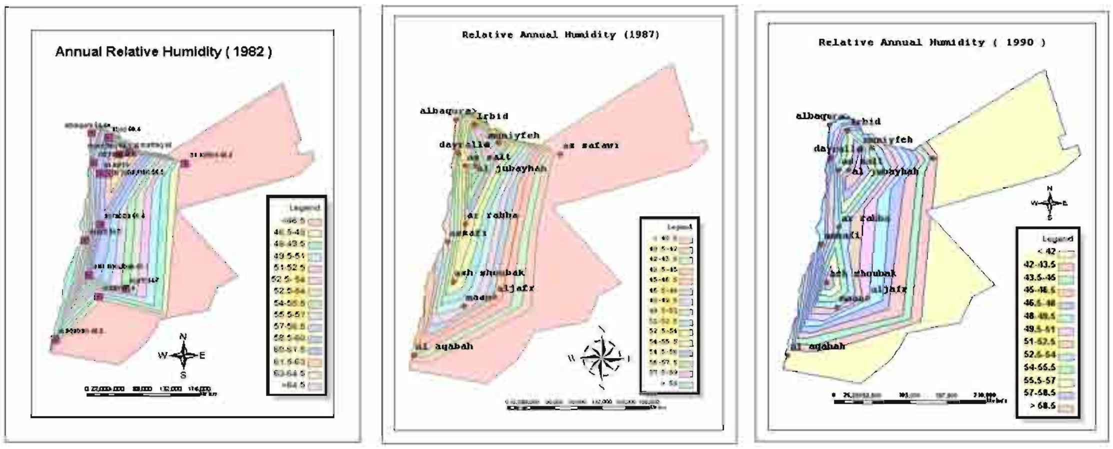

Fig. 9: Annual relative humidity data distribution after treatment over the Kingdom in 1982, 1987 and 1990

