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Monitoring and zoning sultry phenomena in the southern provinces of Iran

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ABSTRACT

Objective: Southern provinces of the country in the Persian Gulf and Oman Sea are under the damp of this undesirable phenomenon in the major part of the year, due to the enormous potential in various fields of industry, transport, trade, warehousing, agriculture, services and tourism in recent decades. The present study examined the occurrence of humid condition in the southern provinces of Iran. The purposes of this study were to determine the start and end time and duration of humid , determine The extent of sultry , monthly zoning of sultry phenomenon by means of geographical Information system (GIS) and finally , determining areas with same sultry by cluster analysis (by distance). **Methodology:** To perform the processes of study , the data related to temperature, RH , saturated vapor pressure at 12 (UTC) related to 54 synoptic and climatology stations in Southern provinces of the country include Khuzestan, Boshehr, Hormozgan, Sistan va Baluchistan were gathered from Meteorological Organization for a period of 12 years (1997 – 2008). The model used for calculation of humid extremity was Lancaster – Kerstin model. **Results:** The calculation of sultry for southern provinces showed that the worst sultry condition was related to southern parts of province and its intensity decreased in north parts. Among under study provinces, Hormozgan was worst in sultry occurrence point of view, due to the more southern latitude and Khuzestan province had the lowest level of humid. The concentration of high pressure beside the torrid in the early of hot period and its stability lead to the aggregation of sultry phenomenon in this part of country. The under study province have had a better sultry condition only in last mouth of fall and early two months of winter due to the regression of high pressure to southern latitudes , so that the sultry phenomenon have not been seen in December, January , and February. **Conclusion:** The result of cluster analysis showed that the first cluster had a highest level of sultry is southern part of Sis tan and Hormozgan. The level of sultry in second cluster include central regions was middle and the third cluster had weak sultry occurrence.

1. Introduction

Humid and hot weather lead to sultry sense a mood that cause to physical power dropping and breathing problems and its undesirable effects is more servers for individual with cordial and blood disorders. The feeling of sultry as any sense is a mental concept that it is apparently impossible to measure it with special tools. However, so many endeavours have been done by meteorologists and climatologists to sense this phenomenon these endeavours have shown that the creation of this sense can be investigated based on experimental studies as a scientific and objectivity sight. Human is very vulnerable against climatically changes. These changes are very significant in our country. The comfort condition is very limited due to the temperature and humidity changes in different months. The occurrence of sultry phenomenon is one of the limitative factors of comfort condition in landside regions than it is controlled by temperature and humidity. The combination of temperature and humidity lead to sultry phenomenon in north and south of Iran. (Masoudian, 2011). The severity of sultry increased with the increase of MH and decreases with temperature decreasing. Southern provinces of the country in the Persian Gulf and Oman Sea is under the damp of undesirable sultry phenomenon for the most of year due to the great Potential in various fields of

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industry , transport , trade , warehousing , agriculture , services and in recent decades tourism. Since the lack of studies and researches about this phenomenon, the need of extensive research in the country to implement it on planning is felt.

The present study has tried to examine the occurrence of sultry condition in the southern provinces of Iran. The purpose of this study was to determine the start and end time and duration of humid , determine the extent of sultry , monthly zoning of sultry phenomenon by means of Geographical Information System (GIS) and finally determining areas with same sultry by cluster analysis (by distance).

Bio-Climatology pressure is occurred by the stress of heat or sultry phenomenon. According to definition, the sultry phenomenon is a condition of climate in which the amount of partial water vapor pressure is equal or more than 8.18 hPa. All of the sultry hours of sun Salvador from 1952 to 1956 were calculated according to sultry critical amount of Sharlo (Dieterichs, 1957). The researches performed by Steadman and its results about marginal sultry led to the development of some special indexes according to human physiology and sciences (Steadman 1979). Moreover some indexes of Bio-Climatology related to sultry in sense and feeling criterion include: equivalent temperature, fraction of physiological saturation and air enthalpy. After that , Lakester & Kirsten have provided marginal sultry according to MH and temperature by performing experimental studies that Its basis was the practical measurement of Lakester on was validated by a large number of climatologist (Kaviani, 1981). The frequency, extent and duration of sultry of El Salvador landsides were investigated by 159 cases which their brume temperature was equal or more than 16.5 C ◦in 1980 (Dieterichs 1980). In addition, the dry weather and sultry periods and comfort condition of Horbono in a period of 1951 to 1980 were investigated by water vapor pressure, temperature and MH (Kvetak, 1986). Tally believe that Philippine is one of the hottest reason of world. He investigated the extent of sultry of this country in different conditions (Tilly, 1988).

