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CLIMATE CHANGES AND THE ROLE OF RECENT DROUGHTS ON AGRICULTURAL ECONOMY OF SISTAN

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ABSTRACT – Regional economy is usually affected by the operation and interaction of environment and human beings in geographical spaces. Warm and dry areas create special economic conditions, which have particular functions, quite different from the characteristics of humid and cold hilly areas or those of the Mediterranean areas. The Sistan Region is located in South East of Iran. Until recent droughts (1999-2005), agriculture sector was the basis of all economic activities in Sistan area, a major share of rural as well as urban income came directly and indirectly from agricultural activities. In accordance with the latest census before the drought period (1996), about 55 percent of the rural population directly depended on the agriculture sector for their income and employment. In addition, almost 24 percent of rural population was depended to cottage and rural industries for their employments. In urban areas, 70 percent of population was linked to service sector as a source of employment. The results of this research show that the environmental changes resulting from drought in Sistan area have had deep impacts on the socio-economic factors in the region. It is clearer in the Hamoon Lake area, which, before the onset drought, had produced crops like fodders, mat, bird meat and fish. The livestock sector also suffered to a great extent. Out of the total of 1.6 million livestock units in the area, more than 0.5 million remained in the production cycle nowadays. The production of these crops reduced to zero with drought. The total direct loss resulted from the drought amounts to 14,057,332 million Rails or 1,561 billion US$. To sum up, the environmental changes resulting from drought caused more than 80 percent of agricultural and livestock activities in the region come to halt, which, in turn, due to a reduced income multiplier effect of agriculture sector resulted in greater damage to socio-economic factors in rural, as well as in urban areas.

Keywords: climate change, drought, agricultural economy, Sistan, Iran

INTRODUCTION

Climate change and increase of temperature is considered as one of the most important environmental issues, to which humans have dedicated many studies in recent years. From the early twentieth century, the earth and the sea temperature has become warmer by more than 0.45 on average.

Also, the climate statistics in Iran shows that in recent years, the temperature of the earth surface has become warmer by 0.25 up to 0.5 (Nouriyan, 1995). In general, the review of changing process in the mean temperature makes it possible to trace the climate changes of an area. The estimates show that the average temperature of the earth by 2030 will be 0.7° up to 2° higher than today (Jahanbakhsh, 2010).

Furthermore, based on IPCC estimation, the Middle East area will become warmer and drier in the future; meanwhile, rising the temperature thresholds and precipitation decrease will cause severe droughts in the region (IPCC, 1995).

It is given that the average air temperature on the earth surface and its changes are the sign of climate change, which almost all climate change theories mention it somehow. Continuous droughts in the last decades are one of the consequences of the increase in earth's temperature. Given the social and economic losses in Sistan, as one of the possible climate change indicators for obtaining

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sustainable development and even maintain the current situation, it is required to have a especial attention to this issue in water resources management and planning as a feature and a multi-dimensional threat. Therefore, a full and comprehensive understanding of dimensions and characteristics of this phenomenon, together with reviewing the processes of climate change parameters, seems necessary for evaluating the possibility of probable climate changes. Usually, drought can occur at any point of the world, and in fact, drought, if compared with other natural disasters, affects a greater number of people (Wilhit, 2000). Researches show that the drought started in 1991 is the most severe drought of this area within the last fifty years (Shurdus, 2001). A population of about 6 million people in the entire region, including some parts of Iran, Afghanistan, West Pakistan, Tajikistan and Turkmenistan, has suffered the greatest damages from the recent drought. In Iran, a seven-year drought in 12 provinces out of 30 exposed a population of about 37 million people (more than half of Iran's population) to the damages resulting from water and food insecurity. At the same time, during winter 2001 and spring 2002, 20 provinces of the country experienced a low precipitation period. Fars, Kerman, Khorasan, and Sistan and Baluchestan suffered most of the damages resulted from this drought. Before the recent droughts (1998-2004), agriculture sector had been considered as one of the most important parts in the economic functions of Sistan. Thus, a major percentage of urban and rural incomes were directly or indirectly dependent on this sector. Consequently, from far past periods up to now, we have experienced frequent and repeated droughts or floods with movement of flowing sands, which have affected the basis of relevant agricultural activities or destroyed them completely (Conolly, 1840). The last phase of direct effects of environmental functions on agricultural economy of Sistan can be seen in the continuous and long droughts from 1998 up to 2005, so that this environmental change has disturbed the basis of agriculture and has practically stopped its activity.

