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The Effect of Drought on Forest and Grassland Fire in South-east of Caspian Sea: a Case Study in Golestan Province (1998-2008)

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Abstract

Golestan province, Iran is a prey to fire every year, current study takes into account the data of rain and examines the drought effect and its intensity on Golestan forest fires. The results of rainfall disorders index showed that 3 widespread drought period, 3 regional droughts happened in recent 11 years in this region, and in other years it had reasonable rainfall and drought was less than regional drought. But in monthly periods, different intensity of drought happened in this province. Finally, it becomes clear that yearly drought can not be used for analyzing the forest fires in Golestan province, but intensity of monthly drought in the regression equation confirms the direct effect of droughts over fires. 14% of fires in Golestan province occurred in wet months which include 10% of affected area from drought. Mean while much intensified droughts which take 10% of fires, cause 24% of burned area (1468 acre).

1. Introduction

Drought and forest fires are multilateral events which affect the function of ecosystem and forest, thereby causes erosion of soil and change of carbon cycle, coverage of land and fields (Van Leeuwen, 2008). Fire, in addition to preceding factors, makes changes in sediments of flows and floods after fire and could lead to a series of biological changes and affects the structure of aquatic ecosystem function. Among natural factors, the role of ecology in forest fire is more important, so that in analysis of forest fires the ecological role such as temperature, rain, humidity and synoptic phenomena has drawn the attention of many researchers. One of the sample studies in this area was done by Dale et al. (2001) on the role of ecology changes in forest disorders and suggested that the frequency, size, intensity, season and the type of fire are depended on weather, ecology, and the structure of forest. Hallett et al. (2003) examined the history of 100 years of forest fire, drought and the change of the lake level in south-east of Canada. The study showed that the least water levels coincided with the period of local drought and forest fire around the lake and periods of ecological humidity coincided with the least forest fire or its absence. Billing (2004) studied the effects of drought over forest fire in south-east of rain forest of Australia. According to his study, increase in forest fire is related to the drought. Mark et al. (2005) analyzed the forest fire, drought and survival of trees in Indonesia's rain forest suggested that before drought, the forest biomass was 7.38 t acre^{-1} and after forest fire it changed to 30±133 t acre^{-1} and after 21 months, it reached ±50 t in the burned forest. Bigler et al. (2005) studied the effect of different disorders and drought which is effective in intensive forest fire through Rocky mountain forest and they understood that imposed conditions before fire have important effects over the intensity of fire along intensive droughts. Flannigan et al. (2003) studied drought transformations which caused forest fire in south east Boral of Canada and ecological analysis from the circle of trees. The results of the study suggested that a

general decline in forest fire activities which it caused was rooted in growing linear movement of humid mass of air toward the east of Canada from 1850 which had produced growing temperature and consequently decreased the number of forest fire. Fredriksson et al. (2007) studied the effect of Alnito over drought and fire over forest and fruit resources in the eastern plains of Borneo with the conclusion that drought and forest fire led to the death of trees for three months period after the fire (76±11). Xiao and Zhuang (2007) in examining the effects of drought on forest fire activities in big forests of Canada and Alaska found out that the ecological warming, anomaly increasing in geo-potential and the model of ocean circle and led to drought which cause the increase of fire inflammation. Balch et al. (2008) studied the negative feedback of yearly fire in transformational forests of south east Amazon and in spite of their expectation they found out that the regime of yearly fire led to the decrease of forest inflammation potential in 3 fire cases and the intensity of seasonal drought decreased the humidity in the area of fire dissemination which harness negative feedback of the intensity and speed of fire. Fire of the forests and grasslands is one of the most important issues and worries in many parts of the world not only from the environment point of view but also from social, economical and security point of view (Merino-de-Miguela et al., 2010). In another side, forest fire releases a lot of green house gases, smoke and dust into the atmosphere which increasingly increases the amount of CO_2 in it (Andreae, 1991). According to statistics published by the organization of forests and grasslands of the country, every year hundred cases of fire take place in different parts of Iran which lead to the destruction of forests and grasslands in different parts of the country, especially in Zagros and Alborz mountain (Sarkaregar Ardakany et al., 2010). Sarkaregar Ardakany et al. (2010) precede to space analyze of fires in Iran using normalized indicators of plant coverage and satellite images (MODIS). They concluded that recent years' fires in Iran had a great relation with the state of plant coverage in such a way that its correlation coefficient with the normalized mean indicator of plant coverage reaches 0.9.

