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The survey of linkage between climate changes and desertification using extreme climate index software (Case study: Kashan)

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Abstract

Climate is the most important factor which control desertification .In order to detect climate changes in desert zones, time trend analysis is applied to extreme indices in Kashan station using extreme climate index software (ECIS). Results show significant trends in extreme indices during the past decade 1995-2004 and the pronounced warming is associated with a negative trend in cold extremes. The finding revealed that the frequency of warm (cold) extreme indices is increased (decreased) and probability, the problem of desertification in Kashan region will be extended.

Keywords: Climate change; Desertification; Extreme Climate Indices; Trend, Return Period.

1. Introduction

Climate is the most important factor which control desertification and changes in surface type may also have important climatic consequences in arid and semi-arid areas. At the 1992 U.N. Conference on Environment and Development held in Rio de Janeiro, desertification was formally defined as" land degradation in arid, semi- arid and dry sub-humid areas resulting from various factors, including climatic variation and human activities" (UNCED, 1992).

Desertification is now a direct threat to over 250 million people around the world, and an indirect threat to a further 750 million people.Current best estimates suggest that roughly 70 percent of all agriculturally used dry lands are to some degree degraded, especially in terms of their soils and plant cover. The total area concerned is 3.5 billion hectares and over a hundred countries are now suffering from the adverse social and economic impact of dry land degradation (Williams, 2001).

Robinson and Henderson-Sellers (1999) studied the role and changes in the character of the surface in climate change on the local, regional and global scales. They showed that climate change can result from the action of any of the processes affecting the climate system and both modeling studies and observations suggested that the major human activities on the surface likely to lead to regional or global climatic as well as practical consequences are deforestation and desertification. Kelly and Hulme (2002) investigated the linkage between desertification and climate change and found that determining the precise contribution of climate variation to the desertification problem is not an easy matter and climate change does alter the frequency and severity of drought in various parts of the world and can cause desiccation. Zehtabian et al. (2005) showed that environmental and human factors all together causes desertification and degradation of

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resources in Iran and environmental factor includes two sub-factor, climate and length of drought period. The geographic distributions of major terrestrial ecosystems (desert, savanna, forest, etc.) are largely governed by patterns of temperature and precipitation. Such systems can migrate hundreds of kilometers over several years in response to climate change.

During the last two decades there has been occurred a dramatic temperature increase in the Northern Hemisphere. The recent warming has dominated the dry land areas and desertification process as a great problem affects most of the arid and semi-arid countries such as Iran. It should be mentioned that the total area of deserts in Iran is about 12 million hectares (Arzani et al, 2005).

One of the main themes of current climatology research is to detection of climate change resulting from anthropogenic activities (see, Brunet India and l Lopez Bonillo, 2001). On the other than, when the second assessment of the intergovernmental panel on climate change (IPCC, 2001) examined whether, globally, the climate was becoming more extreme or variable, studies in climate extremes events as climate change indicators has been increased and trend analysis in extreme daily temperature and precipitation events have been studied for individual countries and stations in the last few years (see, e.g., Klien Tank and Konnen, 2003; Zhang et al, 2001; Zhai et al, 1999; Alijani, 1998; Yan et al 2002; Haylock and Nicholls, 2000; Brazdil and Coauthors, 1999; Collins et al, 2000; Mohammadi, 2000; Bonsal et al, 2001; Goodes, 2004; Frich et al, 2002).

Results from CGCM1simulation also suggest that the extreme lengths of wet periods (days with more than 1mm of rain) may decrease over many tropical and subtropical continental regions as the climate warms. The projected impact on extreme lengths of dry periods (consecutive days with less than 1mm of rain) appears to be more variable. These are projected to increase in the Mediterranean, Southern Africa, and Southeast Asia (MSC, 2004).

Results from the studies' Kardovani (2000) also showed that the climate-related hazards or extreme weather events (droughts, floods and heat waves) take the heaviest toll on human life and exert high damage costs in many countries such as Iran in recent years.

In this study, an attempt was made to find the relation between frequency of extreme events, climate change and desertification. we propose a method for studying the behavior of climate extreme events using Extreme Climate Index Software.

