

Estimating Desertification in the Arab World Using GIS Approach

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Abstract: More than 150 countries of the world are facing the problems of desertification and this figure includes most of the Arab countries. About one-third of desert lands in the world are located in the Arab countries. Approximately, 90 percent of the total area of the Arab world is categorized as dry land and is characterized by harsh environment, fragile ecosystems in addition to limited water resources and arable lands. Several efforts have been made thus far to bring to a halt the desertification in Arab countries but still, it remains the major environmental problem in the region. Several factors such as increasing population growth, increasing demands of food and other natural products and migration are identified to be the major contributing factors for desertification. This paper analyzes the status of desertification in the Arab countries, identifies the major causes and trends of land degradation and accentuates the limitations and constraints in combating desertification. This study also highlights the applications of remote sensing and GIS in estimating and monitoring desertification in the Arab countries. GIS and remote sensing techniques can provide improved quality and quantity of information on degradation trends over large areas and provide for more effective management of the information about desertification.

Key words: Desertification . arab world . human impacts . natural resources . GIS . remote sensing . monitoring . sustainable development

INTRODUCTION

Desertification is a serious environmental problem which takes place worldwide in dry lands and the effects are experienced locally, regionally and globally. Countries suffer due to desertification. Dry lands occupy 41 percent of Earth's land area and are home to more than 2 billion people [1]. Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from climatic variations and human activities. It occurs because dry lands are extremely vulnerable to over-exploitation and as a result of inappropriate land uses such as deforestation, overgrazing, bad irrigation practices.

Desertification threatens the livelihoods of millions of human beings. According to a United Nations report, more than one billion people across the globe are affected by drought and desertification [2]. This population, which constitutes about one quarter of the planet, is facing major problems such as soil degradation and vegetation loss, leading to the deterioration of arable lands and eventually resulting in chronic food insecurity [3].

Reports suggested that approximately 30 million km² (19 percent) of the land surface are vulnerable to desertification or are threatened by it [4]. Additionally,

the United Nations reports indicate that about 35 million km² of lands are subject to desertification [3]. This is accompanied by a loss of approximately USD 52 billion due to reductions in agricultural productions [5]. It is estimated that 200,000 km² of soil loses its fertility or sustains degradation and experience a decline in its productivity worldwide as a result of desertification every year [6]. All the above facts combined have led to the attention of several authorities, specialists and researchers all over the world on desertification as the most important natural phenomena. The problem of desertification is not only confined to arid or semi arid regions in the world, it goes beyond that-to the adjacent semi humid and tropical regions. Reports suggested that the desertification threatened regions include more than 150 countries of the world [7].

The Arab world, which comprises about one-third of desert land in the world, is also experiencing desertification like some other parts of the world [8]. The dry land occupies approximately 90 percent of the total area of the Arab world which is estimated to be more than 14 km² [3]. The annual readings of rainfall within this area is perturbing; 9.9 million km² land area received 100 mm rainfall annually, 2.9 million km² land area received 100-400 mm of rainfall per year and the

Table 1: The arab world land categorized according to rainfall

| Type of land | Annual rainfall (mm) | Area in million of hectares | Percentage of total area (%) |
|--------------|----------------------|-----------------------------|------------------------------|
| Dry | <100 | 99 | 69 |
| Semi dry | 100-400 | 29 | 20 |
| Non dry | >400 | 16 | 11 |
| Total | | 144 | 100 |

Source: [3]

rest of the area (estimated at about 1.6 million km²) received over 400 mm rainfall per year (Table 1). The relatively small area that receives the most rain is experiencing congestion as the majority of the urban and economic centers are concentrated in the area which contains forests and is also utilized as fruit farms [9]. This part represents the pillar of the economy particularly in non-oil-producing countries and is the source of necessities such as food, fiber, medicine etc. However, they are vulnerable to desertification due to the aridity of the Arab countries.

In the year 2000, approximately 65 million hectares of the land are agricultural lands followed by 93.8 hectares of forests and rangelands with an area of 311 hectares. Furthermore, most of the Arab countries have water problems. Total precipitations was reported at around 2282 billion cubic meter per year, but only 205 billion cubic meters per year can be utilized. Underground water is estimated to be about 7734 billion cubic meters, but the water recharge does not exceed 42 billion cubic meters per year and the volume available for use does not exceed 35 billion cubic meters per year.

