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GIS-based Monitoring and EWSs of Desertification (Case study; southeastern of Iran)

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ABSTRACT

Today one of the ecological crisis is the phenomenon of desertification that affecting the world. Desertification is more related to social and anthropogenic issues than natural causes and it becomes more important over the time. Monitoring is the systematic collection and analysis of information as a project progresses. In this study, using AHP method and GIS techniques has been to assess desertification process with IMDPA model in 5.7864 acres of Southeast region in the Iran. The results of the analysis showed that desertification benchmarks and indicators in the three periods had a nonlinear trend of desertification process in the region so that the numerical value is equal to 2.73 in the period 2001-2004 but In the period 2004-2007 the figure has decreased that is show decreasing trend of desertification in recent years and In the period 2007-2010 the numerical value is 2.55 that observed a increasing trend of desertification. Among the indicators studied, aridity and annual precipitation indicators were maximum effect with values 3.81 and 3.4 And SAR values has 1.17 that the least impact on desertification. After analysis of data we understanding that in the many years we had in warning about indicators but we located in not warning years in 2007 and 2008 with climate benchmark. We find that region is not in warning about SAR indicator in all years of study and we are in warning about precipitation indicator in all years except 2007 in region.

Key words: Monitoring, Desertification, EWSs, IMDPA, Iran

INTRODUCTION

Land degradation is a global process which ultimately leads to a reduction of soil fertility (Luca Salvati, 2012). In dry areas Land degradation coupled with extreme bio-physical and socio-economic phenomena, phenomena, may turn into an irreversible process of environmental degradation that is desertification

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(Montanarella, 2007). In the Mediterranean basin, sensitivity to Land degradation has generally been associated to ecological conditions (e.g. climate aridity, soil characteristics and erosion, slope, vegetation cover) together with specific aspects of drought, human pressure (e.g. population density), and unsustainable land use management(Salvati, 2012). Desertification was initially defined as the change of productive lands into desert, caused by human activity, as suggested by Aubreville in 1949 (Herrmann and Hutchinson, 2005); later as the development of barren mobile sand dunes as described by Le Houerou Houerou in 1968 for the northern edge of the Sahara (Dregne, 1977). The United Nations Environment Program in 1977 defined desertification as "the diminution or destruction of biological potential of land which can lead ultimately to desert-like conditions"; UN member countries have ratified the United Nations Convention to Combat Desertification (UNCCD) which provides international guidelines for responding to desertification. According to the definition in this Convention, desertification is "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities" (Abubakar,1997; Warren, 2002; Singh, 2009; Verstraetel et al.,2009; Andrew,2010; Dawelbait and Morari, 2012; D'Odorico et al., 2013). It is widely recognized that desertification is a serious threat to arid and semiarid environments which cover 40% of the global land surface and are populated by approximately 1 billion humans. Given the potential relevance of this problem, it is surprising that there is no consensus on the proper way to assess the desertification status of a piece of land. During the last 70 years, conflicting definitions have produced both different assessment methodologies and divergent estimates (veron et al., 2006). Desertification is regarded as one of the most serious social–economic–environmental issues in arid, semi-arid and dry sub-humid areas (Sepehr and zucca, 2010). Finally, several studies have been conducted to assess desertification which many regional models are present. The most important offered models are UNEP-FAO (FAO/UNEP, 1984; Grumblat, 1991; Harahsheh, 1998;), TAXONOMY (Babaev et al., 1993: Kharin, et al. 1985) ESAs[1] (Basso, F. et al. 1999; Giordano, et al. 2002; Ladisa, 2002;), MEDALUS (European Commission, 1999; Kosmas, et al. al. 1999; Zehtabian, Gh., et al. 2005, 2008), ICD[2] (Ekhtesasi, M., M. Mohajer, 1995), MICD[3] (Ahmadi, et et al. 2005), IMDPA[4] (Ahmadi, 2004; Zehtabian, et al. 2009). Monitoring is the systematic collection and and analysis of information as a project progresses. It is aimed at improving the efficiency and effectiveness of a project or organization. It is based on targets set and activities planned during the planning phases of work. It helps to keep the work on track, and can let management know when things are going wrong. If done properly, it is an invaluable tool for good management, and it provides a useful base for evaluation. It enables you to determine whether the resources you have available are sufficient and are being well used, whether the capacity you have is sufficient and appropriate, and whether you are doing what you planned to do. In comprehensive management, the monitoring content is systematic collection and storage of data from activities and strategies that provide assessment and report about the overall condition of the study area. It must be understood that the Earth sensitive is not static and it is require to constant monitoring (Salvati,Zitti;2009) and Some of these environmental changes require to an an early warning system Because of the cumulative effect of these changes on society and the environment in the long term will be more and more destructive and ultimately imposes higher costs. Also according to natural and human hazards Such as drought, flood, deforestation, erosion, desertification and etcetera it is so important that we need to monitor and predict these effects to help for

