Feasibility Study of Solar Energy in Iran and Preparing Radiation Atlas

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Abstract: For attaining to a proper feasibility study about solar energy reception the study of solar energy estimation is a necessary factor. For preparing this paper pyranometric data and sunshine hour s data of 21 solar radiation stations of different years are collected from metrological organization. On the basis of performed study sunshine hours has the most impression on the amount of total received solar radiation. for this reason calculation of solar energy is accomplished on the basis of experimental angstrom model which is base on sunshine hours. Because of dependency of Angstrom model coefficients to the regional climatic conditions. therefore the kopen climatic classification based on the temperature and precipitation is presented and accordingly five climatic region is taken in to consideration and cities at the same potential from a climatic point of view the for 139 Iran synoptic stations the amount of total solar radiation by using the visual studio software for several months of the year in terms of $Mj/M2.day$ is estimated. At last kriging interpolation procedures in the GIS media software 12 monthly maps and one annually map is drawn up.

Key words: Angstrom model, solar map, feasibility study, solar radiation software

1. Introduction

Solar radiation affects all the Earth`s processes related to the environment and plays a fundamental role in the development of human activities. Sunshine hours are the only long term, reliable and readily available measured information that can be used to reach highly accurate estimates of solar radiation values on the Earth surface. Global solar radiation and sunshine duration on the horizontal surface are measured with pyranometers and sunshine recorders, also we can estimate solar radiation In the absence of a measuring instrument, by using empirical models , , Solar radiation is dependent on different causes and astronomical and meteorological factors therefore simple but effective models for its prediction use from a few numbers of factors are presented. Angstrom[1] worked on the relation between the global solar irradiation and bright sunshine hoursHis formula has been used in practical applications for many years to estimate the daily, monthly and annual global solar radiation. Iran has various climates and is located in a region where the potential of global solar radiation is considerably high. Many researchers derived their models by using sunshine hours, relative humidity, latitude, air temperature of location of interest. Sabbagh[2] estimated the daily solar radiation at various places, by using sunshine hours. Maximum air temperature, latitude and relative humidity. Daneshyar[3] model using the meteorological data of Tehran and Paltridge[4]method to estimate daily total solar radiation for Tehran, (Iran) Yaghoubi and Sabazevari[5] estimated monthly clearness index for Shiraz,(Iran)by using sunshine hours,Jafarpour and Yaghoubi[6] used four different models in order to estimate monthly and annual radiation for Shiraz,(Iran). Samimi[7]worked on the formula which was suggested by Meinel and Meinel[8] and corrected the coefficients of it by considering the Earth-Sun distance, cloud fraction, Sunshine hours and altitude of the place and used it for various cities of Iran,Sabziparvar [9] used sunshine duration ,cloud cover, relative humidity and average of maximum temperature as the input of several radiation models, the monthly average daily solar radiation on horizontal surface in various cities of Iran,Ashjaee [10]worked on tow radiation models of Daneshyar and Bird and Hulstrom to predict daily solar energy for a few specific location of Iran. Other studies used sunshine hours to estimate surface global solar radiation for different place in the world such as Al-Mohammad[11] Almorox[12] and zhou[13]. The purposes of present study are:

1-According to the Kopen classification and by considering the climatic similarity and taking account of the sunshine hours to determine five climatic regions for Iran.

2 -To Design applicable software which is based upon the empirical Angestrom model, and it can be calculated total solar radiation for 5 climatic regions of Iran,

3-To produce the applicable solar map, which is based on solar radiation for Iran,

2. Material and Method

2.1. Data

The daily measure data obtained from Islamic republic of Iran Metrological office (IRIMO) [14]and then statistical quality control is accomplished using the SPSS software, and the data which were out of standard deviation are omitted. The daily sunshine hours (n) were measured by Campbell Stokes sunshine recorders and the total daily solar radiation were recorded using Kipp and Zonen (CM5) pyranometers and CC1 integrators.