2. Indices of Climate Extremes

Detection of change in climate against its variability is a key issue in climate research. Zwiers et al (2004) investigated detection climate change using trend analysis extreme indices and showed that indices climate extremes have been developed and maintained for the purpose of monitoring climate change. Results obtained from Petersson (2004) also demonstrated that extreme indices as indicators of change are essential tools and they are also potentially useful for climate change detection studies. A number of such indices are defined as the number of days in a year or season that daily values exceeded a time dependent threshold. These thresholds are typically defined as an annual cycle of daily percentiles that are estimated from a base period such as 1961-1990. Most of the indices defined in terms of counts of days crossing thresholds, either absolute (fixed) thresholds or percentile (variables) thresholds. Indices based on the count of days_crossing certain fixed thresholds (e.g. the 0°C threshold as used in frost day's index) can also be related to observe impacts and these indices are more suitable in climate change studies. However , changes in can be very much influenced by changes in other climate factor as well drier soils can also add to the intensity of daytime temperature by reducing cooling from surface evaporation. Conversely while an increase in average temperature will tend to reduce the occurrence of extremely cold temperature. The indices are expressed in annual values and, the temperature indices describe cold extremes (for example FD (frost day) and ID (icing day)) as well as warm extremes such as SU (summer days) and T40 (number of days with Tmax>=40°c) and the precipitation indices describe wet extremes and percentile thresholds for example RR20 (number of days with rain>20mm) and PER90Tmin (number of days with Tmin >90^{th} percentile). Annual day-counts indices based on percentile thresholds are expressions of anomalies relative to the local climate from the observed station series in the period 1961-1990 and consequently, the value of the thresholds is site specific.

List of over 50 climate change indices recommended by the research program on climate variability and predictability (WMO-CCl/CLIVAR) available on line at http://www.knmi.nl/samenw/eca (peterson , 2004).

3. Materials and Methods

In this paper, we selected a set of 24 indices of climate extremes. Of this set, 15 indices refer to temperature and 9 to precipitation (Table1.) In order to detect climate change, time trend analysis is applied to extreme indices using extreme climate index software (ECIS) package. The ECIS is a code under Matlab programming language which is contains different subroutines and written by the authors. In ECIS using daily data provides estimates of trends

Table1. Indices of Daily Temperature and Precipitation Extremes

INDEX	Description	Formula
FD	Frost Day	Number of days with Tmin<0
SU	Summer Day	Number of days with Tmax>25
ID	Icing Day	Number of days with Tmax<0
T40	Tmax >=40	Number of days with Tmax>=40
HWDI	Heat Wave Duration	Number of days with Tmax>5+mean
CWDI	Cold Wave Duration	Number of days with Tmin>-5+mean
TR	Tropical Day	Number of days with Tmin>20
RR1	Rain>=1mm	Number of days with Rain>=1mm
RR5	Rain>=5mm	Number of days with Rain>=5mm
RR10	Rain>=10mm	Number of days with Rain>=10mm
RR20	Rain>=20mm	Number of days with Rain>=20mm
CDD	Cold Degree- Day	sum of degree- days with Tmean-21
HDD	Heat Degree- Day	sum of degree- days with 18-Tmean
GDD	Growing Degree- Day	sum of degree- days with Tmean>=5.5
SDII	Simple Daily Intensity index	Annual pericipitation/no. of wet days
ETR	Extreme Temperature Range	Difference:Tmax-Tmin
PER10 TMIN	10^{th} percentile Tmin	Number of days withTmin<10^{th} percentile
PER90MIN	90^{th} percentile Tmin	Number of days with Tmin>90^{th} percentile
PER10MAX	10^{th} percentile Tmax	Number of days with Tmax>10^{th} percentile
PER90TMAX	90^{th} percentile Tmax	Number of days with Tmax>90^{th} percentile
PER10RR1	10th Percentile RR1	Number of days with Rain>10^{th} percentileRR1
PER90RR1	90th Percentile RR1	Number of days with Rain>90^{th} percentile RR1
PER95RR1	95th Percentile RR1	Number of days with Rain>95^{th} percentile RR1
WD	Wet Day	Number of days with Rain

in indices of climate extreme (Taghavi, 2005), and as an example, the methodology is applied in climate extreme in Kashan station near to desert of Dasht-e Kavir in Iran.

