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RESEARCH TITLE

CHANGE IN CLIMATIC (PHYSIOLOGICAL) COMFORT LEVELS IN THE BANI-WALID REGION (1962-2021)

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Abstract

This article conducts a thorough examination of evolving physiological comfort levels in the Bani Walid region by analyzing climatic data spanning six decades. The study covers seasonal and annual temperature and wind speed variations, categorized into two distinct periods: 1962-1991 and 1992-2021. To assess comfort levels, SIPILE (Seasonal Index of Physiological Impact due to Long-Term Effects) and PASSEL (Physiological Analysis of Seasonal Stress Evaluation Index) are utilized, highlighting the intricate relationship between temperature and wind speed in determining suitable conditions for various activities. Additionally, an Independent-Samples T-Test is employed for period comparison. The study reveals a noticeable temperature increase in Bani Walid during the second period, averaging one degree Celsius. Conversely, wind speed experiences a marginal decrease not exceeding 0.2 m/s. These climate changes were statistically significant at a level below 0.05, and they were found to impact the region's physiological comfort levels. This research enhances our understanding of the intricate connection between climate change and human comfort, particularly in regions like Bani Walid. Here, even slight climate shifts can have significant consequences for daily life and well-being. The study's insights provide valuable input for local policymakers and planners as they address the challenges presented by climate change on the region's inhabitants' comfort and adaptability.

Key Words: climate change - physiological comfort - temperature - wind speed - wind cooling coefficient, KO.

Introduction:

The issue of climate change holds immense significance for nations, institutions, and regulatory bodies worldwide. Its discernible characteristics have become increasingly evident, both on a global scale and within various regional contexts. Reports from the United Nations Intergovernmental Panel on Climate Change (IPCC) have notably indicated a recorded rise of approximately 0.6°C in the Earth's surface temperature, with ongoing projections suggesting this trend will persist. Furthermore, the IPCC's assessments forecast a heightened incidence of droughts, intensified hurricanes, and more frequent floods (IPCC 2013 p20). These climatic shifts are poised to extend their repercussions beyond the realm of agricultural production.

These environmental transformations encompass all systems responsible for the generation of biological elements, thereby perturbing the delicate equilibrium of the ecosystem (Lama, 2014, p. 34). Such perturbations are poised to exert adverse effects on human life, given the profound connection between individuals and their immediate surroundings. This connection hinges on the functioning of the sensory and nervous systems, which play a pivotal role in determining the extent of an individual's comfort or discomfort. Climatic alterations to which an individual is exposed can significantly influence these systems, either alleviating or precipitating ailments and even mortality. The increase in accidents, criminal activities, and suicides during severe, arid, and dusty wind conditions underscores this phenomenon, as individuals experience a diminished capacity for concentration, stemming from concurrent mental and physiological disorders (Moses, 1982, p. 125).

Furthermore, the interplay between air temperature and wind speed exerts a profound influence on human comfort. Moderate heat coupled with gentle breezes fosters a sense of comfort and zeal for industrious endeavors. Conversely, turbulent weather marked by extreme temperatures, whether high or low, leads to bodily exhaustion, anxiety, and a lack of motivation to engage in tasks. In the latter scenario, individuals contend with cold sensations, bodily shivers, and muscle contractions, resulting in uncomfortable cold pangs that may necessitate medical intervention due to substantial heat loss from the body (Maqili, 2003, p. 97).

The importance of Rasa:

This study's significance lies in its revelation of the alterations in both temperature and wind speed within the Bani Walid region and their direct influence on physiological comfort levels. It specifically delves into the pivotal role played by these two climate elements, namely "temperature" and "wind speed," in reshaping the boundaries of human physiological comfort.

Study Objectives:

1- To examine the characteristics of temperature and wind speed, encompassing their monthly, seasonal, and annual distributions and averages, within the Bani Walid region.
2- To assess the disparity in temperature and wind speed changes in the region between the two study periods.
3- To elucidate the monthly and seasonal attributes of the bioclimate in the study area.
4- To identify the most suitable seasons and months for the residents of the study area.

Study Problem:

1- Does a statistically significant shift occur in temperature and wind speed between the two study periods in Bani Walid?

2- Is there an alteration in monthly, annual, and seasonal climatic (physiological) comfort levels between the two study periods in the study area?