2.2.Calculation procedure (Model)

The first model that used sunshine duration to estimate monthly average daily solar radiation on a horizontal surface is the Angstrom [1] equation

$$\frac{\overline{H}}{\overline{H}_\circ} = a + b(\frac{\overline{n}}{\overline{N}}) \quad (1)$$

Where $\overline{H}$ ($Mj/M^2.day$) monthly average daily global solar radiation on a horizontal surface. $\overline{H}_\circ$ is the extraterrestrial daily radiation available outside the atmosphere on a horizontal plane. The monthly average daily extraterrestrial solar radiation on a horizontal surface ($\overline{H}_\circ$) was calculated from the following Duffie and Beckman[15] equation (2)

$$\overline{H}_\circ = \frac{24\times 3600\, G_{sc}}{\pi}(1+0.033\cos\frac{360\,n}{365})\times\left[\cos\phi\cos\delta\sin\omega_s + \frac{\pi\,\omega_s}{180}\sin\phi\sin\delta\right] \quad (2)$$

Where G_{sc} is the solar constant in energy unit (1373 $\frac{W}{M^2}$ which is calculated in this paper), ϕ is the latitude of the location (degrees), n is the day of the year, δ is the declination angle in degrees (-23.45$\leq\delta\leq$23.45), ω_s is the sunset hour angle in degree. The solar declination and sunset hour angle calculated by the following equation (3), (4)

$$\delta = 23.45\sin(360\frac{284+n}{365}) \quad (3)$$

$$\omega_s = \cos^{-1}(-\tan\phi\tan\delta) \quad (4)$$

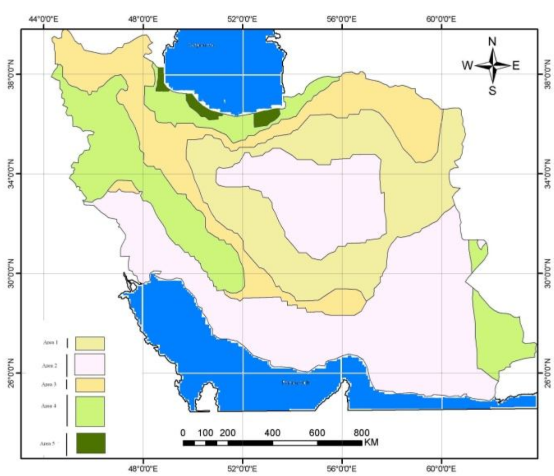
$\overline{n}$ Is the monthly average daily bright sunshine hours. $\overline{N}$ is the maximum possible monthly average daily sunshine hours (the day length) which is calculated by following equation (5)

$$N = \frac{2}{15}\omega_S \quad (5)$$

Many researchers such as: Akinoglu and Ecevit (1989) [16]; Gopinhathan (1988) [17]; Rietvel (1978) [18]; expressed Angström coefficients (a,b) in terms of different geographical and climatic parameters such as the latitude, altitude, sunshine fraction, temperature, precipitation.

2.3. Climate Classification

As mentioned before the angstrom coefficients is depended to the condition of the region climatic so considering the köpen climatic [19] Classification which is based on the precipitation and temperature and also considering the sunshine hours, five climatic region for Iran is taken in to consideration(Fig 1).



(Fig 1)

2.4. Solar radiation intensity calculating software

Received energy from the sun for 139 Iran synoptic stations by using the angstrom model is calculated. This software is able to calculate declination angle, sunset hour angle, maximum possible number of day light, extraterrestrial radiation and the global solar radiation on a horizontal surface by selecting the city and month.

2.5. Solar map

In general there is tow procedure for providing the solar map. first procedure is accomplish by using the satellite data and in the second ,for this in this paper , interpolation is used. For Preparing the radiation atlas in Iran it is used 21 primary stations (the stations that solar radiation on which is measure) and 118 secondary stations (the

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stations that solar radiation on which have been calculated) and on the basis of this measurement and calculation the monthly and annually solar map is prepared. Consequently 12 maps for 12 month by using the ArcGIS software is down.(Fig 2, a to l)

3. Results and Discussion

In this paper we want to have a suitable fusibility study of solar energy amount absorbed by the different region of Iran. Because of dispersion and limited quantity of pyranometric stations, suitable classification of climate is prepared. So considering the accomplished climatic classification the cities which have approximately the same climatic and are settled in same group are arranged in Table1.having the pyranometric data and sunshine hours for several years and calculating other parameters, using the Spss software Angström coefficients for the Iran climatic region is calculated, which are presenting at the Table 2.