The synoptic station of Kashan is located in 33° 59́ N latitude, 51°27́ E longitude with the elevation of 982.3 meter. In this study, the values of the percentiles thresholds were determined from the observed Kashan daily series in the period 1966-1990 and the percentiles were calculated straight forward from the sample of all days in the series.

The ECIS includes several subroutines, such as Homogen Data, Index, Statis and Return Period (diagram1). In the Homogen Data program, daily data observations of synoptic stations with standard format are extracted and decoded. In the Gap subroutine, the missing value data are replaced. Output file is the Matrix of daily data of synoptic stations in the study period. In the Statis program, the statically characteristics of data such as mean ,max ,min and percentiles(10,90,95) of the variables are calculated .In the Index program, defined indices and trends are calculated and linear trends are fitted on the basis of the default functions in Matlab. In the Return Period program, the return period of indices and the annual amount of rainfall are estimated. In this program, the annual amount of rainfall in the 10 yr drought is calculated on the basis data of annual precipitation in the period study. For the day-count indices, the corresponding mean return period (Tret) is given by:

$$Tret=365/\overline{X}$$

Tret is expressed in days and the value $\overline{X}$ is mean of the number of days per year.

ECIS allows user to calculate trends of extreme climate indices for different time periods and for multiple stations. The final output of ECIS consists of Excel file include longitude, latitude, the trend of indices, the return period of indices and value of annual rainfall of station. This matrix includes m (sum of days in the period study) rows and 7 columns including year, month, day, daily precipitation, daily maximum temperature, daily minimum temperature and daily mean temperature, respectively. The results can then be displayed on a map using the user’s software of choice.

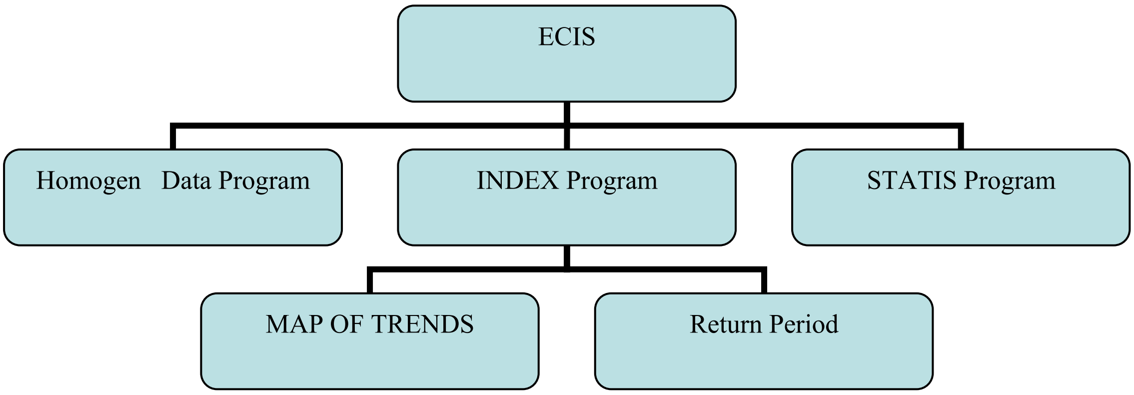

Diagram1. Flouchart of Extreme Climate Index Software

4- Results

Based upon data analysis the following results detected different trends in climatic extremes in the ~40-yr study period 1966-2004 in Kashan station (Table2). The cold extreme indices for example FD (frost day) show pronounced decreasing trend with value -0.395 .On the other hand the warm extreme indices such as SU (summer days) has increasing trend (Fig1). Analysis of the HDD (heating degree-days), GDD (growing degree-days) and SDII (simple daily intensity index) indices show increasing trend but the CDD (cooling degree-days) index has negative trend (Fig2). The cold wave duration (CWDI) index show increasing trend with values 0.487 but the TR (tropical days) and ETR (extreme temperature range) indices have minor negative trend (Fig3).

