T.R.
KAHRAMANMARAŞ SÜTÇÜ İMAM UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

Determining Thermal Comfort Zones for Outdoor Recreation Planning:
A Case Study of ERBIL – IRAQ

TWANA ABDULRAHMAN HAMAD HAMAD

MASTER'S THESIS

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I hereby declare that all information in the thesis has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Twana Abdulrahman Hamad HAMAD

REKREASYON ALANLARI PLANLAMASINDA TERMAL KONFOR ALANLARININ BELİRLENMESİ: ERBİL-IRAQ ÖRNEĞİ

(YÜKSEK LİSANS TEZİ)

TWANA ABDULRAHMAN HAMAD HAMAD

ÖZET

Bu çalışma Erbil il sınırları içinde açık hava rekreasyon alanları için termal konfor alan ve zaman dilimlerini bulmaktadır. Bu amaçla, termal konfor ölçüsü olan Fizyolojik Eşdeğer Sıcaklık (PET) indeksinin haritası Erbil deki 6 farklı meteoroloji istasyonundan elde edilen veriler yardımı ile elde edilmiştir. Hava sıcaklığı, nem, ve rüzgar hızı PET hesabı için gerekli parametrelerdir. 1992-2015 arasında saat 15:00 için Erbil deki 6 farklı meteoroloji istasyonundan alınan veriler RayMan 1.2 programı yardımıyla aylık PET hesabı için kullanılmıştır. Elde edilen bu PET değerleri ArcGIS 10.2 deki IDW enterpolasyon yöntemiyle nokta değerler sürekli yüzey haline dönüştürülerek termal konfor haritaları oluşturulmuştur. Açık hava rekreasyon aktiviteleri için en uygun alanlar ve aylar bu haritaların analiz edilmesi sonucu elde edilmiştir. Çalışma sonucunda en düşük termal konfora sahip ilçelerin Ocak ayındaki 7.2 PET değeri ile Masifslahaddin, Temmuz ayındaki 56.4 PET değeri ile Makhmoor olduğu tespit edilmiştir. Buna ilaveten, Mart ve Kasım aylarının açık hava rekreasyon aktiviteleri için en ideal aylar olduğu; ayrıca Shqlawa ve Masifslahaddin ilçelerinin de rekreasyon aktiviteleri için en ideal ilçeler olduğu bulunmuştur. Aralık, Ocak ve Şubat aylarının aşırı düşük PET değerlerinden dolayı, Mayıs tan Eylüle kadar olan zaman diliminin ise aşırı yüksek PET değerlerinden dolayı Erbil için uygun olmadığıda bu çalışmanın sonucunda tespit edilmiştir.

Anahtar Kelimeler: Biyoiklim Durumu, Fizyolojik Eşdeğer Sıcaklık, Meteoroloji Verisi

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Determining Thermal Comfort Zones for Outdoor Recreation Planning: A Case Study of Erbil –Iraq

(M.Sc. THESIS)

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Abstract

This study finds out thermal comfort zones for outdoor recreation planning in Erbil. Therefore, spatial distribution of Physiologically Equivalent Temperature (PET), which is a measure of thermal comfort, was obtained for the City of Erbil using meteorological data collected from 6 different weather stations located in the study area. Air temperature, relative humidity, and wind speed are required for the calculation of PET. Data obtained from 6 meteorological stations recorded at 15:00 over the period from 1992 to 2015 were used to calculate monthly PET values with RayMan 1.2 software. PET was spatially interpolated using IDW tool in ArcGIS 10.2 to convert the point-data consisting of PET-values for individual meteorological station into a continuous surface so that maps of spatial distribution of PET values could be created. The most comfortable months and areas for outdoor recreation activities were determined by analyzing these maps. The results reveal fundamental information which is of particular relevance to recreation authorities. According to the results, the lowest PET determined was around 7.2 °C in Masif slahaddin district during the month of January and the highest PET determined was 56.4 °C in Makhmur district during the month of July. In Erbil, it was found that both March and November can be the best months for outdoor recreation during the year. December, January and February are not comfortable due to the low PET values, and May to September is also not suitable for the outdoor recreation due to the extreme PET values.

Keywords: Bioclimatic Conditions, Meteorological Data, PET, Physiological Equivalent Temperature

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Twana Abdulrahman Hamad HAMAD

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LIST OF SYMBOLS AND ABBREVIATIONS

PET	: Physiological Equivalent Tempreature
PMV	: Predicted Mean Vote
GIS	: Geographical Information System
ET	: New Effective Tempreature
LST	: Land Surface Temperature
LU/LC	: Land Use/Land Cover
RS	: Remote Sensing
OUT_SET	: Outdoor standart equivalent temperature
W	: Width
H	: Height
IDW	: Implementing Inverse Distance Weighted
USGS	: United States Geological Survey
UTM	: Universal Transverse Mercator Coordinate System
WGS	: World Geodetic System
Csa	: Mediterranean climate region
Bwh	: Arid Climate region
CLO	: Clothing
MEMI	: Munich Energy-balance Model for Individuals
T ºC	**:** air tempeature
H %	: Relative Humidity
W s/m	:Wind Speed

1. INTRODUCTION

1.1 Background

Throughout history, urban open spaces have been linked with people and activities, serving as a meeting space, marketplace, and connection space (Gehl and Gemzøe, 2001). People of all ages participated in city life where streets and the squares were festive, sociable and jovial. These patterns were extended to the early years of the twentieth century.

As the twentieth century evolved, the number of urban inhabitants rose and the use of motor cars increased. The modern movement, from mid 1920s and after, led to a radical segregation between transport, work, residents and recreation and, therefore, downgraded the importance of public spaces and changed them to be become unpleasant and undesirable. However, in the second half of the twentieth century, the concept of public space and public life emerged again and became the topic of many books, such as the life and death of great American cities by Jane Jacobs (1961). Although shopping was the main reason for people to be in public spaces, changes were taking place. Street vending and performing were back with outdoor cafés becoming popular. Pedestrian streets were introduced and old parks and squares were renewed.

1.2 Thermal comfort

Thermal comfort can be defined through three different approaches psychological, thermo physiological and heat balance of the human body. ASHRAE defines thermal comfort from the psychological approach as the condition of mind, which expresses the satisfaction with the thermal environment. The thermo physiological approach is based on the firing of the thermal receptors in the skin, so the thermal comfort is defined as the minimum rate of nervous signals from these receptors. According to heat balance approach, thermal comfort is when heat flows to and from the human body is balanced, and skin temperature and sweat rate are within a comfort range (Hoppe, 2002). Keeping in view the definitions above, we need to take into account a variety of parameters, which include environmental and personal factors when deciding what will make the people to feel comfortable. The combination of these factors constructs what is known as the human thermal environment.

The Parameters That Interfere with Thermal Comfort in Urban Space Are Similar to Those of Inside spaces, but they are more extended and variable (Letícia Zambrano et al., 2006). The thermal comfort in an urban space depends on environmental factors such as air temperature, Mean radiant temperature, Air velocity, relative humidity, solar incidence and radiation exchanges, and local characteristics of winds. Personal factors such as person's clothing CLO, activity level MET also influence the thermal comfort of the users. Beyond these factors, the urban design, the morphology of the buildings, the characteristics of the surfaces, the topography, the vegetation, the presence of water and the behavior of the individuals are furthermore factors that influence the thermal conditions of these spaces (Dessi, 2001).

From earlier research (as reported and reviewed in e.g. (Fanger, 1970, Gagge, 1986) we know that thermal comfort is strongly related to the thermal balance of the body. The human energy balance shows the various factors affecting human outdoor comfort. Out of these heat gain/loss factors.

The most significant one is the total radiation, which can amount to up to half the total heat gain on the subject. On the other end of the spectrum is the ambient temperature, which accounts for only 7% of the heat gains (Rowe, 1991). Therefore, lessening the exposure to and reducing the

Temperature of the surrounding surfaces (i.e., MRT) is the most effective means to achieve Outdoor thermal comfort for pedestrians in urban spaces (Bryan, 2001). Recently, open urban spaces have started accommodating recreational, cultural, and sport activities. Urban spaces are used for longer hours including evenings and weekends. Attracting visitors and hosting activities are essential for the success of such outdoor spaces. Many factors in the open urban space contribute towards this success. Open urban spaces, therefore, should provide visitors with essential qualities, such as: enjoyment; opportunities for passive and active engagements, and comfort Outdoor public spaces play a significant role in improving public health and wellbeing of people and reduce government expenditure. A recent study by Roberts-Hughes (2013) examined the relationship between the quality of public spaces and human health and wellbeing in England. The study claimed that if 75% of people across the country did meet the recommended exercise level such as walking for 20 minutes five days a week, one in eleven early deaths could be avoided and 900 million could be saved every year.

Moreover, outdoor public spaces are considered to be a key aspect in improving the health and wellbeing of young people by facilitating physical activities. In a multidisciplinary study, Mahdjoubi (2007) and his team explored the effect of the design of outdoor public spaces on the decline of young people's physical activities. The study revealed that social and physical environments are two critical areas to offer better opportunities for young people to engage in outdoor physical activities.

Furthermore, outdoor public spaces play a substantial part in enhancing the health and wellbeing of older people. As part of the research project I'DGO (Inclusive Design for Getting Outdoors) Sugiyama and Ward Thompson (2007) aimed to comprehend the link between health, outdoor activity and the quality of environments. They concluded that the local environment may influence the health of older people in two ways. The first one is by providing opportunities to be active i.e. physical activity. The second way is through providing suitable places where people can meet outdoors i.e. social activity. The study suggested that both the quality and quantity of outdoor activities contribute to the wellbeing of older people.

According to UN State of the World Population 2007 report (UNFPA, 2007), the majority of the global population is living in urban areas for the first time in history. Since the number of inhabitants in urban areas increases, the physical environment of cities and human activities are expanding and affecting the environmental quality and causing increase in ambient temperatures and pollution. Therefore, the demand is greater than before for adequate outdoor public spaces that meet the social, cultural and comfort needs of people. Fulfilling this demand will encourage people to stay longer outdoors socializing, exercising and enjoying nature, hence improving their health and wellbeing.

In order to achieve better outdoor spaces, people needs must be fulfilled. Carr (1992) considers comfort as one of the user needs that should exist in order for open space to be well used. Other needs can hardly be met without the existence of comfort. Whyte (1980) found that "the most popular plazas tend to have more seating than the less well-used ones". Other attractive elements of open space cannot make people come and sit if there is no place to sit. "Sitting should be physically comfortable. It is more important, however, that it be socially comfortable." This means that users should be able to choose their seating area whether in the sun or in the shade when they are in groups or alone. Bosselmann et al., (1983) considered access to the sun or having shelter from it is an important factor in the use of open space, while Gehl (1996) linked the level of activities in an urban open space with the microclimate of this space.

The thermal environment in public spaces can significantly influence users' thermal perception and thus their use of the space. Thus, aiming at improving microclimatic conditions in urban spaces and enhancing the thermal comfort will most likely encourage people to spend more time outdoors, with the potential to boost the social cohesion of a space and increase economic activity. This should improve the environmental quality of cities in which people live and work and should eventually improve their quality of life.

Research related to thermal comfort in urban spaces can be characterized into two aspects:

1- Studying the impact of urban geometry on the environmental parameters and hence outdoor thermal comfort.
2- Studying the effect of microclimatic conditions on thermal comfort and the behavior of people in urban open spaces through field surveys.

The first aspect, the impact of the physical environment on thermal comfort in hot climates, has been the focus of many urban climatology studies (Ali-Toudert et al., 2005; Dalman et al., 2011; Krüger et al., 2010; Shashua-Bar et al., 2004; Pearlmutter et al., 2007). The main themes investigated in literature include the influence of street canyon geometry on pedestrian thermal comfort (Pearlmutter et al., 1999; Ali-Toudert and Mayer, 2006), the influence of shading and trees on the microclimate (Shashua-Bar et al., 2011; Hwang et al., 2010). Simulations, measurements, and physical open air scale models have been used as methods of investigation. Simulations or numerical modeling has been described as a perfectly suited methodology to deal with the complexities and nonlinearities of urban climate studies (Arnfield, 2003).

In the second aspect, local microclimates influence the thermal sensation of people in urban open spaces and accordingly they affect behavioral aspects, such as attendance and activities

(Nikolopoulou et al., 2001, Zacharias et al., 2001, Zacharias et al., 2004; Dessi).field surveys have been used to study the behavioural aspects of people, in relation to their thermal environment outdoors (Makaremi et al., 2012; Ng and Cheng 2012; Xi et al., 2012). Other studies have examined thermal adaptation of users, including thephysical and psychological adaptation (Nikolopoulou et al., 2001; Thorsson et al., 2004b; Lin et al., 2011). In recent years, there has been an increasing interest in the association between culture and climatic characteristics that influence the thermal comfort and the use of outdoor spaces (Knez and Thorsson, 2006; Thorsson et al., 2007). Field surveys in outdoor thermal comfort studies are often carried out by measuring relevant microclimatic variables or objective data. These data include air temperature, wind speed, relative humidity and solar radiation, from which thermal indices can be calculated. In addition, subjective data, such as thermal evaluation and preference, are collected from participants on site by structured interviews and questionnaires. Attendance and the activities are usually monitored by observations. However, very few studies in this category have been carried out in hot climate areas and in particularly hot arid climates.

1.3 Research objectives

- to determinee PET (physiological Eequivalent Ttemperature) for all districts of Erbil (Erbil, Makhmur , Masif Slahadin , Shaqlawa , Soran and Koyea)
- to determine which district is the most comfortablee for outdoor recreation throughout the year
- to examine which factors that affect to PET most in all districts

2. LITERATURE REVIEW

2.1. Thermal Comfort

Comfort defined as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE, 2004). Therefore, the term ‘comfort’ might be used to describe a feeling of satisfaction, a sense of relaxation, or a state of physical and mental well-being (Giridharan et al., 2008). Some theories has dealt with the physical aspect and of thermal comfort such as the heat balance model, others dealt with psychological aspect such as the adaptive approach.

2.1.1 Heat balance model

The conventional thermal comfort theory is based on the balance between the human body and its environment so that the internal body temperature is kept closely around 37°C. The balance is maintained by a continuous exchange of heat the human body and its surroundings. The exchange may occur by conduction, convection, radiation and evaporation and these physical processes are influenced by environmental components such as air temperature, wind speed, humidity and solar radiation and personal factors that can be controlled by individuals, such as activity and clothing (Park et al., 2012).

ASHRAE Standard 55 (2004) and ISO7730 (2005) are based on a heat balanced model of the human body and are derived from extensive climate-chamber experiments in multitude climate regions. They are often considered to be universally applicable as a model for comfort, however they do not work as well for buildings that are naturally ventilated, or in environments that provide the opportunity for individual localised control. Neither are they fully applicable to outdoor spaces.

Fanger (1970) developed the Predictive Mean Vote (PMV) which is a steady-state model that represents the heat balance between heat production and heat dissipation by the human body. The PMV is expressed by a thermal comfort equation uses air temperature, humidity; mean radiant temperature, relative air velocity, activity level and clothing insulation value. The PMV model has been used frequently to underline the effect of adaptation in outdoor settings. However, it is important to highlight that the PMV model was intended for indoor, fully conditioned buildings. According to the steady-state heat balance theory, the human body is a passive recipient of thermal stimuli (Brager and de Dear, 1998) and the PMV does not take adaptation opportunities into account. More recently, studies have been conducted to widen the applicability of the original PMV (Van Hoof, 2008). For example, Fanger and Toftum (2002) introduced an extension to the PMV by proposing an expectancy factor "e" to explain the overestimation of thermal sensation in non-air-conditioned boiling in warm climates. Yao et al. (2009) have considered factors such as culture, climate, and social psychological and behavioral adaptations in developing the PMV model.

In the outdoor settings, the PMV was compared with the actual thermal sensation vote of the visitors of urban public spaces in temperate climates, the results indicated that a purely physiological approach, which is based on heat balanced models such as PMV, cannot adequately characterize thermal comfort conditions (Nikolopoulou et al., 2001) and other socio-cultural and psychological parameters become increasingly important (Knez and Thorsson, 2006; Thorsson et al., 2004a). The PMV, however, is not yet appropriate for use outdoors.

The Physiological Equivalent Temperature (PET) (Mayer and Höppe, 1987) is another thermal index that gives the thermal assessment of a given environment. PET is based on the Munich Energy-balance Model for Individuals (MEMI)1 (Höppe,1984) is defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed. On hot summer days, for example, with direct solar irradiation the PET value may be more than 20 K higher than the air temperature, on a windy day in winter up to 15 K lower.

2.1.2 Adaptive approach

The adaptive approach to thermal comfort suggests that people can take actions to ease their comfort conditions by increasing or decreasing their activity levels and clothing or by interacting with the built environment (Sugawara et al., 2008). This led to the idea of "adaptive opportunity", which indicates the level to which people can thermally adapt to their surrounding space. When the adaptive opportunity is inadequate, leaving thermal neutrality leads to discomfort sensation (Baker and Standeven, 1996).

Field surveys in the adaptive context enable the study of subjects in their "real world" settings, with the purpose of including the full complexity of conditions that subjects may experience, whereas other approaches, such as the heat-balance, depend on laboratory or climate chamber conditions for their experiments.

There is much interest in the adaptive approach in studies of thermal comfort for two reasons according to Nicol (2008). Firstly, there are doubts as to whether it is possible to transform results obtained under laboratory research settings to represent the complex conditions of the "real world" settings. Secondly, filed studies such as Brager and de Dear (1998) and Nikolopoulou et al., (2001) show that people adapt to their own climates and tend to tolerate much more variation of thermal conditions than those predicted by laboratory-based thermal models.

Field survey is even more central in thermal comfort research in outdoor settings. Outdoor environmental conditions are even more complex than in side buildings. Moreover, people in outdoor spaces have less control over the surrounding environments compared with some indoor spaces. Hence, adaptation is likely to be the only option for people to cope with the outdoor thermal conditions. An individual may adjust his temperature range by 6˚C (McIntyre 1980) This involves wearing or taking off clothes or reducing the metabolic heat by 10% with the consumption of cold drinks (Baker and Standeven,1996) or changing positions

Adaptive models are generally linear regression models that relate indoor design temperatures or acceptable temperature ranges to outdoor meteorological or climatological parameters (Brager and de Dear, 1998). Therefore, thermal neutrality is an important term when talking about the adaptation approach. Thermal neutrality is defined as the temperature which gives a neutral thermal sensation, neither warm nor cool, in the environment (Humphreys, 1975) or the thermal index value (temperature) corresponding with a maximum number of building occupants voting neutral on a thermal sensation scale (Brager, 1998). Nikolopoulou et al., (1999) defined three types of adaptation: physiological, physical, and psychological. The physiological adaptation is not of fundamental importance in this context because it is caused by exposure to a stimulus, leading to a gradually declining strain from such exposure (Clark and Edholm, 1985).

2.1.3 Physical adaptation

Physical adaptation is one of the three types of thermal adaptation defined by Nikolopoulou et al., (1999) and refers to the physical adjustments that a person makes to alter him/herself or to change the environment to meet his/her needs. Therefore, physical adaptation has two types: reactive and interactive. The reactive adaptation, or personal adaptation, includes subjective changes such as altering one's clothing level, or changing position or activity. The reactive adaptation types will be further explained in the following sections. The interactive adaptation includes actions made by individuals to the environment to improve their thermal conditions, such as closing a blind or opening a window. This type of physical adaptation is limited in open spaces due to the nature of outdoors spaces (Nikolopoulou , 2011b).

2.13.1 Activity

Activity level influences energy production in human body and can considerably affect the comfort level. Activity level is expressed by mets: each met is the metabolic rate of a seated relaxed adult and equals 58 W/m^2 (Clark and Edholm, 1985). Different types of activities with the relevant metabolic rates some activities such as hard physical work or sport may produce conditions that cause thermal discomfort. For example, an outdoor thermal condition that is comfortable for activity such as walking can be uncomfortable for running. This is due to the surplus of energy added to the energy budget of the body. Therefore, one may take action such as removing some clothing. Another option is providing appropriate design for running paths which allows suitable thermal conditions for running.

2.1.3.2 Clothing

Clothing influences human thermal sensation by offering thermal insulation that is suitable to one's environment. It is expressed by m2K/W or in CLO units which equals 0.155 m^2K/W. In hot climates, clothes protect the body from solar radiation. However, it might stop the body from releasing surplus body heat. In hot climates, it is important for clothing to allow the cooling effect of air movement. For example, a western outfit has a thermal insulation value of 0.3 CLO while a North African traditional loose dress in bright colours CLO value of up to 0.5 (Clark and Edholm, 1985). The traditional clothing in hot arid zones helps the cooling effect of air movement. Long open dresses boost ventilation between the body and the dress because of air movement from the bottom upward (Zrudlo, 1988).

