

Farm Workers Exposure to Heat Extreme in Upcoming Years in Southern Part of Iran

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Abstract

Excessive ambient air temperature due to global warming and climate change is capable of imposing heat stress on outdoor workers. In this study data of three synoptic metrological monitoring stations (locating at the cities of Ahvaz, Dezful and Dehdez) in a 30 years duration (1986-2016), was used. In order to predict the future trend of air temperature Hadley Atmosphere-Ocean General Circulation Model (HadCM) and Long Ashton Climate Generator (LARS) were applied. Also, Wet bulb global temperature (WBGT) index was used to determine heat stress. The results showed that the temperature will increase throughout the year in the coming years in the 3 cities. The rise of temperature rate between time duration of 2011-2040 and 2041-2070 will be about 5 °c. And the rate of increase in air temperature in the city of Ahvaz will be higher than the other two cities. Also, WBGT index showed an increasing trend in each time period. According the results it was revealed that heat stress coincidence with global warming will increase and exposure to heat for farm workers will be much more severe.

Introduction

Global climate change- an increase in temperature of at least 1.5 ° C with an expected increasing frequency and intensity of heat waves - is an expectable negative consequence in the near future [1, 2]. Although the increased exposure to heat in the climate change scenario is likely to have adverse health outcomes, the harmful effects of heat waves are likely to have the greatest impact on outdoor workers [3]. It is estimated that about 30 % of 16.1 million Iranian workers, work in agriculture sector. Also, Iran is listed in the Global Climate Risk Index [4] as one of the vulnerable regions exposed to extreme weather risks, with heat-related economic losses due to a tangible rise in the temperature. The climate is influenced by increasing greenhouse gases in the air. This leads to an increase in temperature called global warming. Due to the rising temperature in the world, we are witnessing the side effects of this global warming. As a result, the heat waves from this phenomenon puts all people, especially outdoor workers, at risk of exposure to heat-related illnesses and even death [5, 6]. Heat stress at work have previously been associated to skin, cardiovascular and kidney diseases in workers due to high working temperatures [7]. Heat stress causes sweating and dehydration with subsequent blood volume depletion, which can lead to acute kidney damage [8]. Measurement of weather factors including air temperature, relative humidity (RH) and precipitation are necessary for conducting climate change surveys. In this regard, heat stress in the workplaces is determined by thermal stress indices [9]. The Wet-Bulb Globe Temperature (WBGT) is one of the most accurate and reliable indices. First introduced by Minard and Yaglu in 1957, this index became a part of ISO 7243 standard in 1989 [10, 11]. Hadley atmospheric-ocean general circulation model (HadCM) is one of general circulation models (GCM) which was developed by Gordon et al. in 2000 [12]. The HadCM model is implemented at the Hadley center for climate prediction and research in the UK. This model has a grid-point with dimensions of 2.5 degrees of latitude and 3.75 degrees of longitude. This model has many advantages such as high resolution of ocean components, good coordination between the atmosphere and ocean components and etc. But this model, has little spatial resolution, that in order to solving this problem, the output must be scaled up

before it can be used to assess the impact of climate change [13]. This model can also be used without the use of super computers, which is why it has received so much attention in climate studies. The Long Ashton Research Station Weather Generator (LARSWG) model is one of the models used based on statistical methods. This model is widely used in predicting and modeling future climate change [14, 15]. The present study aimed at 1. Modelling the trend of climate change by HadCM and LARS in order to predict future climate change trend, 2. Determining heat stress in exposed farm workers.

Results

Table 1 shows the model output results for the three climatic classifications (Ahvaz, Dezful and Dehdez) in three different time periods. As shown in Table 1, it is expected the temperature will increase throughout the year in the coming years in these cities. The rate of increase in air temperature in the city of Ahvaz will be more than the other two cities. Also, the rate of increase in temperature (minimum and maximum) until 2070 in the city of Ahvaz will rise with an average of 4 to 5 degrees Celsius. This increase in air temperature is in the summer and during the months of July to August. In addition, the same upward trend can be seen in two other cities. The calculation of the mean WBGT in these 3 cities during the months of the year shows a trend of increasing heat load and heat stress (Figure 1). In Ahvaz, Dezful and Dehdez, the WBGT index increased between 3 to 4 ° C during all months in each time period. In time duration of 2011-2040, the WBGT index in the months of June, July and August was obtained as very hot (Danger; >28° C). Also, in time duration of 2041-2070, the WBGT index was obtained as very hot (Danger; >28° C), hot (Extreme caution; 24-28° C), warm (Caution; 18-24° C) and comfortable (<18° C) for 5, 2, 4 and 1 months, respectively. This index was higher in all months of the year in Ahvaz. In terms of heat stress hazard classification according to the WBGT index, the city of Ahvaz is in the area of extreme caution and danger.