Hypotheses:

1- There exists a statistically significant change in temperature and wind speed between the two study periods in Bani Walid.

2- Alterations in monthly, quarterly, and annual physiological comfort levels can be observed between the two study periods in the study area.

Study Area Boundaries:

The Bani Walid region is situated in the northwestern part of Libya, within the southern sector of the Tripoli region. It covers an approximate area of 19,710 square kilometers and is geographically located between latitudes 30°30' and 00°32'N and longitudes 30°13' and 00°15'E. The southeastern border adjoins the Sirte region, while the southwest border neighbors Mizdah (Planning Secretariat, 1978, p. 26).

Study Methodology and Data Source:

1- Study Methodology: In this research, we employed a comprehensive descriptive and analytical statistical approach to examine climate elements, with a specific focus on temperature and wind speed. Furthermore, we conducted an evaluation of the physiological comfort levels within the Bani Walid region. To discern differences in the arithmetic means between two distinct study periods, we utilized statistical tests, including the (t) test. These analyses were conducted using the SPSS statistical package.

2- Data Sources: This study drew upon climatic data obtained from authoritative sources. Firstly, we accessed climatic data from the National Center of Meteorology in Tripoli, specifically collected at the Bani Walid Meteorological Station during the period from 1980 to 2000 (as detailed in Table 1). To complement this dataset and enhance its temporal coverage, we integrated data from the Google Earth Engine cloud computing platform, which provides access to climate data and remote sensing information based on the Terra Climate satellite. The validity of this additional dataset was confirmed up to the year 2021, following authorization by the Food and Agriculture Organization (FAO).

Table (1) Location of the study station

Station	Longitude	Latitude	Altitude (m)	Distance from the sea (km)
Baní Walid	**23.9464**	**32.0835**	**64**	**2.2.3434**

Source: The two researchers based on:

1. Data of the National Center of Meteorology, Tripoli, 2021.

2. Google Earth Engine Cloud Computing for Climate Data and Remote Sensing https://app.climateengine.com/climateEngine

The first topic: the change in average dry temperatures (°C) and wind speed (m/s) annually and seasonal for the two study periods

First: Change in annual rates.

The data presented in Table (2) and depicted in Figure (1) clearly demonstrate a noticeable shift in temperature between the two study periods. During the second period, there was a noteworthy increase in temperature, with a significant rise of 1°C compared to the first period.

Moreover, the data in Table (2) shed light on the relationship between temperature changes and wind speed. It is worth noting that during the second period, there was a modest reduction in wind speed, not exceeding 0.2 m/s. This decrease in wind speed was also found to be statistically significant.

Table (2): Change in annual averages of temperature (°C) and wind speed (m/s) in the study area

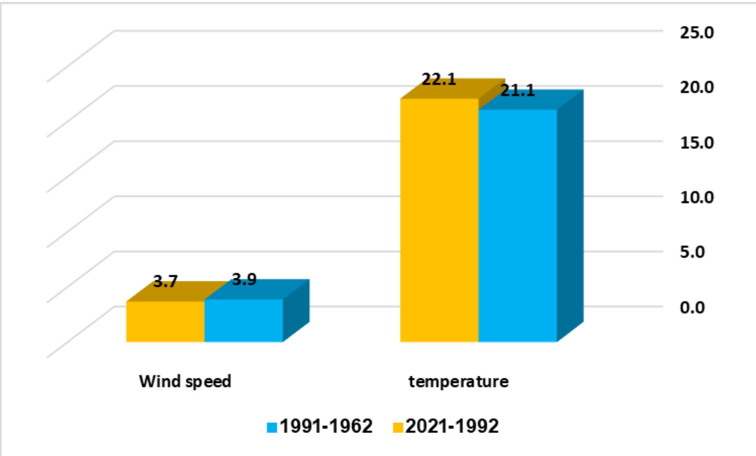
The climatic component	Period	Annual mean	standard deviation	difference in mean	level of statistical significance
température	1991 – 1962	21.1	0.4045	1	0.000
	2021 – 1992	22.1	0.4856		
Wind speed	1991 – 1962	3.9	0.3416	0.2	0.000
	2021 – 1992	3.7	0.0951		

Source: The two researchers using SPSS based on:

1. Data from the National Center of Meteorology, Tripoli, for the Bani Walid station.

2. Google Earth Engine Cloud Computing for Climate Data and Remote Sensing https://app.climateengine.com/climateEngine

Figure (1) Annual averages of temperature (°C) and wind speed (m/s) in the study area



Source: The two researchers based on Table (2).