2.1.4 Psychological adaptation

The response of people to a physical stimulus, in a certain situation, depends on the information that people have for this situation rather than on the magnitude of the stimulus. Therefore, thermal perception of a space is influenced by psychological factors (Nikolopoulou and Steemers, 2003). The following factors affect psychological adaptation.

2.1.4.1 Naturalness

People tend to have more tolerance to non-artificial changes occur in their physical environments (Griffiths et al., 1987). In outdoor spaces as opposed to buildings interiors, most of changes to the physical environment take place naturally. Therefore, Nikolopoulou and Lykoudis (2006) found that people in outdoor spaces tolerate a wide range of air temperatures the changes For example, in the comfort levels are very high for a wide range of air temperatures across Europe, where all environmental changes occurs naturally.

2.1.4.2 Expectations and Experience

People's perceptions are prominently influenced by what the environment should be like, rather than what it truly is like Nikolopoulou and Lykoudis (2006). Expectations and experience explain the difference in comfort temperature between the transitional season i.e. autumn and spring. The first one is preceded by warmer temperatures therefore people tend to be less tolerant to cold, hence the temperature in which people feel comfortable is higher than that in spring (Zrudlo, 1988).

2.1.4.3 Time of exposure

Thermal perception of people in external spaces influences the period of their stay out i.e. how long they intend to spend in the area (Nikolopoulou and Steemers, 2003). This issue is of particular importance when talking about the level of activity in outdoor public spaces because level of activity can be stimulated by both high numbers of people and by longer individual stays (Gehl, 1996). People are able to tolerate thermal discomfort if they anticipate that their exposure to it will be brief.

2.1.4.4 Perceived control

Perceived control as opposed to actual control advises available choice. It is a state of being in control over a source of discomfort and according to Evans (1984) this increases tolerance and reduces people's annoyance. Therefore, when an outdoor space offers seats in the shade and others in the sun, people are expected to stay longer than if only one option was available, regardless of whether they use the other option or not. Since actual control over thermal discomfort source is limited in outdoor spaces, perceived control is important in such places (Nikolopoulou and Steemers, 2003).

2.1.4.5 Environmental stimulation

Environmental stimulation is one of the main reasons why people spend time outdoors, breaking the boredom and seeking satisfaction. When outdoor spaces offer various types of environmental stimulations, people tend to have higher tolerance to weather conditions in them. This leads to more people visiting the outdoor space and more time being spent in it. The reason is that neutrality does not necessarily lead to satisfactory; however, environmental stimulations such as sun or fresh air after being in the office for a long time on a warm day do (Nikolopoulou, 2011b).

2.2. Environmental parameters affecting thermal comfort

The prevailing climatic environment of a hot arid region is the product of the interaction of several meteorological components of climate, such as air temperature, solar radiation, wind, and humidity.

2.2.1 Air temperature

The body exchanges heat with the surrounding air which occurs by convection. Thus, when the air temperature of a room increases, occupants become warmer and when it decreases, they become cooler. However, in the outdoors, a particular air temperature such as 21°C could be perceived as uncomfortably cool (in a windy and shaded place) or uncomfortably warm (with no wind in sunshine and a humid place). It might be also perceived as comfortable. Thus, air temperature alone is not a sufficient indicator of human thermal comfort outdoors. Although air temperature strongly influences outdoor thermal comfort, the design of outdoor spaces has very little impact on mitigating air temperature (Yang et al. 2011). Yet a few strategies have been learnt and used in practice to increase or decrease air temperature. To increase air temperature, designers may maximize solar exposure by creating sun traps facing south and using dark materials. Minimizing the flow of cold wind by providing windbreaks is another method. To decrease air temperature, vegetation can provide both shade and evaporative cooling which can also be obtained from water features.

2.2.2 Solar Radiation

When solar radiation arrives from the sun at the surface of any object, it will be reflected, absorbed and/or transmitted through the object. Hence, an object in outdoor space is subject to direct solar radiation from the sun, diffused radiation from the sky, and reflected radiation from the environment. Designers of outdoor space aim at allowing maximum access to solar radiation when heating is required and provide protection from undesirable solar radiation when cooling is required. Solar radiation is an environmental component that can be modified. Some techniques are available to modify solar radiation towards acceptable thermal conditions. For example, providing deciduous trees gives shade in summer and allows solar radiation access in winter. Moreover, suitable location and orientation to outdoor spaces provides suitable shading and solar access throughout the year.

2.2.3 Wind

Wind, as an environmental factor, is one of the key differences between outdoors and indoors. Wind influences the use of outdoor spaces directly by its mechanic force or indirectly by manipulating thermal conditions. Buildings can modify wind and increase or decrease its mechanical effect. For example, high buildings can change strong wind flow at the top and divert it to the ground level. This accelerating wind flow in front of the building and around its corners may take different shapes. The strong wind produced at the bottom of high buildings may cause undesirable conditions for pedestrians. Vegetation has the ability to modify wind so that it decreases the wind flow and alters its direction when required.

2.2.4 Globe temperature

The globe temperature is the temperature measured inside a globe thermometer, typically a 40mm ball, and it is affected by the balance between the radiant gain at the surface of the globe and energy loss by convection (Erell et al., 2011). The globe temperature will lie somewhere between air and radiant temperature and has been so widely used in comfort surveys that it has almost become a basic variable. It worth considering using a globe thermometer as a temperature measuring instrument as Nicol (2008) suggested, because of its property of reacting to the environment in much the same way as a human occupant.

2.2.5 Humidity

Humidity refers to the water vapor content of the atmosphere which might be gained as a result of evaporation from water surfaces, moist objects and plant transpiration (Konya 1980). The vapor pressure increases with temperature. Nevertheless, there is a limit to the amount of water that air can hold as vapor.

Relative humidity is the ratio of the amount of vapor in a given volume of air to the maximum vapour capacity at that particular temperature. High levels of relative humidity may cause discomfort indirectly by affecting the environmental probability evaporation. The body responds to this by spreading sweat over the skin to increase its surface to boost evaporative cooling. The increased dampness of skin causes discomfort in some situation, when wearing formal clothes, for example. Low levels of humidity may cause discomfort directly. The excessive dryness of the air causes cracks in the lips and soreness in the throat (Clark and Edholm, 1985).

Under steady-state conditions and moderate air temperature (15-25 °C) in temperate climates, the average relative humidity has little impact on thermal sensation. However, by moving from indoors to outdoors, the change in relative humidity can have a greater influence on thermal comfort (Nikolopoulou, 2011b). Moreover, relative humidity changes have even more significant effect on thermal comfort in warm environments (>30 °C) (Park et al., 2012).

2.3 Factors affecting climate

2.3.1 Topography

Solar radiation, air temperature, and wind will be affected by the altitude; slope and exposure of the site i.e. higher altitudes have greater temperature variations (Clark and Edholm, 1985). During the night, the ground cools quickly due to heat loss by radiation to a clear sky and cool air drains down to the bottom. During the day, on the other hand, solar radiation intensity is remarkable due to the relatively short distance it has to pass through the earth's atmosphere at such altitude. The heating effect of solar radiation will differ when it falls on slopes facing different directions. This is because the variation in solar radiation will be greater on a sloping surface compared with horizontal. Wind also is affected by topography. Raised sites are exposed to more and stronger wind whereas basins are more protected from wind.

2.3.2 Ground cover

The closer to the ground the more extreme the environmental conditions are. This is because the solar radiation increases the temperature of the ground during day time. At night, the temperature decreases next to ground level. This is due to evaporation and outgoing radiation. Thus, the ground cover has a major role in moderating extreme temperatures.

Artificial surfaces and urban areas tend to increase temperature and reduce humidity. Such surfaces store, radiate and reflect heat to air layers close to them. On the other hand, natural cover of ground, grass for example, helps in moderating extreme temperature (Konya, 1980). Therefore, using paved surfaces should be kept at minimum when designing outdoor spaces in hot climate zones.

Vegetation in the urban environment affects not only the thermal environment, but also air quality and noise levels. Vegetation reduces air temperature by direct shading and moderation of solar heat gain through evapotranspiration (Dimoudi and Nikolopoulou, 2003).

Materials are thermally defined by their albedo (Cunningham, 1998). The albedo of an object is the ratio of the diffusively reflected radiation to the incident electromagnetic radiation and it is closely related to the colour of the material. Rough and dark-coloured surfaces tend to absorb more solar radiation than smooth, light-coloured and flat surfaces. Dark-coloured surfaces are therefore warmer than light coloured surfaces. The use of cold materials can be advantageous in designing outdoor spaces and urban environments in hot climates, reducing air temperature due to heat transfer, and mitigating the urban heat island effect.

2.3.3 Water

Water has larger specific heat capacity2 compared to the dry land and therefore it has less daily and annual temperature variations. This moderates the thermal conditions in areas located near the sea where the on-shore breezes replace the hot air over land and cool down the land which has already heated up by solar radiation during the day. This process will be reversed at night because the land cools faster than the sea.

2.3.4 Densities and Building fabric

When the urban fabric is dense, buildings provides shade to surrounding outdoor spaces, reducing the heat gain from solar radiation. The aspect ratio H/W of a street canyon is important geometric variable that indicate the density of an urban fabric. The aspect ratio of a street canyon can is the ratio of the canyon height (H) to canyon width (W). A regular canyon usually have an aspect ratio H/W=1, while a deep canyon has an aspect ratio H/W=2 or more (Vardoulakis et al., 2003). In addition to urban density, buildings and paved surfaces store heat, radiate, and reflect solar radiation thus increasing air temperature in the urban environment of hot climate zones. Therefore, in such climates, it is very important to recognize the balance between the shading that can be provided by building fabric and the influence urban fabric density on air temperature. This can be achieved by minimizing the paved areas, increasing vegetation and using suitable.

3. MATERIAL AND METHODS

3.1 Study Area

Erbil it is one of the oldest continuously inhabited cities in the world and has an urban life that could be dated back to at least 6000 BC (UNESCO, 2010). Erbil is one of the governorates of the north Iraq. The location of Erbil governorate is between latitudes 35.30 and 37.15 N, and longitudes 43.22 and 45.05 E and (136 - 3609 m) altitude. The Erbil border Extends to Iran in the East and to Turkey in the north. It is the third largest city in Iraq figure (3.1), as well as its fastest growing city figure (3.2) & (3.3) the plains in the south of Erbil governorate are important parts of the agricultural production.

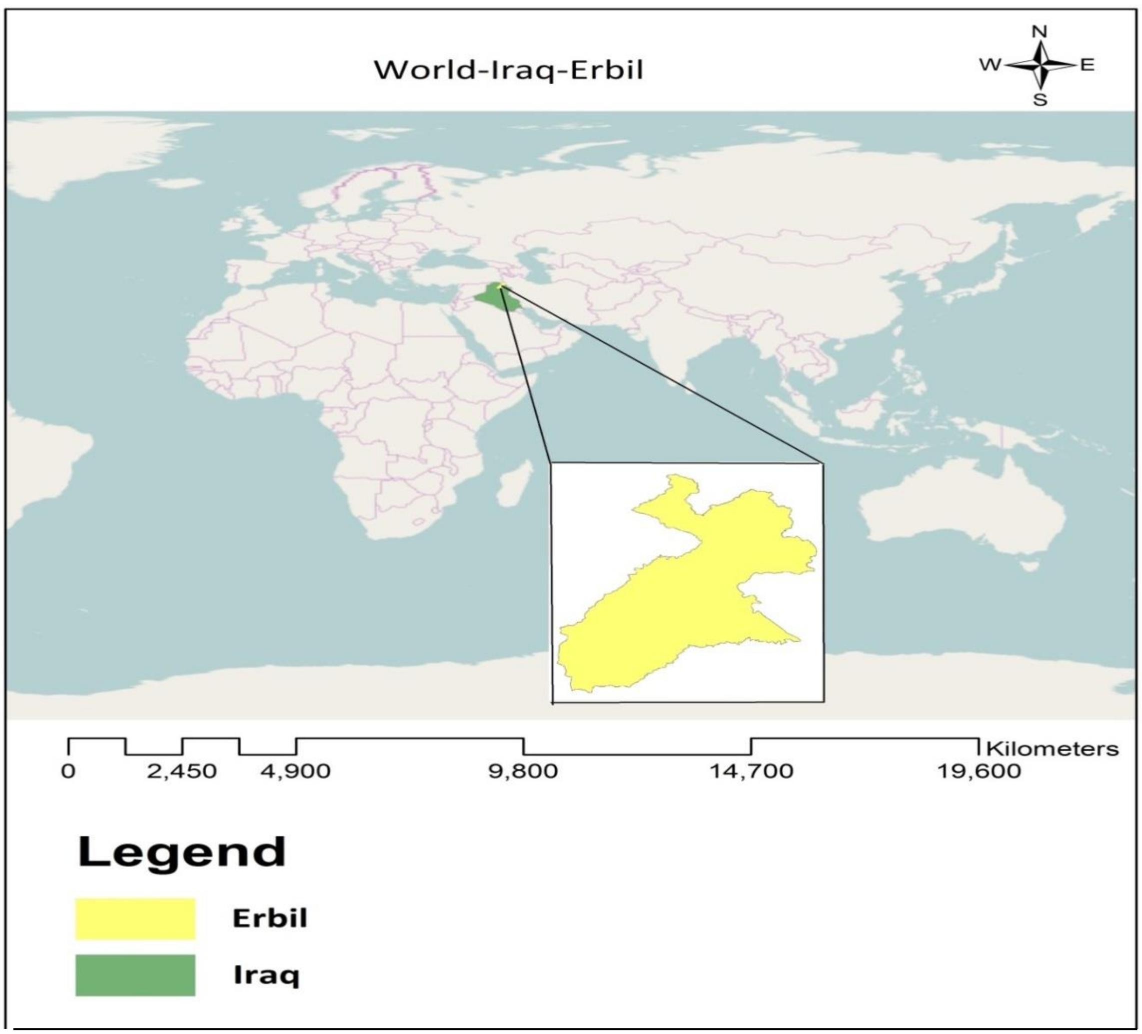


Figure (3.1) Erbil location in world

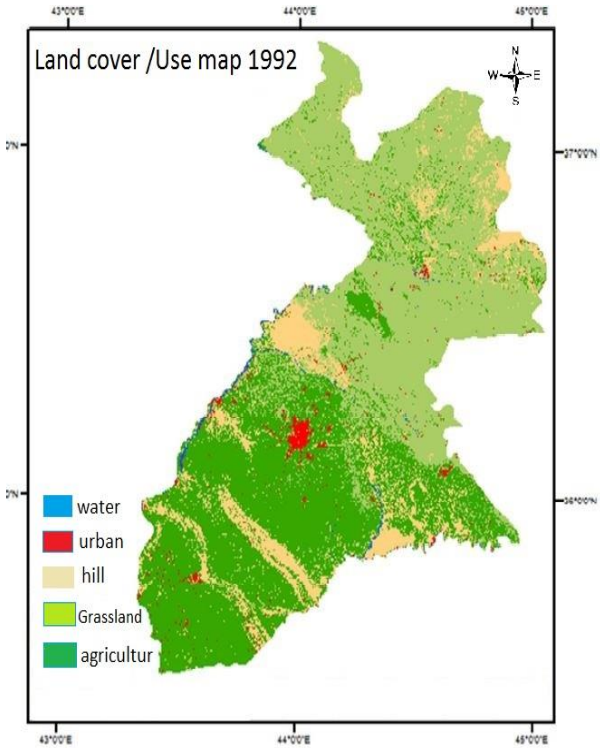


Figure (3.2) land cover for ERBIL in 1992

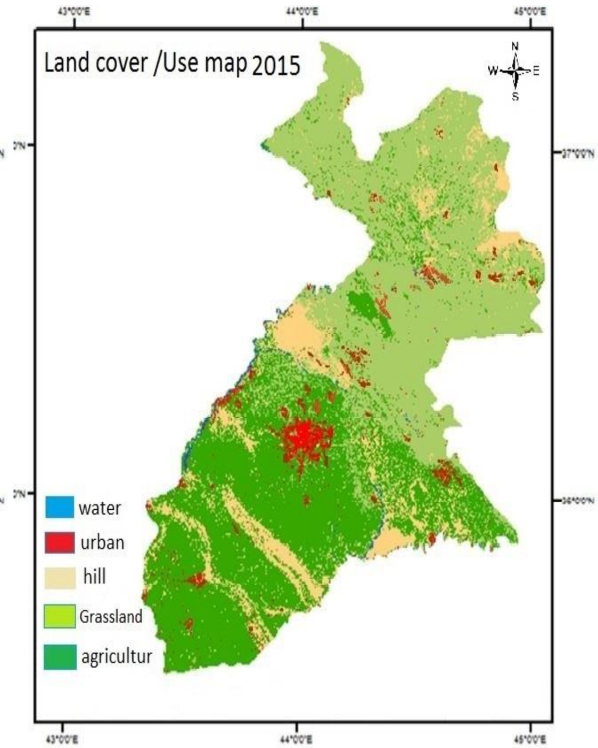


Figure (3.3) land cover for ERBIL in 2015

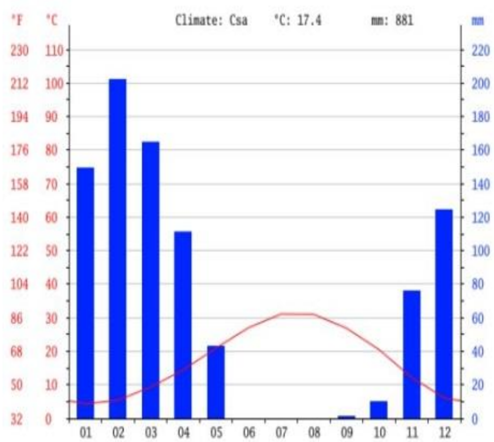
Erbil governorate is located between the two rivers known as the Greater Zab in the west and the Lesser zab in the east. The area of the governorate is around 15074 km2. It consists of seven districts (Erbil, Makhmur, koyea, Shaqlawa, Choman, Soran and Merqasur). In Erbil Governorate 41% of the area is arable land and 59% is non-arable land. 93% of agricultural crops depend on rainfall and only 7% of the land is irrigated.

Erbil City, according to Köppen's climate classification system, is located in climate zone between the Mediterranean climate (Csa) and the Arid climate (Bwh).The climate of the Erbil governorate is comprised of cool snowy winters and warm dry summers. The plains in the south have semi-arid climate conditions. Usually precipitation starts in October and ends in May. Erbil governorate climate can be classified into two main Categories:

1. **Mediterranean climate region**: this is in the north and northeast of Erbil governorate. This region is characterized by abundant rains between 600 and 900 mm per year. Figure (3.4)

2. **Warm climate region of steppes**: This region is located in the south and south-west of Erbil governorate. The average temperature is approximately 20.2 C°. Rainfall changes over

the year. Rainy days are low in this region compared to the Mediterranean climate region. The rainfall is less than 543 mm per year, Figure (3.5) and therefore the winter agriculture is at risk of drought (Kahraman, 2004).



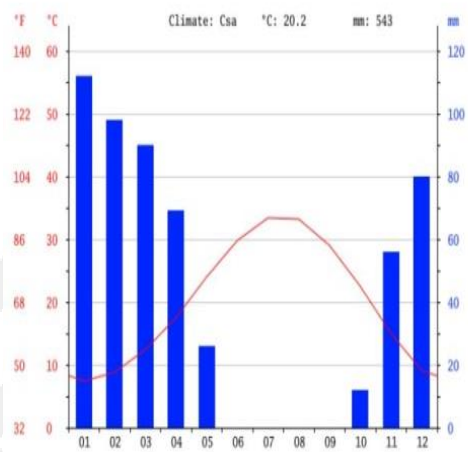


Figure (3.4) Mediterranean climate region

Figure (3.5) Warm climate region

Rain and snow in Erbil are changing from year to year since precipitation depends on the Geographical location and climatic conditions of the region. Changing amount of precipitation has impacted the water levels in the rivers and springs. January is the coldest month of the year and July is the hottest month of the year (Heshmati, 2009).

3.1.1 Slope

The slope is generated from a topographic ratio, which represents the ratio of the elevation Difference between two points divided by the horizontal straight distance between the two points. Figure (3.6) (Winnaar, 2007). The slope is derived from the Digital Elevation Model (DEM), and classified into 5 slopes. Table (3.1) percentage classes according to the FAO slope classification (Winnaar, 2007).

Table (3.1) slope classification by Winnaar, 2007.