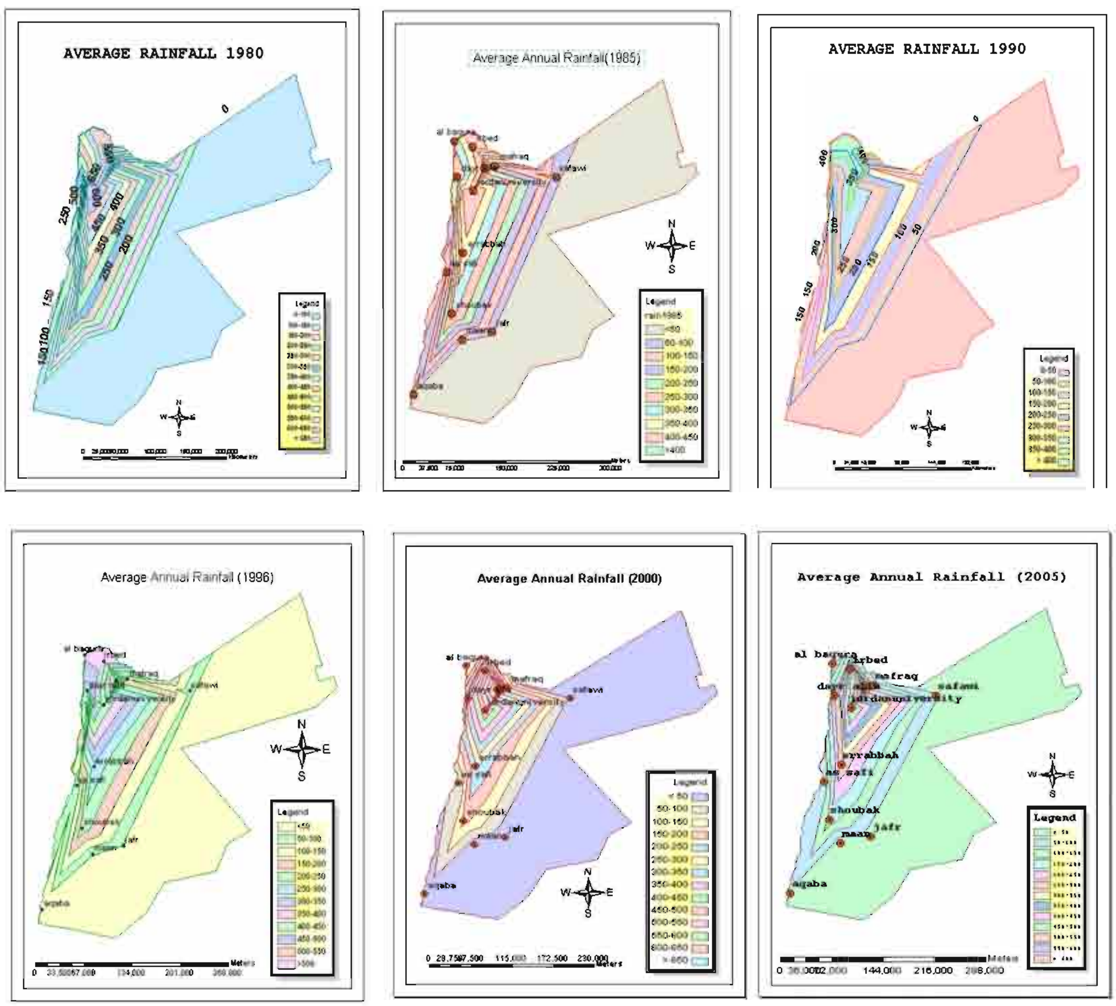

Fig. 10: Average annual rainfall data distribution after treatment over the Kingdom in 1980, 1985, 1990, 1996, 2000, and 2005

demonstrated zones in Fig. 10, give a clear indication that desert area where rain fall is occurring has been increased by simple comparison rainfall data zones in 1980 with that one of 1990, in Fig. 10. This will give a sign that the rain will fall in the desert region where people used not to witness its fall in that region and they will also witness more rain fall in quantity, however due to the increase in temperature as mentioned before the evaporation rate will also increasing.

The average annual rainfall for the northern part of Kingdom zones are given in Table 2. Here in Jordan, the northern part of the kingdom is considering one of the best agricultural zones for the country. Table 2, indicates a constant rainfall of 400 mm over the period of 1985-2005.

For the facile region of the kingdom the average annual rainfall for the period of 1975-2005 is also given in Table 2. It is clear from Table 2 that the average annual rainfall had increased by about 50 mm over the period of 1996-2005, while it is almost constant over the period of 1985-1985.

CONCLUSIONS

- Through the spatial analyses of data and the applications of (GIS) technology, it was possible here to study the real existence of the global warming phenomena in Jordan.
- Annual, minimum and maximum mean temperatures have tended to increase, particularly over the eastern and facile regions of Jordan. The majority of the urbanized and rapidly urbanizing stations in Jordan (middle region) have been experiencing an apparent warming, especially during the warm and dry period of the year. Minimum temperatures have shown a statistically significant positive trend at these stations. Therefore Jordan region, will have in general a positive trend in temperature increase which is the same trends in the Mediterranean region of the country.
- The study based on the data obtained officially from Jordanian metallurgical department has been analyzed and plotted in charts, with an interesting outcome. The results have approved that there is a significant changes in maximum and minimum annual mean temperatures all over the Kingdom and during the period of 1985-2005. This increase in temperature has been found to be within the rage of 1.5°C.
- The results have shown that no change in the average annual rainfall in both northern and eastern part of the kingdom, while it has been increases in the middle region of the kingdom. One possible reason for this behavior in the middle region (facile), may be attributed to the increase of the air pollution due to the high numbers of automobile vehicles and rapid urbanization.
- Although local temperatures fluctuate naturally, over the past 30 years the average global temperature has increased at the fastest rate (1.5-2°C) in a historical recorded in Jordan that is if continue with the same trends will be unacceptable.
- It is worth to mention here that the global warming impact on Jordan weather has been notice to start after the 1990. The Kyoto protocol is basically insist that most countries in the world to go back to the emission of 1992, base-line at that time the phenomena of the global warming was clearly identified.
- Due to the rise up in both maximum and minimum temperatures, the rate of evaporation will also be increasing; therefore the humidity will also be increasing in some region most likely the northern part as the rainfall is high at that region, however evaporation will be high and hence relative humidity will be increasing.
- The rainfall in Jordan increasing approximately around 20 mm yearly, this will need a precaution to be taken from now on for the flooding possibility occurring. At the same time the increased amount of rain will also enhance the evaporation rate and consequently water cycle will be affected. Although, this rise in rainfall but during our study we noticed that the amount has increased but the season when it rain has been shifted, a sign for a climate change probability is coming a head.
- This study conclude that winter precipitation is projected to increase slightly throughout the region; summer precipitation is projected to remain the same in the northeastern part of the country.
- Soil moisture is projected to decrease in most parts of the country because the projected precipitation increases are small and evaporation will increase due to the rising in both maximum and minimum temperatures.
- The country due to this instability in temperature distribution and fluctuation will witness a waves of hotness from time to time during the year, as well witness strong rain fall in huge amount in different region and not necessary during the rain season.
- Mean, maximum and minimum surface air temperatures recorded at 15 climatological stations in Jordan during the period from 1982 to 2002 were analysed to reveal spatial and temporal patterns of long-term trends and significant warming (cooling) periods and locations.

- By considering the marked increasing trends in annual minimum temperatures of the facile region, this will recognize that this is a clear and significant indication for the existence of urban warming climate in Jordan.

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