The main direct effective factor of environmental functions on agricultural activities of Sistan is due to its Androeek feature. The Hirmand River, as the only effective factor in supplying drinkable and agricultural water in the area, after flowing about 1200 km from the source in the Soleiman and the Babayaghma Mountains in North of Kabol in Afghanistan, it falls into the Sistan Plain in southeast of Iran. From past times to nowadays, the water regime of this river has depended directly on the amount of precipitation in Afghanistan's Hindukush Mountains and a change in the precipitation regime in that area has a direct effect on the ratio and flow rate of this river (McMahon, 1906). During the period 1998-2004, the western part of Asia, Middle East, Iran and Afghanistan, found under the effect of climate change, have experienced a prolonged drought. This river also had a variable and low flow rate due to the effect of this climate change. Therefore, during 1999 and 2000, it was completely dried for more than 20 months. Subsequently, up to the end of 2004, it frequently experienced low water or dry periods. The severity of drought in the river water regime was unprecedented in history (field studies 2005). On the other hand, precipitation in Sistan area was extremely low and the fifty-year average was less than 70 mm and average of the last 7 years was less than 40 mm. Its average annual evaporation was more than 480 mm (Sitiran Consultant Engineers, 1958). Meanwhile, its underground water resources, due to the presence of sandy and rigid alluvium up to 50 m depth from the earth surface, is low and does not provide conditions for the formation of a suitable underground water table (Pourkermani, 1998). However, the droughts of the recent years practically stopped 80 percent of the agricultural activities in Sistan and severely restricted employment and income in this sector.

RESEARCH METHODOLOGY

The behaviour of temperature series of Zabol synoptic station in period 1963-2005 was studied and the average temperature and the average of maximum temperature were determined by using time series graph. The maximum temperatures had a rising trend, but the average temperature did not show certain irregularities. Continuing by using SPI index, periodic droughts were determined in Zabol station (Figure 4). The SPI index is more common for regional drought and comparative studies between different regions (Hayes, 1999). Although the time series of the average temperature did not show high irregularities, based on the time series graph of the average maximum temperature,

a rising trend is visible (Figure 1 and 2). This is a standard index and can be used in field studies to provide a time relation between drought events in different regions of a zone (Lashni Zand, 2004).

Since the standardized index of SPI precipitation follows the normal distribution, it is possible to classify severe and wide spread drought events for each area and any time scale (Byun and Wilhite, 1998). In this study, statistics series (1963-2005) were assessed by using this index.