	Slope Class	Slope %
1	Flat	< 2
2	Undulating	2 – 8
3	Rolling	8 – 15
4	Hilly	15 - 30
5	Mountainous	>30

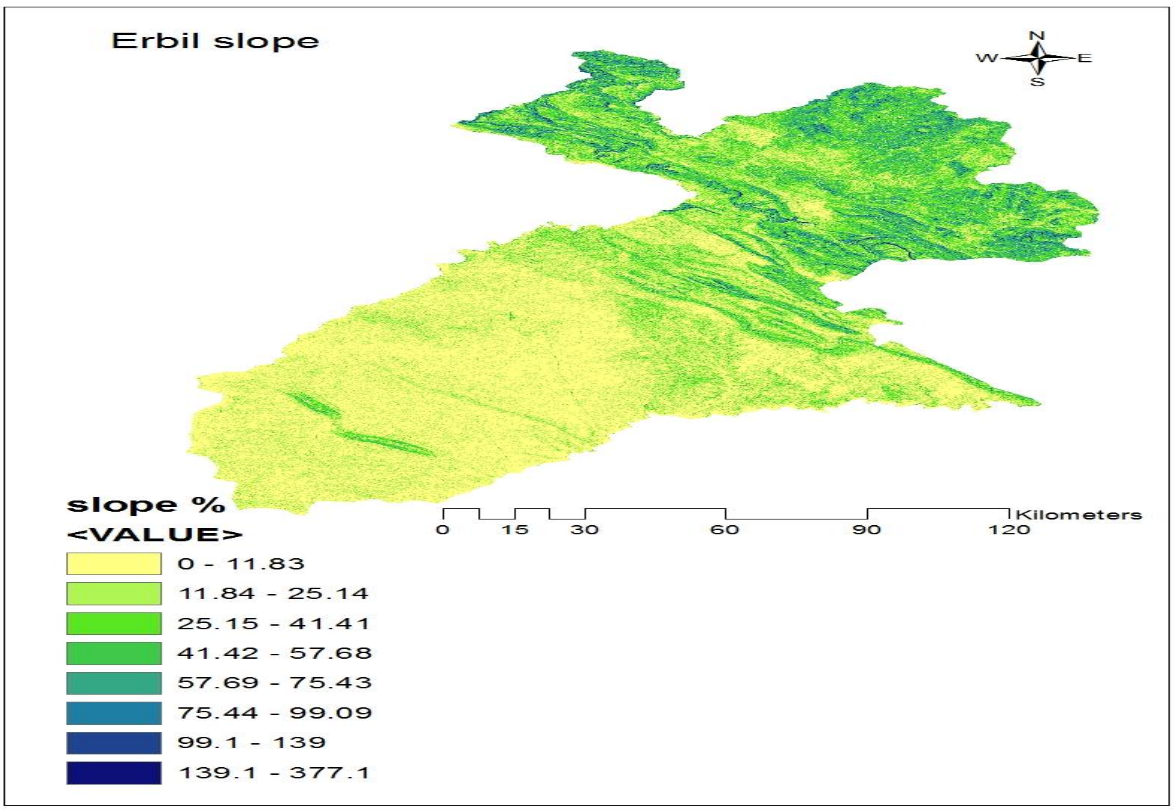


Figure (3.6) Slope classification map of Erbil governorate

3.1.2 Soil

Soil is one of the important resources in achieving food security through direct association with agricultural production. The depth of the soil is changing over the study area. The soil in the mountain areas, which are located in the north and northeast, is shallow. The soil in the mountains has been created from the original rocks and it has a low potential for agriculture, but it is rich in the natural rangeland (Kahraman, 2004).

3.1.3 Mountains

All mountain in Iraq contain to north Iraq. Exactly in Erbil governorate such as (Halgurd , Qandil Safin , Zagros , Karux , Hasan bag , Bradost, Korak , Shirn , Hasarost . Awagrd , Bawaje , Sakran , Hndreen , Zozk , Argosh , ….)

Halgurd is the highest mountain in Iraq (3609) m above sea level. Figure (3.7)

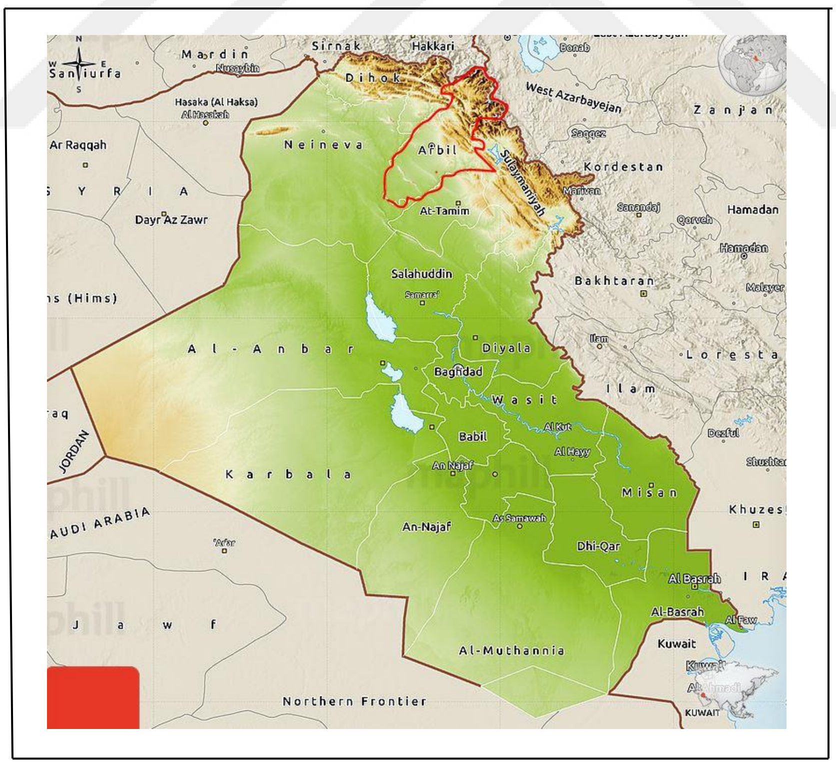


Figure (3.7) Show the mountain location in Iraq-Erbil

3.2 Data and Methodology

3.2.1 Data

1. Digital Elevation Model (DEM) was obtained from the United State Geological Survey (USGS) website (http://earthexplorer.usgs.gov/). Figure (3.8) The DEM has 30 m resolution. The format of data is raster data. The datum of the data is WGS-84.

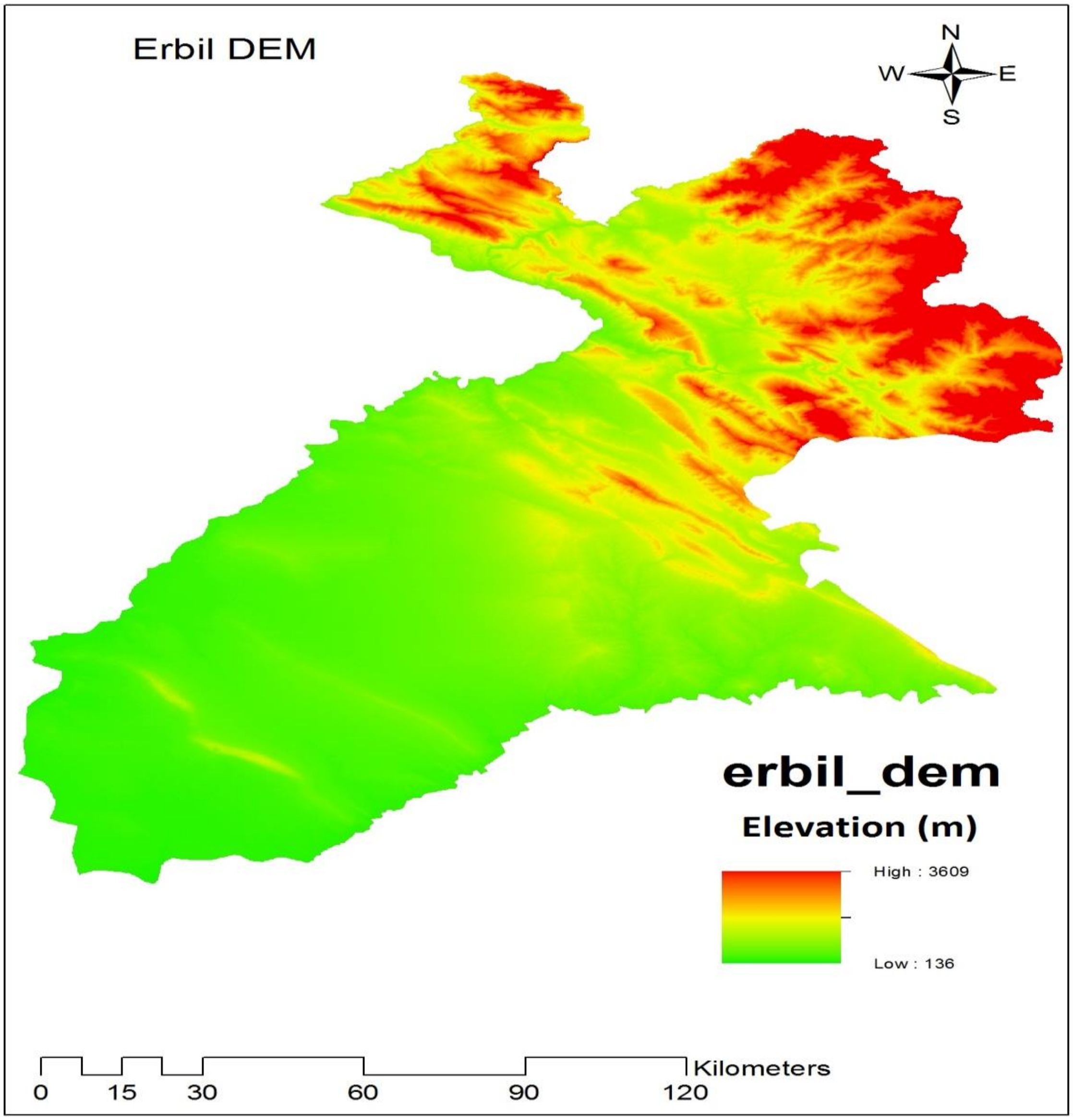


Figure (3.8) Erbil governorate digital elevation

2. Climate data were provided by the Ministry of agriculture and water resources in Erbil. The temperature, humidity and wind speed data is Monthly from 1992 to 2015. There are records from 6 weather stations at 15:00 afternoon in the Study area. Table (3.2) and (3.3)

Table (3.2) Coordinates, altitudes and years for all weather stations.

Meteorology Stations	latitude	longitude	Altitude(m)	years
Erbil	36.19	44.01	425	1992-2015
Masif Salahaddin	36.37	44.2	1088	1992-2015
Makhmur	35.77	43.58	275	1992-2015
Koyea	36.08	44.62	631	2002-2015
Shaqlawa	36.4	44.31	980	2002-2015
Soran	36.65	44.54	680	2002-2015

Table (3.3) Mean monthly wind speed, humidity and temperatures values of all stations (1992-2015).

Meteorology stations		Erbil	makhmur	masif slahaddin	shaqlawa	soran	koyea
Jan	**T ºC**	12.8	13.9	8.7	9.7	9	10.8
	H %	70.81	74.9	73.66	67.6	75.4	71
	W s/m	2.3	3.3	1.9	2.2	1.5	3.2
Feb	**T ºC**	14.6	16.3	9.8	18.9	11.4	12.6
	H %	67.25	67.8	70.3	69.2	74.1	68.3
	W s/m	2.4	3.6	2.3	2.1	1.6	2
Mar	**T ºC**	26.6	21	14.5	15.6	16.4	17.4
	H %	60	58.4	61.27	61.3	68.4	63.1
	W s/m	2.5	3.8	2.6	1.7	1.7	2.2
Apr	**T ºC**	24.6	27.1	19.9	20.5	21.8	23.7
	H %	54.14	47.5	56.12	57.9	68.1	58.5
	W s/m	2.6	4	2.8	1.8	1.8	2.5
May	**T ºC**	33.9	34.5	26.4	27.3	28.2	30.8
	H %	39.41	33.8	43.1	48.3	61.7	46.8
	W s/m	2.7	4.3	2.5	1.8	2	2.6
Jun	**T ºC**	38.4	40.8	32.2	35.3	35.4	37.6
	H %	27.34	25.2	35.29	38.1	51.3	38.2
	W s/m	2.4	4.4	2.5	1.6	2.2	2.6
Jul	**T ºC**	41.8	44.3	36.4	39.1	39.2	41.6
	H %	25.18	23.1	35.7	30.4	49.2	35.9
	W s/m	2.3	4.3	2.2	1.8	2.1	2.7
Aug	**T ºC**	41.6	44	36.7	38.4	39.4	41.6
	H %	26.77	24.6	34.58	27.9	49.5	36.7
	W s/m	2	4.1	2.1	1.5	1.9	2.5
Sep	**T ºC**	36.6	38.5	31.9	34.1	34.5	36.7
	H %	31.14	28.3	39.83	29.1	50	40.3
	W s/m	2	3.7	2	1.3	1.7	2.4
Oct	**T ºC**	29.8	32.1	25.3	26.9	26.9	29.6
	H %	42.15	39.2	56.66	38.1	62.2	48.5
	W s/m	2	3.5	2	2.1	1.9	2.3
Nov	**T ºC**	20.6	22.4	16.6	17.1	17.6	19.3
	H %	59.41	57.8	62.76	55.8	69.4	60.3
	W s/m	1.9	3.2	2	1.6	1.6	2.2
Dec	**T ºC**	14.2	16	11.5	11.9	11.1	13.3
	H %	68.63	69.4	67.56	66.1	74.1	65.3
	W s/m	1.7	3.2	1.8	2	1.6	2.2

3. Satellite Imagery (Landsat 5 + Landsat 8 L8 OLI/TIRS) was downloaded United State Geological Survey (USGS) (http://earthexplorer.usgs.gov).

The image Land sat5 was taken by the satellite on 24_Aug_1992 and + Landsat 8 was taken by satellite on 11_oct_2015. The resolution of image is 30m. These data are used to describe the land use of the study area. Figure (3.9) & Table (3.4)

The geo-reference of the satellite image is WGS_84 Datum project 38N.

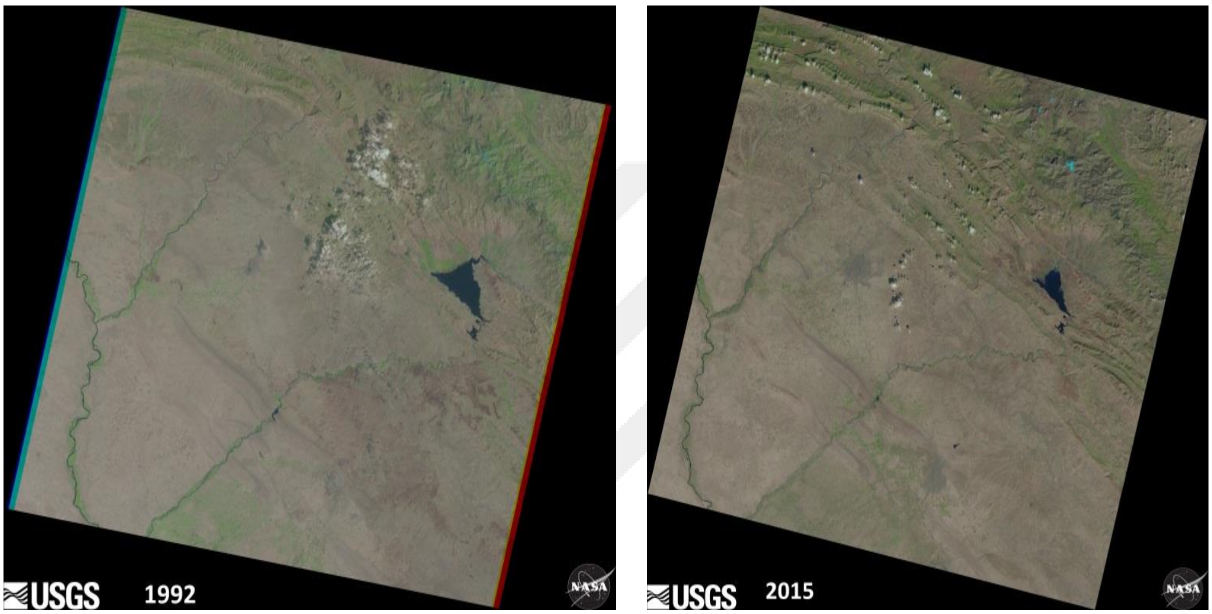


Figure (3.9) Satellite Imagery relationship (Landsat 5 + Landsat 8 L8 OLI/TIRS) 1992 & 2015

Table (3.4) Satellite Imagery details

satellite	Landsat 5	Landsat 8
Date	1992_08_24	2015_10_11
time	07:01:12 am	07:39:17 AM
Image ID	LT51690351992237XXX02	LC81690352015284LGN00
WRS Path	169	169
ROW	035	035
Projection	UTM Zone 38N	UTM Zone 38N
Ellipsoid	WGS 84	WGS 84

3.2.2 Software Used

RayMan 1.2 program was used to obtain the monthly PET values of the stations, and ArcGis 10.02 were used to analyses the PET and to evaluate the result and mapping .Microsoft Excel was used for statistical and regression analysis purposes, and producing charts and graphs, Remote Sensing RS for classificaton landsat image.

3.2.2.1 Calculation of physiologically equivalent temperature (PET)

The PET was calculated using the PC application RayMan (Matzarakis, 2002; Matzarakis, Rutz, & Mayer, 2000) Figure (3.10). RayMan, developed in accordance with guideline 3787 of the German engineering society (VDI, 1998), calculates the radiation fluxes within urban structures based on certain parameters, including Ta, air humidity, degree of cloud cover, air transparency, time of day and year, albedo of the surrounding surfaces, and their solid angle proportions (VDI, 1994).