[1] Environment Sensitive Areas to Desertification
[2] Iranian Classification Desertification
[3] Modified Iranian Classification Desertification
[4] Iranian Model of Desertification Potential Assessment

reduce these effects. There are many definitions of an EWS that are used to guide the actions of individuals, groups, and governments. The formal UN definition is as follows: "The provision of timely and effective information, through identifying institutions, that allow individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response" (ISDR, 2003). Masudi(2011) provide an early warning system for the study of desertification in Kashan plain with water and climate indicators. She used from IMDPA model and GIS and defined it in terms of both hardware and software. After evaluation of benchmarks she found that the numerical value of water benchmark is 3.36 and had the greatest impact on desertification intensity. Finally, the sensitive areas were identified in order to monitor the relevant data necessary equipment shall be installed in those areas. Khosravi (2012) presented presented an early warning system for the study of desertification in Kashan plain with use of IMDPA and GIS. With regards to region condition he was evaluated 8 benchmarks and 32 indicators. Eventually for present of an EWSs information on criteria and indicators for desertification over a nine year period was the systematic collection and analysis. Finally base on the Benchmarks and indicators affecting desertification, sustainable threshold was defined for each indicator. Timothy M. Lenton(2013) in his study offer a new classification of environmental shocks from a dynamical systems perspective, and reviews early warning systems for environmental shocks, particularly in climate systems and ecosystems. And he said that Three main categories of environmental shock are identified; extreme events, abrupt swings, and tipping points.

MATERIALS AND METHODS

Case study

The study of area is located between 2840107 to 2828886 longitude and 733558 to 747693 latitude in the UTM system. This area restrict from north and northwest to Nikshahr city, from southwest is limit to Jask area of the Hormozgan province in Iran, the south is by the gulf of Oman and the east curb in the range of Chabahar in Iran and The area is 5/7864 acres. Politically the region is part of coastal Konarak city and located in 120 kilometers from it. The main occupation of this area is Farming and fishing. According to right conditions of soil and groundwater, this area is one of the poles of agricultural in the Sistan and Balochestan province in Iran. The main river in the region is the Rabch that emanates from the heights of Nikshahr and after a long distance entering to Oman gulf. Coastal dunes with a height of 5 meters along the coast have formed and the majority of these hills have been active and moving. In the study area in summer there is monsoon rainfall and so in the winter systematically regime that influenced by the origin of the Red Sea and the Mediterranean. Most of the rainfall in autumn and winter, and the long-term average rainfall are 94/98 mm and the average temperature estimate to 26/6 ° C. The average relative humidity was 65%, the mean wind speed is 6 knots, the prevailing southwest wind and 40% is the percentage of calm winds. Geologically the study area is part of the Makoran region and also follows from the nature of the zone. And in the long term the average potential evapotranspiration estimated to 2180/3 in the region.