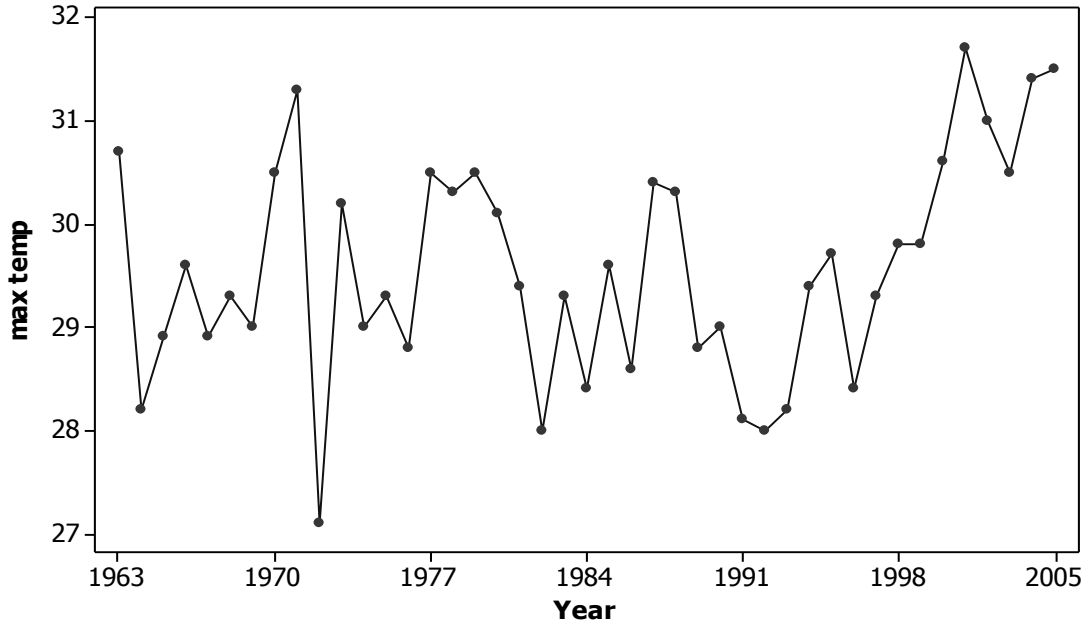

Figure 1. *Maximum temperature time series at Zabol station*

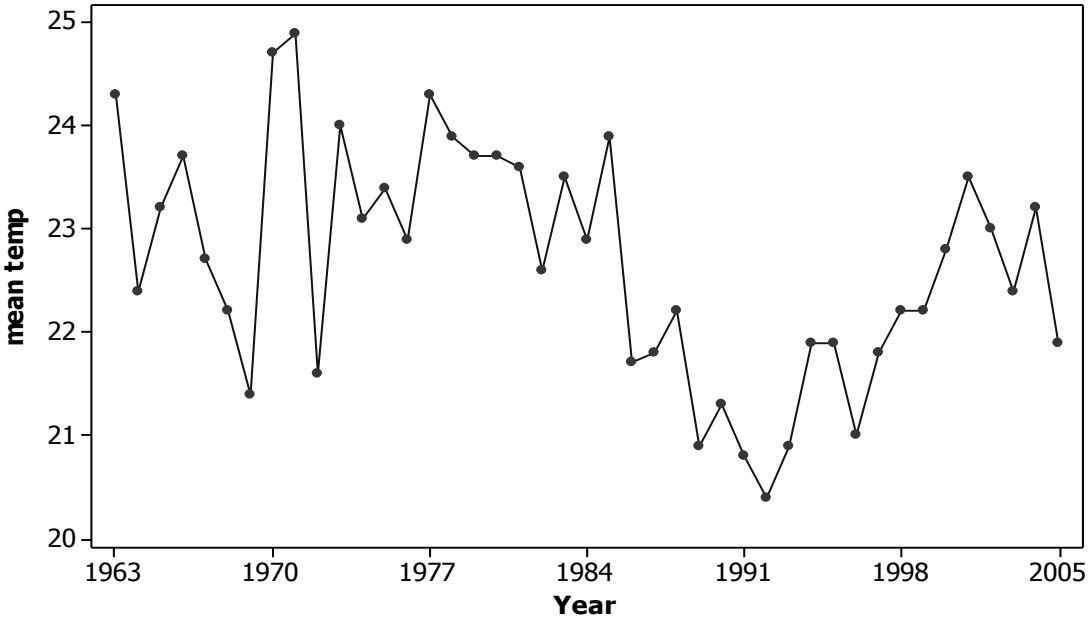

Figure 2. *Mean temperature time series at Zabol station*

In order to analyse the warming trend, the graph of maximum temperature at Zabol station was drawn, which shows the rising trend of high temperatures in Zabol (Figure 3).