Table 1 climatic city information

.	City	Climate Type	Climate Catagory	No.	City	Climate Type	Climate Category
1	Esfahan	BWK	1	59	Tabriz	Bsk	3
2	Naeen	BWK	1	60	Maragheh	Bsk	3
3	Ardestan	BWK	1	61	Miyaneh	Bsk	3
4	Kashan	BWK	1	62	Marand	Bsk	3
5	Kabotarabad	BWK	1	63	Sahand	Bsk	3
6	Kerman	BWK	1	64	Bonab	Bsk	3
7	Anar	BWK	1	65	Ahar	Bsk	3
8	Shahrbabak	BWK	1	66	Kalibar	Bsk	3
9	Rafsanjan	BWK	1	67	Makoo	Bsk	3
10	Sirjan	BWK	1	68	Khoy	Bsk	3
11	Marvset	BWK	1	69	Ardabil	Bsk	3
12	Semnan	BWK	1	70	Meshkinshahr	Bsk	3
13	Biyarjmand	BWK	1	71	Parsabadmoghan	Bsk	3
14	Ghom	BWK	1	72	Khalkhal	Bsk	3
15	Saveh	BWK	1	73	Golpayegan	Bsk	3
16	Gonabad	BWK	1	74	Meymeh	Bsk	3
17	Torbatjam	BWK	1	75	Shahreza	Bsk	3
18	Sarakhs	BWK	1	76	Khoramdareh	Bsk	3
19	Kashmar	BWK	1	77	Mahneshan	Bsk	3
20	Sabzehvar	BWK	1	78	Shahrood	Bsk	3
21	Birjand	BWK	1	79	Garmsar	Bsk	3
22	Khor	BWK	1	80	Hamedan	Bsk	3
23	Ferdos	BWK	1	81	Shiraz	Bsk	3
24	Boshroyeh	BWK	1	82	Zarghan	Bsk	3
25	Ghayen	BWK	1	83	Abadeh	Bsk	3
26	Zahedan	BWh	2	84	Neyriz	Bsk	3
27	Iranshahr	BWh	2	85	Mashhad	Bsk	3
28	Chabahar	BWh	2	86	Golmakan	Bsk	3
29	Kenarak	BWh	2	87	Neyshaboor	Bsk	3
30	Bam	BWh	2	88	Torbatheydariyeh	Bsk	3
31	Jiroft	BWh	2	89	Bojnoord	Bsk	3
32	Kahnooj	BWh	2	90	Baft	Bsk	3
33	Bandarabass	BWh	2	91	Koohdasht	Bsk	3
34	Jask	BWh	2	92	Boroojen	Bsk	3
35	Hajiabad	BWh	2	93	Saravan	Csa	4
36	Minab	BWh	2	94	Khash	Csa	4
37	Darab	Bsh	2	95	Zahak	Csa	4
38	Fasa	Bsh	2	96	Zabol	Csa	4
39	Lar	BWh	2	97	Sadedoroodzan	Csa	4
40	Ahvaz	BWh	2	98	Yasooj	Csa	4
41	Bandarmahshahr	BWh	2	99	Khoramabad	Csa	4
42	Shooshtar	Bsh	2	100	Dorood	Csa	4
43	Booshehr	BWh	2	101	Aligoodarz	Csa	4
44	Bandardayr	BWh	2	102	Boroojerd	Csa	4
45	BandarKangan	BWh	2	103	Aleshtar	Csa	4
46	Yazd	BWh	2	104	Noorabad	Csa	4
47	Tabass	BWh	2	105	Oroomiyeh	Csa	4
48	Bafgh	BWh	2	106	Salmas	Csa	4
49	RobatPoshtbadam	BWh	2	107	Mahabad	Csa	4
50	Khorbiyabanak	BWh	2	108	Piranshahr	Csa	4
51	Dehloran	Bsh	2	109	Sardasht	Csa	4
52	Poldokhtar	Bsh	2	110	Sanandaj	Csa	4
53	Arak	Bsk	3	111	Marivan	Csa	4
54	Tafresh	Bsk	3	112	Baneh	Csa	4
55	Tehran	Bsk	3	113	Saghez	Csa	4
56	Firozkooh	Bsk	3	114	Ghazvin	Csa	4
57	Karaj	Bsk	3	115	Ilam	Csa	4
58	Avaj	Bsk	3	116	Abali	Csa	4