The analysis of daily precipitation observations show that the extreme precipitation indices RR1 (days with rain>1mm), and RR20 (days with rain>20mm) have negative trend but RR5 (days with rain>5mm), RR10 (days with rain>10mm) indices have positive trend (Fig4). The extreme precipitation indices such as PER10RR1 (10th percentile RR1) and PER95RR1 (95th percentile RR1) have positive trend but the WD (the number of wet days) and PER90RR1 (90th percentile RR1) have negative trend.

Table2. Trend in Indices of Extreme Temperature and Precipitation in Kashan in the period 1966-2004 and the recent decade 1995-2004

INDEX	Annual Trend (1966-2004)	Trend|annual (1994-2004)
FD	-0.4	-1.19
SU	0.235	1.05
ID	-0.037	-.05
T40	-0.59	0.55
HWDI	0.185	1.3
CWDI	0.487	-2.6
TR	-0.07	1.49
RR1	-0.19	0.290
RR5	0.022	0.109
RR10	0.022	0.254
RR20	-0.004	-0.045
CDD	-4.7	39.45
HDD	3.0	-39.5
GDD	0.43	0.027
SDII	0.017	0.11
ETR	-0.004	-.072
PER10 TMIN	-0.257	-1.034
PER90MIN	-0.062	1.7
PER10MAX	-0.143	0.046
PER90TMAX	-0.263	-0.227
PER10RR1	0.68	0.263
PER90RR1	-0.09	0.263
PER95RR1	0.008	0.245
WD	-0.12	0.01

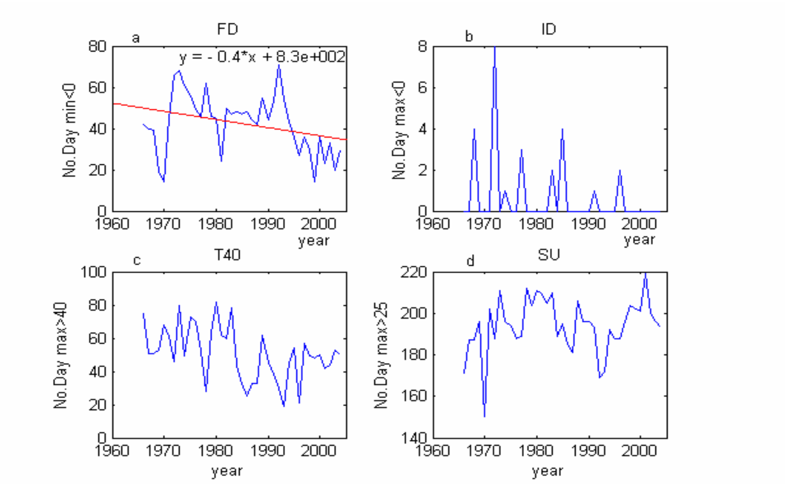

Fig. 1. Trend in indices a) FD, b) ID, c) T40, d) SU in Kashan station in the period 1966-2004

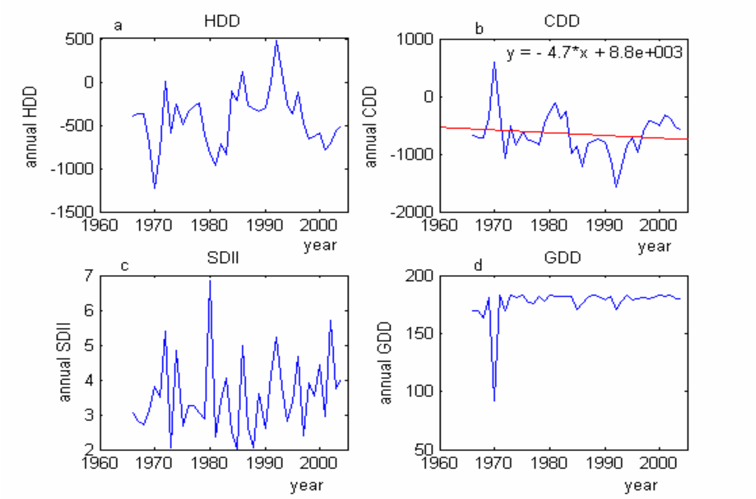

Fig. 2. Trend in indices a) HDD, b) CDD, c) SDII , d) GDD in Kashan station in the period 1966-200