The studies about sultry phenomenon in Poland performed by Falarz (2005), showed that, the average number of sultry days in all over of Poland increased which moving from northwest to southeast and it doesn't occur in more than 1200 meter altitude. Moreover the worst climatology condition about sultry in Poland is related to southeast of this country, while the best condition is related to north and west parts and far from landsides. Moreover, Kozminski & Mishalska (2007) have investigated the frequency and changing direction and the number of cold, hot and very hot days of Poland in Semi-hat part of year from Baltic Sea for a period of 1986 to 2007. In this matter, Blazejczyk (2006) whit we of heating stress concluded that the sultry days have started from the mid of April and continue to September (2007:63). The sultry phenomenon have classified as a index of new climate classification by Blazejczyk (2007). Other researchers also investigated the heat stress index and sultry days. Among them, Zarnowiecki (2001) have investigated this index in hot season in a lagoon ant Negin Park of Palestine and concluded that however a large number of days in hot season have middle heat stress and some of its days are sultry but one should not forget the effect of landside on the weather of environment. Soaroni (2007:119) have investigated the sultry phenomenon in & different urban view. The results of this study include: the sultry periods often occur in a areas with aggregated buildings and pitch and concrete lands like subway station and also near to water resources like landsides. In areas which buildings are diffuse and in the areas with wide roads or in the areas with plant covers like gardens and parks it rarely occurs. Wypych (2009) has investigated long term changes of weather humidity in Krakow (a city in Poland) for a period between 1901 to 2000 by analysis of vapor pressure, the fraction of saturation and temperature and he concluded that long term changes of humid in Krakow was mostly observed in saturation fraction and the amounts of this index is higher in the hot parts of year. Wang & GONG (2010) with the study of thermo waves and humid weather in Pekinese by gathering climatology data from 1940 to 2000 concluded that the most number of sultry and hot days were happen in 40th decade. The study of sultry phenomenon is very limited in our country. Among them we can refer to Kavyani (1981), study. the start and ending time of sultry months of southern landside of country were determined by investigating proper approaches of sultry month calculation and with enjoying from experiences and with selection 35 climatology station in south of country and statistical study of these station for a 10 years period (Kaviani, 1981).

2. Materials and Methods

The main perspective for investigating the condition and extent of monthly sultry in southern landsides of country was based of statistical approaches. Data related to temperature , MH and saturated vapor pressure (UTC) of 54 synoptic and climatology stations in southern provinces of country include Khuzestan, Boshehr, Hormozgan and Sistan va Baluchistan for a period of 1997 to 2008 were received from meteorology organization to perform the process of study. Their characteristics mentioned in table (1).

In the first step of research, the severity sultry and partial water vapor pressure indexes were calculated for each month by special equation:

$$D = \frac{Rh}{21/55} - \frac{100}{T} + 1/3 \qquad (1)$$

Where, D is the severity of sultry, RH is Relative Humidity and T is temperature. Based on this equation and since the MH was 100 percent, the threshold sultry temperature was 16.8° C. In the other words the sultry phenomenon doesn't happen in the temperatures less than 16.8° C (Masoudian 2011).

$$e = \frac{RH \times es}{100} \qquad (2)$$

Where, e is partial water vapor pressure (h Pa). RH is Relative Humidity and es is water vapor pressure (h Pa).