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No.	City	Climate Type	Climate Catagory	No.	City	Climate Type	Climate Category
117	Lordegan	Csa	4	129	Amol	Csa	4
118	Koohrang	Csa	4	130	Nahavand	Csa	4
119	Zanjan	Csa	4	131	Malayer	Csa	4
120	Kermanshah	Csa	4	132	Zarinehoobato	Csa	4
121	Ravansar	Csa	4	133	Bijar	Dsa	4
122	Kangavar	Csa	4	134	Sharekord	Dsa	4
123	Eslamabadgharb	Csa	4	135	Ramsar	Cfa	5
124	Gorgan	Csa	4	136	Siabisheh	Cfa	5
125	Gonbadkavoos	Csa	4	137	Sari	Cfa	5
126	Rasht	Csa	4	138	Noshahr	Cfa	5
127	Anzali	Csa	4	139	Astara	Cfa	5
128	Manjil	Csa	4				

Table 2 Angstrom coefficient

Climate Category	a	b
1	0.352	0.373
2	0.317	0.386
3	0.343	0.347
4	0.360	0.359
5	0.404	0.204

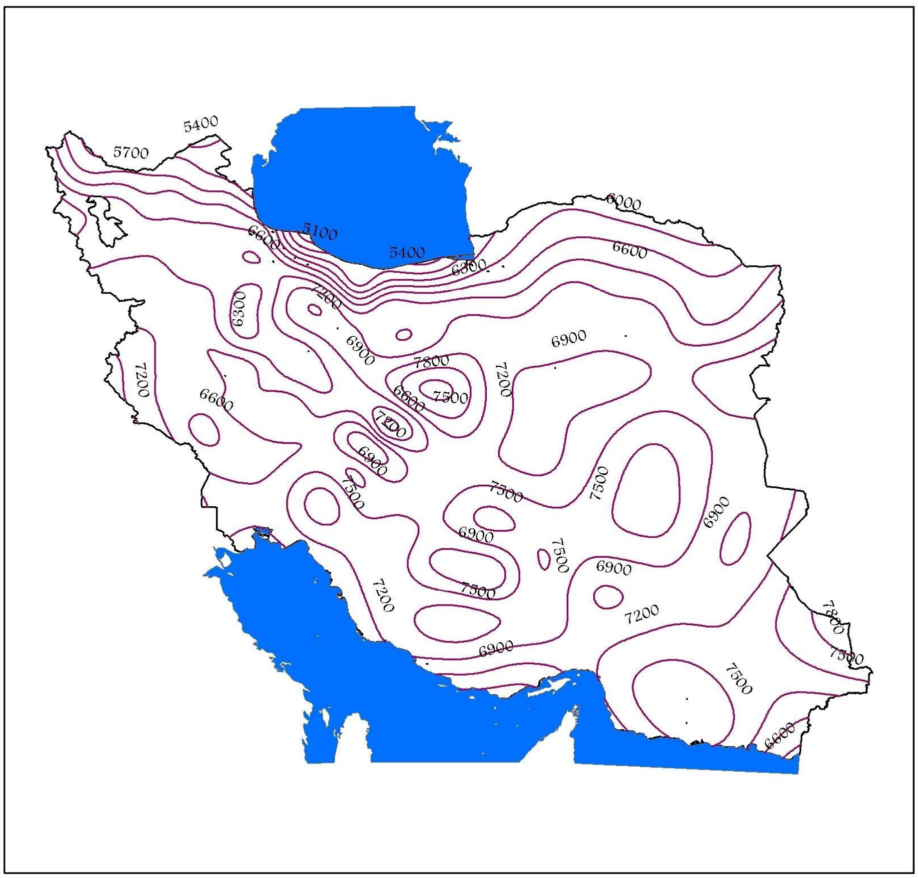
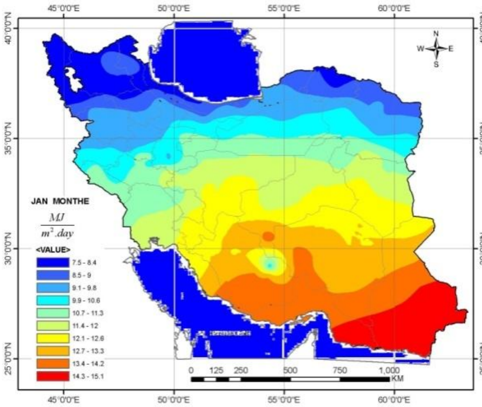