Discussion

One of the general concerns of the current world is climate change and global warming. As temperatures rise over the next century due to climate change, increasing heat stress becomes more important, especially for outdoor workers such as farmers, industrial workers, construction workers, and so on. Due to the consideration of safety principles, workers should use personal protective equipment such as shoes, helmets, face masks and ear muffs. Doing strenuous physical activity with protective equipment in hot weather conditions can increase the risk of heat stress [16]. The output of results of models showed the minimum and maximum air temperature in different months of the year in the three studied climatic zones an increasing trend. The temperature will increase more during the summer season. In a way, this rate of temperature increase in July and August is significant. Also, the trend of temperature increase until 2099 will be about 5 degrees Celsius. The study of Haghtalab et al., (2013) showed similar results for the city of Tehran [17]. Vaghefi et al., (2019) stated that Iran will have warmer climates during the period 2025–2049 than during the period 1980–2004, which is more severe in the southern part of the country [18]. This findings support the results of the present study. Also, several studies have

surveyed the effect of climate change on disease rates as well as mortality. By using the AR5 scenario, Petkova et al., (2013) stated that heat-related deaths in New York, Philadelphia, and Boston would increase in 2020, 2050, and 2080, indicating more difficult conditions for heat adaptation and most people are vulnerable to heat increase [19]. Nastos and Matzarakis (2012) studied the effect of air temperature and heat stress indices, with the application of the Universal Thermal Climate Index (UTCI) and the Physiologically Equivalent Temperature (PET) on mortality over a 10-year period in Athens. The results showed a significant relationship between air temperature, UTCI, PET and mortality rate [20]. Considering that physiological capacities will be more limited in heat conditions, if the Earth's temperature rises to at least 7 degrees Celsius, over populated areas of the world will be uninhabitable due to climate change. In this study, the WBGT index was used to assess heat stress in agricultural workers. This index is one of the most widely used tools for estimating heat stress worldwide and the WBGT index is well correlated with physiological parameters [9]. The study findings showed that the WBGT index has an increasing trend until 2099, which is much higher in Khuzestan province and Ahvaz city. The results also showed that the mean monthly WBGTs occur in March in Khuzestan (caution, 24-28 ° C). So more farm workers can be affected by this risk factor in following years. In a study based on time series modeling, the trend of past and future heat stress in outdoor workplaces in Tehran showed an increasing trend in the average annual WBGT (1961–2009). It also estimated a 1.6 ° C increase in WBGT index until 2050 [21]. In another study using the WBGT index, the effect of climate change during the period of 1973 to 2003 was examined for 15 regions of the world on increasing the heat stress threshold. The results showed an upward trend in all zones except the northeastern United States and northeastern Australia [22]. Also, using the HadCM3 model, regional changes in mean summer air temperature, RH% and WBGT were identified under the A1B scenario in 2020-2050. The results showed that WBGT index is incremental for all zones, but changes in air temperature and RH% depend on climatic conditions in the study areas (Willett and Sherwood, 2012). Similar finding is obtained in this study. Maeda et al., (2006) revealed that deaths in August and July were higher than in other months of the year [23]. Furthermore, the results of the study showed that the WBGT index increased to 5.5 ° C in July and August, thus outdoor workers can be the most vulnerable. Studies have shown that global warming and rising temperatures will be a major challenge in the coming years. Developed countries have a significant role to play in increasing fossil fuel consumption. And developing countries are more vulnerable to the effects of the global warming. Earth temperatures are estimated to rise between 2.5 and 7 degrees Celsius during the current century. Therefore, attention to this phenomenon should be considered [24]. Due to climate change, outdoor workers can be the most vulnerable affected population. Extreme heat combined with various job needs such as clothing, workload, metabolism, long hours of exposed to heat, and personal protective equipment may lead to severe heat stress. And other complications associated with hot weather such as skin rash, muscle cramps, heat exhaustion, and death may occur in hot months. Also, ignoring heat stress in the workplace can lead to a decrease in physical capacity and mental performance and has a negative effect on the work ability, in addition to a wide range of heat-related complications and diseases [6, 9, 25].