Table 1: characteristics of under study stations of study

Height	Longitude		Longitude		station	province
	degree	Minutes	degree	Minutes		
19.8	28	59	50	50	Bushier	Bushehr
4	27	50	51	56	Dir Port	
655	27	49	52	22	Kangan	
8.4	28	54	50	49	Boshehr sea	
110	29	20	51	17	Borazjan	
720	28	49	21	41	Boshkan	
25	29	04	51	09	Chah k	
120	29	20	51	06	Shabankare	
6.6	30	22	48	15	Abadan	KHuzestan
34.9	30	46	49	39	Omidiyeh	
27	30	46	49	40	Omidiyeh	
22.5	31	20	40	48	Ahvaz	
767	31	51	49	52	Ezeh	
7.8	31	43	8	00	Bostan	
6.2	30	33	49	09	Mahshahr port	
313	30	36	20	14	Behbahan	
143	32	34	48	23	Dezful	
15.5	31	16	49	36	Ramhormorz	
67	32	03	4	50	Shoshtar	
82.9	32	16	48	25	Safi Abad	
3	30	17	49	44	Hendijan	
32.9	31	56	49	17	Masjed soleyman	
710	31	31	9	53	Bagh Malek	
300	30	36	50	14	Behbahan	
63	32	05	48	21	Haftapeh	
21	31	29	48	26	Hamidiyeh	
59	32	05	48	42	Karoon	
450	32	47	48	31	Mazo	
50	31	36	48	53	Molla sani	
485	32	30	48	48	Sardasht	
150	32	03	48	50	shoshtar	
159.1	27	12	60	42	Iranshahr	Sis tan va Blouchestan
8	25	17	60	37	chabahar	
1394	32	13	61	12	khash	
489.9	31	02	61	29	zabol	
1370	29	28	60	53	zahedan	
495	30	54	61	41	zahak	
1195	27	20	62	20	Saravan	
12	25	26	60	22	Kenarak	
120	25	42	61	25	Yahoo Kalat	
360	27		60	27	Bampor	
500	26		60	44	Ghasr ghand	
1385	32	12	60	31	Gohar kooh	
1065	27	13	60	46	Karondaz	
1430	28	13	61	14	Khash	
510	26	14	60	13	Nick shahr	
1000	29	53	59	58	Nosrat abad	
880	26	38	61	16	Sarbaz	
1200	29	25	60	25	Mohammad abad	
5.2	25	38	57	46	Jask	HOrmozgan
9.8	27	13	56	22	Bandar abas	
22.7	26	32	54	50	Lenge Port	
6.6	25	50	54	50	Abomosa Island	
931.2	28	19	55	55	Haji abad	
4.4	25	53	54	29	Siri Island	
30	26	30	53	59	Kish	
6	26	55	55	55	gheshm	
29.6	27	06	57	05	Minab	
750	28	11	55	27	Tashkoyeh	
60	27	08	57	05	minab	

The next step was to extract sultry days. The calculated sultry severity index was equal or more than 0/1. Although the sultry severity index was considered in this research but the statistical study was also performed based on partial water vapor pressure. The sultry days were classified in 4 groups according to the amounts of sultry severity index that among them the special focus was on very sever sultry days in order to investigate the circulation patterns.

Table 2 the classification of sultry intensity index

the classification of sultry intensity index	
Poor sultry	0.1-00.49
Middle sultry	0.5-00.99
Sever sultry	0.1-01.49
Very sever sultry	1.5

The cluster analysis was performed for under study stations about sultry phenomenon, after determining the characteristics of sultry in south of country.
Distance method (clustering)
Clustering analysis is a way to dividing a data set into homogeneous and useful subsets (clusters or categories) that have similar characteristics. The similar data put in a cluster and dissimilar data put in separate clusters. The distance method usually used to multi criteria grouping and every climatology variable like temperature or raining can be a criterion. The main purpose of clustering is to reduce variation or intra-group variance and increase between groups variance (Alijani, 2003). The clustering analysis can be performed hierarchically or none hierarchically. In hierarchical approach the clusters at first are identified through clustering process and then are merged together according to the degree of their similarity and finally all of the clusters are gathered in a same cluster.
The K-mean method is the most common way to non hierarchical clustering. At this methods, individuals at first divided in K desired groups and then each individual is clustered in a group has the least distance to the mean of that group (Masoudian, 2003). The number of observations and clusters are equal at the start of clustering process and at the last step; all of observations are gathered in a cluster (Alijani, 2002). Two points are belonged to a climate zone, when their climate is sufficiently close to each other. Therefore, dissimilarity degree of places with each other firstly was measured by measuring the Euclidean distance of climate elements of all points in Matrix P (equation 3)