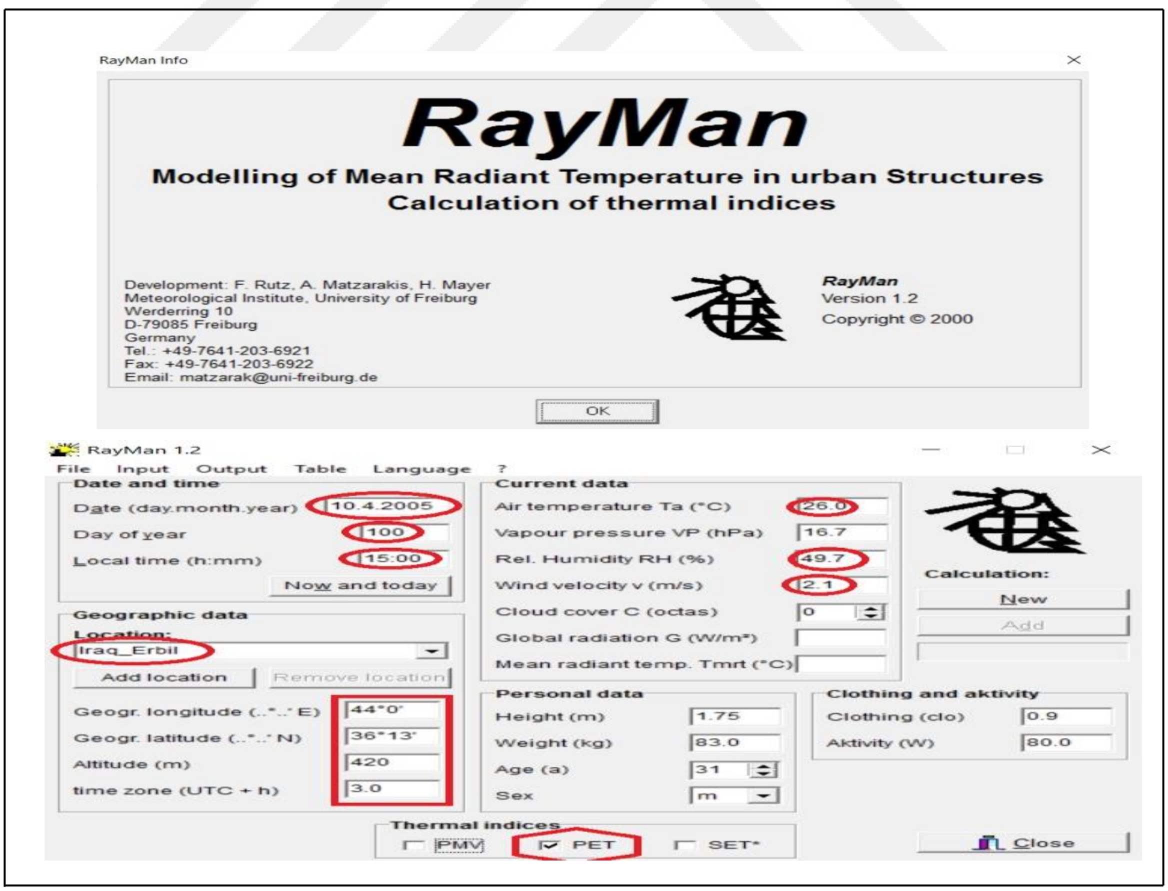


Figure (3.10) RayMan method application

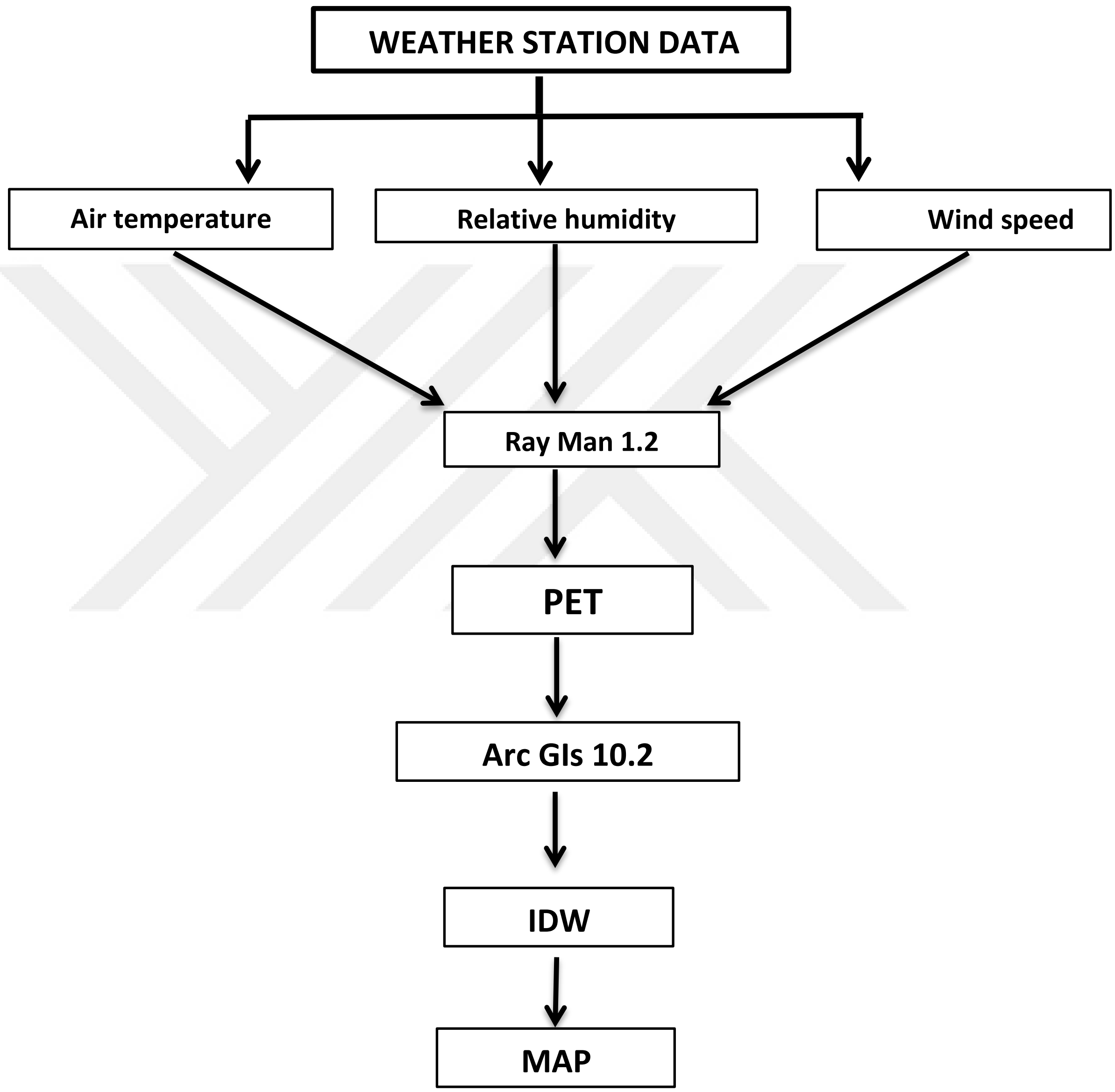


Figure (3.11) Analyze weather data change to PET map

In my study area working for calculate PET in Erbil City and 5 districts (Makhmur , Koyea, Masif Slahaddin , Shaqlawa , Soran). In Erbil governorate for all months in 24 years. To determine comfortable month and locations and good time for outdoor activity. A PET value around 23°C is characterized as comfortable. Higher values indicate increasing probability of heat stress, and lowe values indicate increasing probability of cold stress. PET index values obtained by considering these aspects of human physiology.

Table (3.5) Distribution of PET index values, thermal perception, and physiological stress relating to these values (Matzarakis and Mayer 1996; Matzarakis et al., 1999).

PET (°C)	thermal perception	Grade of physiological stress
> 4	Very cold	Extreme cold stress
4 - 8	Cold	Strong cold stress
8 – 13	Cool	Moderate cold stress
13 – 18	Slight cool	Slight cold stress
18 – 23	Comfortable	No thermal stress
23 – 29	slightly warm	Slight heat stress
29 – 35	Warm	Moderate heat stress
35 – 41	Hot	Strong heat stress
< 41	Very hot	Extreme heat stress

The PET values obtained from the stations at entire province using Arc Map 10 software. Therefore, the inverse distance weighted (IDW) method, generally used as a simple local interpolation technique (Lo et al., 2002), was used. The IDW creates an interpolated surface by calculating the values of unknown locations as the weighted sum of the known values within a certain neighborhood of the unknown point. The weights of known points are inversely proportional to their distance to the unknown point. Hence, known points that are close to the unknown point have a greater influence on the precision value than the points that are farther apart. Eq. (1) is used to calculate the output cell value for the IDW method.

4. RESULT AND DISCUSSION

In this research, this has been done in Erbil field area. Areas with comfortable for weather. Six districts have been included in this study (Erbil Central, Makhmur, Masif Slahaddin, Koya, Soran and Shaqlawa). All months of the year have been included for the 24 years between (1992-2015) Figure (4.1).