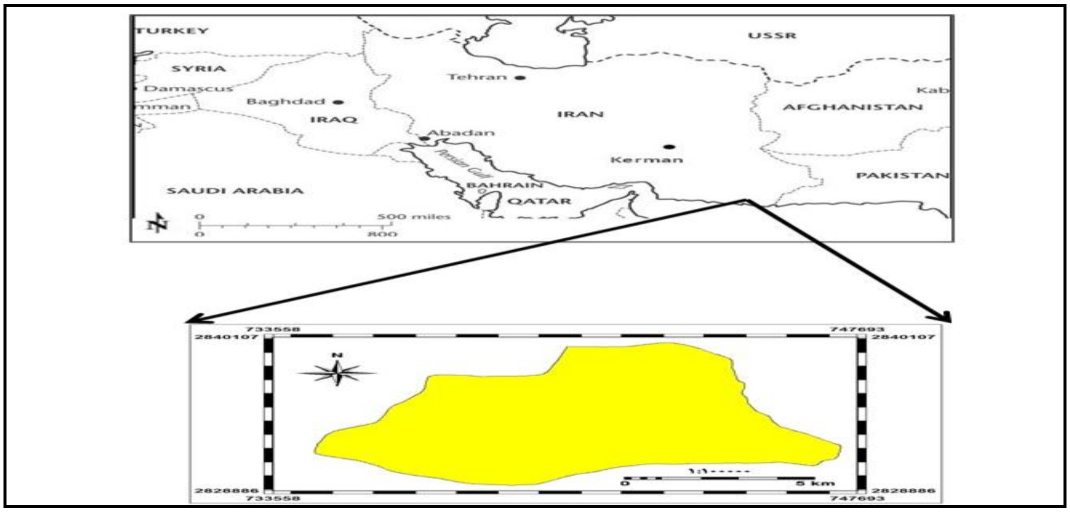

Fig1. location map of the study area

Methodology

At the start, the study area determined on topographic maps, geology map, geomorphology map, and then these area did control with a field visit. We selected 2 benchmarks and 6 Criteria with used of IMDPA model and AHP Technique in this region.

Tab 1. Weight of all benchmarks in IMDPA model with AHP

benchmark	Climate	Geology-geomorphology	Soil	Agriculture	Erosion	Water	Economic-social	Technology - Urban Development	Vegetation
Weight	0.207	0.063	0.072	0.114	0.074	0.192	0.153	0.047	0.098

The next step we used from IMDPA model to evaluate the extent of desertification during the period. Based on its effect on desertification with regard to region condition, field survey, and expert opinion, a weigh between 1 to 4 was gave to each index; so that value 1 and 4 are the best and worst, respectively(Tab2). Based on the performed weighing a map was prepared for each index. Then, to determine desertification intensity for each criterion, geometric average of indices of the same criterion and relation (1) were used, and finally based on performed weighing a map was prepared for each criterion.

Index-X= [(Layer-1).(Layer-2)…(Layer-n)]1/n Relation (1)

Where, Index-X is the related criterion; Layer is the indices of each criterion; and n is number of indices in each criterion.

We mapping region about water benchmark(Tab3) and climate benchmark(Tab4) then eventually we have analysis about change trend with it in case study.

Tab 2. Frequency distribution of intensity classes of present desertification conditions

Unconsidered	Low	Medium	High	Very High
0/01-1	1 - 1.50	1.51 - 2.5	2.51 - 3.50	3.51 - 4

Tab 3. details of water benchmark in IMDPA model

Evaluation indicator	Desertification class	Very high	High	Medium	Low	Unconsidered
	score	3/51-4	2/51-3/5	1/51-2/50	1/00-1/50	0/01-1
(Decline in groundwater) cm/year		>50	30-50	20-30	10-20	0 - 10
(EC) µmhos/cm		>5000	-5000 2250	750-2250	500-750	<500
(SAR) µmhos/cm		>32	26-32	18-26	15-18	<15

Tab 4. details of climate benchmark in IMDPA model

Evaluation indicator	Desertification class	Very high	High	Medium	Low	Unconsidered
	score	3/51-4	2/51-3/5	1/51-2/50	1/00-1/50	0/01-1
Annual precipitation (mm)		< 75	75 – 150	150 - 280	280- 600	≥600
Aridity index(P/ET)		< 0/05	0/05 - 0/2	0/2 -0/45	0/45 - 0/65	>0/65
Drought index(Class code)		1	3،2	4	6،5	7

Due to the special climate region 6 stations have been selected that had a similar climate zone. Because the lack of statistical information we used only Konarak station for climate indicators. The study area is lacking station of hydrometric and the variation of stations in the radius of 200 km from the study area, eventually 7 stations were selected for the study.

RESULTS AND DISCUSSION

Climate benchmark

To calculate the aridity index we used from (P/ET) that P is annual precipitation and ET is evapotranspiration. So we used from Standardized annual precipitation ($P-P_{M/}SD_P$) for drought index that P is annual precipitation and P_M is average of annual precipitation and SD_P is Standard deviation of Long-term rainfall data (Fig2). To calculate indicators of water we used from hydrometric stations in the area and declining aquifer levels are not the same at all points and depend to topography, the withdrawal of ground water, hydraulic gradient, texture and thickness of aquifer in each area.