The resources of the Arab world are shrinking due to the problems of degradation and desertification. Degradation is mostly reported in the form of loss of land fertility and changes in its salinity and the hazards of pollutions, loss of forestry and range land areas and the decline in vegetation, forage and meat productivity. Degradation can also be explained by the spreading of wind and water erosion as well as the decrease in the standard of living of the populace and the escalating poverty [7].

GIS APPLICATION IN ESTIMATING AND MONITORING DESERTIFICATION

Geographical Information System (GIS) is a computer-assisted system that is used for the capture, storage, retrieval, analysis and display of spatial data within a particular system [10]. Due to the serious consequences of desertification, it became an important priority to combat desertification. The first step is to monitor desertification by measuring land degradation

and desertification processes. The standard methods of undertaking such measurements are substantially imperfect and economically impractical. The GIS serves as a means of integrating and manipulating in situ surface observations, satellite-based environmental indicators, aerial photography and other available spatial information in support of effective dry land planning, decision making and researches. GIS is a more efficient way of performing tasks due to lesser time requirement to complete the task. By using GIS management and analysis of spatial data in the digital form, the results could be easily communicated which is visually effective. Most of the researchers are more inclined to understand pictures (maps and graphs) as compared to other literatures. GIS applications in natural resources management seek to maximize the information that can be derived from remote sensing or topographic maps and other sources as shown in (Fig. 1). Remote Sensing and Geographic Information System has been identified to be powerful tools in monitoring and assessing desertification. The use of remote sensing provides a wide array of opportunities and advantages in desertification monitoring because it provides a large-scale, repetitive and accurate coverage [11]. GIS technique could be very useful in the assessment of desertification and in identifying the high-risk areas particularly in the Arab countries. In the past two decades, several studies applied the GIS techniques for assessing and monitoring desertification at the national and regional levels in the Arab region. The Arab Center for the Studies of Arid Zones and Dry Lands [5] used remote sensing and geographic information systems to monitor and combat desertification in the Arab land.

Arab world: A brief overview: The Arab world occupies a large area of the northern African continent and the southwestern part of the Asian continent (Fig. 2). It accounts for an area of about 14.1 million km² (approximately 10.15 percent of land areas of the world). The Arab world is located between 2^o south and 37^o north of the latitude and it extends from north to south along the 39^o latitude, covering a distance of 4500 km. It extends between 15^o west and 60^o east of the longitude and along the 75^o longitude from east to west for a distance of more than 7500 km. Thus, all the Arab territories fall under the northern hemisphere. This area is mostly characterized by tropical warm climate, except for the high mountain ranges and the northern areas located to the north of latitude 30 degrees N where the climate are moderate [13]. Arable lands are about 14.5 percent of the land area; out of this only 4.2 percent arable land are utilized for various agricultural purposes. Some areas of this land are affected by

Table 2: The desertified land and the lands threatened by desertification in the Arab world and their percentage by regions

| The region | Decertified land (%) | The threatened by (%) | Total (%) | The remaining (%) |
|-------------------------------------|----------------------|-----------------------|-----------|-------------------|
| The Arabian Peninsula | 89.6 | 9.0 | 98.6 | 1.4 |
| The Arab Maghreb | 77.7 | 16.5 | 94.2 | 5.8 |
| The Nile basin & the Horn of Africa | 44.5 | 28.6 | 73.1 | 26.9 |
| The Arab East | 35.6 | 48.6 | 84.2 | 15.8 |
| The Average | 61.9 | 25.6 | 87.5 | 12.5 |

Source: [5]