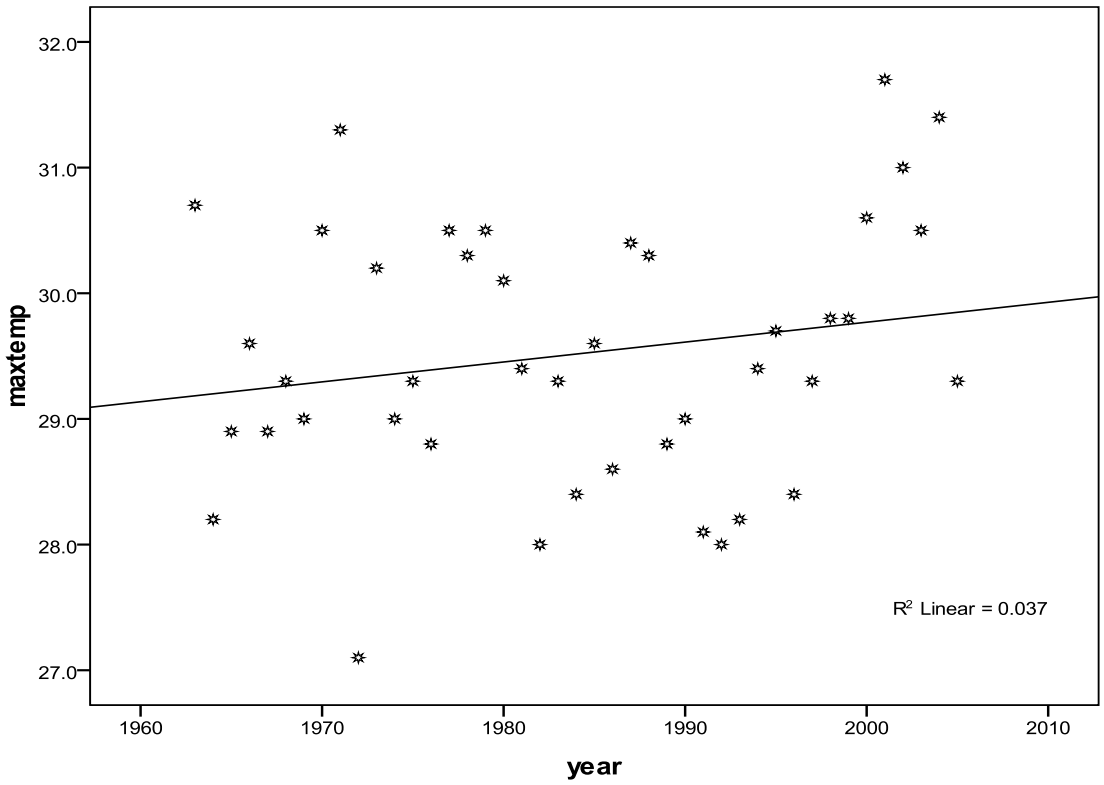

Figure 3. *Trend of maximum temperature mean at Zabol station*

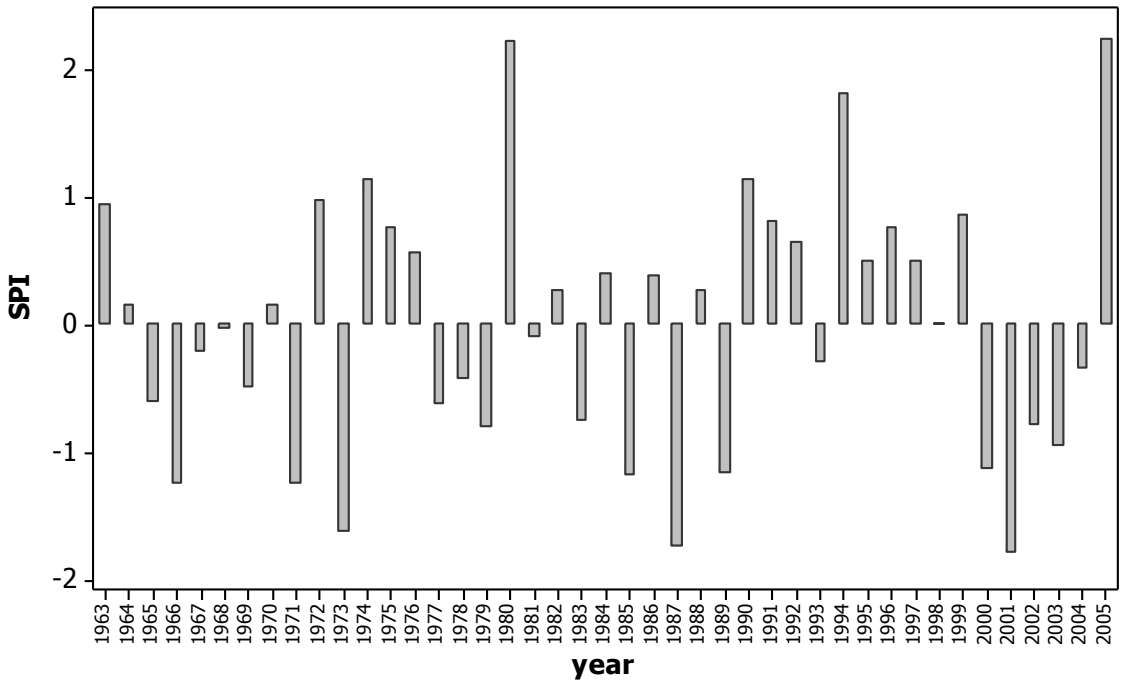

Figure 4. *SPI at Zabol station*

In addition to the use of the existing library sources and information, field studies were also carried out. Meanwhile, the research methodology was based on the system and analytical-comparative method, by using the information obtained through field studies and satellite photos. Thus, the displacement and change of the water resources of the Hirmand River and the Hamoon Lake, on the one hand, and the surface under cultivation of agricultural products and live stock productions in Sistan, on the other hand, were studied. The achieved information was compared with the existing information in the documents published by local and international researchers, and its results show a declining trend of water flowing into the Sistan Plain and the Hamoon Lake since 1999 up to now, which proportionately has devastating effects on the agricultural economy of the area.