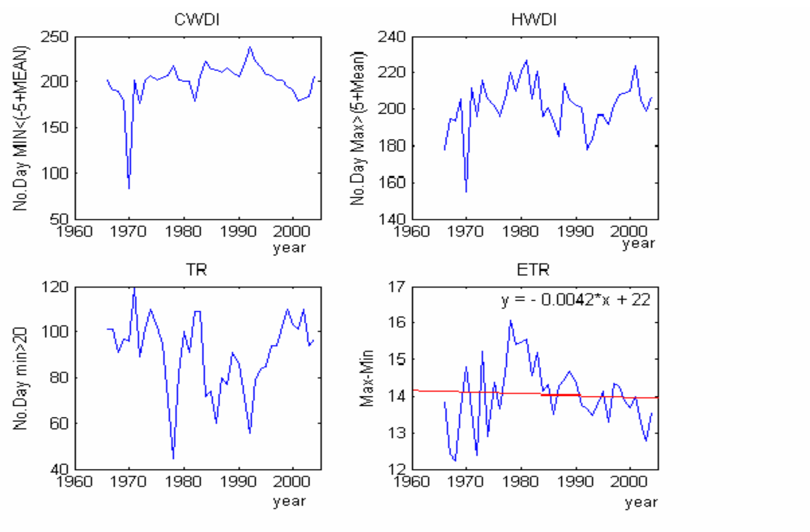

Fig. 3. Trend in indices a) CWDI, b) HWDI, c) TR, d) ETR in Kashan station in the period 1966-2004

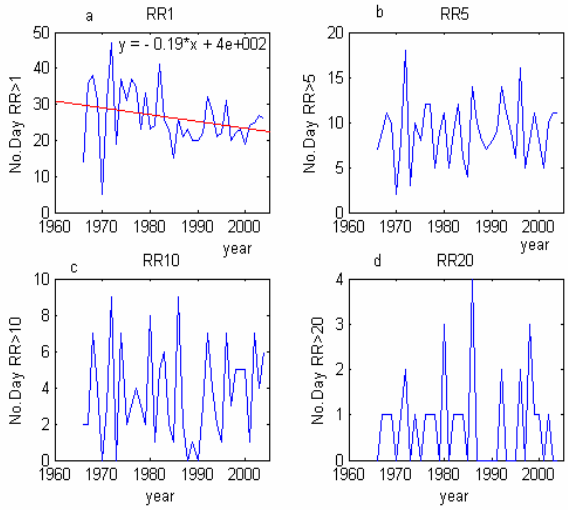

Fig. 4. Trend in indices a) RR1, b) RR5, c) RR10, d) RR20 in Kashan station in the period 1966-2004

The PER10Tmin (days with Tmin<10th percentile), PER10Tmax (days with Tmax>10th percentile) show pronounced decreasing trend but the PER90Tmin (days with Tmin>90th percentile) and PER90Tmax (days with Tmax>90th percentile) indices have minor-negativee trend (Fig6).

For the 10-yr sub period 1995-2004 significant trends could be detected in all of extreme indices and systematic warming in warm and cold extremes is seen. Our results in Table2. indicate the temperature rise in the Kashan in recent decade is basically associated with an increase in warm extremes, For example, the indices such as T40, SU, HWDI, and TR show pronounced increasing trends with values, +0.55, +1.05, +1.3 and +1.49, respectively. Besides, the results indicate that the cold extreme indices for example, FD and ID have pronounced decreasing trend and the warm extreme indices such as T40 and SU have increasing trend (Fig7). The analysis of daily precipitation observations during 1995-2004 showed that the extreme precipitation WD, RR1, RR10 and SDII have positive trend (Fig7). In order to compare the return period of indices in two periods ~30yr (1966-1994) and 10 yr (1995-2004), we investigated the return period of 8 extreme indices in Kashan station which have significant trends such as FD, SU, etc (Table3). Results in Table3 indicate that the Tret of cold extremes indices such as FD and ID increased and the Tret of warm extreme index (SU) decreased and therefore the frequency of warm (cold) extreme indices are increased (decreased). The Tret of precipitation extremes indices WD and RR1 are increased and the Tret of precipitation extremes indices SDII and RR10 are decreased. Data analysis of droughts in Kashan shows that if a 10-yr drought is occurred, the amount of annual precipitation will be 77mm.