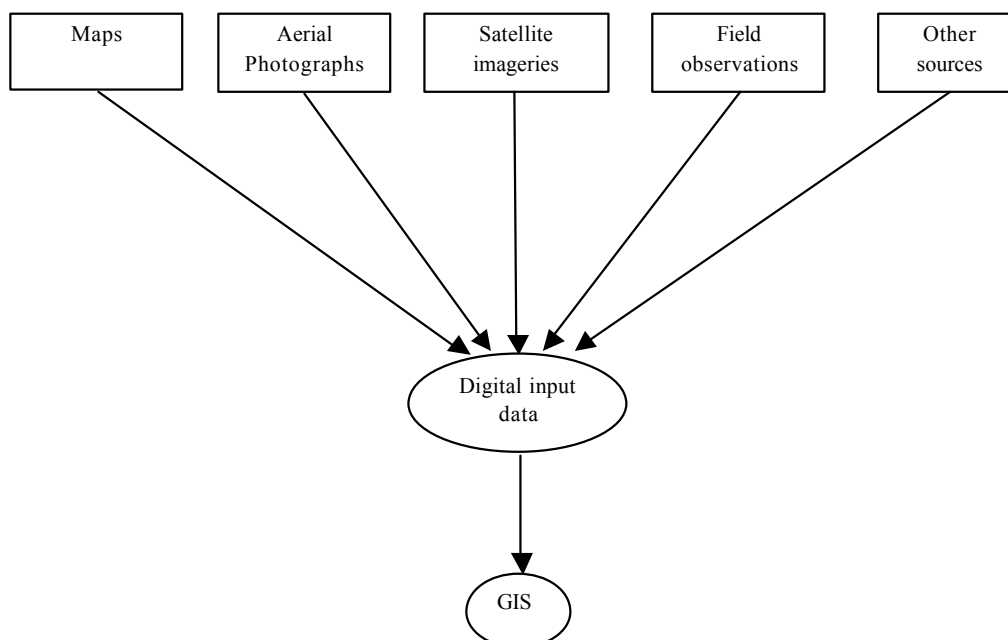


Fig. 1: Input data for GIS. (Source: [12])

desertification [7]. Table 1 shows that 69 percent of the total area of the Arab world is located under dry weather conditions or severe drought and 20 percent of it received 100-400 mm rainfall annually. Only the remaining area (11 percent) received more than 400 mm rainfall annually. The desertified land in the Arab world is estimated to be about 9.76 million km² or 68.4 percent of the total area. Generally, the Arab region can be classified into four regions as shown in Fig. 3: Arabian Peninsula, Arab Maghreb, Nile basin and the Horn of Africa and East Arab. The different regions vary in the seriousness of desertification they experience (Table 2). The region with the widest area desertified (89.6 percent) is the Arabian Peninsula followed by Arab Maghreb (77.7 percent), Nile basin and the Horn of Africa (44.5 percent) and the least being the Arab East (35.6 percent). However, the areas that are threatened by desertification are highest in Levant (48.6 percent) followed by the Nile Basin and the Horn of Africa (28.6 percent), Maghreb (16.5 percent) and Arabian Peninsula (9 percent of the total area).

The Arab region, by virtue of its geographical location, is mostly experiencing scarcity of natural water resources. Water scarcity levels in most of the Arab countries are the world's highest, with low and irregular rainfall causing the problem of desertification. The amount of rainfall is estimated to be around 2282 billion cubic meters per annum and most of the rain fall (57.3 percent) occurs in the central region i.e. the Nile Basin and the Horn of Africa. Some 25.7 percent of the rain falls in the Maghreb region [7]. The volume of traditional renewable water resources available for investment in the Arab world is estimated at about 338 billion cubic meters a year. According to an estimate, the groundwater reserve in the Arab world is 77300 billion cubic meters, while the annual feeding is about 42 billion cubic meters. In consequence of drought and mismanagement, the water reserve is depleting and is deteriorating in quality [5]. The demand for water in 2000 was 127 billion cubic meters and it is expected to rise to 176 billion cubic meters by 2035 [14]. However, the availability of water in per capita term is estimated at about 977 cubic meters, which is the lowest in the