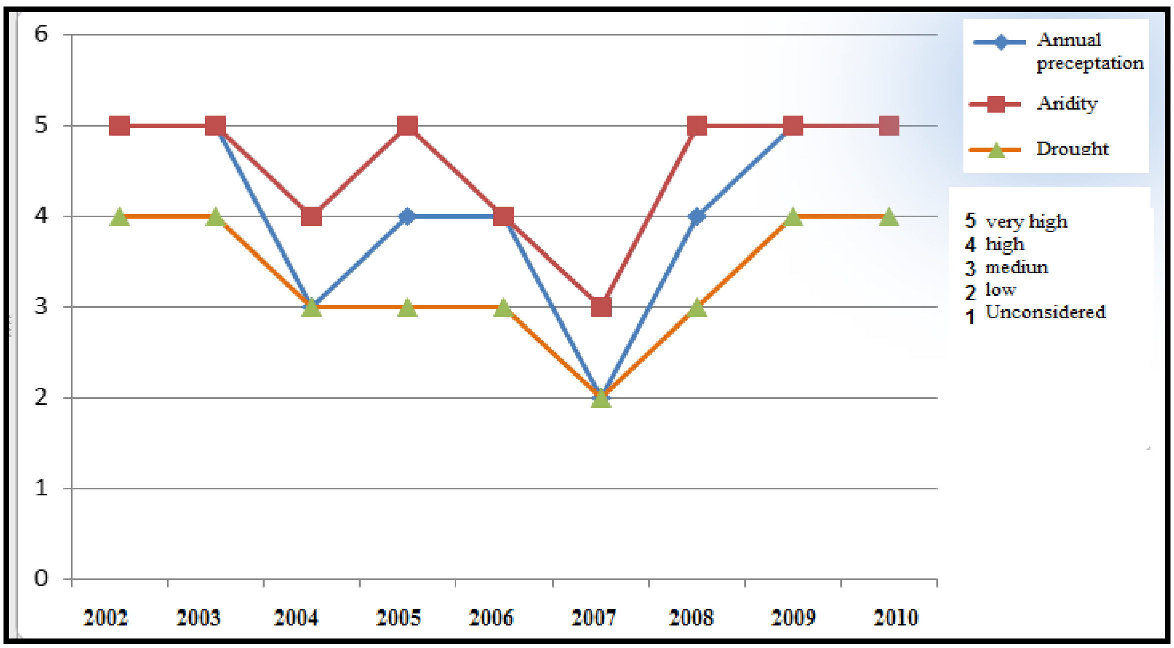

Fig 2. Schematic view of climatology indicators

Water benchmark

The fig3 show intensity of desertification in the study area of the Fluctuation groundwater table indicator (decline in groundwater).