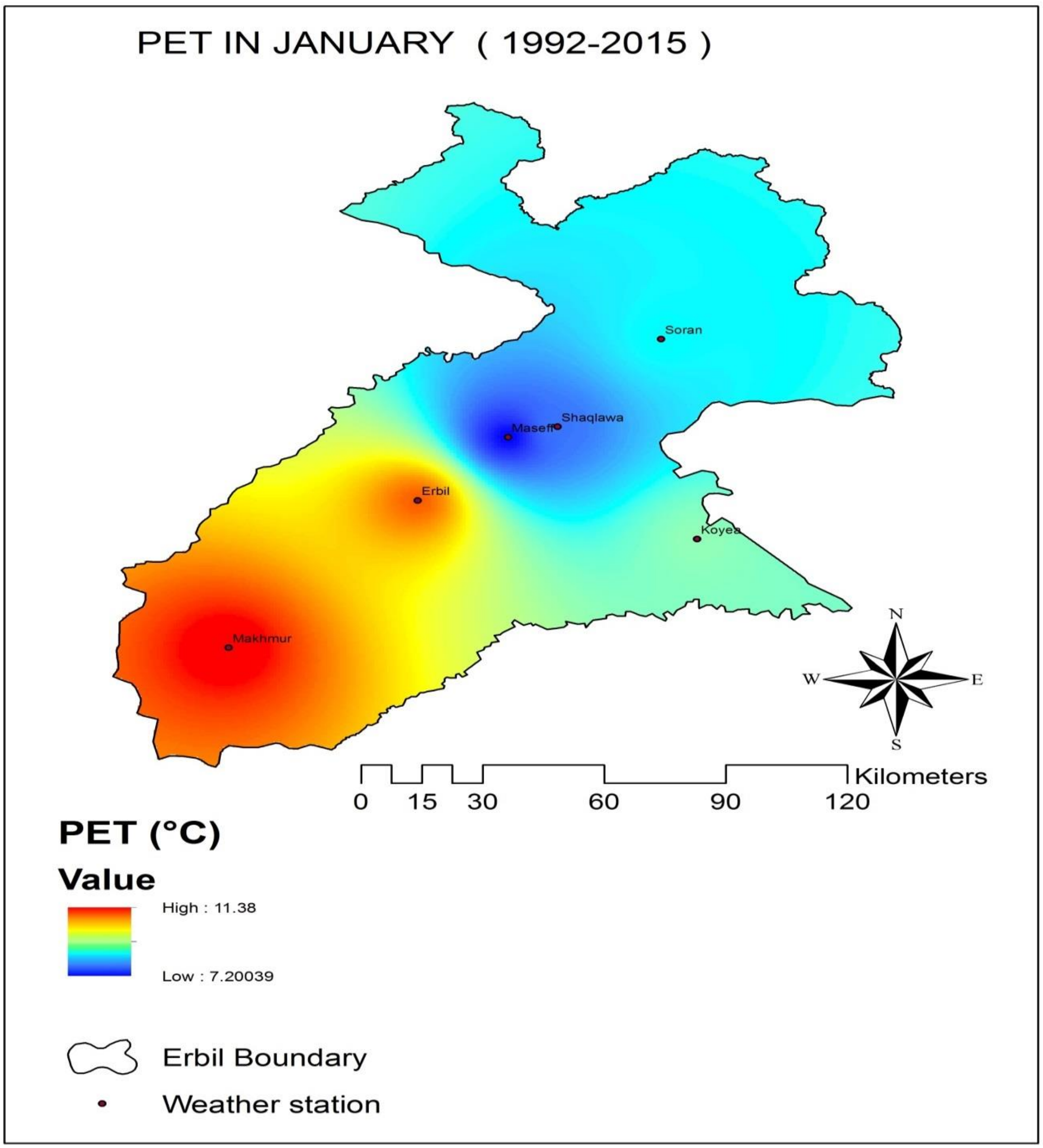


Figure (4.1) PET value in January for Erbil governorate

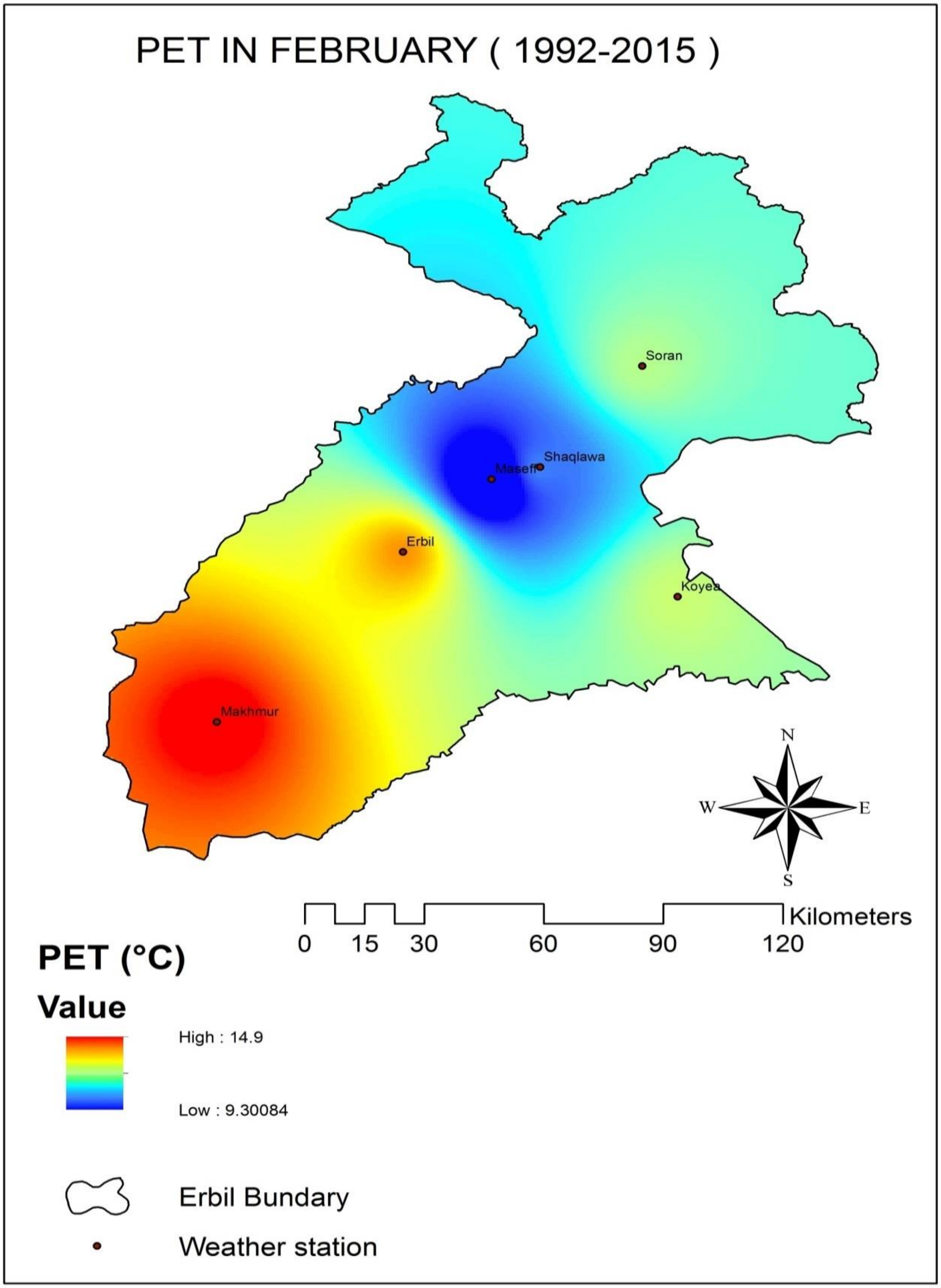


Figure (4.2) PET value in February for Erbil governorate

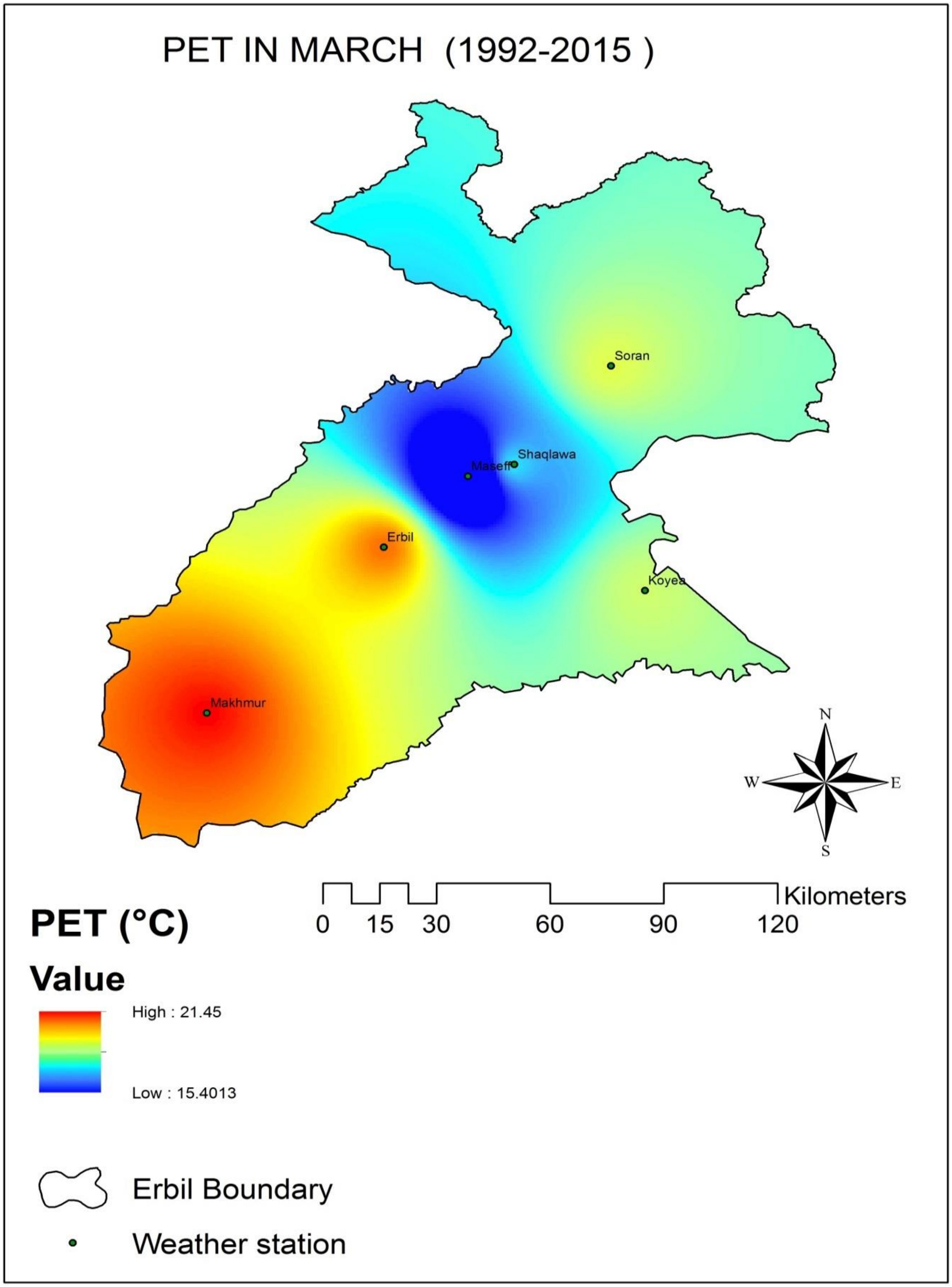


Figure (4.3) PET value in March for Erbil governorate

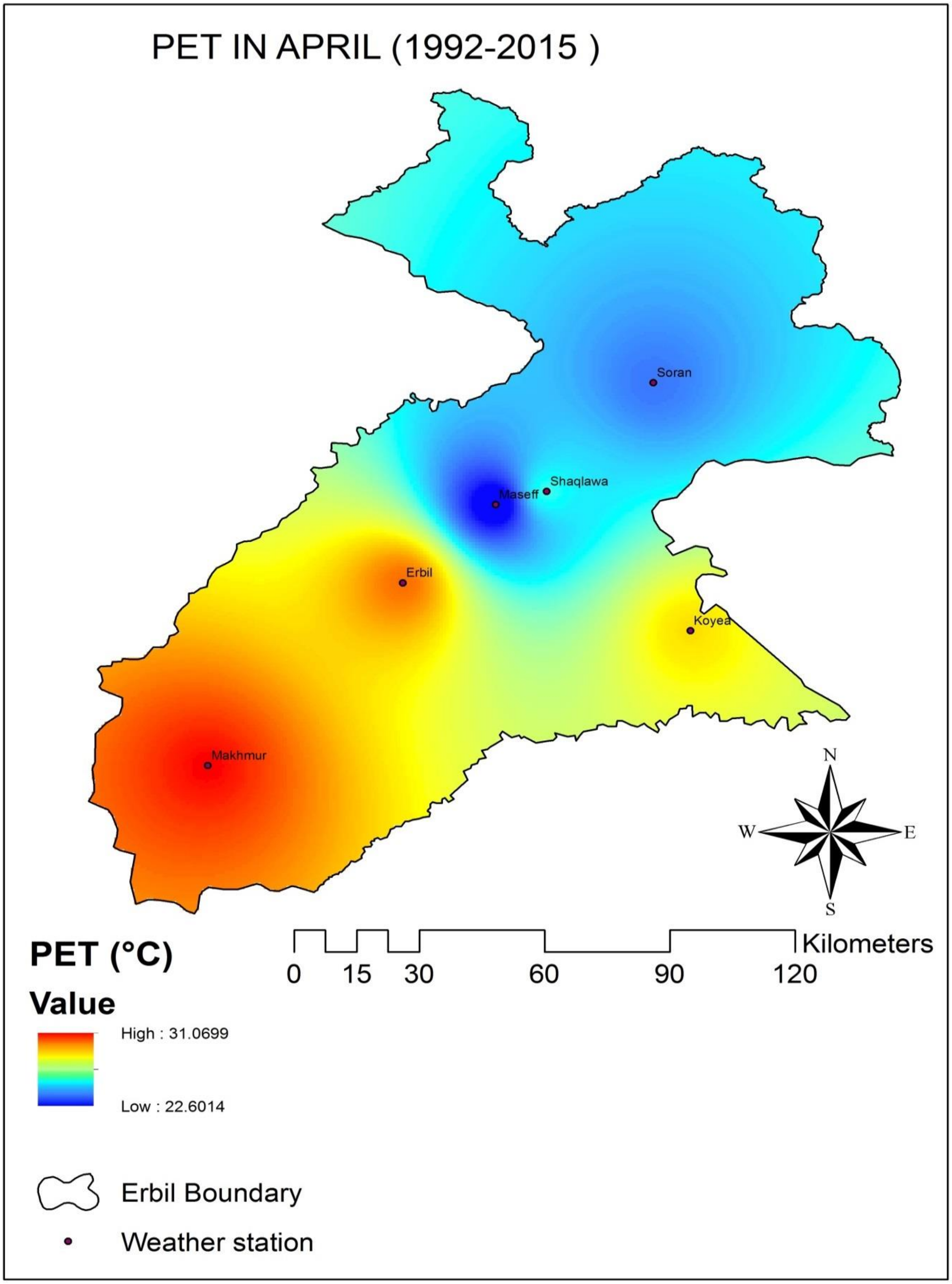


Figure (4.4) PET value in April for Erbil governorate

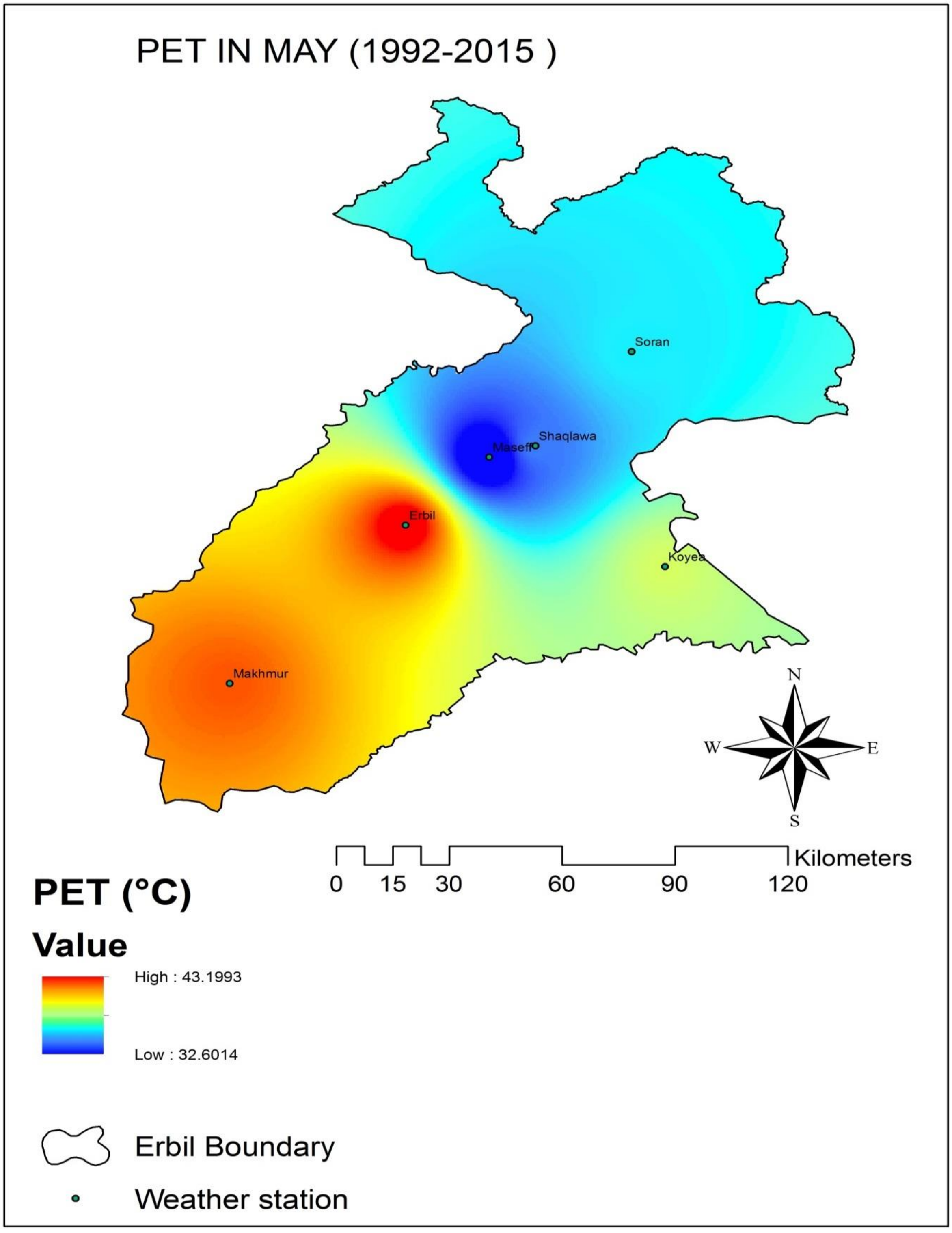


Figure (4.5) PET value in May for Erbil governorate

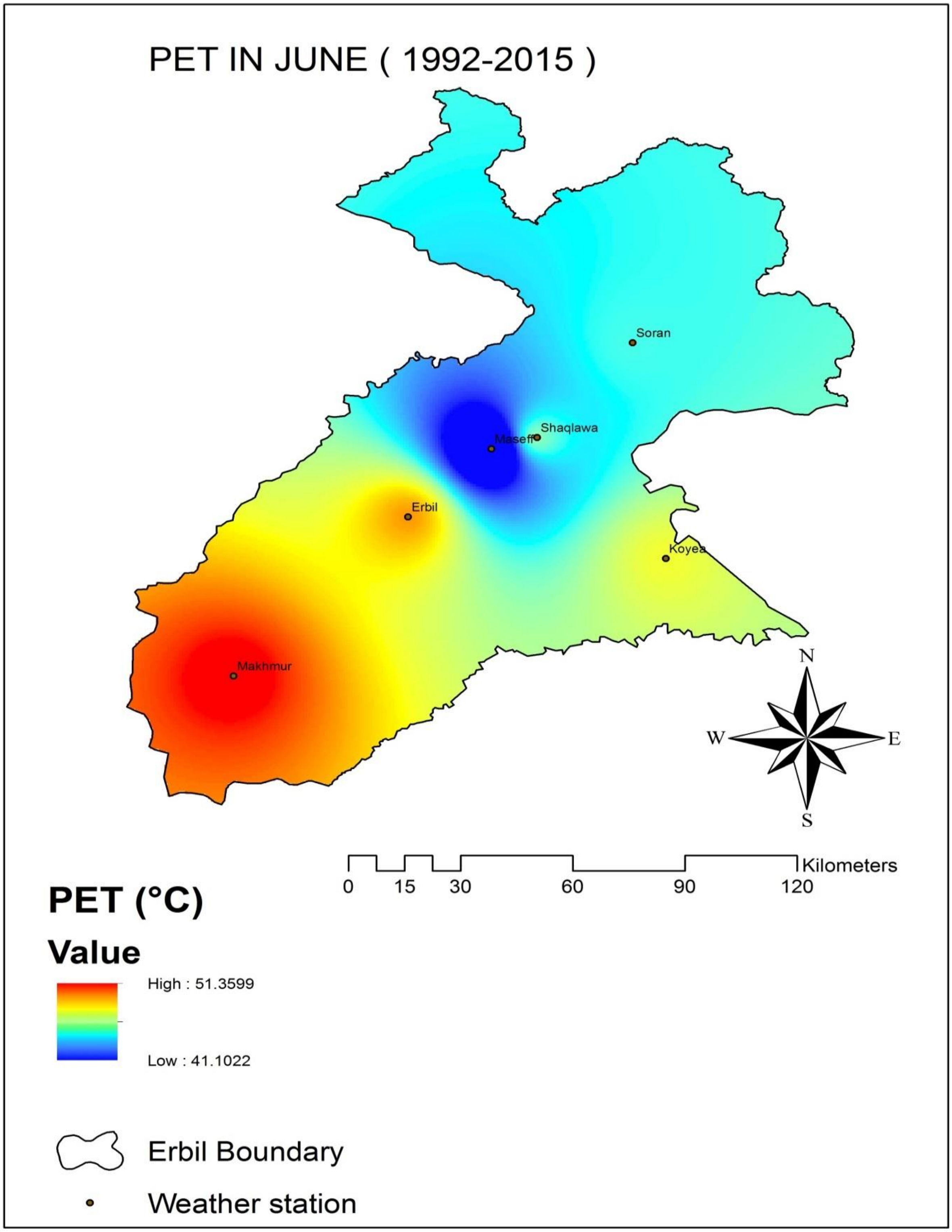


Figure (4.6) PET value in June for Erbil governorate

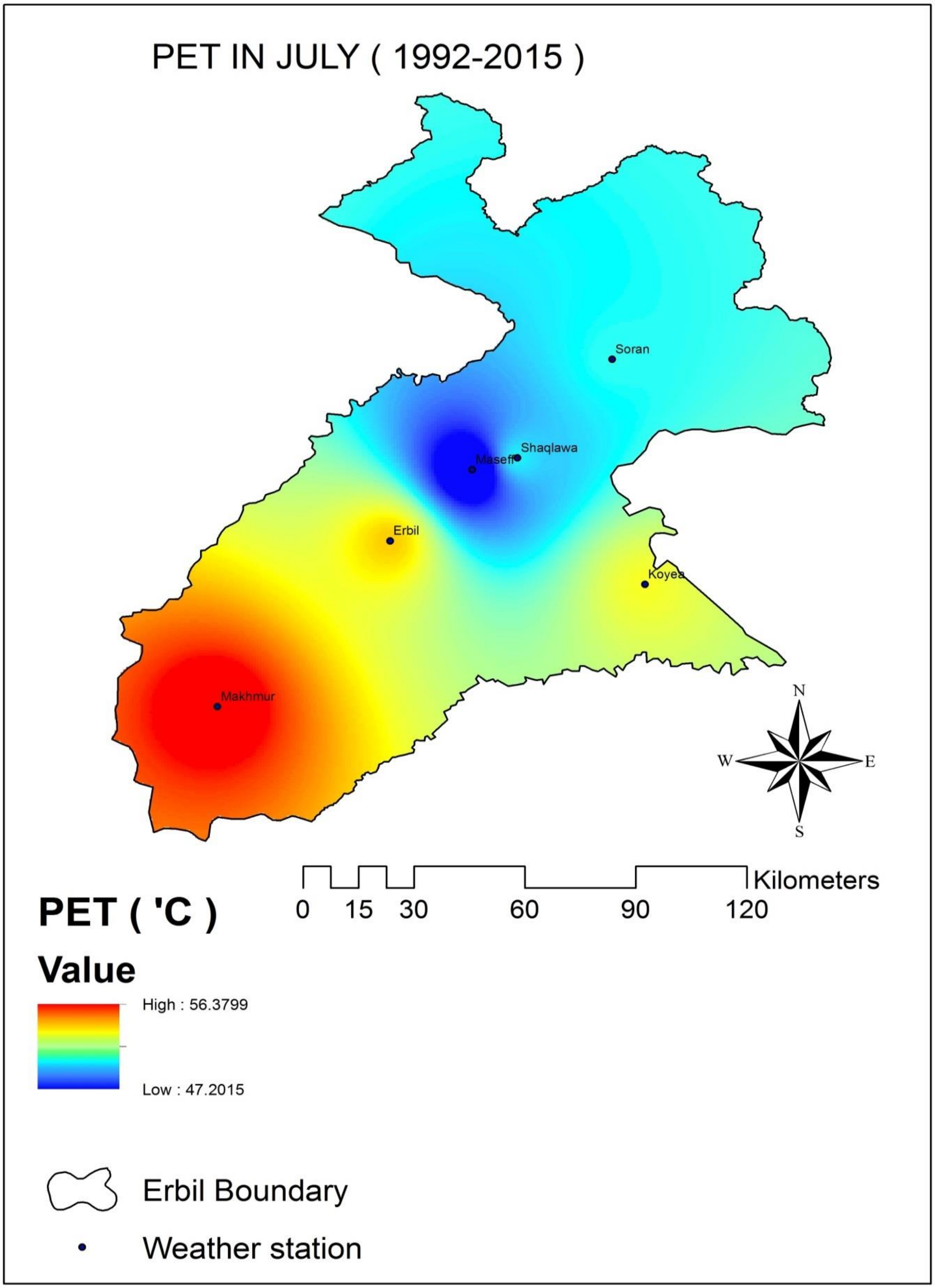


Figure (4.7) PET value in July for Erbil governorate

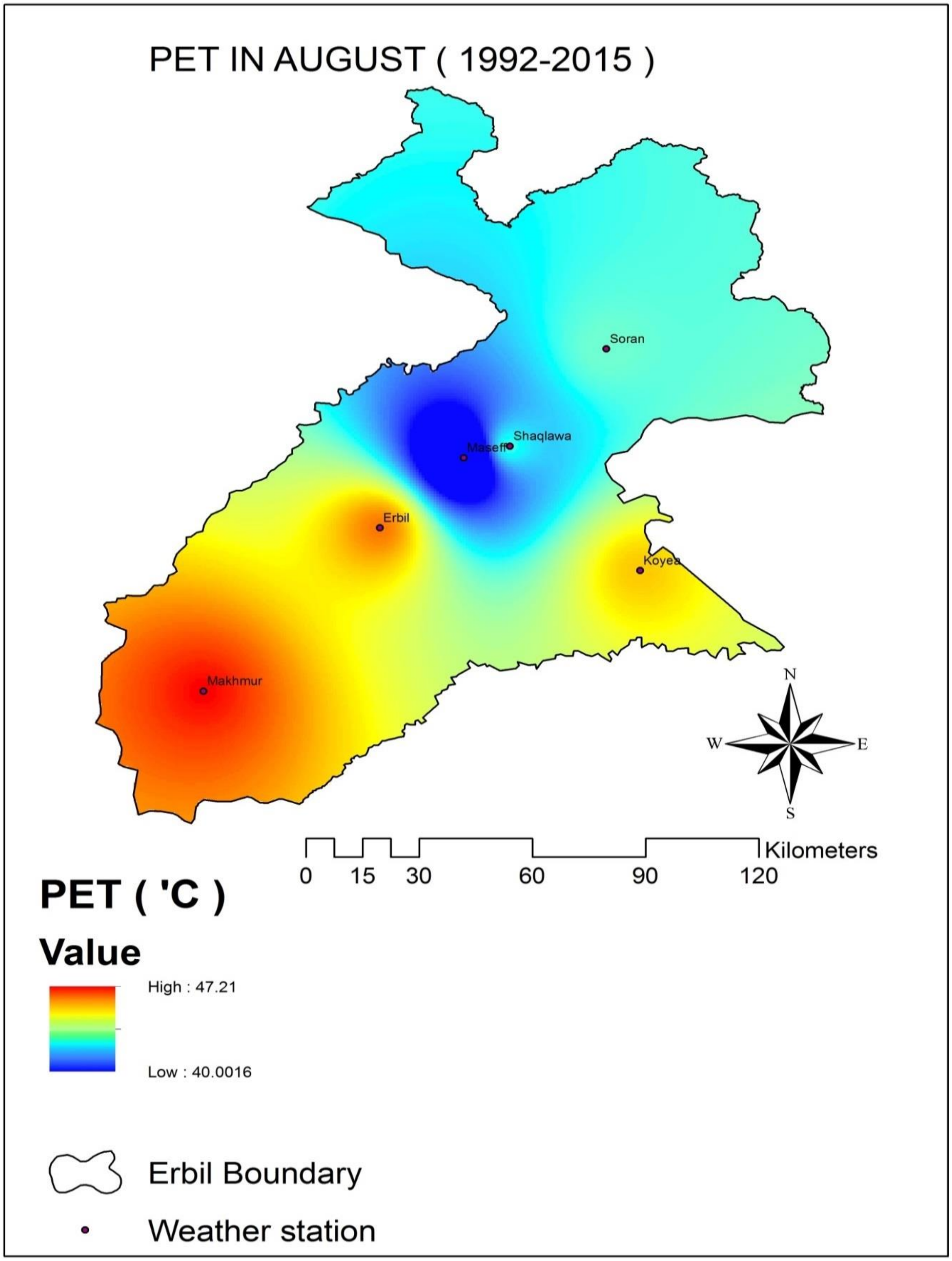


Figure (4.8) PET value in August for Erbil governorate

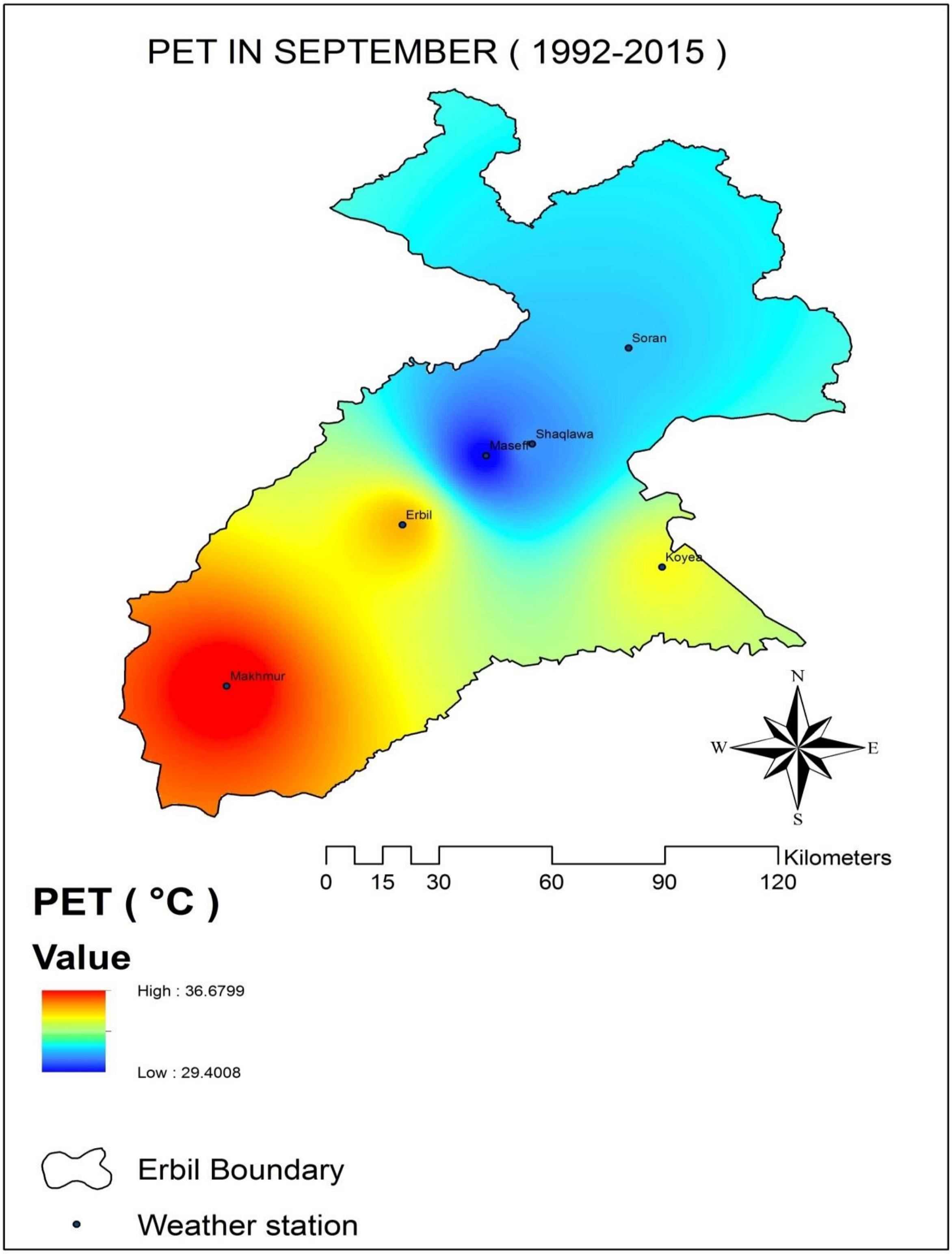


Figure (4.9) PET value in September for Erbil governorate

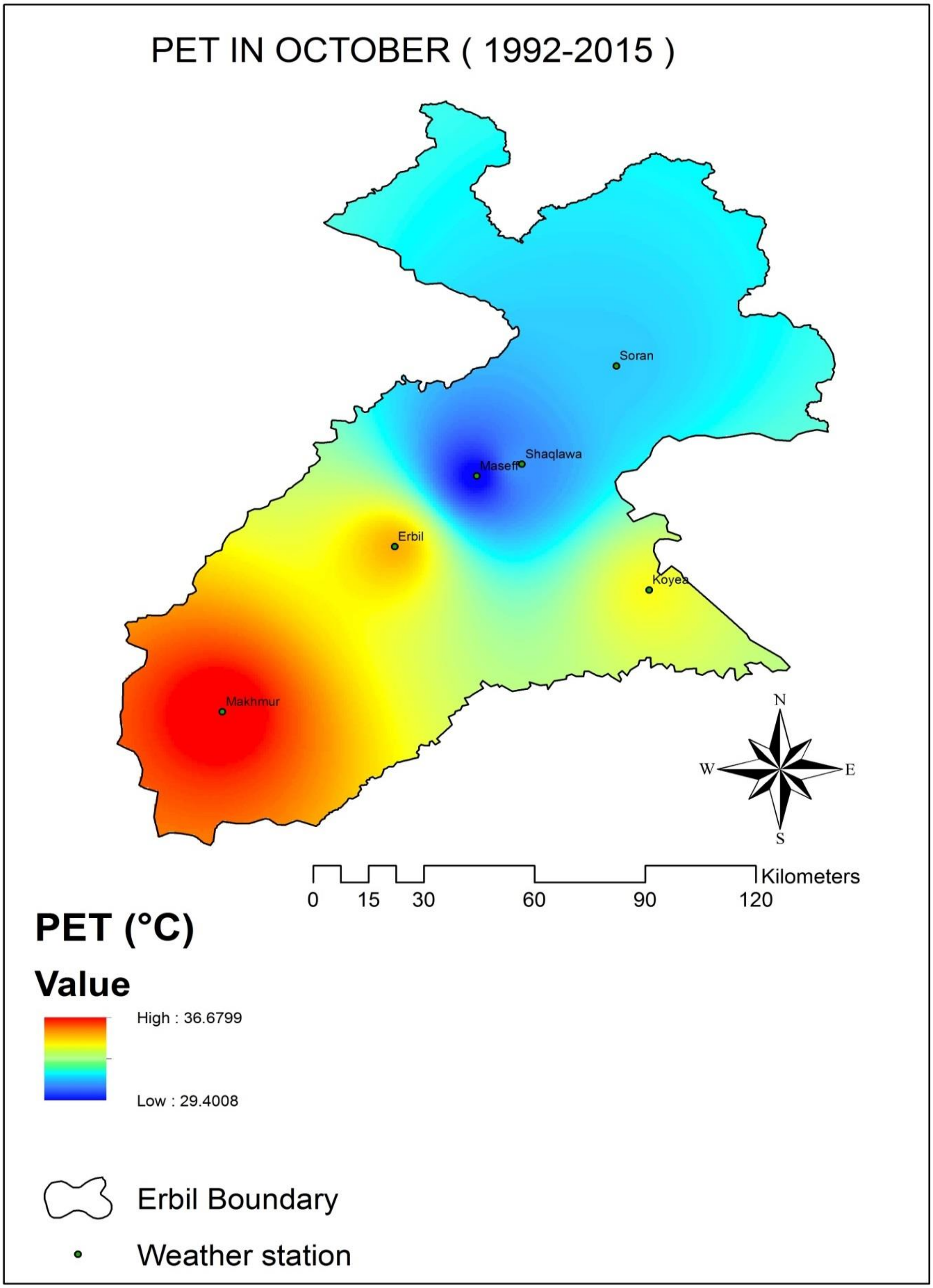


Figure (4.10) PET value in October for Erbil governorate

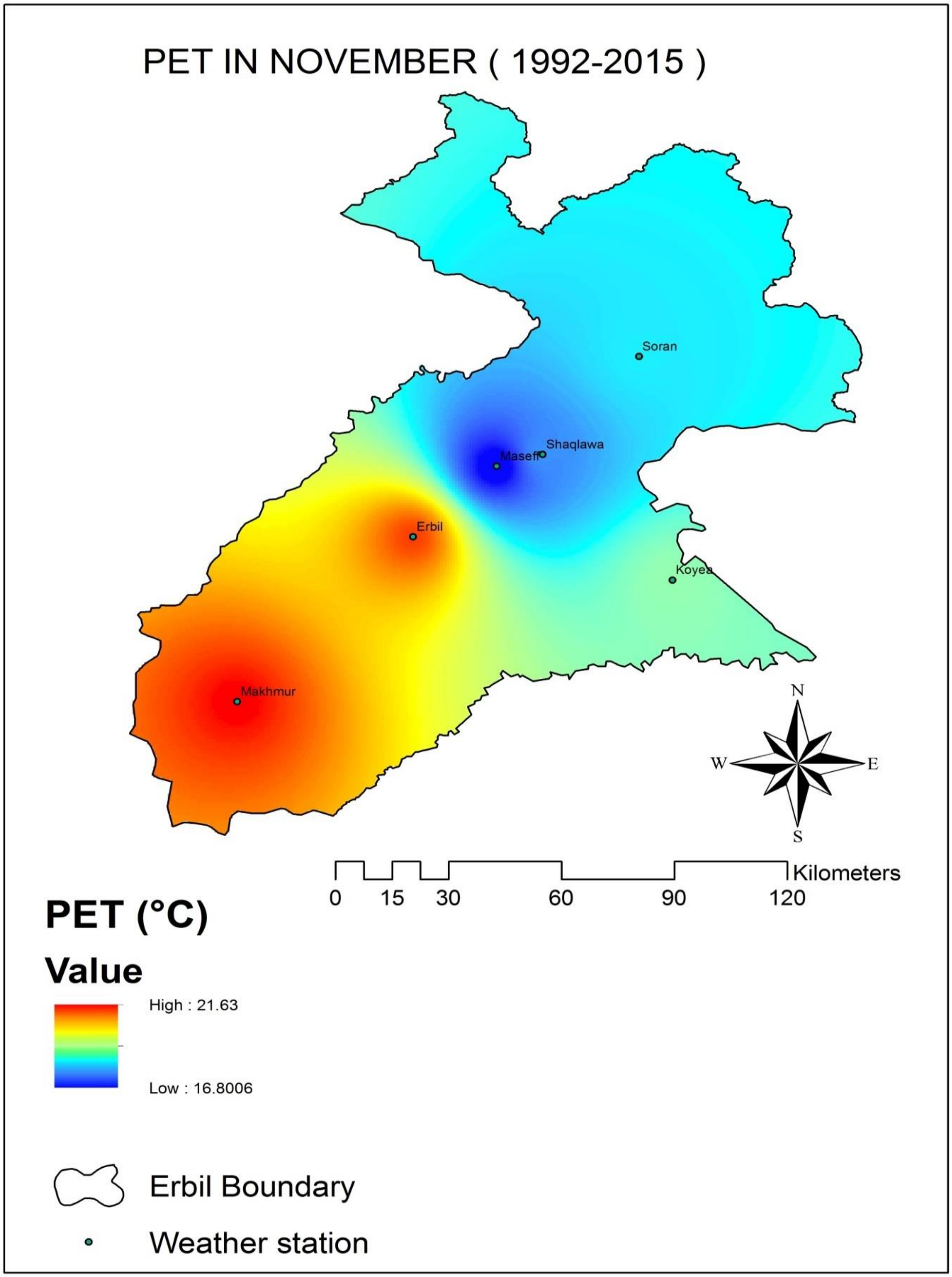


Figure (4.11) PET value in November for Erbil governorate

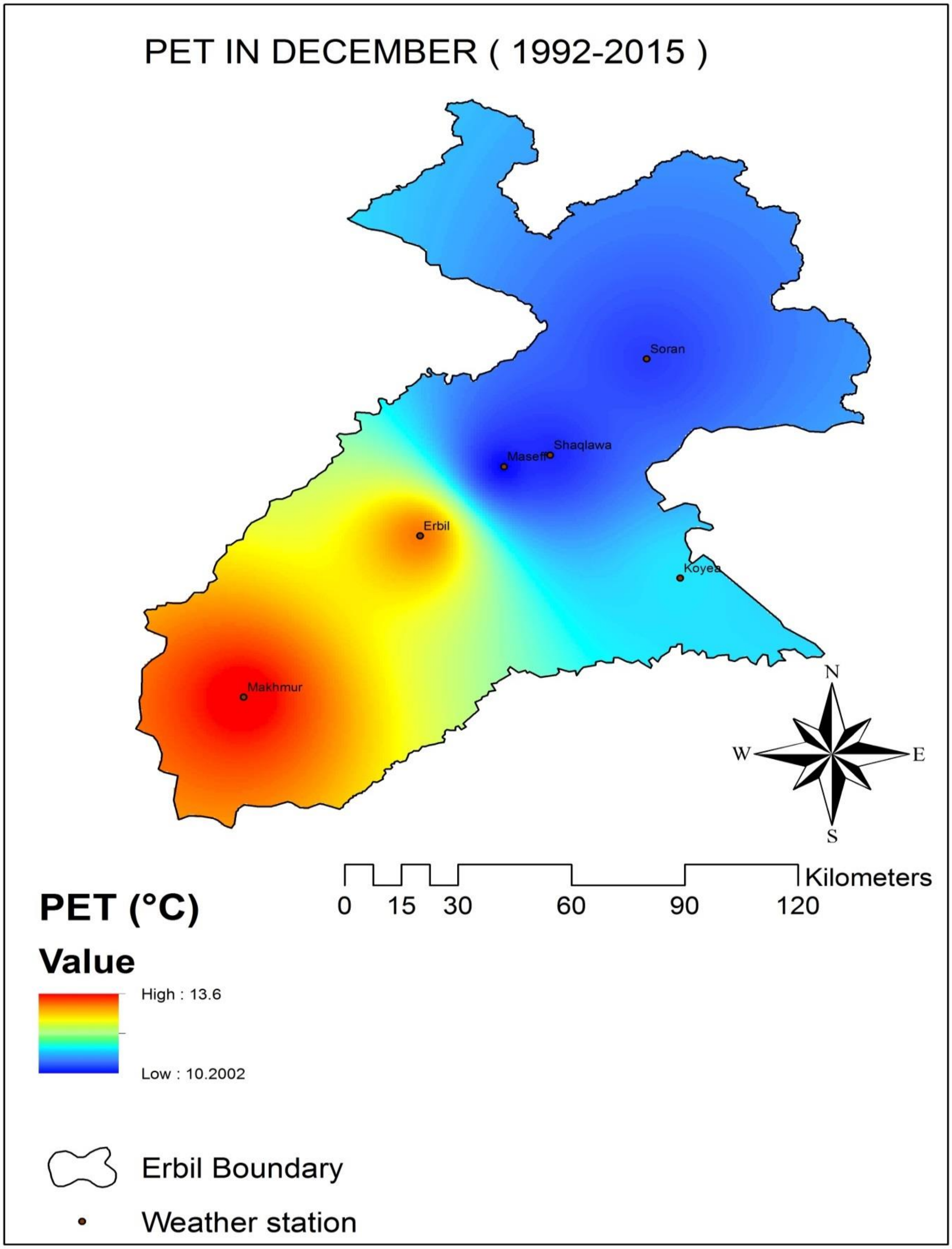


Figure (4.12) PET value in December for Erbil governorate

The lowest PET determined was around 7.2 in Masif Slahaddin district during the month of January. And the highest PET determined was 56.4 in Makhmur district during the month of July. Table (4.1) Distribution of PET index values, thermal perception, and physiological stress relating to these values (Matzarakis and Mayer 1996; Matzarakis et al. 1999). (>4) very cold , (4 – 8) cold , (8 – 13) cool , (13 -18) slightly cool , (18 -23) comfortable , (23 – 29) slightly warm , (29 – 35) warm , (35 – 41) hot , (< 41) very hot ,Table (4-2)

Table (4.1) All PET in all months Erbil governorate classification by color

weather staions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
erbil	10.9	14.0	21.0	30.2	43.2	49.8	54.1	53.6	46.6	34.9	21.4	13.1
makhmur	11.38	14.9	21.5	31.1	41.9	51.4	56.4	55.7	47.2	36.7	21.6	13.6
masif slahaddin	7.2	9.3	15.4	22.6	32.6	41.1	47.2	47.4	40.0	29.4	16.8	10.2
shaqlawa	7.8	11.2	18.7	26.0	35.5	47.1	51.1	50.2	44.1	30.9	17.9	10.3
soran	8.57	12.63	19.9	24.4	36.8	46.6	51.3	51.4	44.3	31.4	18.5	10.41
koyea	9	12.8	19.7	28.8	38.9	48.5	53.4	53.2	46.0	34.0	19.1	11.2

> 4 : very cold	
4 - 8 : cold	
8 - 13 : cool	
13 - 18 : Slightly cool	
18 - 23 : Comfortable	

23 - 29 : Slightly warm		
29 - 35 : warm		
35 - 41 : hot		
< 41 : very hot		

Table (4.2) Distribution of PET index values, thermal perception, and physiological stress.

PET (°C)	thermal perception	Grade of physiological stress
> 4	Very cold	Extreme cold stress
4 - 8	Cold	Strong cold stress
8 – 13	Cool	Moderate cold stress
13 – 18	Slight cool	Slight cold stress
18 – 23	Comfortable	No thermal stress
23 – 29	slightly warm	Slight heat stress
29 – 35	Warm	Moderate heat stress
35 – 41	Hot	Strong heat stress
< 41	Very hot	Extreme heat stress

In general Erbil governorate can be divided into two zones:

1- Very Hot areas (i.e. places with lower elevation)
2- Semi cold areas (i.e. places with high elevation)

- **Very Hot areas** can be determined as the following districts: Erbil Central, Makhmur and Koya. These places are generally has a high PET records, with the raining ratio less than 530mm. In these areas highest PET can reach 56.4 and lowest reaches 10.9 in Erbil central during January. Taking into count yearly ratio the temperature in Makhmur are higher than Erbil Central except during May its Vise versa. This can be due to several reasons which are ; population ratio is bigger in Erbil central than Makhmur, Number of factory are more in Erbil than Makhmur , Cars Numbers and also there are lots of air conditions which are switched on during May and they contribute to rise in temperature. Moreover, there are no any water surface in both places Erbil central and Makhmur, and there are differences in the topography between Erbil central which is 425 m and Makhmur which is 275 m.