BRIEF INTRODUCTION TO SISTAN NATURAL ENVIRONMENT

The Sistan Plain, undulating and relatively even, with an area of about 15,197 km^2 is located in the northeast of Sistan and Baluchestan province. It has about 410,020 inhabitants, out of which 250,795 (61%) live in 837 villages (Sharmand Consultant Engineers, 2004). The dominant climate of Sistan, according to all climatic classifications, is a hot and dry one (Negaresh and Khosravi, 2000). The mean annual temperature is 21°C, the mean of annual precipitation is 54 mm, the mean of air relative humidity is 38%, and its evaporation and perspiration which is calculated by means of different methods is about 4,196 mm (Negaresh and Khosravi, 2000) up to 5,700 mm (Ganji, 1974). The most significant atmospheric phenomenon of the area were the 120-day winds with west - northeast - south direction between 10 May and 11 September, which completely dominated the area and made the inhabitants' life difficult. The cause of such winds is said to be the pressure gradient between low pressure on India, Pakistan, and Afghanistan and high pressure on the Caspian Sea (Hossein Zadeh, 1997). The Sistan Plain is watered by the Hirmand River and its branches, i.e. Sistan and Pariyan. The Hirmand, with a catchment area of 350,000 km^2 and an approximate length of 1,200 km, originates from the Hendukush mountain range and, after joining different tributaries, eventually flows into the Hamoon Lagoon.

The annual flow rate of this river is so variable, for example, between 1956 and 1957, it reached to 14,741 million cubic metre, but during the recent droughts, the water flow was completely stopped. The average flow rate of this river has also a severe oscillation. However, the average was estimated to reach about 56 m^3/s (Sistan and Baluchestan Regional Water Company, 2004).

DROUGHT EFFECTS ON THE AGRICULTURE AND GARDENING OF SISTAN

Besides the irregular trend of agriculture in all parts of Iran, in the southeast of Iran, including Sistan, conditions have been worse than in other areas during the last decade (Ebrahim Zadeh, 2000). Sistan lies on the geographical coordinates of 30°12' and 31°28' N, 60°48' and 61°52'E and is conterminous with Afghanistan, being surrounded by a dry and desert area.

The Sistan plain delta begins at the extreme southeastern end from the place where the Hirmand River divides itself into two branches, namely Sistan and Pariyan, and has an average height of 492 m. It continues with a low slope at two sides of Hamoon Hirmand, with an overall height of 470 m above the seabed. The slope of Sistan is low and, on average, at each kilometre is 40 cm from southeast towards northwest, so that it is higher near the Afghanistan border and it is lower near the Hamoon lagoon in the northeast of Sistan. In this plain, there are masses of flowing sands that affect the area repeatedly, so that, during the last decades they have changed the direction and the riverbed of the Hirmand River. Since these changes have been done slowly, flat lands and fertilized highlands were formed close to the deltas, which are called "terraces" (Ferpak Consultants, 1984).

This plain, due to its plenty of suitable water and soil, as well as its Androeek basin, has always been in a rather distinct situation compared to the other surrounding dry and desert areas during different historical periods. Thus, in the ancient Avesta, it is mentioned as the eleventh nice area of Ahura Mazda for its great talents and fertility (Mostafavi, 1982). In the periods after Islam, it is mentioned as the granary of Iran or even the granary of Asia (Pour Davood, 1977). In other periods, following the peaks and drawdowns occurred in the drought and flood trend of the Hirmand River, the development and the decline of agriculture economy was affected by such environmental functions.

Drought has major differences from the other natural disasters. One of the main differences is that usually drought has no direct impact unlike other natural disasters such as tornadoes, hurricanes and earthquakes. Drought effects are usually non-structural and are distributed broadly and extensively. This difference makes the measurement of economic losses resulting from drought very difficult, but also harder to understand how a drought can be devastating. Up to now, most of the estimates about economic effects of drought have been hypothetical and incomplete (Wichael et al., 2003).