2. Materials and Methods

2.1. Study area

Golestan province with an area around 2,437.7 km² covers $^1/_3$ of Iranian territory. This province is located in east-north of Iran between 53°51' to 56°19' E longitude and 36°30' to 38°8' N latitude. The types of forests of the province which are more Caspian extend over 43,8799 acres of the province's territory and grasslands also cover 126,000 acres of the province's territory (Plate 1) (Management and plan organization, 2007).
For the present study, the rain of Synaptic stations, climatology and rain measurement data of the weather forecasting

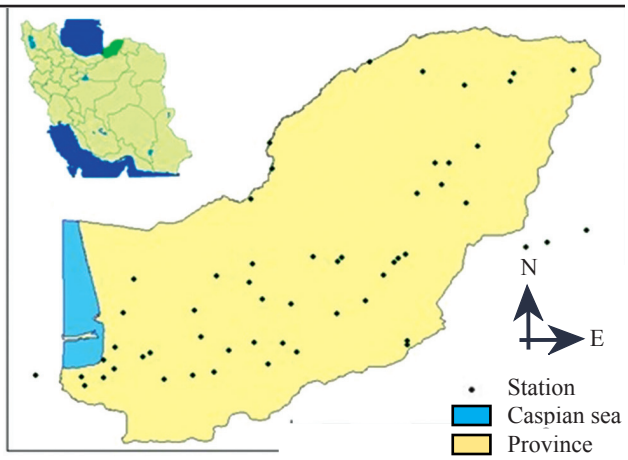

Plate 1: Distribution of station of climatology Zone study

organization of the country and rain measurement stations of power ministry and also the data of forest fire in Golestan province from the organization of forests and grassland were used. Data were obtained using the indicators of rain disorders of droughts in recent years and months in the Golestan province. This indicator was presented by Van-Rooy (1965) taken by measuring comparative rain with the accidental figures of -3 and +3, so that it is related to the rain disorders of 10 coast lines. Additionally, this indicator was used with two time scale of month and year. This index analyses the determined yearly or monthly rain over a line scale which was drawn out from the data serials. The process of the index calculation is as follows:

- Calculating the long term mean of yearly rain (p) in the considered station.
- Drawing out of the mean of 10 cases of the most amount of rain taken place during the study (m)
- Drawing out of the mean of 10 cases of the least amount of rain taken place during the study (x)
- Comparing of yearly rain data (p) with the long term mean. If p is less than $\bar{p}$ then RAI is drawn out with the relation A, and if p is larger than $\bar{p}$ then RAI is drawn out with the relation B as stated below:

A: $RAI = [(p - \bar{p}) / (m - \bar{p})] + 3$

A: $RAI = [(p - \bar{p}) / (x - \bar{p})] - 3$

In the first case, the disorder is positive and in the second case negative. Relating the thresholds of +3 and -3 orderly to the 10 cases of largest amount of positive disorders and 10 cases of the smallest amount of negative disorders at the end was drawn out with line scaling over the drawn figures of the rain disorders index, 9 layers of disorders from the most intensive year with humidity and the most intensive year with drought. Different category of this index was reflected with the drough intensity > -0.3 (normal and humid), -0.3 to -1.2 (weak), -1.2 to -2.1 (mean), -2.1 to -3 (intensive) and < -3 (very intensive)

(Van-Rooy, 1965).

2.2. Kriging interpolation model

Kriging method is the best way of linear unbiased estimator which is based on the logic of weighed moving mean (Hassani Pak, 1998). *Kriging* model methodology covers the experiential region, in another word it is local not general and usually presents better local products in comparing to neighboring observations (www.tilburguniversity.edu). In this model for each of the internal and external stations of the arena, a specific weight is considered according to its distance and situation in such a way that estimate variance becomes minimum. One of the most important features of this model is that each related error can be calculated for each estimation. So for each amount of estimation the range of assurance can be calculated. *Kriging* estimator as a weighed movable mean is defined as follows:

$$z_v^* = \Sigma_{i=1}^{n} \lambda_i Z_{vi}$$

In which z_v^* equals the estimated amount, λ_i equals the weight or the importance of quantity related to the sample (I), and equals Z_{vi} the amount of sample (I) (Hassany Pak, 1998). According to Krig K G, the estimator of *Kriging* is one of the most prominent estimators of linear unbiased estimates, because firstly it is without the systematic error and secondly its estimate variance is the least (Ghohroudi Tali, 2003). In the *Kriging* method, it is assumed that the location changes of phenomenon such as rain in a range has an accidental deliverance and it consists of three factors- ocation correlation, procedural and accidental error. Existence or lack of each factor and the type of these has led to creation of any kind of *Kriging* methods. The factor of location correlation and its rate is defined according to the change of index. From the analysis of this factor and related changes weight indexes for the control points for the value of unknown point can be calculated.