- **Semi Cold Areas** can be determined as the following district; Masif slahaddin, Soran and Shaqlawa. The highest PET ratio reaches around 51.3 in Soran during July, and lowest PET ratio are around 7.2 In Masif slahaddin during January. Raining ratio are around 600 – 900 mm. Masif slahaddin are determined to be the coldest between all these three district, this can be due to the high elevation which reaches 1088m , Shaqlawa are 980 m and Soran 680 m. There are no any water surface and green areas within any of these three areas, except Shaqlawa has more green areas than the other two mentioned above but this doesn’t effect on PET as topography.

5. CONCLUSION

In this study, I have used two software's, Ach GIS and RayMan 1.2, which they are so important for the determination of the PET and showing it on the map by using IDW in GIS. Outdoor and indoor comfort zones may differ from each other. There may be larger influences of psychological aspects when we stay in outdoor than in indoor environments.

After working on Erbil Central area for PET determination at 15.00 o'clock the following results have been obtained:

1- Topography is the main reason for the differences in the PET within the areas.
2- Expansion and overcrowded cities and manufactures are the second reason for PET differences.
3- Water Surfaces and Green areas can be effective in this differentiation.

In Erbil central, we have concluded that both March and November can be the best months for outdoor activity during the year. December, January and February are the months coldest. During May to September are the hottest months especially July.

As result, we conclude that increased vegetated area and water surface could be helpful to decrease the high temperatures in the city.

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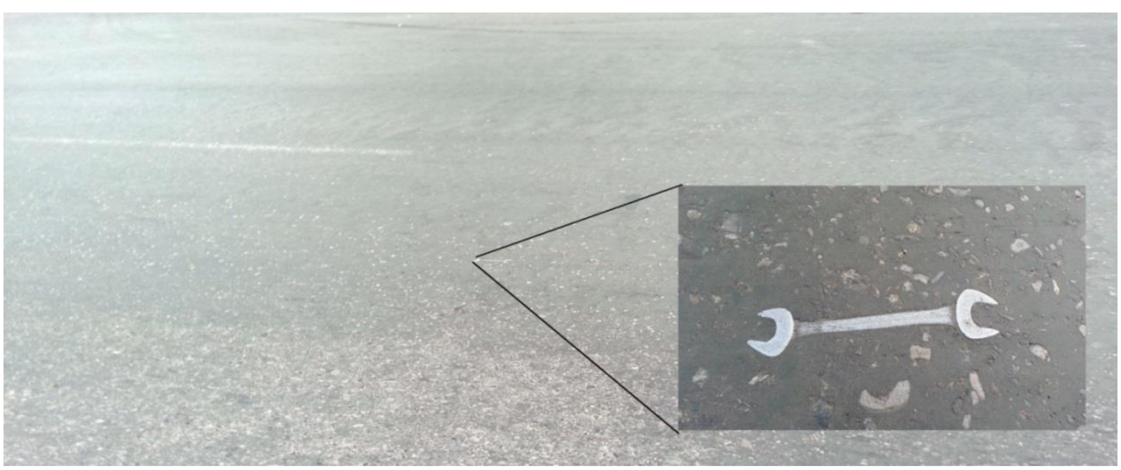
Appendix A: Observation photo in summer



Appendix B: Observation the weather station data in Erbil center

	Weather	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	T ºC	12.1	13.7	201.0	22.4	27.5	35.6	39.7	40.3	35.8	30.4	18.7	10.8
	H %	70.4	63.0	57.0	57.0	51.0	32.0	26.0	26.0	28.0	31.0	68.0	83.0
	W s/m	2.3	1.9	2.0	3.0	4.4	3.0	2.4	2.0	2.8	1.7	2.7	2.5
1993	T ºC	11.0	12.5	17.2	22.3	31.7	36.5	41.9	41.0	37.0	30.4	17.5	15.3
	H %	25.0	73.0	65.0	67.0	60.0	31.0	27.0	25.0	29.0	39.0	72.0	82.0
	W s/m	7.4	2.9	2.8	3.4	3.4	2.5	2.6	2.8	1.7	2.4	1.9	0.9
1994	T ºC	14.7	13.9	19.2	26.8	32.3	37.9	41.2	40.6	37.7	29.5	18.5	10.3
	H %	77.0	76.0	65.0	59.0	39.0	35.0	28.0	26.0	27.0	51.0	82.0	85.0
	W s/m	2.4	2.5	3.2	3.2	3.3	3.0	2.3	1.6	3.7	2.2	3.1	2.5
1995	T ºC	13.8	15.6	19.2	22.9	32.5	37.3	40.2	40.9	35.8	29.2	20.1	14.5
	H %	88.0	85.0	74.0	72.0	48.0	20.0	31.0	28.0	32.0	23.0	54.0	63.0
	W s/m	1.9	2.4	2.3	3.5	3.5	2.6	2.3	1.4	2.0	1.8	1.7	1.6
1996	T ºC	12.7	16.5	17.2	23.0	37.2	37.2	43.3	41.9	35.8	28.9	22.8	16.9
	H %	71.0	68.0	72.0	62.0	41.0	27.0	20.0	23.0	31.0	35.0	44.0	71.0
	W s/m	3.6	2.5	3.6	2.7	3.2	2.7	2.9	2.1	2.3	2.6	1.7	3.2
1997	T ºC	13.4	12.3	14.3	22.2	38.5	38.5	40.9	39.5	35.2	28.9	20.8	13.7
	H %	69.0	64.0	64.0	56.0	37.0	23.0	24.0	27.0	18.0	46.0	63.0	79.0
	W s/m	2.0	2.6	3.2	2.7	3.4	3.1	3.7	1.9	2.2	1.9	2.5	2.1
1998	T ºC	9.5	13.4	17.5	24.6	40.4	40.4	42.5	43.2	36.8	31.1	25.3	17.7
	H %	80.0	66.0	64.0	60.0	42.0	23.0	25.0	23.0	28.0	32.0	48.0	57.0
	W s/m	2.6	3.1	3.5	2.2	2.1	3.1	3.4	2.1	2.3	3.0	1.6	1.2
1999	T ºC	15.2	15.7	20.1	26.1	38.8	38.8	41.2	42.6	36.2	30.8	20.1	16.8
	H %	68.0	68.0	51.0	46.0	28.0	24.0	23.0	24.0	29.0	37.0	53.0	67.0
	W s/m	2.1	2.6	3.1	2.4	3.3	2.8	3.3	2.6	2.1	2.3	2.3	1.6
2000	T ºC	11.4	13.8	17.8	27.3	38.9	38.9	45.0	42.0	36.5	28.0	21.6	14.1
	H %	74.0	61.0	53.0	45.0	30.0	21.0	17.0	21.0	27.0	40.0	50.0	73.0
	W s/m	1.8	2.2	2.3	3.3	2.9	2.6	3.2	3.0	3.4	2.9	2.7	3.1
2001	T ºC	14.3	15.3	21.8	25.9	38.8	38.8	42.6	42.5	37.7	30.3	20.0	14.8
	H %	74.0	50.0	35.0	26.0	23.0	24.0	23.0	35.0	53.0	63.0	65.0	65.0
	W s/m	2.6	2.5	2.7	3.0	2.7	2.6	3.0	3.6	2.9	2.6	3.8	2.0
2002	T ºC	11.5	16.5	20.6	21.5	39.6	39.6	42.0	40.3	37.5	31.4	22.5	11.5
	H %	76.0	61.0	59.0	64.0	36.0	22.0	23.0	26.0	28.0	39.0	51.0	73.0
	W s/m	3.0	2.7	3.7	3.5	3.7	3.4	2.6	2.5	1.9	2.0	1.9	2.1
2003	T ºC	14.1	12.7	16.3	23.6	33.0	38.7	41.6	42.9	36.3	31.0	20.4	13.5
	H %	83.0	71.3	63.8	56.3	35.9	25.2	25.0	25.1	32.2	42.1	57.1	75.1
	W s/m	2.2	2.6	3.1	2.7	2.7	2.6	2.3	2.1	1.8	2.3	1.9	2.0