In the present study, temperature changes in the coming years were modeled using WBGT index and general circulation models. The results indicate an increase in temperature and an increase in heat stress load for people working outdoors, including agricultural workers. Therefore, exposure to heat stress in Khuzestan is increasing in most months of the year, especially in the hot months due to global warming. Rising temperature is known to be a health concern in the coming decades and it can exert adverse effects on the health of people, especially vulnerable people such as the elderly, children and patients. Heat stress can also affect the level of health, safety and productivity of outdoor workers, including farmers. It is suggested that working on farms should be limited to early morning and late evening hours in order to reduce heat stress risk as much as possible.

Methods

Study area

Khuzestan province is located in the southwest of Iran (31.4360° N, 49.0413° E). The region is located in a hot semi-arid climate zone and most meteorology stations have recorded a maximum air temperature of 50°C in recent summer. This region is divided into three different climatic classifications and in each of them, a meteorology station was selected. 1- hot semi-arid climates; [Dezful](#) (32.3831° N, 48.4236° E), 2- hot desert climates; [Ahvaz](#) (31.3183° N, 48.6706° E) and, 3- cold semi-arid climates; [Dehdez](#) (31.7011° N, 50.2946° E).

Collection of data

The environmental parameters such as minimum and maximum air temperature, RH% and solar radiation were obtained from the stations of the Meteorological Organization of Iran. The data was recorded in Ahvaz, Dezful and Dehdez weather stations in 1986-2016 time period.

Hadley Atmosphere-Ocean General Circulation Model

The HadCM version 3 model was used to predict the weather in the coming decades. The GCMs were three-dimensional and able to adapt the climatic system to most processes simulation in the global scale or continents. Also, many scenarios such as A1B, B1, A2 and A1 were introduced by Intergovernmental Panel on Climate Change (IPCC). The scenario A1B was used in this study. The hypotheses is the balanced use of different energy sources, low population growth and rapid growth of new technologies [26]. Also, in order to downscale the HadCM3 output the LARS-WG model was used.

Long Ashton Climate Generator Research Station

The original version of the Lars model was developed by Racsco et al. (1991) as part of an agricultural risk project [27]. Later, this model was improved by Semenov and Barrow (2002) [28]. LARS is a random generator of meteorological data that is used to generate daily data on maximum and minimum air temperature, precipitation and daily radiation in a station under current and future weather conditions [13]. In LARS, precipitation and probability modeling is performed by quasi-experimental probability

distributions and the Markov chain. Radiation and temperature modeling are based on the experimental probability distribution and the Fourier series [29]. This model has been reported at 18 stations in Canada and 20 stations in different parts of the UK in the production of climate data (temperature and precipitation) and is very accurate [30, 31]. Calibration, evaluation and production of weather data are three stages that are carried out in the model to generate the data. Input data from each station included location name, altitude, and daily meteorological data. After the data is analyzed, the output file contains statistical characteristics of the data, including the simulated monthly average for the entire study period. In this study, climate modeling has been done for the years 2011-2040, 2041-2070 and 2071-2099. The minimum and maximum air temperatures were used as data generation in each time duration. Due to the fact that the LARS model does not predict the relative humidity (RH) factor, it is necessary to introduce a correlation coefficient between the mean air temperature and RH in the meteorological data from 1986 to 2016. Also, to calculate RH, a linear regression formula was performed (Table 2). The SPSS 19 and Excel 2013 soft wares were used to data analysis.

Calculating WBGT

The WBGT equation was used as below [32].

$$WBGT = 0.567 \times t_a + 3.94 + 0.393 \times E \quad (1)$$

$$E = \frac{RH}{100} \times 6.105 \times e^{17.27 \times \frac{t_a}{237.7 + t_a}} \quad (2)$$

Where, t_a : average air temperature ($^{\circ}\text{C}$), E : Vapor Pressure of Water (hpa), RH : Relative humidity (%).

Declarations

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Author Contributions

B.F.D, M.A and L.I.G prepared data and performed model runs, B.F.D, M.A, H.R and L.I.G designed the study, interpreted the results, and wrote the manuscript.