3. Results and Discussion

3.1. Drought

Among the natural phenomena which lead to abundant damages is drought. Drought has been defined as the decrease of rain as compared with a long period of time in an area. Golestan province for its natural situation encounters a high fluctuation in rain and it has caused to experience different drought and wet climate with different intensities in just one year. According to current study, during recent 11 years (1998 to 2008) droughts had taken place in three periods and among these periods, even though between the years of 1998 and 2008, nearly all the province was dominated by the drought an, in 2008 drought was more evident. Regional drought has been taken place in three periods in the province (1998, 2006, and 2007). What can be found out from the Table 2 was that the widespread and regional drought has taken place during these years and the years before and the droughts in these years have been accordingly so intensive. This shows that with more careful studies about drought in Golestan province it was possible to estimate the time of widespread droughts and present appropriate plans to decrease their effects. The high fluctuations of rain and rain regime in Golestan province had caused the monthly droughts in comparison with the yearly ones had been more intensified and widespread, in spite of wet year occurrence with the yearly rain. So, according to the evaluation of rain disorders and interpolation method of *Kriging*, it was clear that dominantly all months of 2008 (except January) faced widespread drought in the province. June, July and August were exposed to drought more than the other months of the year and December and January stood in the next order.

3.2. Fire

According to the data of fire cases during 11 years it was observed that Golestan province was exposed to natural and unnatural fire in each year. Meanwhile, January and December orderly with 19% and 16.8% had the maximum droughts. Minimum droughts with the rate of 1.1% and 1.7% belonged to the May and April months. The maximum range of effects by drought had taken place in September and August in which the occurrences of fires stood in the third place. The process of the province fires had an increasing trend in each year and the Regressions' relation with its 13.2 slope confirms this case (Figure 1).

Table 2: Drought occurred during 1998 to 2008 in Golestan Province

Row	Widespread	Regional	Local
1	2000	1998	-
2	2001	2005	-
3	2007	2006	-

The increasing process of fires in monthly periods was also observed. The range of fires was also different according to the seasons and months. Two seasons of fire were observed in the province. One of it was seen during December to February and another during June to September (Figure 2).

During the summer season because of the increasing amount of drying plants and the warmness of weather and down falling of humidity, the factor of inflammation acts with more power and increases the extension of fires in an area. During fall also, the existence of dry leaves is the first factor as fuel, is secured and the other one is the origin of fire which is the combination of thunder and small drops of dew and rain and also broken glasses. The occurrence and continuation of droughts and the degree of the dryness of weather in some periods act as more powerful factors for the speed and intensity of fires.