$$d_{rs}^2 = (P_r - P_s)(P_r - P_s)' \quad (3)$$

Where, dr^2_s is the Euclidean distance of r-th point with (ϕr, λr) coordinates and S-th point with (ϕs, λr) coordinates or is the Euclidean distance of r-th group and S-th group. Pr is the climate variable of r-th point or group. Ps is the climate variable of S-th point or group.
In above approach r and s are merged if increased scattering due to their integration be minimized compare with integration each of them with other groups (equation 4).

$$d(r, s) = (n_r n_s d_{rs}^2)/(n_r + n_s) \quad (4)$$

Where, d^2_n is the distance between r and s groups that obtained from central graft method. Nr is the number of members in group r and ns is the number of members in groups (Kaviani & Masoudian, 2009).

3. Discussion and Results

After determining the appropriate test to determine the degree of sultry, the sultry phenomenon was calculated for southern provinces in Persian Gulf and Oman Sea based on equations of model. Results of these calculations for different stations are presented in table (3).

Table 3. Sultry estimate of the stations studied by the Lancaster-Kerstin

Station	January	February	March	April	May	June	July	August	September	October	November	December
Chabahar	-0/80	-0/35	0/34	0/94	1/40	1/73	1/72	1/58	1/44	1/14	0/34	-0/43
Konarak	-1/11	-0/75	-0/3	0/43	0/94	1/38	1/52	1/41	1/23	0/74	-0/01	-0/63

Bahoo kalat	-1/80	-1/35	-0/59	-0/21	0/27	0/88	1/13	1/08	0/85	-0/6	-0/79	-1/33
Nick shahr	-2/51	-2/11	-1/03	-0/57	-0/20	0/24	0/51	0/58	0/27	-0/28	-1/11	-2/22
rGhasre ghandn	-2/29	-1/79	-1/09	-0/51	0/5	0/43	0/83	0/78	0/48	-0/35	-1/19	-1/80
Kish	-0/94	-0/65	-0/4	0/53	0/90	1/38	1/56	1/64	1/48	0/96	0/16	-0/40
Lenge Port	-1/38	-1/05	-0/34	0/27	0/80	1/24	1/44	1/46	1/27	0/73	-0/18	-0/82
Jask	-0/82	-0/56	0/09	0/60	1/09	1/49	1/76	1/70	1/46	0/95	0/22	-0/35
Sarbaz	-3/97	-2/76	-1/68	-0/96	-0/56	-0/16	0/32	0/33	-0/07	-0/97	-1/98	-3/05
Gheshm	-1/05	-0/50	0/14	0/72	1/21	1/52	1/62	1/60	1/60	1/07	0/04	-0/52
Bandar abas Port	-1/30	-0/68	-0/04	0/48	0/87	1/27	1/54	1/55	1/36	0/90	0/00	-0/88
Bampor	-4/37	-2/91	-1/57	-0/97	-0/49	-0/35	-0/10	-0/28	-0/68	-1/28	-2/34	-3/51

After calculating the sultry coefficients, the amounts of sultry were zoned for under study provinces to identify the spatial distribution and intensity distribution of the sultry phenomenon. Zoning the amount of sultry for stations was performed based on Inverse Square of distance method with 4*4 Km cells. December, January and February months were not participated in zoning, because they don't have sultry phenomenon. 9 maps were extracted for remained months after zoning. The figures 2 to 10 show the interpolation and zoning of sultry intensity.

- April: sultry intensity was included poor and middle class in April. Any sultry phenomenon didn't appear in Khuzestan in this month. The southern parts of Sis Tan VA Baluchistan and Hormozgan provinces had poor class and the stations of Boshehr, Kish, Gheshm, Chabahar, Konarak and Sarbaz had middle class sultry.

- May: the under study province also included a higher degree in May and have severe sultry. At this month, sever sultry was appeared in stations, which had middle sultry in last month (April). A large part of Hormozgan province have experienced sultry phenomenon in May that its intensity increased from north to south.