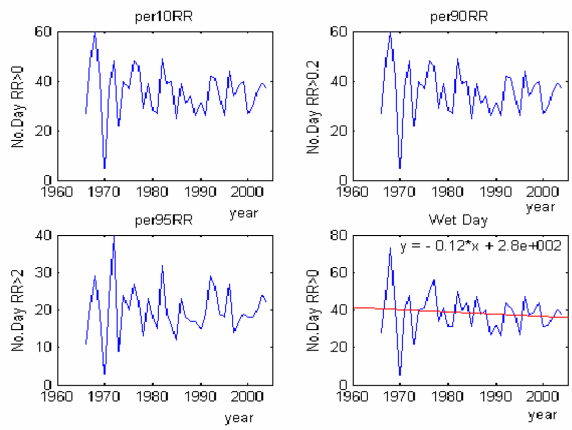

Fig. 5. Trend in indices a) PER10RR, b) PER90RR, c) PER95 RR, d) Wet day in Kashan station in the period 1966-2004

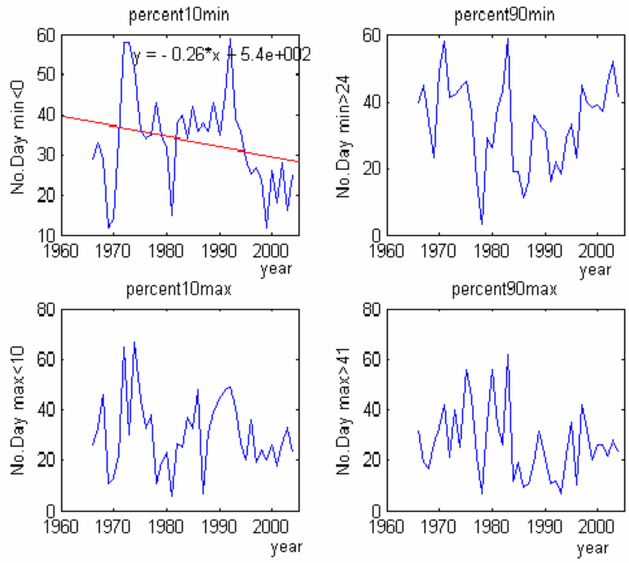

Fig. 6. Trend in indices a) percent10min , b) percent90min , c) percent10max, d) percent90max in Kashan station during period 1966-2004

Table3.The Return Period of climatic extreme indices in Kashan

INDEX	Tret (1966-94)	Tret (1995-2004)
FD	7.35	12.8
ID	460	1825
T40	7.01	7.8
SU	1.9	1.84
WD	9.4	9.86
SDII	106.7	94.5
RR1	13.52	15.27
RR10	106.7	82.9

5-Discussion and Conclusion

There can be little doubt that climate change during this century will significantly alter the distribution and abundance of terrestrial species. In this study, we propose a method for studying the linkage between climate changes and desertification using ECIS package. Results show pronounced trends in the period 1995-2004 in Kashan. The pronounced warming in this decade is associated with a decrease in cold extremes. The result The analysis of daily precipitation observations show that the extreme precipitation indices RR1, RR20, PER90RR1 and WD have negative trend but the extreme precipitation indices such as RR5, RR10, PER10RR1 and PER95RR1 have positive trends. Besides results show that the return periods for the ID, WD, FD, RR1 indices have increased. On the other hand the return periods for the SU, SDII and RR10 indices decreased and therefore the frequency of these extreme indices are changed. On the basis of a systematic analysis of observed changes in indices of climate extreme we conclude that probability, the climate of Kashan is changed and, the problem of desertification in Kashan region will be extended. Additional research will undoubtedly provide even more accurate scenarios for the future.