Secondly, the study delved into alterations in quarterly averages.

The utilization of the Independent-Samples T-Test for this analysis revealed a discernible shift. Specifically, there is a pronounced trend towards increasing temperatures and decreasing wind speeds in favor of the second period (1992-2021). Furthermore, the findings elucidate variations in the magnitude of this change across different seasons of the year, as expounded in Table (3) and the subsequent analysis.

Table (3) the differences between the seasonal averages of temperature and wind speed in the study area.

Season	The climatic component	Pernod	Mean	Standard Deviation	The difference in the mean	The P value of the statistical significance
Autun	température	1991 – 1962	22.2	0.7194	1.4	0.000
		2021 – 1992	23.6	0.6633		
	Wind speed	1991 – 1962	3.4	0.4221	0.1	0.002
		2021 – 1992	3.3	0.1492		
Winter	température	1991 – 1962	12.8	0.6056	0.6	0.002
		2021 - 1992	13.4	0.7733		
	Wind speed	1991 - 1962	3.4	0.5706	0.1	0.006
		2021 - 1992	3.3	0.4694		
Spring	température	1991 - 1962	19.4	0.7136	1	0.000
		2021 - 1992	20.4	0.7866		
	Wind speed	1991 - 1962	4.4	0.3621	0.2	0.014
		2021 - 1992	4.2	0.1684		
Summer	température	1991 - 1962	28.1	0.6365	1.2	0.000
		2021 - 1992	29.3	0.7168		
	Wind speed	1991 - 1962	3.9	0.3533	0.3	0.000
		2021 - 1992	3.6	0.2153		

Source : The two researchers using SPSS based on Table (2).

1- Autumn Season: In the Autumn season, there is a noticeable upward trend in average temperature during the second period (1992-2021), with an increase of 1.4°C. This temperature shift is statistically significant, registering at less than 0.05. When examining differences in average wind speed between the two study periods, a minor reduction is observed during the second period (1992-2021), with a decrease not exceeding 0.1 m/s. This decrease is also statistically significant at a level below 0.05.
2- Winter Season: Contrasting the two study periods, the winter season witnessed an increase in temperature during the second period (1992-2021) by 0.6°C, a change that attains statistical significance below 0.05. Meanwhile, the average wind speed displayed a slight alteration in the second period (1992-2021), with a difference of 0.1 m/s, also maintaining statistical significance below 0.05.
3- Spring Season: The Spring season exhibits a tendency towards higher average temperatures during the second period (1992-2021), with an increase of 1°C. This temperature change is statistically significant at a level below 0.05.
4- Summer Season: Comparing average temperatures and wind speeds during the summer season in the two study periods, a conspicuous temperature rise emerges during the second period (1992-2021), with a substantial difference of 1.2°C. This temperature increase maintains statistical significance below 0.05. Simultaneously, there is a clear reduction in average wind speed, with a difference of 0.3 m/s between the averages of the two periods. This reduction is also statistically significant at a level below 0.05.

The second topic: the change in climatic comfort levels in the study area, depending on the wind cooling presumption KO.

Climatic comfort refers to the perception of comfort or discomfort in relation to the prevailing climate conditions and is often quantified using vital climatic indicators. These indicators can be categorized into two main types: comprehensive climate indicators, which consider the combined influence of multiple climate elements, and single climatic element indicators, which focus on the impact of a specific climate factor that strongly affects human comfort and health (Moses, 2002, p. 36).

The foundation for measuring climatic comfort begins with the thermal balance of the human body.

When a person interacts with their environment, which involves the exchange of heat through various mechanisms such as radiation, convection, conduction, and evaporation, they experience comfort when their body maintains a state of thermal equilibrium. In this state, the exchange of heat with the surrounding environment ensures that climatic conditions do not impose additional physiological demands on the individual, which could negatively affect their health and physical well-being. This state of balance is often referred to as natural comfort or a state of neutrality (Nashwan 2002, p. 45).