Conflict of interest: The authors declare that they have no conflict of interest.

Data Availability

All data used in this paper for Iran were extracted from global data, which are available at <https://ndc.irimo.ir> and can also be requested from the corresponding author.

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Tables

Table 1: Predictions for minimum and maximum air temperatures (°C) based on the LARS and HadCM3 models for the coming years in different months of the year for three area

Month	ta	Ahvaz		Dezful		Dehdez	
		2011-2040	2041-2070	2011-2040	2041-2070	2011-2040	2041-2070
January	Min	4.1	5.2	3.5	5.9	-3.2	-1
	Max	16.1	17.1	16.2	17.1	9.8	10.9
February	Min	3.1	5.3	3.02	4.5	-1	1.2
	Max	17.1	21.8	17	20.7	11.3	12.5
March	Min	8.2	12.8	8.2	11.8	7.34	9
	Max	21.3	24.9	21.3	23.1	16.5	18
April	Min	14.1	17.1	14.1	16.1	15.5	16.2
	Max	29.4	32.6	29.4	31.9	29.1	29.9
May	Min	24	27.3	24	26.8	18.5	19.3
	Max	38.9	42.2	38.9	40.7	32	32.8
June	Min	29.6	32.1	29.6	31.4	22.6	25.1
	Max	44.3	48.3	44.3	46.5	36.9	37.5
July	Min	32.1	34.2	32.1	33.1	26.8	29.2
	Max	51.2	54.1	51.2	53.4	37.9	40.2
August	Min	32.1	35.3	32.1	34.3	25.6	27
	Max	49.3	52.2	49.3	51.1	27.1	39.5
September	Min	30.1	32.1	30.1	31	21.5	23.3
	Max	42.2	45.2	42.2	44	33.3	34.5
October	Min	21.2	25.3	21.2	24.3	14.8	16.1
	Max	35.4	39.2	35.4	38	25.2	26.2
November	Min	10.2	13.4	10.2	12.9	8	9.5
	Max	29.3	34.1	29.3	33.1	17.5	18.6
December	Min	4.21	9.4	4.21	8.5	-2.1	1.3
	Max	23.5	27.4	23.5	26.9	10.9	13.7

Table 2: Pearson correlation coefficients (r) and regression relations between air temperature (ta) and relative humidity (RH) for 1986–2016 data at three stations

Station place	r	Linear regression equation
Dezful	0.82	$RH = -1.56 \times ta + 68.33$
Ahvaz	0.91	$RH = -1.62 \times ta + 69.52$
Dehdez	0.75	$RH = -1.49 \times ta + 66.91$