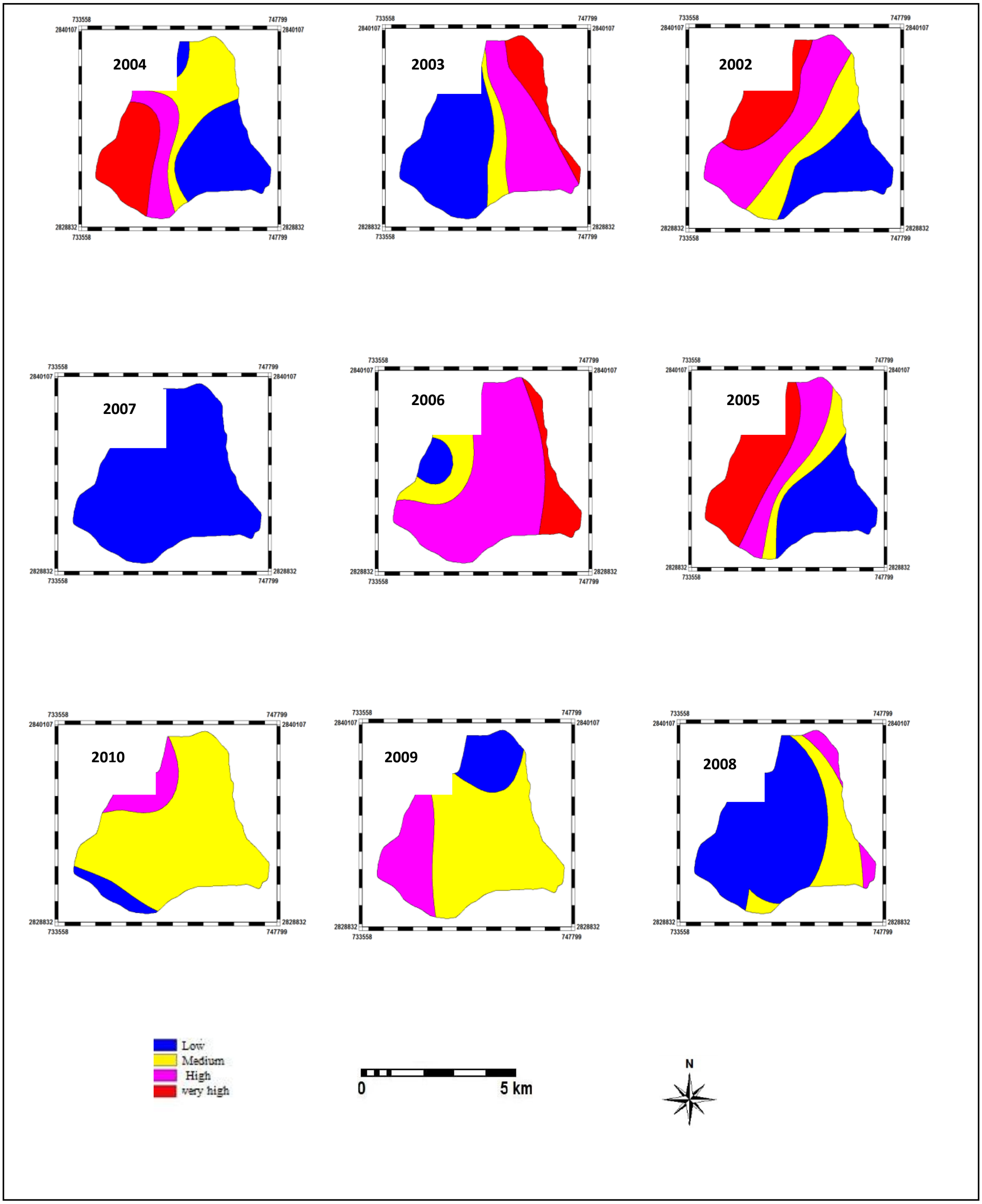

Fig 3. Mapping of desertification with fluctuation groundwater table indicator

The Fig4 shows electrical conductivity indicator in a three-period of study. As the result, along the uncontrolled withdrawal of groundwater resources and Aquifer decreased levels of aquifer we can apperceive Sever decline of groundwater quality and more salinity of before.