One valuable tool for assessing the impact of wind on the perception of temperature, whether it contributes positively or negatively, is the Wind Cooling Equivalent Temperature Index (KO). This index is selected because it provides a suitable measure to gauge the effectiveness of wind in influencing how people perceive temperature.

First: Wind chill index.

In 1945, SIPILE and PASSEL introduced the concept of the Wind Cooling Index, a metric designed to quantify the amount of heat that air can absorb from an open square meter surface within an hour. This index serves as a direct indicator of the cooling capacity of wind, in relation to the temperature in a shaded environment, without factoring in evaporation. The rate of cooling is contingent upon the average skin temperature, typically around 33°C, representing how swiftly the human body cools when exposed to moving air. Notably, clothing and hand coverings play a significant role in this context, particularly when temperature drops coincide with increased air movement and contact with the body (Moses, 2002, p. 49).

The Wind Chill Coefficient, rooted in SIPILE and PASSEL's work, aids individuals in making informed decisions regarding their clothing choices, outdoor activities, and occupational pursuits (Muqili, 2003, p. 110). Moreover, it has a substantial impact on the economies of countries, influencing recreational and tourism industries, as well as certain machinery and air conditioning systems. Its significance extends to both human and animal well-being. The relationship between temperature and wind speed, as represented by the SIPILE and PASSEL equation in Table 4, is further expounded upon by Ghanem in 2010 (p. 67).

$$KO = \sqrt{100V} + 10.45 - V\,(33 - T)$$

whereas:

V = cooling wind speed T = temperature

K = Equivalent Degree of Wind Cooling (33/10.45) = Constants

Table (4) The relationship between the wind cooling coefficient, K0, and the atmospheric condition that humans feel

Evidence value calories (m2/hour)	Sensation	Evidence value calories (m2/hour)	Sensation
50 أقل من	hot	800 – 600	cold
100 – 50	warm	1000 – 800	so cold
200 – 100	Refreshingly cute	1200 – 1000	freezing
400 – 200	cold inclined	1400 – 1200	Exposed meat freezes
600 – 400	I tend to be cold	2000 – 1400	The meat freezes in one minute
not possible		2000and over	

Source: Ali Ahmed Ghanem, 2010, Applied Climate, Dar Al-Masira for Publishing, Distribution and Printing, Amman, Jordan, p. 72.

Table (5) shows the degree of wind cooling with the level of comfort in the study area

summer				Spring				winter				Autun				Season / Indicator
average	8	7	6	average	5	4	3	average	2	1	12	average	11	10	9	
1991 -1962																
128.4	116.6	114.5	154.1	368	279.3	377	447.6	513.2	4962.	537.4	506	272.9	378.8	268.9	170.9	KO
Refreshingly cute	Refreshingly cute	Refreshingly cute	Refreshingly cute	Cryogenic	Cryogenic	Cryogenic	Cryogenic	cold inclined	cold inclined	Cryogenic	Cryogenic	Cryogenic	Cryogenic	Cryogenic	Refreshingly cute	comfort level
2021 -1992																
96	81.2	81.8	125	337.7	2407.	346	426.2	495.8	493	516.5	478	236.8	345.4	227.9	137	KO
warm	warm	warm	Refreshingly cute	Cryogenic	Cryogenic	Cryogenic	Cryogenic	cold	cold	cold	Cryogenic	Cryogenic	Cryogenic	Cryogenic	Refreshingly cute	comfort level

Source: The two researchers based on tables (3, 4)

During the summer season, there was a discernible uptick in temperatures during the second period (1992-2021). This increase was statistically significant with a significance level of less than 0.05. Simultaneously, wind speeds decreased, although this change lacked statistical significance. This shift in weather conditions had a noticeable impact on overall comfort levels, primarily due to the second period (1992-2021) experiencing warmer temperatures compared to the first period (1962-1991). To illustrate, the cooling coefficient KO exhibited a value of approximately 128.4 for the first period, while it dropped to 96 in the second period (refer to Figure 2).