In recent years, notably between 1998 and 2004, when a widespread drought dominated the area for about 7 years, the extent of its damages was visible in all economic, social and environmental areas, so that in agriculture and gardening sectors, the region had to face a crisis.

Thus, the cultivation area has decreased from 119,640 hectares in farming year 1997-1998 to less than 10,000 hectares in 2003-2004 and caused irreparable damages to the rural society of Sistan (Agriculture Organization of Sistan and Baluchestan, 2005). The same problem appeared in the case of garden products. From the total surface of 2,306 hectares covered with fruit trees, including young trees and fruitful trees, in farming year 1997-1998, it reached to zero in 2004 (Agriculture Organization of Sistan and Baluchestan, 2005), and an ecological and economic disaster took place in the area. In fact, in the last year, over 236,851,685$ of drought loss occurred in the agriculture sub-sectors.

The areas cultivated with grapes and pomegranates, as the two main garden crops in Sistan, practically decreased from 2,051 hectares in 1997 to zero in 2004. As regards the production efficiency of about 5 tonnes per hectare, as result of the damages in each year, grapes and pomegranates are now sold 3,000 Rials for each kilo in the area, namely 30,765,000,000 Rials. On the other hand, actually the resulting damages of the lack of such fruits have been 3,111,056 $.

The other agricultural and garden products were also damaged in the same proportion. During the drought years, on average, at least 90% of damages occurred to the agriculture of the area each year, compared with the period before the drought. Therefore, hundreds of million dollars were lost from environmental changes resulting from droughts during the last 7 years.

Table 1. *Area of cultivation and the number of net before and after drought in Sistan*

Agricultural year 1997-1998 (Before drought)			**Agricultural year 2001-2002 (After drought)**		
Area of Cultivation and the number of net (hectare)	**Crop or Net**	**Row**	**Area of Cultivation and the number of net (hectare)**	**Crop or Net**	**Row**
70000	wheat	1	1570	wheat	1
13650	barely	2	1358	barley	2
35990	other crops	3	4315	other crops	3
	agricultural	4		agricultural	4
119640	Total of agricultural crop		7243	Total of agricultural crops	
1974	grape	4	363	grape	4
77	pomegranate	5	0	pomegranate	5
66/7	other crops of gardens	6	184	other crops of gardens	6
2117/7	Total of garden crops		547	Total of garden crops	
114500 heads	cow	7	30000	cow	7
1148390	sheep	8	380000	sheep	8
12000 ton	fish	9	0	fish	9
1606390	total of net unit		500000	total of net unit	

Source: Jahad-e- Agriculture Organization, Sistan & Baluchestan, Statistical Unit, 2005

DROUGHT EFFECTS ON LIVESTOCK, LIVESTOCK PRODUCTS, FISHING AND HUNTING IN SISTAN

Livestock in Sistan, like agriculture and gardening, has a long history in the area. In the past, it also had a great and important role on its agriculture and rural economy. During the recent periods, it was considered in the regional planning of Sistan as the focal point of agriculture and livestock (Generalities of Development Strategies of East Axis, 1998). However, this economic sector was actually faced with serious crisis due to the damages of the recent droughts (1998-2004) and the loss of a great part of fodder and pasture areas. So that, from the total area of Hamoon lakes in Sistan, of over 294,150 hectares, in 1983 about 76.6 percent was water surfaces, 19.2 percent covered with wet grass and 4.2 percent was covered by canebrake. Unfortunately, in 1999, approximately 100% of it was dry and free from any watery surfaces, pasture, or canebrakes (Ebrahimzadeh, 2000). Therefore, due to the removal of canebrakes and pastures surrounding the Hamoon lake area and the disappearance of all watery surfaces, heavy damages were incurred to the livestock of Sistan area.

As result, out of 110,000 cows and calves, about one million sheep and goat, and a significant number of camels, horses and donkeys existing in Sistan area in the period prior to drought, only about 20% of them remained in the area. The rest disappeared due to the impossibility of providing fodders (Field Studies, 2009).

In addition, more than 80 million m^2 of reed mat were produced from the lake canebrake and more than 478 thousands of birds were hunted from the lakes. However, they all reached to zero. In addition, the amount of fish caught from the lake was more than 12,000 tonnes in 1997, but, today, it reached to zero.