Table 3: Population size and population growth in arab countries

| Country | Population (thousands) | | | Annual growth rate (percent) | |
|----------------------|------------------------|---------|------------|------------------------------|-----------|
| | 1980 | 2000 | 2020 | 1980-2000 | 2000-2020 |
| Jordan | 2 225 | 5 035 | 7 560 | 4.08 | 2.03 |
| United Arab Emirates | 1 015 | 2 820 | 3 786 | 5.11 | 1.47 |
| Bahrain | 347.000 | 677.000 | 969.000 | 3.34 | 1.80 |
| Tunisia | 6 469 | 9 519 | 11 621 | 1.93 | 1.00 |
| Algeria | 18 740 | 30 245 | 40 479 | 2.39 | 1.46 |
| Comoros | 387.000 | 705.000 | 1 154 | 3.00 | 2.46 |
| Libya | 3 043 | 5 237 | 7 378 | 2.71 | 1.71 |
| Syria | 8 959 | 16 560 | 25 077 | 3.07 | 2.07 |
| Djibouti | 327.000 | 666.000 | 912.000 | 3.56 | 1.57 |
| Sudan | 19 387 | 31 437 | 44 493 | 2.42 | 1.74 |
| Somalia | 6 487 | 8 720 | 17 928 | 1.48 | 3.60 |
| Iraq | 12 962 | 23 224 | 37 992 | 2.92 | 2.46 |
| Oman | 1 187 | 2 609 | 4 349 | 3.94 | 2.56 |
| Palestine | 1 476 | 3 191 | 6 064 | 3.85 | 3.21 |
| Qatar | 229.000 | 581.000 | 752.000 | 4.65 | 1.29 |
| Kuwait | 1 375 | 2 247 | 3 647 | 2.46 | 2.42 |
| Lebanon | 2 669 | 3 478 | 4 395 | 1.32 | 1.17 |
| Egypt | 43 915 | 67 784 | 96 852 | 2.17 | 1.78 |
| Mauritania | 1 609 | 2 645 | 4 473 | 2.49 | 2.63 |
| Morocco | 19 382 | 29 108 | 38 726 | 2.03 | 1.43 |
| Saudi Arabia | 9 604 | 22 147 | 36 253 | 4.18 | 2.46 |
| Yemen | 8 140 | 18 017 | 36537.000 | 3.97 | 3.54 |
| Total Arab countries | 169 935 | 286 650 | 431397.000 | 2.61 | 2.04 |

Source: [19]

world. It is expected that this average will further decrease due to increasing population. It is estimated that the demand for water will increase up to 460 cubic meters by 2025 [15].

The population growth rate was higher (2.6 percent) compared to the whole world (1.6 percent) in the past two decades. However, it is expected that the population growth rate in the Arab world will decline in the next two decades, reaching the expected 2.04 per cent during the period of 2000-2020. Nonetheless, the projections indicate that the population will continue to grow in the coming years [16]. The population of Arab world increased from 36 million at the beginning of the twentieth century to 80 million in mid-twentieth century and further rise to about 307 million in the middle of the year 2003. It is expected that the population will have surpassed 400 million by the year 2020 [17] and increase to 598.5 million by the year 2050 [18]. It is a common wisdom that an increase in population will increase the threat to the environment, particularly in countries that depend on agriculture. Table 3 shows the population size and population growth in Arab countries for the period of 1990 until 2020.

In general, the low annual rates and irregular distribution of rainfall, overgrazing, deforestation, depletion of water resources and other factors have accelerated the destruction process of natural vegetation cover and land degradation in many parts of the countries. Ultimately, this has increased the severity of the desertification problem as well as environmental degradation.

CAUSES AND CONSEQUENCES OF DESERTIFICATION

Throughout the geologic times, the significant effects of climate changes have led to the emergence of the Sahara. The frequent winds, fluctuations in rainfall and water erosion are symptoms of land degradation and desertification [19]. Climate change along the past decades has played an important role in the emergence of fragile ecosystems in the arid and semi-arid areas which are characterized by poor vegetation cover and extensive shallow soils. The dry land is receiving fluctuated amounts of rainfall leading to drought, which is often associated with land degradation [3]. There are many factors contributing towards the deterioration of