2004	**T ºC**	13.3	13.9	21.9	23.8	30.8	38.4	42.4	41.0	38.3	32.1	18.7	13.2
	H %	76.4	72.6	51.6	47.8	39.5	23.8	23.2	25.0	24.5	35.1	72.9	69.7
	W s/m	2.3	5.8	1.7	2.8	3.3	2.8	2.8	2.1	1.9	1.6	1.9	0.5
2005	**T ºC**	12.6	12.9	18.7	26.3	31.9	38.5	43.3	42.1	36.9	30.2	21.2	19.4
	H %	70.1	68.7	58.8	48.0	38.2	28.1	22.0	26.9	29.3	34.5	53.0	57.4
	W s/m	1.9	2.5	2.0	2.1	1.9	1.7	1.7	1.8	1.4	1.7	1.1	1.2
2006	**T ºC**	11.8	14.8	21.6	25.7	33.0	41.4	41.0	43.3	36.8	29.7	19.5	14.0
	H %	71.6	68.9	53.3	61.3	42.9	25.8	28.8	26.2	32.4	52.2	61.3	53.8
	W s/m	1.7	2.0	1.7	2.1	1.7	1.1	1.2	1.1	0.8	1.8	1.0	1.9
2007	**T ºC**	11.5	14.2	18.2	21.1	33.2	38.8	41.2	41.0	37.8	31.1	21.4	15.5
	H %	69.4	75.0	64.3	62.8	43.1	32.4	29.4	32.5	32.5	35.6	46.9	57.7
	W s/m	1.8	1.7	2.2	2.8	3.0	2.5	2.4	2.2	1.9	1.9	1.4	1.6
2008	**T ºC**	10.6	13.9	24.2	28.8	31.2	38.3	41.5	42.0	36.3	27.9	20.6	15.0
	H %	61.7	63.1	48.4	37.2	31.0	27.6	24.3	26.6	32.0	48.8	58.1	58.8
	W s/m	2.2	2.3	2.5	2.5	2.6	2.4	2.1	2.5	2.3	2.1	2.5	2.3
2009	**T ºC**	13.0	16.1	17.4	23.3	31.9	37.9	39.9	39.5	33.3	30.2	19.9	9.1
	H %	59.5	56.8	61.3	51.2	31.4	24.7	27.0	27.9	33.1	36.9	61.7	72.5
	W s/m	1.6	3.0	2.7	2.7	2.4	3.0	1.7	2.0	2.0	2.0	1.6	2.0
2010	**T ºC**	15.0	15.9	20.5	24.3	31.4	38.9	42.2	42.4	38.2	30.1	25.5	18.4
	H %	67.0	66.0	60.2	58.6	40.1	27.0	26.2	24.6	30.7	45.6	45.2	59.3
	W s/m	3.4	2.3	3.4	2.6	2.9	2.5	2.2	3.0	1.6	1.6	1.4	1.5
2011	**T ºC**	12.4	13.8	18.9	23.9	30.3	37.7	41.9	40.7	35.7	27.4	17.0	16.0
	H %	75.4	73.0	65.5	58.4	45.3	39.1	25.7	27.3	34.1	43.6	55.6	56.0
	W s/m	1.9	2.3	2.6	3.5	2.5	2.6	1.9	1.7	1.4	2.2	1.9	1.2
2012	**T ºC**	11.8	13.5	15.5	27.0	32.5	39.1	41.8	41.5	37.2	29.8	21.0	4.9
	H %	74.4	63.6	61.7	49.0	41.5	25.8	22.1	28.5	29.0	48.6	64.6	77.2
	W s/m	1.5	2.3	1.9	2.9	2.4	2.8	2.5	1.8	1.9	2.0	1.7	1.7
2013	**T ºC**	12.7	16.4	19.9	26.2	31.2	38.0	41.3	41.0	35.6	28.9	21.9	13.6
	H %	73.9	75.6	61.6	53.9	47.7	31.2	29.1	28.7	37.8	39.4	67.9	66.0
	W s/m	2.2	1.6	1.9	1.8	1.9	1.4	1.2	1.1	0.8	1.5	1.1	1.1
2014	**T ºC**	15.0	16.8	20.7	26.7	33.7	38.5	41.8	42.7	36.0	27.9	19.5	15.9
	H %	72.1	56.0	66.2	48.6	39.8	30.3	29.1	28.3	39.8	58.6	65.6	74.7
	W s/m	1.0	1.4	2.0	0.8	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.7
2015	**T ºC**	13.6	16.0	19.7	25.0	33.6	38.0	43.4	42.6	38.6	29.6	20.1	15.3
	H %	72.5	68.4	64.3	52.2	34.5	33.2	25.4	30.8	29.9	54.6	66.0	71.0
	W s/m	2.0	0.5	2.0	0.5	0.5	1.7	1.3	1.3	1.9	2.3	1.2	0.9

Appendix C: Observation the weather station data in MAKHMUR

	Weather	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	T ºC	13.2	17.0	18.0	24.7	30.4	38.8	42.0	42.7	38.2	32.6	20.2	11.2
	H %	71	59.5	67.0	56.0	51.0	32.0	27.0	26.0	30.0	36.0	68.0	87.0
	W s/m	3.7	2.9	3.3	2.5	4.1	3.2	2.9	3.3	2.7	2.4	3.1	2.9
1993	T ºC	12.3	14.1	19.4	24.6	30.4	39.3	44.6	43.5	40.2	33.1	18.7	16.6
	H %	77	75.0	63.0	66.0	55.0	31.0	27.0	29.0	30.0	39.0	73.0	84.0
	W s/m	3.2	3.5	3.1	4.1	4.0	3.5	3.4	3.3	2.8	3.3	2.8	2.3
1994	T ºC	15.6	15.6	21.6	29.9	35.5	40.8	43.7	43.4	40.3	32.2	19.5	11.6
	H %	83	76.0	67.0	53.0	34.0	28.0	28.0	28.0	26.0	46.0	78.0	81.0
	W s/m	3.2	3.0	4.3	4.8	3.9	4.1	3.4	2.9	4.1	4.0	3.5	3.9
1995	T ºC	14.4	17.3	21.3	26.1	36.0	40.6	43.1	44.0	38.9	32.2	21.7	16.5
	H %	83	77.0	70.0	59.0	34.0	28.0	27.0	26.0	32.0	34.0	52.0	65.0
	W s/m	3.1	4.0	4.0	4.6	5.3	4.8	4.5	4.3	4.0	4.3	3.6	3.2
1996	T ºC	13.7	17.8	19.1	25.1	36.6	40.0	46.2	44.5	38.4	31.3	24.5	17.8
	H %	75	70.0	75.0	62.0	34.0	27.0	24.0	27.0	38.0	40.0	57.0	77.0
	W s/m	5	3.8	4.9	4.8	4.8	5.0	5.6	4.7	4.7	4.7	4.1	5.3
1997	T ºC	14.5	14.5	17.4	25.7	35.7	41.5	43.5	42.2	38.0	31.6	22.8	15.5
	H %	81	71.0	77.0	55.0	35.0	27.0	25.0	34.0	31.0	51.0	70.0	84.0
	W s/m	3.5	4.1	4.4	4.6	5.0	4.9	4.9	4.4	3.8	3.2	2.9	3.5
1998	T ºC	11.5	15.8	20.2	28.2	35.8	43.3	45.7	46.6	39.9	33.4	27.7	20.6
	H %	86	71.0	68.0	56.0	38.0	25.0	24.0	24.0	31.0	34.0	48.0	59.0
	W s/m	3.3	3.3	3.1	3.2	3.7	4.7	4.4	4.2	3.8	3.7	3.3	3.5
1999	T ºC	16.3	18.4	23.0	29.0	37.0	41.4	43.9	44.9	38.5	32.8	23.1	17.9
	H %	75	66.0	47.0	43.0	26.0	25.0	24.0	24.0	32.0	38.0	49.0	68.0
	W s/m	3	3.6	4.5	3.1	4.4	3.8	4.0	4.2	3.1	4.0	4.7	4.6
2000	T ºC	12.9	16.1	21.9	30.3	35.1	41.3	47.3	44.4	38.4	29.6	22.8	14.9
	H %	76	61.0	48.0	38.0	29.0	23.0	18.0	22.0	27.0	45.0	58.0	83.0
	W s/m	5.3	4.8	5.1	6.0	5.3	5.5	5.7	5.6	4.6	4.6	4.6	4.8
2001	T ºC	15.3	16.6	23.7	27.9	33.7	40.8	44.5	44.6	40.0	32.1	21.9	16.3
	H %	77	69.0	63.0	54.0	36.0	27.0	24.0	26.0	30.0	40.0	60.0	75.0
	W s/m	3.4	4.3	3.6	3.8	4.4	4.1	4.0	4.1	3.8	3.4	2.9	3.5
2002	T ºC	14.3	18.3	22.8	24.8	34.1	40.0	44.3	42.4	39.4	33.2	24.5	12.4
	H %	76	74.0	55.0	55.0	32.0	24.0	19.0	22.0	23.0	35.0	43.0	67.0
	W s/m	3.4	3.1	4.2	4.3	4.1	4.3	5.0	4.2	3.9	3.6	3.1	2.8
2003	T ºC	13.9	16.7	17.8	26.2	36.7	42.7	43.5	44.9	37.9	32.5	21.9	14.2
	H %	79	58.0	67.0	54.5	30.0	25.0	26.0	22.9	28.2	40.0	55.2	76.7
	W s/m	3.1	4.0	3.4	3.8	3.7	3.4	3.4	3.6	3.0	3.5	2.9	2.9
2004	T ºC	14	15.0	23.2	26.4	33.3	40.1	44.4	42.8	40.2	33.6	20.0	13.9

	H %	**79.1**	73.0	49.2	40.6	31.8	22.2	19.1	24.5	19.5	27.3	67.2	65.2
	W s/m	**3.3**	3.5	3.7	3.8	4.2	4.7	4.2	4.6	4.1	3.2	4.0	2.6
2005	**T ºC**	**13.7**	14.0	20.9	28.9	34.3	40.1	45.0	43.7	38.6	31.5	22.4	20.7
	H %	**70.3**	71.1	57.3	41.7	27.8	19.4	18.3	21.5	22.3	30.2	48.0	53.4
	W s/m	**3.3**	3.3	3.5	3.8	4.1	4.6	4.6	4.5	4.0	3.8	3.5	2.9
2006	**T ºC**	**13**	16.4	22.7	26.6	35.3	40.9	44.4	44.1	39.7	32.8	21.4	15.8
	H %	**73.2**	67.0	48.2	51.9	28.5	22.8	17.0	20.1	24.0	33.0	54.0	55.0
	W s/m	**4.2**	5.3	3.8	4.0	5.1	4.3	4.1	3.7	4.2	2.9	3.1	3.5
2007	**T ºC**	**12.3**	15.9	20.7	24.8	36.3	41.7	43.8	44.4	40.8	34.1	23.5	16.5
	H %	**70**	74.0	54.0	49.0	31.0	22.0	21.0	23.0	23.0	31.0	44.0	51.0
	W s/m	**3.4**	2.9	2.9	3.7	4.3	4.5	3.8	3.7	3.5	2.8	3.2	2.9
2008	**T ºC**	**11.9**	15.3	25.5	30.9	35.4	40.4	43.7	43.7	25.3	30.2	22.2	16.1
	H %	**61**	62.0	45.0	30.0	27.0	22.0	19.0	21.0	30.0	45.0	57.0	59.0
	W s/m	**2.9**	3.1	3.5	3.9	4.6	4.6	4.4	4.6	3.9	3.0	2.4	3.2
2009	**T ºC**	**14.4**	18.0	19.9	25.4	33.9	40.2	42.3	41.6	35.7	32.3	20.8	16.9
	H %	**55**	57.0	55.0	41.0	27.0	22.0	24.0	23.0	29.0	40.0	61.0	70.0
	W s/m	**2.9**	4.0	3.3	2.0	4.0	4.4	4.2	4.1	3.7	2.9	2.6	2.8
2010	**T ºC**	**16.4**	17.8	22.5	27.5	33.6	41.2	44.7	45.4	40.6	32.8	27.6	18.7
	H %	**67**	61.0	54.0	46.0	33.0	25.0	22.0	19.0	26.0	39.0	39.0	61.0
	W s/m	**3.8**	3.4	3.8	4.1	4.1	4.8	5.0	3.9	3.4	3.4	2.3	2.9
2011	**T ºC**	**13.8**	16.0	21.3	26.1	32.4	40.4	44.8	43.6	38.6	29.8	18.7	17.1
	H %	**79**	67.0	48.0	50.0	40.0	27.0	21.0	24.0	28.0	50.0	50.0	56.0
	W s/m	**2.4**	3.6	3.6	4.7	4.0	5.2	4.5	4.3	3.5	3.5	3.2	2.3
2012	**T ºC**	**12.9**	15.3	18.3	28.8	35.1	41.5	44.4	44.8	39.8	32.0	23.1	15.7
	H %	**71**	59.0	53.0	40.0	30.0	23.0	25.0	25.0	28.0	46.0	62.0	78.0
	W s/m	**2.3**	3.2	3.2	4.1	4.0	4.1	4.2	3.9	4.5	4.0	3.5	2.5
2013	**T ºC**	**14**	18.0	21.6	28.9	34.0	40.8	44.2	44.4	38.9	31.2	23.5	14.8
	H %	**75**	72.0	55.0	4.4	37.0	28.0	29.0	29.0	35.0	42.0	72.0	72.0
	W s/m	**3.1**	3.0	3.7	4.1	4.4	4.4	4.1	4.1	3.8	3.1	1.9	1.7
2014	**T ºC**	**15.9**	16.0	21.3	27.3	34.9	41.0	44.5	44.1	38.3	32.0	22.4	16.4
	H %	**83**	67.8	57.8	46.3	32.1	24.6	22.7	24.3	28.2	39.3	56.6	68.0
	W s/m	**1.8**	3.7	3.8	4.0	4.4	4.5	4.4	4.2	3.8	3.5	3.2	3.2
2015	**T ºC**	**13.9**	16.4	21.0	26.0	32.4	39.9	44.0	44.7	39.0	30.6	23.0	15.0
	H %	**75.1**	68.1	58.0	47.1	33.1	24.9	22.9	24.5	28.2	39.3	65.0	71.0
	W s/m	**32.3765**	3.3	3.4	3.7	4.1	3.9	4.0	3.3	3.2	3.4	2.7	3.0

APPENDIX D: Observation the weather station data in MASIF SLAHDDIN

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	**T ºC**	3.9	3.7	9.9	17.8	20.4	29.9	32.8	34.7	30.3	23.4	16.7	14.0
	H %	82.0	85.0	63.0	55.0	61.0	40.0	32.0	38.0	55.0	49.0	70.0	77.0
	W s/m	2.0	3.0	3.0	4.0	2.0	4.0	2.0	3.0	3.0	2.0	1.7	2.0
1993	**T ºC**	7.0	7.7	19.7	17.4	22.6	31.5	36.9	35.9	32.4	25.7	13.5	12.3
	H %	79.0	70.0	42.0	37.0	33.0	30.0	35.0	57.0	69.0	61.0	72.0	65.0
	W s/m	2.0	2.0	3.0	3.0	3.0	3.0	2.0	3.0	2.0	2.0	2.0	1.0
1994	**T ºC**	11.0	8.9	14.4	22.0	26.2	32.8	36.1	36.2	32.5	24.9	14.2	5.6
	H %	92.0	73.0	66.0	59.0	26.0	38.0	33.0	28.0	37.0	51.0	78.0	72.0
	W s/m	3.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	3.0	2.0
1995	**T ºC**	9.7	11.3	14.9	18.2	26.9	31.4	35.8	36.3	30.5	24.7	15.7	10.5
	H %	76.0	69.0	64.0	60.0	36.0	36.0	35.0	38.0	41.0	41.0	61.0	59.0
	W s/m	2.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
1996	**T ºC**	8.2	11.7	11.6	17.8	28.1	21.6	38.5	36.9	31.1	23.8	18.5	12.4
	H %	72.0	65.0	74.0	60.0	41.0	34.0	33.0	32.0	37.0	43.0	49.0	74.0
	W s/m	2.0	2.0	3.0	4.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
1997	**T ºC**	9.6	7.4	9.4	17.1	25.8	32.8	34.7	35.2	30.4	24.7	16.7	10.0
	H %	69.0	70.0	73.0	59.0	46.0	31.0	34.0	29.0	30.0	49.0	63.0	79.0
	W s/m	2.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	2.0	2.0	2.0
1998	**T ºC**	5.6	9.5	12.5	20.1	27.0	33.8	34.4	38.1	32.2	26.5	20.8	15.3
	H %	82.0	66.0	60.0	56.0	43.0	28.0	28.0	24.0	31.0	36.0	49.0	55.0
	W s/m	2.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1999	**T ºC**	10.9	11.3	14.9	20.8	28.9	33.8	36.7	37.8	31.6	25.3	16.6	14.2
	H %	69.0	68.0	52.0	46.0	32.0	30.0	31.0	28.0	33.0	47.0	53.0	57.0
	W s/m	2.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	2.0	2.0
2000	**T ºC**	7.2	9.7	13.7	22.1	27.4	33.4	39.9	37.3	31.8	23.2	17.5	10.3
	H %	73.0	65.0	54.0	48.0	35.0	26.0	28.0	30.0	34.0	46.0	62.0	73.0
	W s/m	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0
2001	**T ºC**	10.7	10.5	17.5	20.8	26.0	33.1	37.4	37.3	32.7	25.2	15.9	11.1
	H %	65.0	69.0	66.0	60.0	43.0	29.0	33.0	35.0	36.0	43.0	56.0	76.0
	W s/m	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0
2002	**T ºC**	7.9	12.5	16.1	17.1	26.2	31.9	34.8	35.0	32.5	26.5	18.1	7.8
	H %	76.0	63.0	58.0	69.0	43.0	31.0	31.0	30.0	31.0	47.0	59.0	81.0
	W s/m	2.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0
2003	**T ºC**	10.4	7.7	11.6	19.5	26.8	30.4	36.2	37.8	31.5	26.1	16.7	10.1
	H %	67.0	76.0	68.0	54.0	35.0	34.0	37.0	33.0	47.0	51.0	61.0	77.0
	W s/m	2.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0
2004	**T ºC**	8.9	6.6	17.5	19.1	24.6	32.3	36.5	35.7	32.9	27.2	14.0	9.6