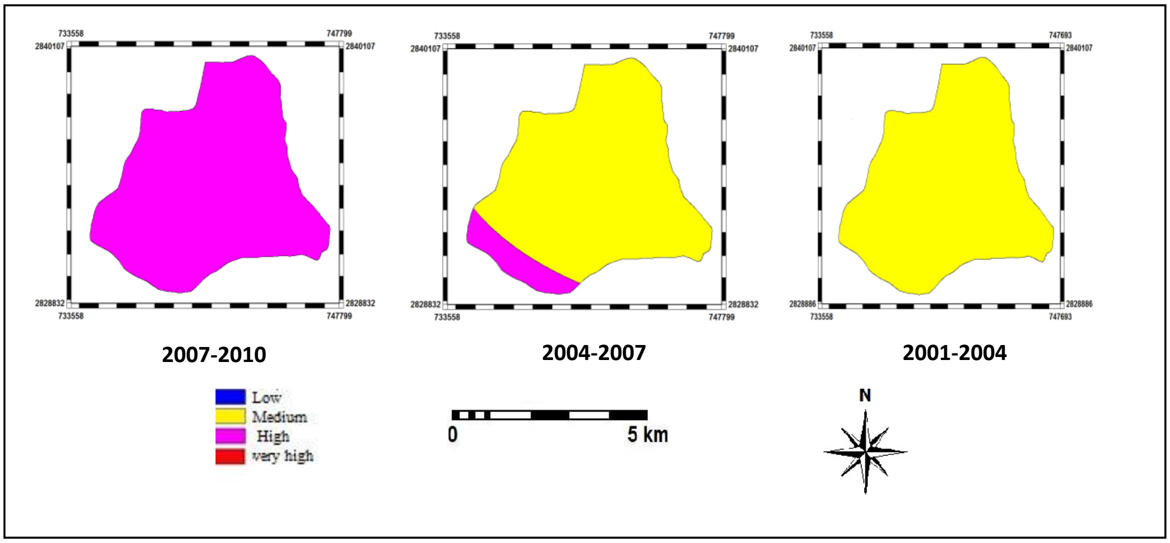

Fig 4. Mapping of desertification with EC indicator

Fig5 show Classes of status desertification of sodium absorption ratio indicates. Results showed that the region is in the last 10 years in both Class 1 and 2 of the sodium absorption ratio and means that it is in low and medium class of land degradation.

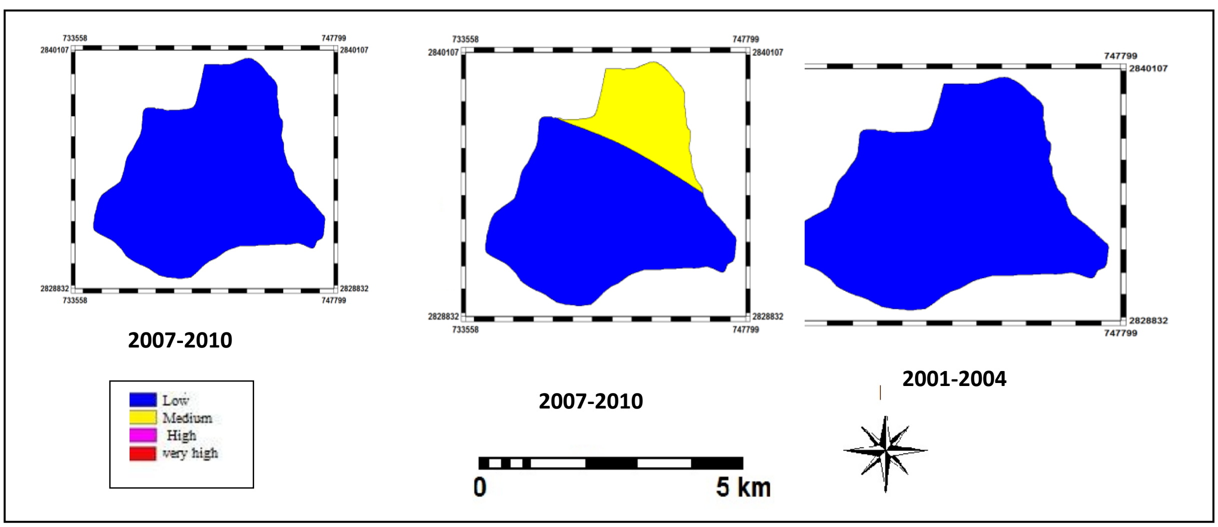

Fig 5. Mapping of desertification with SAR indicator

Tab5 shows the extent of desertification class from the Fluctuation groundwater table indicator (decline in groundwater) in the study area. The result show that in 2007-2010 periods with this item the region is not located in very high class of desertification While in 2005 more than 34 percent of the study area has been in very high desertification class.

Tab 5. Extent of desertification class with fluctuation groundwater table indicator

extent / year	Very high		High		Medium		Low	
	Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)
2002	20/49	1612	34/16	2686/5	19/83	1559	25/52	2007
2003	11/52	906	31/96	2514	9/01	708/5	47/51	3736
2004	23/59	1856	13/98	1099	27/71	2179/5	34/72	2730
2005	34/49	2712	21/13	1662/5	11/81	929	32/57	2561
2006	11/64	916	68/93	5420/5	13/87	1091	5/56	437
2007	-	-	-	-	-	-	100	7864/5
2008	-	-	5/37	422/5	21/07	1657	73/56	5785
2009	-	-	22/13	1740	63/58	5000/5	14/29	1124
2010	-	-	12/84	1010	82/02	6450/5	5/14	404

Extent classes of desertification of electrical conductivity and sodium adsorption ratio indicators are given in the table6. During this year decrease in desertification class of electrical conductivity in this region is visually evident as decrease from low class and increase to high class in these years. In 2002 the area has not been subject to severe class but in 2010 the entire area has been intense class. The result show that changes in the sodium absorption ratio in this region is not significant in this period.