In Sistan province all of three degrees were seen that maximum amount of its intensity was in Chabahar, Konarak and Sarbas stations.

In boshehr province, sultry phenomenon was appeared on southwest parts of province. In Khuzestan province, a poor sultry was seen in some part of central and northwest zones.

- June: Sultry phenomenon reach to its upper bound in southern provinces in June. A large part of Boshehr and Hormozgan had sultry phenomenon in this month, but it was more severe in Hormozgan compared with Boshehr. The maximum sultry was seen in Sabac, Chabahar and Konarak stations with very sever degree. Sistan province had sultry phenomenon in south of Iranshahr and bampor that its intensity increased from north to south.

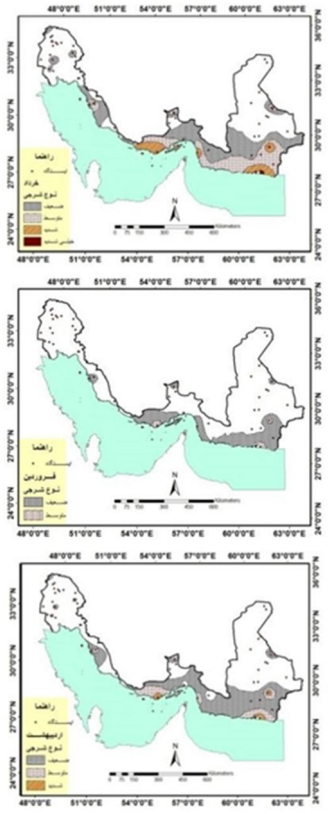


Figure 1. Zoning the sultry intensity of June
Figure 2. Zoning the sultry intensity of May
Figure 3. Zoning the sultry intensity of April

- August: It can be said that August and September had the highest level of sultry phenomenon in surface/area point of view. Large parts of Khuzestan, Boshehr, Hormozgan and south of Zahedan have had sultry phenomenon at this month. In addition all parts of Khuzestan province experienced sultry, except Dalki and it was increased from northeast to southwest. There was not significant sultry at Bampor, Iranshahr, Khash, Karvander, Zahedan and Zabol stations in Sis tan VA Baluchistan.
- September: September didn't have significant differences with August in zoning and sultry extensity point of view, maybe due to the gradual recess of high pressure.
- October: The high pressure didn't have egress from country in October and the climate was yet stable. The most parts of southern province had poor sultry in this month and middle and sever sultry only have been seen in some southern parts of Hormozgan and Sistan VA Baluchistan provinces.

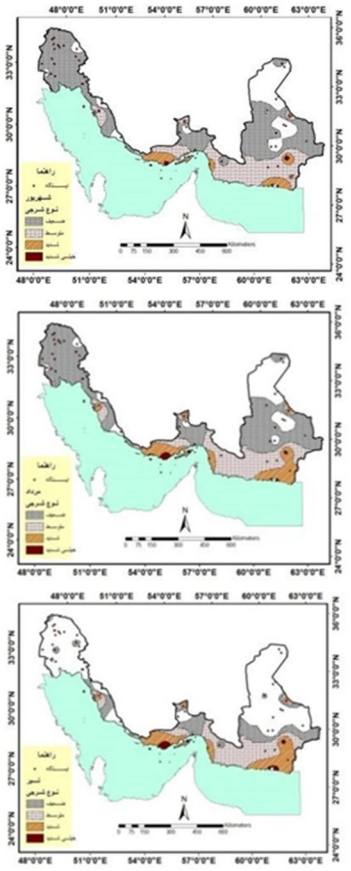
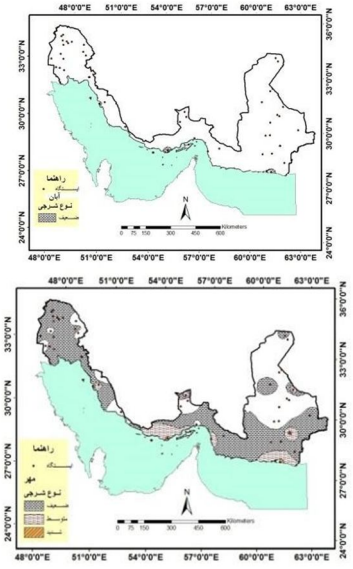


Figure 4. Zoning the sultry intensity of July
Figure 5. Zoning the sultry intensity of Aguste
Figure 6. Zoning the sultry intensity of September

- November : the sultry phenomenon have been not seen in this month except Sarbaz, Chabahar and Kish stations , due to the progress of western winds to country and high pressure recess to southern latitudes.
- March: like November, the sultry have been seen expect Sarbaz, Chabahar and Kish stations.