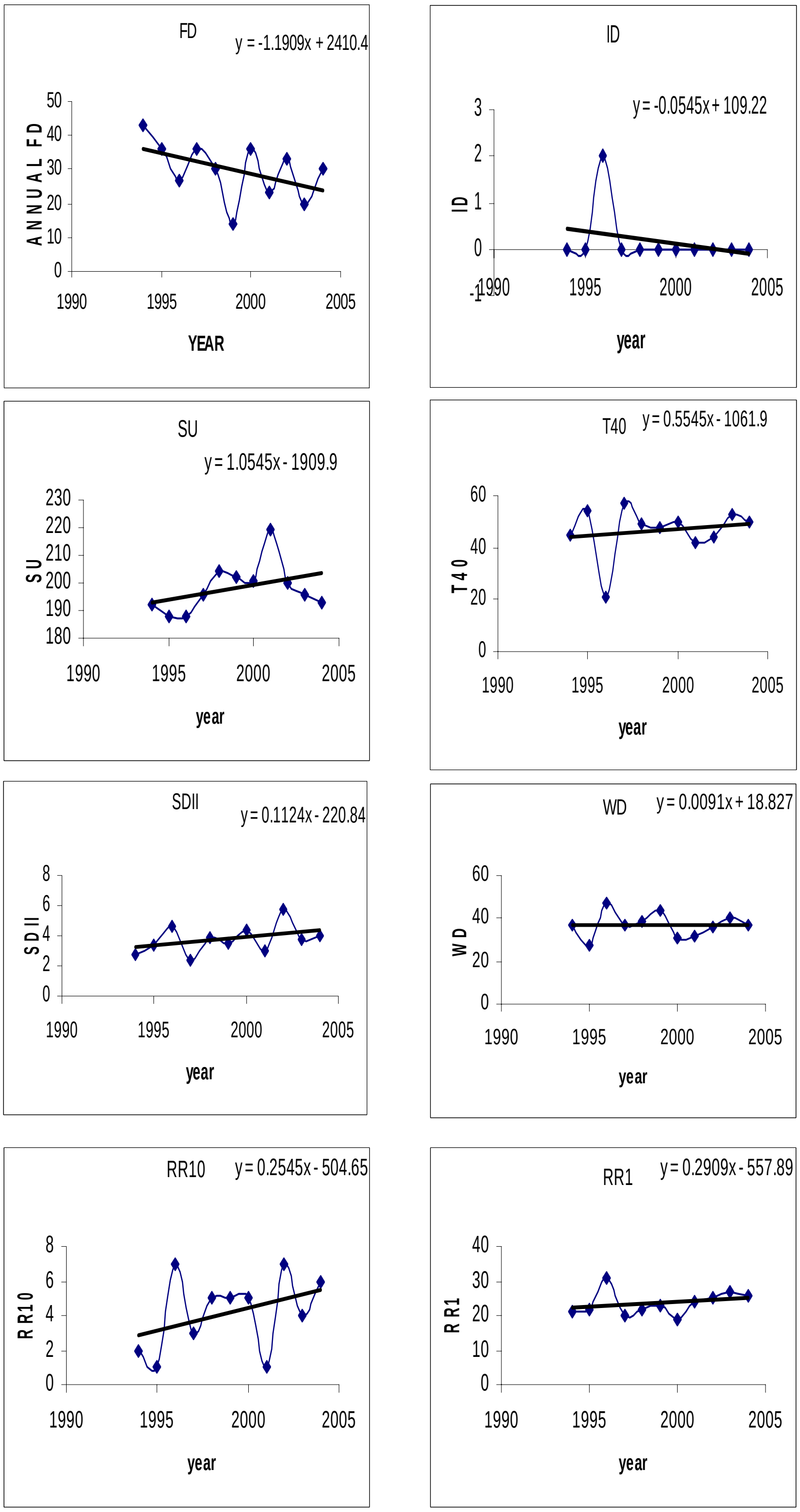

Fig. 7. Trend in indices a) FD, b) ID, c) T40, d) SU, e) WD, f) SDII, g) RR1, h) RR10 in Kashan station during period 1994-2004

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