Tab 6. Extent of desertification class with EC and SAR indicator in three periods

Class / period		High		Medium		Low	
		Percent	Area(ha)	Percent	Area(ha)	Percent	Area(ha)
2001-2004	EC	-	-	91/42	7189/5	8/58	675
	SAR	-	-	-	-	100	7864/5
2004-2007	EC	-	-	100	7864/5	-	-
	SAR	-	-	77/60	6102/5	4022	1762
2007-2010	EC	100	7864/5	-	-	-	-
	SAR	-	-	-	-	100	7864/5

Long-term average of rainfall in region was considered as the threshold of Precipitation and for aridity indicator that obtain from (P/ET) we used from long-term data of them too and then we used from ($P-P_{M}/SD_{P}=0$) to threshold of drought indicator (Tab7). According to experts and previous studies 20 cm drop in the groundwater table was set as the threshold loss of levels. In addition base on the graphs Schuler (Mahdavi,2007;Alizadeh,2002) 2500 μmoh/cm was considered as the threshold of electrical conductivity and also 16 μmoh/cm was considered as the threshold of sodium absorption ratio. After analysis extent of warning region and not warning region with climate benchmark (Tab8) and extent of warning region with water benchmark (Tab9) also made.

Tab 7. Warning years with climate benchmark

Year / indicator	2002	2003	2004	2005	2006	2007	2008	2009	2010
Precipitation	warning	warning	warning	warning	warning	-	-	warning	warning
Aridity	warning	warning	warning	warning	warning	-	-	warning	warning
Drought	warning	warning	warning	warning	warning	-	-	-	warning

Tab 8. extent of warning region and not warning region with climate benchmark

Area / Year	Range warning		The threshold value or less	
	Percent	Area(ha)	Percent	Area(ha)
2002	54/65	4298/5	45/35	3566
2003	43/48	3420	56/52	4444/5
2004	37/57	2954/5	62/43	4910
2005	55/62	4374/5	44/38	3490
2006	80/57	4336/5	19/43	1528
2007	-	-	100	7864/5
2008	5/37	422/5	94/63	7442
2009	22/13	1740	77/87	6124/5
2010	12/84	1010	87/16	6854/5

Tab 9. extent of warning region and not warning region with water benchmark

Area / Year		Range warning		The threshold value or less	
		Percent	Area(ha)	Percent	Area(ha)
2001-2004	EC	-	-	100	7864/5
	SAR	-	-	100	7864/5
2004-2007	EC	8/58	675	91/42	7189/5
	SAR	-	-	100	7864/5
2007-2010	EC	100	7864/5	-	-
	SAR	-	-	100	7864/5

CONCLUSION

Surveys performed on the weighted average indicate shows that aridity indicator had the most influence and sodium absorption ratio had the lowest influence in the region.Between these two criteria, water criteria show an increasing trend that means a lack of proper nutrition and taking too much of the aquifer. Climate benchmark shows a decreasing trend during 2004-2007 that the climate in this region is represent improvement but again in the next period 2007-2010 has increased that it is fully consistent with the conditions prevailing in the area in recent years. The results show that the climate benchmark is dominant during periods and it is classified in high class. With little careful analysis of the charts of criteria and indicators of desertification in the three periods studied, we had found that the nonlinear process of desertification. As in the period 2001-2004 the numerical value equal to 2.73 but the number has decreased in the period 2004-2007 and showed a decreasing trend which was estimated the main cause of desertification in recent years to improve the climate variables including precipitation. In the period 2007-2010 the number was 2.55 and the observed trend of increasing desertification. In this during drop in term of EC indicator in region is evident so in these years decrease from low class and increase to high class. In this during changes in SAR is not evident and investigations shows that region is in low and medium class in term SAR. Of the two indicators of water quality in the area, EC is greater than the SAR in region. This factor has been directly related to increased harvest levels and increased salinity of groundwater in the study area. In the end, it is suggested that the thresholds vary from place to place and over time then every few years to be determined threshold of each indicators by monitoring and after we have more realistic EWS. To monitoring just some indicators that in every region are important must be measured and with this way the costs are estimated to be logical and easier inventory and coordination between departments and agencies.

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