	H %	80.0	78.0	57.0	64.0	50.0	33.0	30.0	36.0	33.0	43.0	75.0	66.0
	W s/m	3.0	2.0	2.0	3.0	3.0	2.0	3.0	2.0	2.0	2.0	3.0	2.0
2005	**T ºC**	9.1	8.7	13.7	21.5	25.8	31.8	37.0	36.3	31.1	29.5	17.0	15.2
	H %	70.0	73.0	61.0	54.0	49.0	36.0	40.0	37.0	32.0	39.0	55.0	56.0
	W s/m	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2006	**T ºC**	7.2	9.8	16.2	20.2	26.7	34.4	35.0	37.5	31.2	24.4	14.8	9.8
	H %	77.0	80.0	55.0	67.0	51.0	39.0	43.0	35.0	41.0	59.0	63.0	61.0
	W s/m	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0
2007	**T ºC**	8.2	10.3	13.5	16.9	28.0	33.0	35.6	36.2	33.2	26.4	17.1	11.3
	H %	72.0	78.0	69.0	67.0	50.0	38.0	37.0	34.0	33.0	43.0	62.0	66.0
	W s/m	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	2.0	2.0
2008	**T ºC**	6.3	9.3	19.7	23.9	26.2	31.7	36.4	37.2	31.8	24.2	17.9	11.7
	H %	70.0	69.0	51.0	44.0	43.0	37.0	36.0	36.0	46.0	61.0	64.0	59.0
	W s/m	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0
2009	**T ºC**	9.7	12.1	12.9	19.1	27.1	32.8	35.8	35.3	29.4	27.0	16.6	12.0
	H %	57.0	63.0	63.0	53.0	38.0	35.0	43.0	35.0	49.0	51.0	69.0	75.0
	W s/m	2.0	2.0	3.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0
2010	**T ºC**	11.4	11.9	16.9	19.9	26.1	33.6	37.9	38.6	35.1	26.6	22.9	16.2
	H %	72.0	69.0	60.0	63.0	48.0	38.0	34.0	33.0	40.0	50.0	47.0	55.0
	W s/m	2.0	2.0	2.0	2.0	2.4	2.3	2.1	1.7	1.4	1.6	1.1	1.3
2011	**T ºC**	8.6	9.4	15.1	19.7	26.5	32.9	38.0	37.2	32.0	24.1	13.2	13.2
	H %	70.0	76.0	59.0	61.0	52.0	45.0	36.0	44.0	53.0	69.0	62.0	57.0
	W s/m	1.2	1.8	2.3	2.9	1.7	2.2	1.6	1.7	1.5	1.8	1.1	2.5
2012	**T ºC**	8.2	9.1	10.9	22.9	27.9	34.2	36.8	36.6	32.7	25.3	17.3	11.4
	H %	78.0	64.0	66.0	53.0	48.0	37.0	35.0	40.0	34.0	56.0	74.0	72.0
	W s/m	1.0	1.8	1.6	2.1	2.2	1.0	1.9	1.5	1.4	1.3	5.1	1.1
2013	**T ºC**	8.4	12.1	15.2	21.8	26.4	32.8	35.9	36.0	31.0	24.2	17.6	9.7
	H %	76.0	72.0	60.0	52.0	50.0	44.0	69.0	31.0	37.0	53.0	70.0	67.0
	W s/m	1.5	1.6	2.4	1.8	1.7	1.6	1.0	0.9	0.9	1.4	0.9	1.1
2014	**T ºC**	10.5	12.5	16.1	22.3	28.1	32.9	36.6	37.5	31.2	23.1	14.9	12.0
	H %	71.4	58.8	66.2	50.5	43.4	39.5	32.6	32.5	39.2	62.2	67.8	75.2
	W s/m	1.0	1.5	2.0	2.1	1.7	1.7	1.6	1.1	1.4	1.1	1.4	1.1
2015	**T ºC**	9.5	11.4	14.8	19.9	27.7	33.3	38.1	37.5	33.7	24.5	15.3	9.9
	H %	72.4	67.5	63.3	55.4	37.9	38.4	31.2	34.3	37.8	65.7	64.5	67.2
	W s/m	1.7	1.6	1.9	2.2	2.2	1.9	1.2	1.3	1.4	1.5	1.7	1.9

APPENDIX E: Observation the weather station data in SHAQLAWA

	Weather	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	**T ºC**	7.7	11.9	16.5	17.8	26.5	33.7	37.7	36.4	33.2	28.0	18.4	8.3
	H %	73.0	71.0	59.6	74.0	55.8	38.6	38.1	35.5	38.0	43.0	51.0	74.0
	W s/m	2.0	1.4	1.7	1.4	1.5	1.1	2.0	1.3	1.0	1.5	1.3	1.0
2003	**T ºC**	10.0	8.6	11.7	19.0	28.5	34.3	38.4	38.8	32.2	27.6	16.5	10.2
	H %	69.6	74.4	67.6	53.1	38.0	39.8	31.0	30.3	35.4	44.9	60.8	72.5
	W s/m	1.7	1.1	1.5	1.7	2.0	1.8	1.9	1.6	1.2	1.5	1.9	1.3
2004	**T ºC**	9.0	9.6	19.1	20.8	25.6	33.8	37.9	36.7	32.7	27.6	11.8	10.0
	H %	74.2	73.5	61.8	63.6	58.3	34.4	28.6	28.6	29.0	30.5	63.0	66.0
	W s/m	2.1	1.6	2.0	2.5	1.7	1.6	2.3	1.6	1.3	1.7	2.1	1.1
2005	**T ºC**	9.6	8.9	15.5	22.7	26.0	33.4	39.9	37.8	34.2	26.2	15.7	16.2
	H %	58.0	73.0	63.0	63.6	50.7	37.6	32.6	29.1	22.1	39.5	58.3	70.8
	W s/m	2.9	2.6	2.4	2.3	1.8	1.2	1.2	1.0	0.8	1.9	1.4	3.0
2006	**T ºC**	8.7	10.8	18.5	18.9	28.6	37.1	37.2	38.6	32.9	25.0	14.9	11.1
	H %	68.7	73.0	63.2	66.0	50.7	42.0	32.0	27.0	25.2	37.3	56.9	72.9
	W s/m	2.5	5.8	2.2	2.1	2.0	1.1	1.7	1.4	1.9	1.9	0.6	2.2
2007	**T ºC**	9.7	11.1	15.3	16.5	28.8	36.3	38.6	38.1	36.5	27.8	19.0	12.1
	H %	75.1	66.5	54.6	49.9	35.4	36.5	31.8	29.7	30.6	38.6	43.5	46.2
	W s/m	2.6	2.3	2.6	1.7	1.3	1.5	1.4	1.2	2.0	1.8	0.9	2.7
2008	**T ºC**	9.7	12.0	20.8	26.3	28.6	35.7	39.3	40.0	35.0	26.4	20.6	15.4
	H %	52.2	52.5	37.4	31.9	35.3	34.9	33.6	30.8	31.6	37.1	50.2	55.8
	W s/m	1.1	1.7	2.1	2.4	1.6	2.1	1.4	1.0	1.1	2.3	1.5	3.4
2009	**T ºC**	11.6	13.3	15.2	20.1	28.2	35.3	40.7	39.4	34.7	29.8	19.0	14.7
	H %	63.8	60.1	63.9	62.8	52.5	33.0	30.9	28.0	31.4	42.7	58.7	68.6
	W s/m	2.4	1.2	1.9	1.9	2.0	1.6	1.1	1.4	1.0	2.2	1.4	2.8
2010	**T ºC**	12.9	13.6	17.1	20.5	27.2	37.5	40.1	39.3	36.6	31.8	20.9	15.4
	H %	68.7	70.6	65.1	66.1	63.8	44.4	25.6	23.6	21.3	26.7	40.9	54.3
	W s/m	3.0	2.4	1.3	2.0	1.7	1.6	1.9	2.0	0.8	1.9	2.0	1.3
2011	**T ºC**	10.9	10.3	15.5	18.5	24.9	34.3	39.4	36.9	32.2	23.8	13.3	11.3
	H %	53.3	66.3	61.7	52.4	52.2	40.5	31.3	23.4	21.6	32.2	52.0	57.9
	W s/m	3.1	2.1	1.4	1.3	2.8	2.1	2.3	2.1	1.4	2.3	2.2	1.6
2012	**T ºC**	8.7	8.7	11.0	21.7	26.0	33.9	38.1	38.2	33.4	27.8	19.0	10.0
	H %	65.3	67.3	64.7	54.0	43.5	28.7	21.0	29.3	29.2	37.3	76.5	85.4
	W s/m	2.0	1.6	0.9	1.7	2.5	2.0	2.5	1.6	1.7	3.0	1.7	2.3
2013	**T ºC**	7.9	9.7	12.0	17.8	22.8	35.8	38.3	38.8	34.0	23.4	16.7	7.9
	H %	85.8	83.6	78.5	64.7	50.3	49.6	36.3	26.0	28.3	36.7	56.1	65.0
	W s/m	1.8	1.3	1.1	1.6	2.1	0.8	2.0	1.5	2.0	2.7	1.9	2.1
2014	**T ºC**	10.8	12.3	15.5	27.9	31.8	38.2	41.0	40.2	35.8	25.2	16.0	11.5
	H %	66.3	66.7	60.8	67.0	63.7	51.5	35.0	30.4	33.9	48.5	57.4	68.5
	W s/m	1.9	1.7	1.2	1.9	1.5	1.4	2.1	1.7	1.3	2.4	2.0	1.1
2015	**T ºC**	9.3	11.4	14.2	18.2	28.5	34.2	40.5	38.9	34.4	26.8	17.0	12.3
	H %	72.2	70.5	56.3	42.1	25.7	22.1	18.0	19.0	29.6	38.2	55.8	67.7
	W s/m	2.2	1.9	1.8	1.3	1.1	2.0	1.8	1.3	1.2	2.6	1.7	2.2

APPENDIX F: Observation the weather station data in SORAN

Weather		Jan	Feb	Mar	Aprl	May	June	July	Aug	Sep	Oct	Nov	Dec
2002	T ºC	7.3	8.8	12.8	19.0	29.2	35.6	39.8	39.1	35.7	24.4	18.6	6.0
	H %	73.1	74.0	66.0	70.7	52.5	36.7	37.6	38.0	41.0	54.0	65.0	81.0
	W s/m	1.1	2.0	1.8	1.6	1.7	3.4	2.9	0.9	2.0	1.7	1.1	0.6
2003	T ºC	9.0	8.6	12.5	21.6	29.5	35.3	39.2	40.6	33.8	27.9	17.2	10.2
	H %	75.7	79.4	70.9	68.6	58.0	46.7	44.0	42.5	51.1	60.4	66.7	75.2
	W s/m	0.9	1.3	2.1	1.9	2.9	2.1	2.0	2.3	1.9	2.0	1.4	1.1
2004	T ºC	8.3	11.0	18.8	20.5	25.7	34.4	39.1	38.5	35.5	29.6	14.8	8.8
	H %	79.5	77.7	65.7	70.6	66.7	54.5	49.2	48.5	50.3	55.3	78.9	72.6
	W s/m	2.2	1.8	1.4	2.0	2.8	2.3	2.8	2.5	2.4	1.2	1.9	1.0
2005	T ºC	7.9	9.0	15.1	23.5	27.3	34.6	40.8	39.9	33.8	27.4	18.0	14.8
	H %	78.0	71.6	68.6	64.0	61.8	48.5	48.7	47.9	53.9	57.9	66.5	68.4
	W s/m	1.4	1.4	2.7	2.6	2.5	2.7	2.4	2.7	2.4	1.8	1.3	1.0
2006	T ºC	6.8	10.4	19.1	21.0	27.6	38.4	39.4	41.9	35.3	26.5	16.0	11.3
	H %	77.6	75.8	64.1	73.7	61.4	49.9	52.1	48.5	50.5	65.6	70.2	64.5
	W s/m	1.1	1.9	2.2	2.2	2.3	2.4	2.4	2.6	2.4	1.8	1.0	1.7
2007	T ºC	8.1	11.4	16.2	17.8	28.3	35.6	38.5	39.3	36.5	29.4	19.2	12.5
	H %	75.5	73.3	68.4	71.5	63.3	49.9	47.6	51.0	52.7	60.1	65.1	76.4
	W s/m	1.4	1.0	2.0	2.0	2.1	2.0	2.1	1.8	2.6	2.2	0.8	2.1
2008	T ºC	9.3	11.2	21.5	17.8	28.4	34.7	39.1	40.3	33.9	25.6	18.1	11.9
	H %	67.9	71.3	61.0	56.8	53.8	52.4	49.2	50.1	56.0	68.0	68.7	68.5
	W s/m	1.7	1.0	1.4	2.3	1.7	1.8	1.9	2.6	1.4	1.8	1.7	2.3
2009	T ºC	10.0	12.5	15.3	17.8	28.7	35.0	37.5	37.3	31.7	28.6	16.8	11.6
	H %	69.7	74.8	72.1	66.2	56.5	52.7	50.4	51.2	26.8	58.7	73.1	83.0
	W s/m	1.4	2.3	1.9	1.8	2.2	1.8	2.2	1.4	2.0	1.5	2.1	1.6
2010	T ºC	12.5	13.3	17.7	17.8	27.4	36.3	39.7	40.2	36.8	27.6	23.0	15.5
	H %	78.9	79.1	70.3	71.8	65.8	54.0	50.1	51.1	53.4	62.9	57.0	66.6
	W s/m	1.0	2.5	1.6	1.4	1.5	2.6	1.7	1.8	0.8	3.8	1.9	2.0
2011	T ºC	9.2	10.4	17.1	17.8	26.9	35.0	39.4	38.2	34.0	26.1	14.1	11.7
	H %	77.4	74.0	63.7	69.0	64.4	55.5	51.9	54.0	56.6	62.4	71.5	69.2
	W s/m	0.8	1.4	1.6	1.6	1.8	2.9	1.3	2.1	1.5	2.0	2.3	2.8
2012	T ºC	6.5	10.6	12.4	17.8	29.4	35.5	38.6	38.8	35.5	27.5	17.8	11.2
	H %	79.6	68.2	71.7	64.4	62.0	52.3	52.2	53.3	55.6	69.3	76.7	79.3
	W s/m	2.5	0.7	1.2	0.9	1.9	2.2	2.8	3.0	1.0	1.6	1.0	1.2
2013	T ºC	8.9	12.6	16.6	17.8	27.5	35.0	39.0	38.5	34.0	27.1	20.2	10.4
	H %	69.6	78.1	72.0	66.7	67.2	52.7	51.6	51.5	54.2	58.9	69.8	75.7
	W s/m	2.0	1.4	2.0	1.7	1.4	1.6	1.8	1.6	1.3	1.6	1.3	1.9
2014	T ºC	12.1	15.7	18.1	17.8	30.4	35.5	39.1	40.1	33.5	23.9	16.0	10.3
	H %	73.7	61.3	72.1	70.4	64.4	54.0	48.6	50.4	58.5	74.8	73.2	82.8
	W s/m	2.0	1.5	1.1	1.5	1.3	1.2	0.9	0.7	0.9	1.8	2.6	2.0
2015	T ºC	10.2	13.5	16.7	17.8	28.6	34.9	39.5	39.2	32.7	25.0	16.3	9.2
	H %	79.6	78.1	70.7	68.8	66.3	58.9	56.0	55.3	40.0	62.2	69.4	74.1
	W s/m	1.6	2.0	1.0	1.9	1.8	1.1	2.2	1.3	1.7	1.9	2.1	1.6

APPENDIX G: Observation the weather station data in KOYEA

	Weather	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	T ºC	10.9	15.9	19.9	21.2	30.4	36.9	40.9	40.5	37.8	32.0	21.1	10.4
	H %	65.6	54.6	50.8	65.8	35.5	21.1	20.8	22.2	22.0	32.0	44.0	77.0
	W s/m	2.2	2.9	2.3	1.9	2.5	3.2	2.9	2.4	1.9	1.5	2.4	2.1
2003	T ºC	11.9	11.7	14.9	23.0	31.4	38.1	40.9	41.6	36.4	31.6	19.6	11.5
	H %	63.6	70.8	64.2	52.7	31.6	24.6	25.0	30.1	31.3	38.1	49.8	59.1
	W s/m	1.4	1.6	2.2	2.0	2.3	1.8	2.6	2.4	1.7	1.9	2.0	1.6
2004	T ºC	12.0	12.1	19.9	23.0	28.2	37.3	41.1	40.8	37.0	31.6	16.0	10.7
	H %	64.2	62.3	40.0	41.9	37.3	20.6	24.1	27.0	31.9	36.1	69.7	53.4
	W s/m	2.0	1.6	2.0	2.4	1.7	2.1	2.9	1.5	2.1	1.6	1.5	1.8
2005	T ºC	10.7	8.9	16.4	25.2	30.4	36.4	44.1	41.9	36.3	28.1	20.7	18.5
	H %	81.0	80.4	56.1	46.9	41.6	34.3	29.5	31.1	35.0	36.2	51.5	52.8
	W s/m	20.0	1.7	1.4	1.7	1.9	1.5	1.8	2.0	1.9	2.0	1.7	1.9
2006	T ºC	7.9	8.8	16.1	24.4	29.8	37.3	41.6	42.3	36.7	29.9	17.0	11.9
	H %	77.0	74.0	70.0	49.0	42.2	37.0	33.6	39.6	41.6	57.8	67.1	60.9
	W s/m	1.9	2.2	3.0	2.7	2.4	2.5	2.1	2.0	2.7	2.5	2.1	2.6
2007	T ºC	8.9	12.6	16.9	19.8	31.2	37.0	40.5	41.9	37.9	31.2	21.0	12.1
	H %	75.5	72.2	62.0	67.6	56.0	50.5	45.3	52.1	47.0	54.0	61.8	72.2
	W s/m	1.6	2.0	2.3	2.8	2.8	2.7	3.0	2.6	2.8	3.0	2.6	2.1
2008	T ºC	8.2	11.9	23.6	29.9	32.8	37.1	43.1	43.0	37.3	27.9	19.1	14.4
	H %	68.7	72.6	64.8	60.3	53.7	50.5	53.8	52.5	58.4	63.1	69.5	67.2
	W s/m	1.9	1.8	2.5	2.2	2.9	3.1	3.6	4.1	2.8	2.9	2.4	2.3
2009	T ºC	12.0	15.7	16.2	23.1	32.0	37.5	41.0	39.9	33.1	29.8	18.8	13.6
	H %	68.3	71.4	72.2	65.3	59.0	55.7	53.4	52.6	58.8	55.9	72.2	77.2
	W s/m	2.3	2.0	2.1	2.9	3.3	2.6	2.8	2.5	2.1	2.2	2.9	2.7
2010	T ºC	13.7	15.2	19.3	22.7	29.8	39.1	42.2	42.0	38.5	31.3	25.5	18.6
	H %	71.8	68.9	68.0	67.7	60.3	49.7	43.0	42.6	48.4	56.3	49.1	59.0
	W s/m	2.0	1.7	1.9	2.4	2.9	3.4	2.2	2.7	2.3	2.9	2.9	2.4
2011	T ºC	9.8	12.1	17.6	22.6	29.0	38.2	41.7	41.3	35.9	28.1	14.5	15.1
	H %	74.3	70.8	63.9	63.9	55.4	45.5	43.4	43.2	49.4	53.7	62.5	62.7
	W s/m	1.3	2.1	2.0	1.9	2.4	2.2	2.5	2.5	2.0	3.0	3.1	2.3
2012	T ºC	10.6	10.7	14.2	25.7	32.3	38.3	40.5	40.7	37.2	29.8	21.1	13.2
	H %	77.7	67.4	70.5	70.0	51.2	43.7	44.7	48.7	51.3	62.5	71.5	73.6
	W s/m	2.6	2.8	2.3	2.9	3.6	3.1	3.2	2.7	2.8	2.1	2.4	2.6
2013	T ºC	10.9	13.8	17.6	23.2	29.2	36.9	41.5	41.7	35.9	28.3	20.0	10.3
	H %	71.9	71.9	66.4	60.2	57.3	41.5	30.0	21.3	25.0	29.7	59.0	61.5
	W s/m	1.7	2.4	2.1	2.5	1.9	2.4	2.6	2.6	3.3	2.7	1.6	2.1
2014	T ºC	11.5	13.6	19.4	24.6	32.9	37.6	40.6	42.5	36.0	26.4	17.6	13.2
	H %	66.3	52.3	65.8	52.3	34.8	29.5	29.3	25.0	29.1	49.2	55.9	69.7
	W s/m	2.8	2.0	2.2	2.6	3.0	3.3	2.8	2.5	2.1	2.4	2.4	2.7
2015	T ºC	12.1	14.1	12.0	23.0	32.3	38.4	42.3	42.7	38.0	28.7	18.2	12.7
	H %	68.5	66.9	68.3	54.9	39.6	30.0	27.0	26.3	34.6	54.7	61.1	68.2
	W s/m	1.0	1.4	2.3	3.7	3.2	2.7	2.6	2.2	3.1	2.0	1.4	1.8

CURRICULUM VITAE

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Oğuz, H., T.A. Hamad , 2015. Determining Thermal Comfort Zones for Outdoor Recreation Planning: A Case Study of Denizli –Turkey. Ulusal çevre kongresi.

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