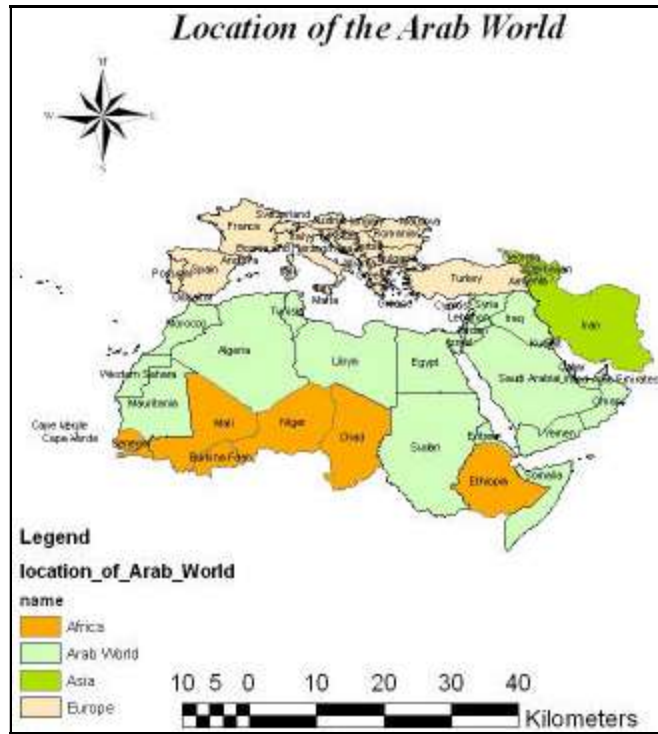


Fig. 2: Location of the arab world

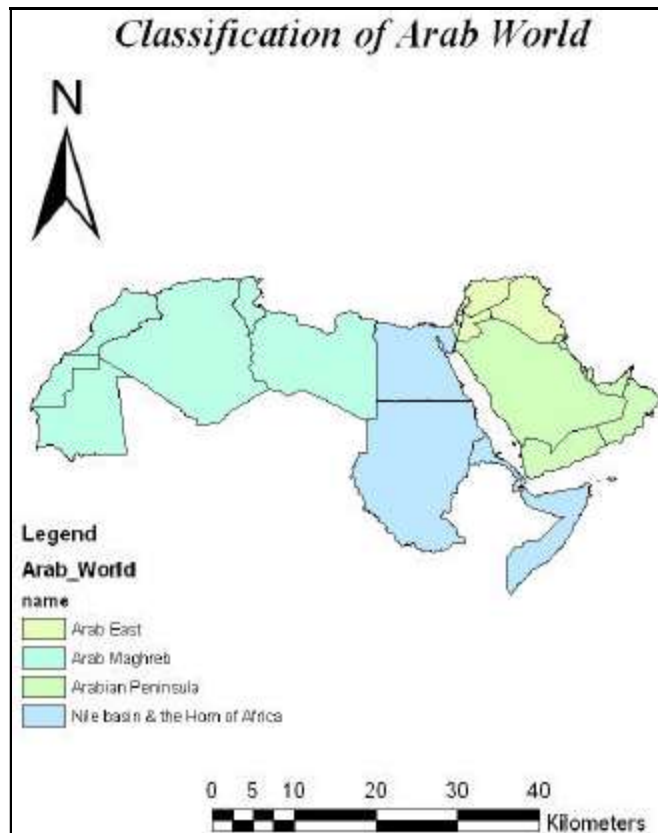


Fig. 3: Classification of arab world

natural vegetations in the Arab region. The climatic factors play an important role in the spreading of desertification and human activities aggravate the effects of the problem [7].

The dramatic increase in the population size and their requirements caused major imbalances in the environment. The most important human activities causing environmental degradation are overgrazing, deforestation, over-exploitation of land, poor irrigation, the spread of mechanized farming especially in marginal areas and misuse of water resources [3, 5, 7]. Desertification caused several negative environmental, economic and social impacts, both directly and indirectly, all of which affect the human life. Desertification is accompanied by the deterioration of soil fertility and a change in their physical and chemical properties, in addition to vulnerability to erosion of water [7]. Studies have shown that the production per hectare production of grain in the dry and marginal areas in the Arab world has significantly decreased. Moreover, the deterioration of the pastoral environment causes a decline in the productivity of livestock and other animals and consequently reduces the production of meat and milk. The dwindling of forest lands and natural pastures due to deforestation is severely upsetting the countries' economy by reducing national income through the loss of revenue from natural resource based products [4]. Desertification leads to many environmental impacts such as the formation of sand dunes and sand encroachment on urban areas and farms, roads and railways. Other impacts include air pollution, dust and reduction in biodiversity as a result of the destruction of the natural habitats for animal and plant species and micro-organisms [6]. Degradation of the natural environment leads to the migration of pastoralists, nomads and residents of rural areas to cities in search of livelihood. Such a process contributes to increased pressure on cities and on their resources. Migration affects significantly the economic and social life of the nomadic tribes especially going forward as migration often occurs among the young and active age groups of the population [4].

DESERTIFICATION DETECTION AND ITS ALLEVIATION

Because of the serious consequences of desertification, there needs to be a sense of urgency in the efforts to combat it. The first step is by monitoring which can be done by measuring land degradation and desertification processes. The existing standard methods of undertaking such measurements are still very much imperfect and are not economically feasible. These conventional methods have traditionally been

short of standardization because of the range of criteria and indicators [20]. The various data sources available using remote sensing offer the possibility of gaining environmental data over both large areas and relatively long time-periods. Although no one can confirm that remote sensing can replace traditional sources of data for inventory and monitoring, there is, however, an obvious role that it will play in assessing and monitoring desertification. It has been demonstrated that satellite-based and airborne remote sensing and geographic information systems offer a considerable potential in assessing and monitoring desertification in the Arab world [3].