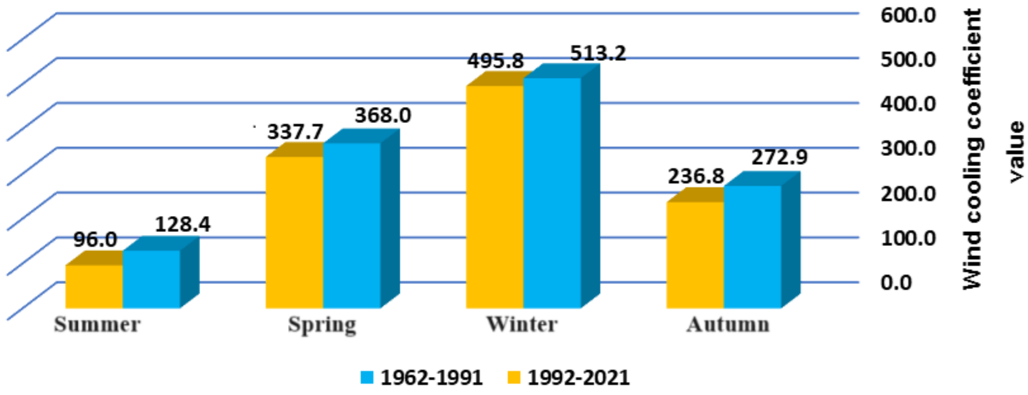


Figure (2) shows the value of the wind cooling coefficient KO in the study area (1962–2021).

Results:

1- In the second period, the study area experienced a statistically significant increase in temperature by one degree Celsius ($p < 0.000$). This temperature change had a consequential impact on wind speed, resulting in a statistically significant decrease of 0.2 m/s ($p < 0.000$).
2- The study findings indicated a noticeable rise in average autumn temperatures during the second period (1992 - 2021) by 1.4°C, which was statistically significant at $p < 0.05$. In contrast, there was a slight decrease in wind speed, not exceeding 0.1 m/s, which was also statistically significant ($p < 0.001$).
3- The results revealed a trend toward increased average winter temperatures by 0.6°C during the second period (1992 - 2021), with a significance level of less than 0.05. Similarly, there was a minor reduction in wind speed by 0.1 m/s with statistical significance ($p < 0.05$).
4- The spring season exhibited a significant increase of 1°C in average temperatures during the second period (1992-2021) with a significance level of less than 0.05. This temperature shift had a minor impact on wind speed, leading to a decrease of not more than 0.2 m/s without statistical significance.
5- The study's results demonstrated a tendency toward increased average summer temperatures by 1.2°C during the second period (1992 - 2021), with statistical significance below 0.05. In contrast, wind speeds decreased by 0.3°C/s, also with statistical significance ($p < 0.05$).
6- A comparison of comfort levels in Bani Walid between the two study periods confirmed that the second period (1992-2021) was warmer than the first period, primarily due to the substantial increase in temperatures witnessed in the study area during the second period.
7- Comfort levels during the fall season were relatively warmer in the second period (1992-2021) compared to the first period (1962-1991), as reflected in the seasonal average cooling coefficient KO, which reached 237.7 in the second period, in contrast to 268 in the first period.
8- The comparison of comfort levels in winter indicated that the first period (1962-1991) was warmer than the second period, with the first period characterized by a tendency toward coldness compared to the second period. This difference was evident in the quarterly average cooling coefficient KO, which reached 513.2 for the first period and 495.8 for the second period.
9- Comfort levels during the spring season tended toward coldness in both study periods. The cooling coefficient KO was recorded at a higher rate during the first period (1962-1991) compared to the second period (1992-2021), reaching 368 and 337.7, respectively. This difference was attributed to the rise in temperatures during the second period and a decrease in wind speed.
10- Summer comfort levels in the second period (1992-2021) were warmer than in the first period (1962-1991). This was evident in the cooling coefficient KO, which reached approximately 128.4 and 96 for the first and second periods, respectively, because of rising temperatures and a decrease in wind speed during the second period.

Recommendations:

1- The substantial increase in temperatures, particularly during the winter and spring seasons, underscores the urgent need to address the health risks associated with climate change.
2- Policymakers in Libya must prioritize and implement measures to mitigate the rising temperatures, as these changes lead to more frequent and intense heat and cold waves in the study area.
3- It is crucial to support relevant authorities in conducting scientific research projects focused on priority areas related to climate change and its impact on human health and comfort.

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