Fig 2 : Total of Global solar radiation received in a horizontal surface at annualy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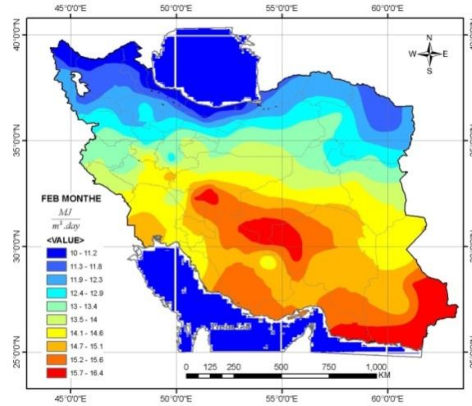
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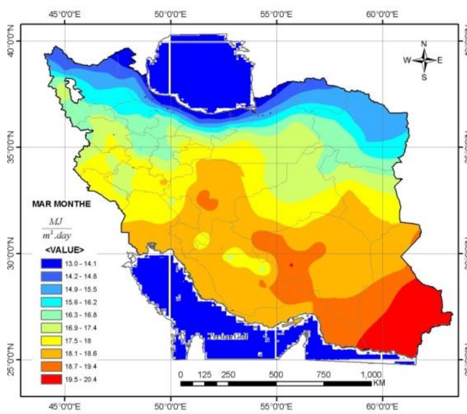
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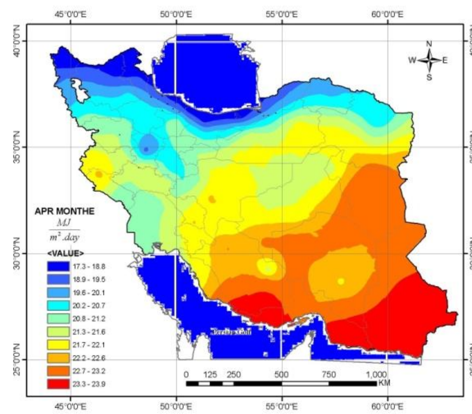
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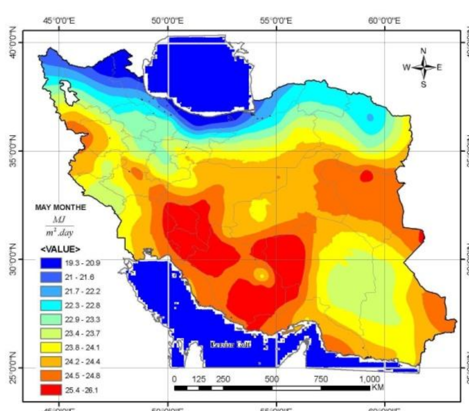
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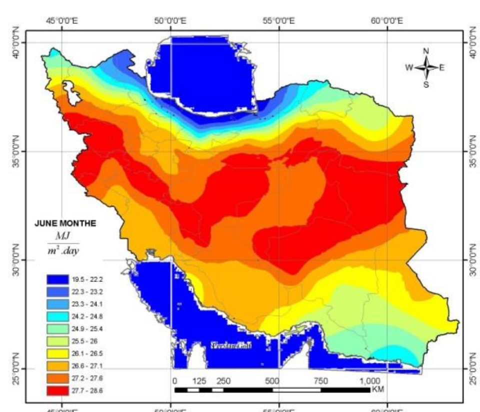
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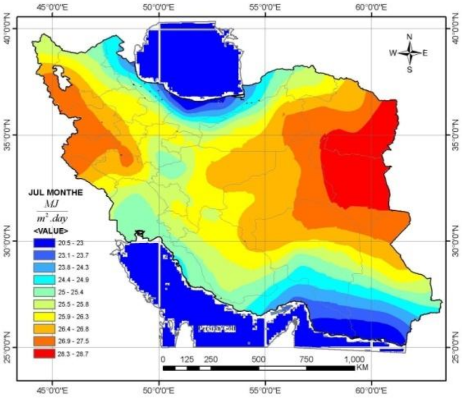