Therefore, the economic income due to livestock and fishery activities, which totalled thousands of million dollars, sharply declined during the recent drought. With respect to this issue, from the total number of 1 million and six hundred animal units in Sistan, each one consumed 300 fodder units and pasture products around the Hamoon Lake. If the value of each fodder unit is given equal to the energy produced from 1 kg of barley (Koochaki, 1987, p. 188) and since barley is purchased 2000 Rials per kilogram in the current situation in the area, it results that,the 960 billion Rials that were produced each year as economic value from the fodders and the postures of the Hamoon River are practically out of access today. If calculations are made for the seven years of drought, more than 672 billion Rials damages occurred in the area.

Meanwhile, the amount of hunted birds from the lake was more than 478,733 birds in the same year. If we assume that each bird has one kilogram meat on average and that the price of each kilogram of bird meat costs 30,000 Rials, it results 14.3 billion Rails earnings. But now, if we calculate taking into consideration the seven-year drought, more than 100 billion Rials losses were incurred by Sistan.

Moreover, about 30 million m^2 of reed mat were produced by using the existing reed and papyrus in the lake. Currently, the price of each square meter of reed mat is equal to 5000 Rials, therefore, more than 150 billion Rials of annual income and economic production were earned by Sistan. If we calculate the income for the 7 years of the recent drought, 1050 billion Rials losses were also incurred by Sistan.

Finally, from 12,000 tonnes of fish, if we take into consideration its present value of 20,000 Rials per kilo, an annual economic income of about 240 billion Rials was provided for the area. Their lack during the last 7 years of drought equals to 1680 billion Rials losses for the economy of Sistan.

Table 2. *Water, dry, grass and rush fields of Hamoon Lake before and after the year of drought, 2005*

Total lake area	Areas of Hamoon			Land cover	Year
	Puzak	Saberi	Hirmand		
225465	14449	67165	143851	watery region of lake	before drought
0	0	0	0	dry region of lake	
12282	4660	2860	4867	rush region of lake	
56398	3481	5485	47432	wet grass cover of lake	
294150	22950	75510	196050	Total Areas of Hamoon	
0	0	0	0	watery region of lake	after drought
294150	22950	75510	196050	dry region of lake	
0	0	0	0	rush region of lake	
0	0	0	0	wet grass cover of lake	
294150	22950	75510	196050	Total Areas of Hamoon	

Source: field study by authors, 2008

THE ROLES AND DUTIES OF GOVERNMENT IN CONTROL AND MITIGATION OF DROUGHT AND ITS EFFECTS

Researches show that the drought started in 1999 was the most severe drought in the area in the last 50 years (Shardul et al., 2001). The government's policies and programs are not able to mitigate the negative impacts of drought to zero, but they are able to decrease them up to a tolerable level. Therefore, the main discussion of this part would not be the negative effects of the drought, but how to reduce such effects, this means trying to stop the negative impacts of drought, planning and trying to decrease their negative impacts.

In this respect, the government can have different options for reducing the drought effects. However, in a general classification, they can be divided into three main or basic categories (Davarpanah, 2001) that include:

1) planning based on the effects of previous droughts to reduce negative effects of future droughts;
2) government intervention to reduce the effects of drought;
3) providing operational plans to deal with unpredictable effects of drought.

The government reactions shall be designed in a way to establish a balance between active reaction (risk management) and inactive reactions (crisis management). This balanced program can be defined as national operational program. This program should consider both subsequent and previous relationships and should have a complete relation with national and international laws and regulations. Furthermore, this national operational program can be very helpful in decreasing the drought effects. This program can include the following:

1) scientific attitude to natural disasters and its effects;
2) creation of previous advanced warning systems;
3) trying to convert system from crisis management to risk management;
4) development of governmental structure abilities to deal with natural crisis;
5) preparation and definition of natural and regional coping strategies to deal with food shortages;
6) planning for short term employment projects (during the period of drought and flood);
7) precisely defined program for insurance of agriculture crops and livestock;
8) exploring participatory approaches for managing the negative effects of drought and flood;
9) utilization of local resources together with preserving natural resources;
10) establishment of intervention policies and providing clear rules and regulations;
11) utilizing international partnerships;
12) changing the social views through education by the use of mass media;
13) coordinating efforts of governmental organizations;
14) use of unusual water resources.