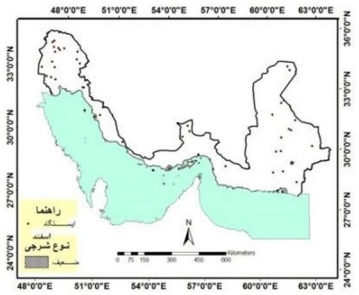


Figure 4. Zoning the sultry intensity of March
Figure 5. Zoning the sultry intensity of October
Figure 6. Zoning the sultry intensity of November

After revelation and zoning the sultry intensity for under study provinces, the points with same sultry were identified by clustering method (distance). The Euclidean distant was selected for clustering of stations after performing different ways and approaches. The results of calculations related to cluster determining and distances between clusters are shown in table 4.

Table 4. Steps for determining the level of cluster and similarity for each stage

Step	1	2	3	4	5	6	7	8	9	10
Number of clusters	53	52	51	50	49	48	47	46	45	44
The level of similarity	100	353/98	332/98	23/98	11/98	8/97	644/97	642/97	541/97	389/97
Between levels	0	374/0	379/0	402/0	429/0	5/0	535/0	536/0	559/0	593/0
Permutations of clusters	42	6	45	34	2	32	6	4	41	49
Step	28	29	30	31	32	33	34	35	36	37
Number of clusters	26	25	24	23	22	21	20	19	18	17
The level of similarity	589/94	483/94	158/94	792/93	557/93	722/92	569/92	543/92	921/91	256/91
Between levels	23/1	254/1	327/1	411/1	464/1	654/1	688/1	694/1	836/1	987/1
Permutations of clusters	34	19	4	15	3	4	39	14	16	15

27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11							
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43							
702/94	89/94	03/95	546/95	033/96	167/96	169/96	349/96	43/96	575/96	791/96	866/96	953/96	989/96	048/97	126/97	287/97							
204/1	161/1	129/1	012/1	901/0	871/0	87/0	83/0	811/0	778/0	729/0	712/0	692/0	684/0	671/0	653/0	616/0							
9	16	9	23	1	26	39	30	4	24	41	12	34	2	53	44	35							
-	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38							
-	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16							
--	34/-376	-119/49	971/-7	287/8	3/55	943/63	899/69	49/72	862/79	37/81	534/83	263/88	65/88	159/89	66/89	031/91							
-	234/108	795/49	533/24	839/20	157/10	193/8	839/6	251/6	576/4	233/4	741/3	667/2	579/2	463/2	349/2	038/2							
-	۱	1	14	1	19	3	9	14	21	9	3	15	14	18	19	1							

After these calculations, three clusters were identified in southern provinces in sultry Intensity point of view that are shown in table (5).

Table 5. determining the distance of each cluster from the cluster center

Month	First cluster	Second cluster	Third cluster	Center
January	-1/96531	-3/71165	-7/98536	-4/23753
February	-1/51722	-2/97186	-5/61066	-3/17111
March	-0/65266	-1/74882	-3/34929	-1/79837
April	0/05644	-0/83654	-1/88341	-0/81029
May	0/48891	-0/54609	-1/24547	-0/38241

June	0/81977	-0/36054	-0/9416	-0/11775
july	1/08081	-0/09066	-0/73751	0/13213
August	1/12488	-0/0304	-0/94082	0/11866
September	0/89852	-0/31761	-1/37752	-0/18703
October	0/42102	-0/67405	-2/12613	-0/68549
November	-0/47766	-1/48196	-3/50345	-1/67128
December	-1/28951	-2/68901	-5/89004	-3/05241

After this step, the middle and maximum distance of each cluster to total average was determined (table 6).