Figures

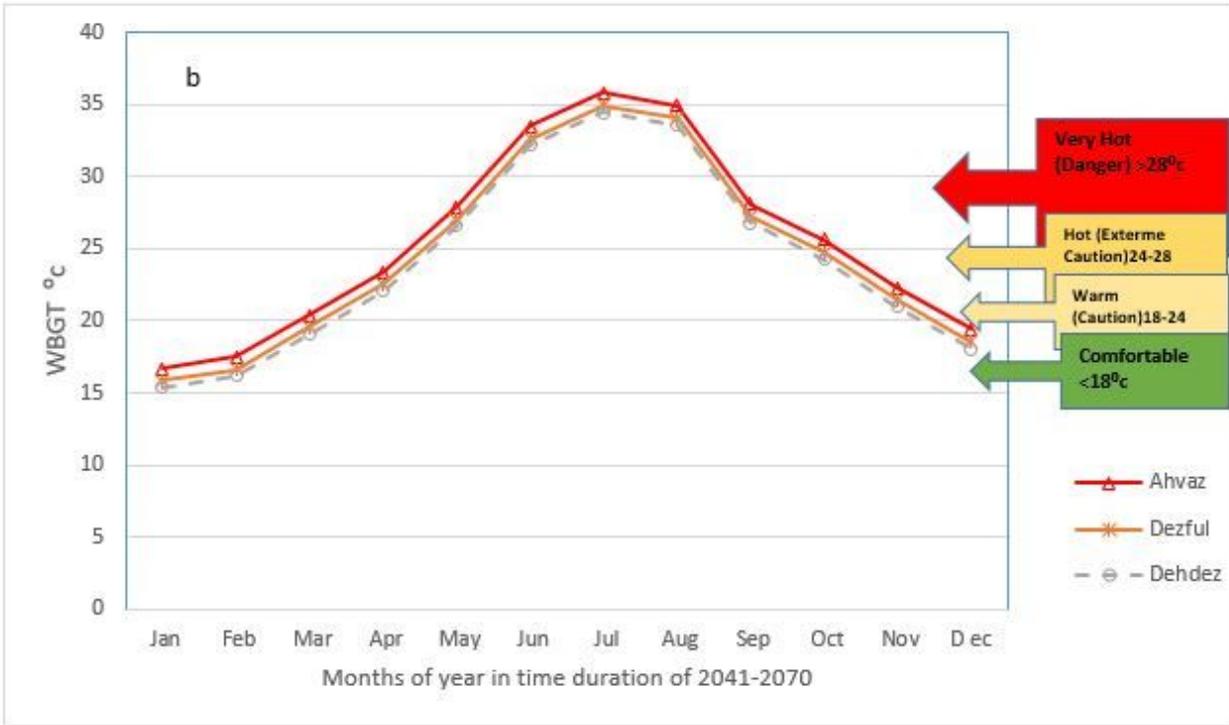
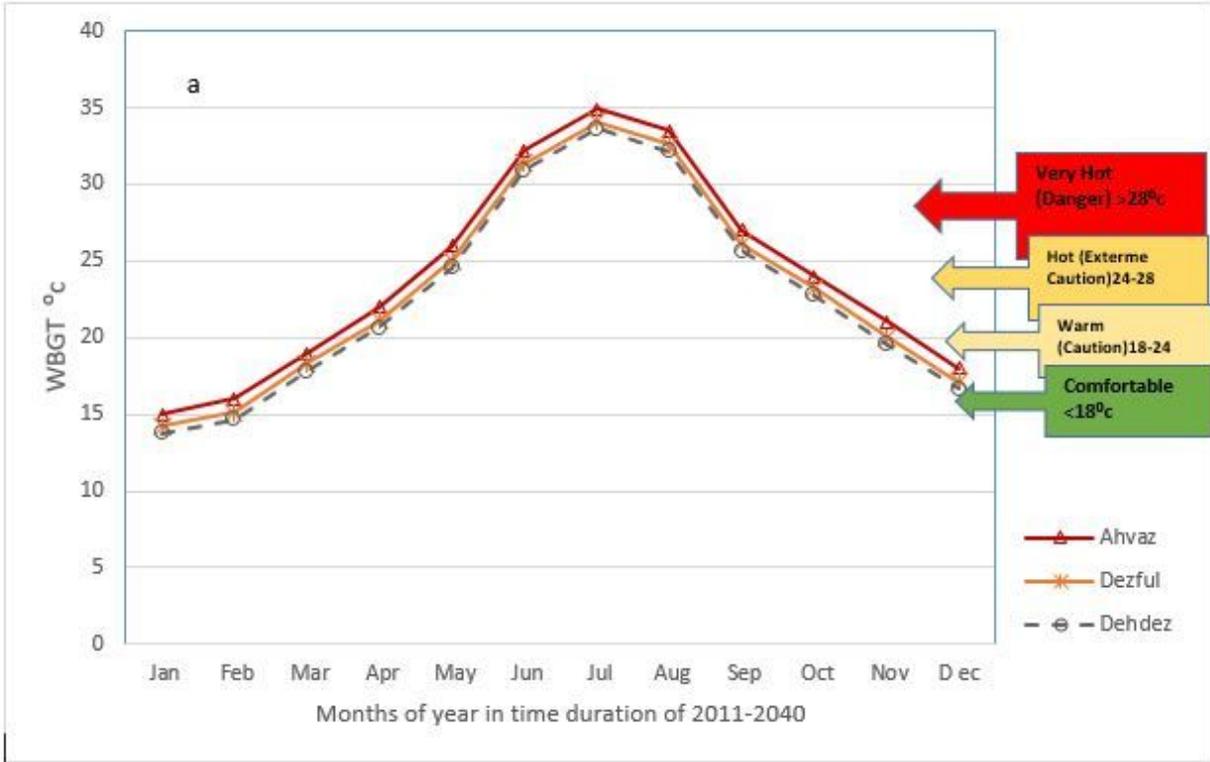


Figure 1

the calculated WBGT index in three cities; a) trends in 2011-2040 and b) trends in 2041-2070