According to the preceding discussion, it can be said that

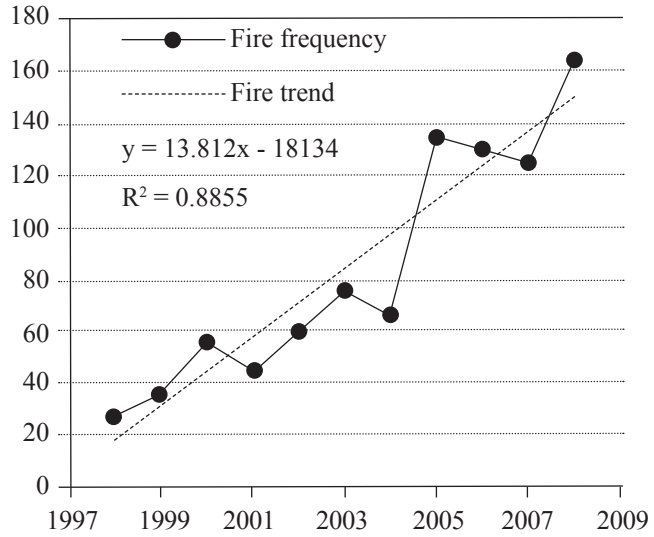

Figure 1: Frequency of fires during the period of 1998 to 2008

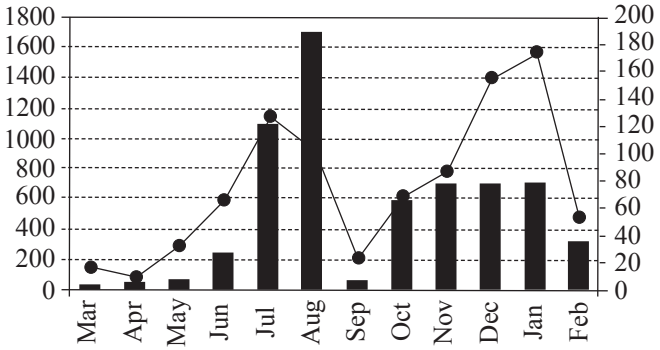

Figure 2: Monthly distribution area and the number of fire study area

the Golestan province is one of the risky areas for fire which is consistent with the studies of Sarkargar Ardakany et al. (2010) who put the province in the areas of high risk to mid risk (Plate 2).

3.3. Relation between drought and fire

Fire is strongly affected by the wet capacity of fuel which in forests and grasslands consists of the remains of dead plants, and the existing dead materials in forests and grasslands inclined toward fire, especially in fire seasons and during droughts increases the risk of fire (Billing, 2004). Since during droughts, in addition to decreasing frequency of rains, the existing humidity in the air decreases and the speed of fires increases. The result of evaluation of the relation between yearly fires and droughts suggested that most of the droughts (55%) have occurred during years with normal or higher rain falls and with increase of hardness in droughts, the cases of fires have been decreased. The affected area of drought, during wet periods in terms of yearly rains, includes the percent of the range of area. For better understanding of the relation between

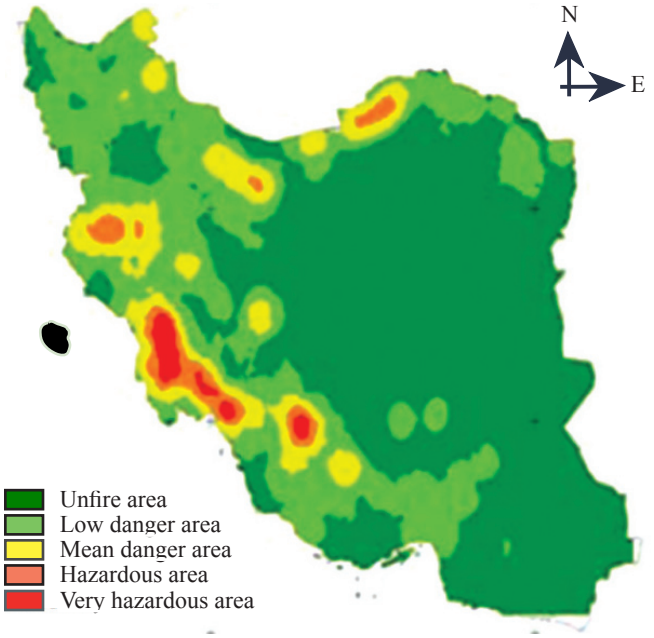

Plate 2: The map of ranging the risk of fire in different parts of the country (Sarkargar Ardakany et al., 2010)

fires and droughts in the Golestan province, monthly analysis were used. Monthly maps of drought intensity and occurred fires showed that the number of fires in wet periods have decreased to 15%. This amount includes 10% of burned area. One important point here is the important effect of drought over the expansion of burned area. Although the intensive drought causes only 10% of the fire frequency, in includes 23% of burned area. This issue suggests the increasing effects of fire intensity over the risk of fire in Golestan province. Yearly statistics of fires showed that the maximum of fires occurred in 2008 followed by 2005. While the maximum area affected by fires occurred in 2003, so that it covers by itself 31% of the affected area by fires. Examining the fires showed that in the preceding year most of the fires occurred in the fire season (July, August and November to December), while these months experienced expanding drought. From the other side 46% of fires in 2003 occurred in very intensive droughts. The recent factor increased the potential of inflammation so the speed of fire and the burned area increased.

4. Conclusion

The present study showed that during recent 11 years Golestan province has experienced some large and regional droughts. The most intensive drought also occurred in 2008 when nearly all of Golestan province witnessed an intensive drought to a mean drought. Golestan province has two fire seasons- one is in July and August and the other one in November to January. Maximum area affected by fires is in July and August months which in terms of ecology (warmness and dryness of weather)

and fuel (dead and dry plants) the capacity of fuel susceptible to inflammation is high. According to the index of rain disorders and maps and the intensity of observed droughts, maximum of drought in Golestan province goes to May and beginning of August. Lack of data for yearly rain and droughts used for analyzing of fires and better implementation of monthly rains is the important point of this study.

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