Table 6. Determine the average and maximum distance of each cluster from the average of the observations in this study

clusters	The number of observations	Ear interpolation of the sum of squares	The average distance from the center	The maximum distance from the center
First cluster	18	81/584	1/97659	3/03956
Second cluster	22	24/101	0/98946	1/75683
Third cluster	14	203/753	3/1606	9/27819

Finally the mono-graph of extracted clusters was drowned and the various points whit same sultry for southern provinces was created. The ranges of same clusters are as follow:

- The first cluster: the southern parts of Sistan, eastern parts of Hormozgan, and Southwest of Boshehr can be put in first cluster. The Sarbaz, Chabahar, Konarik, Ghasrehond, Nick shahr, Jask, Seric and Boshehr stations were put in first cluster.
- Second cluster: the central parts of Sistan northern parts of Hormozgan, north east of Boshehr and the central part of Khuzestan can be put in this cluster. This cluster includes the stations of Saravan, Ezeh, NosratAbbad, Baghmalek, Zohak, Zabol, Khash, and Zahedan and …
- Third cluster : the other parts of under study provinces were put in this cluster that includes the stations of Bampor, Iran shahr, Jam, Ahvaz, Boostan, Dezful, Abadon, Behbahan, Ramhormoz,

Shoshtar, Molla San, and ….

The graph of clustering and the map of these regions are shown in figures 10 and 11

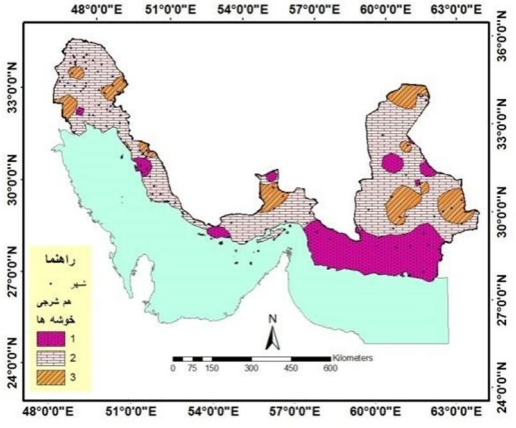


Figure 10. The mono-graph of clustering the points with same sultry

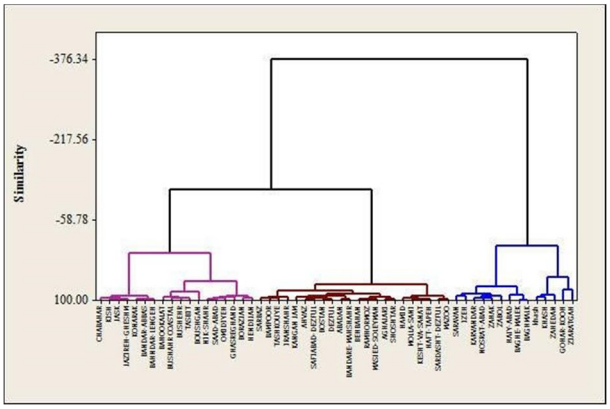


Figure 11. Zoning the areas with same sultry

4. Conclusion

It is necessary to perform wide researches about sultry and using them in programming, due to the lack of studies and researches about this phenomenon inside the country. The purpose of this study was to determine the coefficients and intensity of sultry phenomenon and zoning them for southern provinces of country and finally determining areas with same cluster by cluster analysis (distant). The calculation of sultry intensity for southern provinces showed that March was the start date of sultry phenomenon and November is the end date of it and Its duration was 9 months, the worth condition of sultry was happened in south and decreased to north. Among under study provinces, Hormozgan province had the most sever sultry, because it had more south latitude and Khuzestan had the lowest level of sultry. The concentration of high pressure on this region in beginning of heat period led to sultry. Only in last month the first two months of autumn and winter, the under study provinces had better condition in sultry phenomenon point of view due to the Subtropical high pressure regressed to a more southern latitude. It can be said that the sultry phenomenon have been not seen in the months of December, January and February. The results of analysis showed that the first cluster in southern parts of Sistan and Hormozgan provinces had the most sever sultry and the third cluster had the poorest sultry. The second cluster had regains which were between first and third clusters in sultry phenomenon point of view.

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