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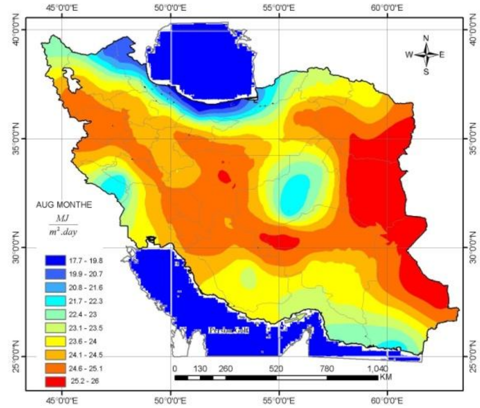

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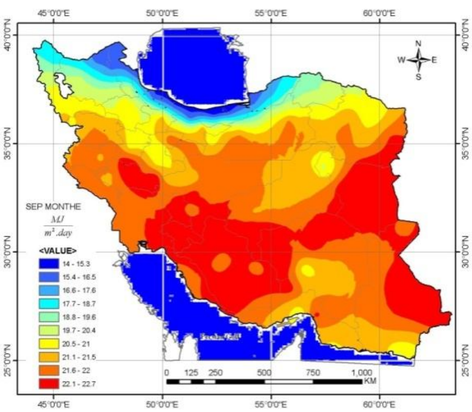

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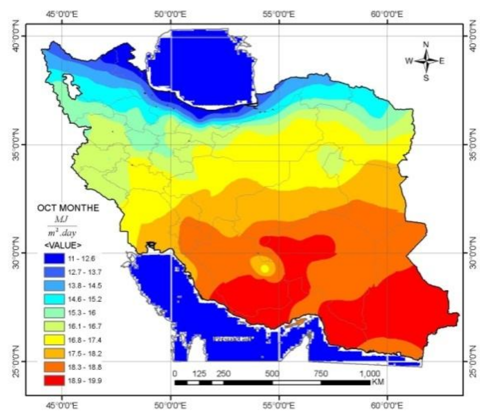

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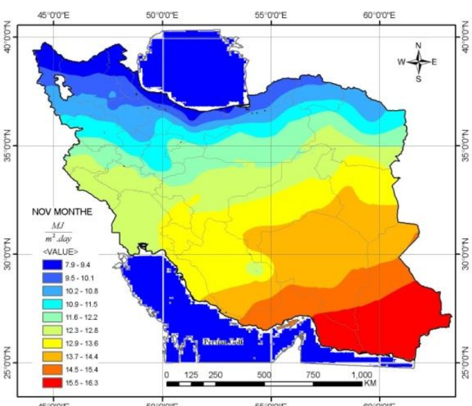

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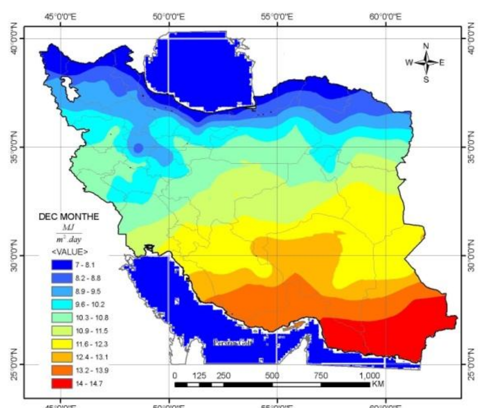

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