Despite the awareness on desertification, the Arab countries have yet to measure the level of threat posed by various environmental, economic, social, cultural, political and security consequences of this problem [21]. Means of combating desertification in the Arab countries vary according to the different causes of desertification as the speed actions and the vision to tackle this problem. Nevertheless, they all seek to alleviate the situation of drought and desertification by taking the appropriate measures in line with the national plans of each country [21]. Since the Nairobi Conference in 1977, most Arab countries tried to develop strategies to combat desertification and implement the recommendations and decisions emanating from the conference and have developed national plans on combating desertification in the short term. The Arab countries have made some attempts to create united structures and institutions to facilitate cooperation to overcome the problem of desertification and to mend the damage it caused. Moreover, some regional projects were established including the Green line project to the countries of North Africa, the project of Green line in the east Arab countries and the project of Green line to the Arabian Peninsula. The main aim was to increase the green areas in order to stop sand encroachment and to protect the agricultural land [22]. At the national level, a host of projects relating to reclamation of land, pasture improvement, irrigation, expansion of forestation and sand dune stabilization in addition to other procedures were implemented in all the Arab countries [5].

CONSTRAINTS AND PROSPECTS

Despite the efforts and achievements, so far, the results have yet to match the hopes and aspirations desired in most Arab countries. It is commonsensical that desertification requires continuous evaluations and reviews, long-term planning and good governance at all levels to achieve satisfactory results [4]. The immediate objective of combating desertification, as stated in the

Action Plan adopted by the United Nations Conference on Desertification in Nairobi in 1977, is to prevent desertification or halt its progress. However, there are many obstacles and challenges to achieve this goal, the most important of which are the following:

- The rapid population growth in most Arab countries and urban expansions in the productive agricultural areas which increase the size of the gap between the rate of production and consumption and thereby increase the shortage of food.
- The pressure of population increase on natural resources and the indiscriminate exploitation without consideration about sustainability.
- The lack of specialized and competent staffs in the field of natural resources protection and in combating desertification.
- Scarcity of water resources and recurrent droughts that limit the success of agricultural projects, land reclamation and cultivation.
- The absence of implementation/execution of laws and legislations concerning environmental protection and natural resources in many cases.

Despite the above mentioned obstacles, combating desertification needs time. Long-term planning as well as rational management of access to the results is also needed. Many specialists and researchers confirm that the problem of desertification and land degradation can be addressed through re-plantation of fruit trees, windbreaks, green lines, plantation of grass to stabilize the soil, prevention of erosion by water and wind, the use of crop rotations and by ending the over-exploitation of resources.

CONCLUSIONS

Causes of desertification and its degree vary depending on the environmental characteristics of the affected areas. Therefore, the required means of resistance and control methods tend to differ between regions depending on the causes and degrees of degradation. Desertification in the Arab states has many environmental, economic and social consequences. As for the environmental consequences, it is represented by the degradation of plant and animal life, the degradation of soil, pasture and the shrinking of areas viable for agriculture, lack of water resources and deterioration in their quality. The economic repercussions are laid out by the United Nations in its survey on the world's environment for the period between 1972 and 1992, in which it stated that the degradation of land and desertification affect countries' capacity to produce food, thus reducing the regional and global production

of food. More importantly, they cause food-shortage in the threatened areas. As desertification involves the destruction of habitats and the loss of many plant and animal groups, it is one of the main causes of biodiversity loss in arid regions, which further reduces the ability of food production. This applies to all the Arab countries.

The social consequences of desertification are represented in the increasing migration of rural residents and shepherds to the cities to seek jobs and a better life. The upshot of this migration is the increasing pressure on the limited potential of cities. Moreover, it contributes to the imbalance of comparative population growth rate between the urban population and the rural population which constitutes a burden on governments to provide social services. Other social problems include low living standards, unemployment, poor health and education services, lack of housing, social conflicts and the loss of security, etc. The exodus from the countryside to abandon the former agricultural land also contributes to the continuation of desertification.

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