CONCLUSION AND RESULTS

Drought affects economy in different ways. Because of drought, agriculture communities encountered with water shortage, loss of products, financial tensions and so on, and, at the same time, aquatic and wild life try to search and find suitable living areas, food and water.

A great deal of public sector costs will be paid each year for land restoration and financial help to the drought victims. Million Rials from the private sector investments have been lost or re-distributed through insurance. Damages to non-insured parts cause the loss of income and revenues of the farms and paralyze the opportunities for reproduction. Although drought costs represent a small part of the national production (Kuntsun, 2001), its effects on communities and local economy is devastating.

The results of this research emphasize that the prevailing condition on hot and dry areas and its environment changes has a deep effect on all its human, economy, social and ecological aspects of such areas, particularly their agriculture economy.

In the Androeek part of Sistan, which once was full of blessings, now, because of climate changes, we can observe considerable changes in its economic life. Thus, the area under cultivation has reached from 120,000 hectares prior the drought to 8,000 hectares after the drought, while the losses were estimated to about 4,506,798.8 million Rials or equal to 506.3 million dollars.

In the case of the Hamoon Lake, which is about 294,150 hectares, in the period before the drought almost 225,465 hectares was covered by water, 12,287 hectares covered with canebrake and 56,398 hectares formed a wet area with grass cover. Today, after the drought, the entire surface of the lake is covered by dry area and has no water. This has caused the drying of the lake and unavailability of livestock forage, making reed mat, hunting birds and fishing. Because each activity reached practically to zero, the damages and losses amount to over 9,550,534 Rials, equal to 1,073 million dollars. Meanwhile, the number of animal units decreased from about 1,600,000 to less than 500,000 units. All the above-mentioned functions due to drought and environmental changes virtually caused the cessation of more than 80% of agricultural activities in this area, so that the income and the employment of the villagers and of the urban inhabitants engaged in relevant agricultural activities decreased to a minimum.

Therefore, we may say that the environmental challenges due to drought has practically faced the agriculture economy of the area with a serious problem and has declined its economic functions. Strategies obtained from this research indicate that the producers in the agriculture sector, in the drought conditions of Iran, have a limited time framework for decision making on production. When these decisions are made, the people working in agriculture will passively encounter the effects of a great number of factors that are out of their control, with the hope that their decision is effective.

More accurate prediction of drought occurrence, its frequency, location and severity enable the local producers to make decisions that are more appropriate. For example, if there is a prior warning about the occurrence, location and severity of drought, producers can select the type of their products more accurately, so that, instead of local products, it is possible to use more products that are drought resistant. If there is prior warning about the drought occurrence, they can programme when to sell their animals and avoid over supplying animals to the market in the time of drought occurrence, and, thus, prevent the price decrease and its resulting losses. At a broader level, accurate prediction of drought can help national producers to be ready for dealing with drought effects on the market (Glantz, 1982; Admge et al., 1995). In order to deal with drought and its effects, the government interactions shall be designed in a way to be able to establish a balance between active interaction (risk management) and passive interaction (crisis management). This balanced programme should be included in the national activity programme, which contains subsequent and previous functions, and also in the national and international programmes. Such kind of scientific programmes can be effective in reducing drought effects.

Table 3 clearly shows how the damages incurred to the agriculture economy of Sistan during the recent drought, which is over 14,057,332.8 million Rials or equal to 1,579.5 million dollars of loss, virtually indicate the crisis occurrence in the area.

Table 3. *Agricultural crops and produce nets in Sistan and the damage during the recent 7-year drought (1998-2004)*

Total of damage to agricultural economy during the 7-year drought in Sistan	**The rate of economic value of damage during drought**	**Percent of damage**	**Economic value (million Rial)**	**Value Rial**	**Unit**	**Production 1997**	**Crop**
million Rial	million Rial						
2107980	30141	90**%**	334600	2000	kilogram	000/300/167	wheat and barley
8/193818	4/27688	90**%**	30765	3000	kilogram	000/255	grape and pomegranate
2205000	315000	90**%**	350000	2000	kilogram	000/000/175	other crops
6720000	960000	100**%**	960000	2000	kilogram	000/000/480	provender
1050000	150000	100**%**	150000	5000	square meter	000/000/30	mat
100534	14362	100**%**	14362	30000	one o bird	733/478	hunting of birds
1680000	240000	100**%**	240000	20000	kilogram	000/000/12	fishing
8/14057332	4/2008190	Total					

Source: accounts by the authors, 2008

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