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Characterization of urban forms within the oases settlements and their long-term impact on the outdoor thermal comfort in Tolga territory

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To my parents, to my wife, my daughter,

my country,

and my profession

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Abstract

Among symbiosis and harmony, there is a close relationship between human settlement and surrounding environment, whereas this link is becoming more and more detached over time. Nowadays, most of big challenges are demonstrated on the environmental balance which is deteriorating the human well-being quality inside cities, and being the imperative actors of the built environment. Accordingly, the oases networks in arid regions, are undergoing serious urban issues which are calling for a new pattern of life style, a truly artificial one. In fact, the transition from the oasis-city to the so-called contemporary city has evoked the production of exogenous urban logics far from being a continuity to ancient settlements and old patterns crowned with their specific Saharan archetypes characterized by compacity, agrarian landscapes, sociability, and their perfect economics' autonomy model, and which are disappearing progressively under the urban sprawl, also mainly benefiting from the important urbanization and residential programs conducted by the Algerian government. Consequently, from the oasis settlement to the new city model, a failure denouncing several series of mediocre consequences, such as an increasingly urbanization, unlimited urban growth, environmental disturbances of the oases entities, and specifically the hard thermal quality inside the oases urban fabrics. Otherwise, the new urban planning strategies in these lands does not presenting any integration's shapes towards the environment which were built only for people's needs in term of residential housing or some specific buildings, in which the main architecture and urban patterns have no place and no value in new cities.

Tolga as one of the largest oases territory in North Africa, as an oasis settlement, and a special urban form reveals an architectural and urban disfiguration that threaten its agricultural potential of millions palm trees as well as its oasis livelihood, especially during the hot season. The thermal aspect inside Tolga oases territory claims a major handicap for their local inhabitants, as well as for the dynamic of many activities. Thus, we are supposed through this study, to standing-up among these environmental issues especially about the outdoor thermal comfort variations, we need to note initially problem questions as well as: what future for the oases settlements and the palm groves, which present the main resource of Saharan agriculture under extreme weather conditions? How is the quality of the outdoor thermal comfort throughout the oases urban fabrics? How can be the long-term solutions for the thermal issues which are spreading under the absence of suitable urban planning strategies for these lands as well as a clear land policy to be apply?

Keywords:

Arid region, oasis settlement, urban fabric, sustainability, outdoor thermal comfort, numerical assessment, climate change, predictions, Tolga city.

Résumé

Entre symbiose et harmonie, une corrélation très étroite est omniprésente entre espace urbain et environnement immédiat, celle-ci qui se détachait plus en plus au cours du temps. La plupart des enjeux aujourd'hui sont concentrés sur la qualité environnementale voire la qualité vitale dégradée au sein de nos mondes urbains, étant qu'acteurs des nos villes.

Le milieu oasien subit sérieusement une agressivité urbaine non-réfléchie qui prévoit à une nouvelle ère de vie, une vraie ère artificielle. A vrai dire, le passage de l'établissement oasien à la ville dite contemporaine a évoqué une production d'une nouvelle logique urbaine loin d'être une continuité à l'ancienne image de l'habitat ksourien couronné doté de son archétype des ksours, la sociabilité, le monde agraire, et le modèle exemplaire l'autonomie économique, tous ces aspects sont perdus et délaissés dans l'oublis conséquence de la croissance spectaculaire des localités sahariennes, celles qui bénéfiçaient d'un massif programme de progressivité étatique. De l'oasis à la ville, une défaillance dénonçant un ensemble de points noirs, tels que l'étalement urbain, une croissance citadine illimité, la mauvaise qualité thermique des micro-agglomérations, une perturbation environnementale des microrégions, en préfigurant des causalités délicates pour le bien-être humain. L'urbanisation algérienne aujourd'hui ne dépend forcément pas à la planification qu'a la concrétisation des besoins des citoyens, dans laquelle les vraies valeurs architecturales et urbaines n'ont plus de places dans les villes actuelles.

Tolga telle qu'un territoire oasien, ville, et urbanité nouvelle dévoile une défiguration architecturale et urbaine qui menace son potentiel agricole de palmeraies ainsi que sa dynamique urbaine, notamment durant la période chaude de l'année. L'aspect thermique des oasis proclame un handicap majeur aux habitants, ainsi que la vivacité de différentes membranes de la ville. Quel devenir peut-on prévoir à nos établissements oasiens, et à nos chapelets verts source de l'agriculture désertique ? Quel est le bilan réel de la qualité thermique aux tissus urbains oasiens ? Y-a-t-il réellement un remède pour ce symptôme qui se propage sous l'absence de la planification et une politique urbaine médiocre ?

Mots-clés :

Région aride, milieu oasien, tissu urbain, durabilité, confort thermique extérieur, quantification numérique, changement climatique, prédictions, ville de Tolga.

ملــخص

بين الحاضر و الماضي تواصلت المؤسسات البشرية بصفة ضيقة مع محيطها المباشر و خلقت تجانس و تآلف دام لمئات السنين، غير أن هذا الأخير أصبح يتفكك و يفقد قوته مع مرور الزمن. أغلب قضايا العصر الراهن و المتعلقة بالاختلالات البيئية هي مسائل تمس بالدرجة الأولى المستوى المعيشي و الرفاهي للإنسان داخل حيز المدن التي تحوي جميع أنشطته و نظام عيشه. المجال الواحاتي في المناطق الحارة بصفة خاصة هو اليوم معرض لجملة من التدخلات المعمارية و العمرانية داخل فضائه المشيد، محدثا عن ذلك اخلالا في النظام البيئي العمراني بهاته المناطق الجد عرضة للاختلالات البيئية كونها هشة و عدوانية في آن واحد. ان الانتقال الناجم عن هذه التحولات الجديدة في المجال الواحاتي قد أحدث شرخا واضحا بين الفضاء المشيد قديما متمثلا في نظام القصور التي تعتبر النمط المستدام و الذي يستمد ديمومته من عناصره الاجتماعية، الثقافية، الزراعية و بدرجة أخص واحات النخيل المتجذرة في مناطق الصحراء، و أيضا انتماءه الى البيئة المباشرة، غير أن كل هاته الركائز أضحت في طيات الإهمال و النسيان في ظل التطور اللامسبوق في تشييد مدن صحراوية لا واحاتية تلبي فقط و آنيا طلبات و حاجات الايواء و الزيادة المتسارعة في التعداد السكاني. ان هذا التحول الجذري في النظام المشيد في المناطق الصحراوية الجزائرية على وجه الخصوص قد كشف عن عمق الاختلال الذي أحدثه التوسع العمراني، زيادة السكان، و المنطق العمراني العشوائي الذي أدى الى عدة أعراض أهمها الذي يصب في قلب إشكالية البحث الاختلال على مستوى الرفاهية الحرارية داخل الأنسجة العمرانية خصوصا خلال الفترات الحارة من السنة و التي تنعكس سلبا عن الديناميكية الحياتية داخل هاته المؤسسات البشرية، و تؤدي في كثير من الأحيان الى النزوح نحو الشمال و شغور المناطق الحارة و شلل شبه تام على كل مستويات الحياة داخل هذه المناطق خلال فترة معتبرة من السنة.

واحات طولقة التي تعتبر من أهم أمثلة العالم، تشهد كشبيهاتها هذا الانتقال من مؤسسات بشرية واحاتية الى إقليم عمراني صحراوي لا تتجلى صورته الواحاتية سوى في غابات النخيل. مجال دراستنا هو الآخر يعاني سنة بعد سنة من الاختلال الحراري خلال أكثر من نصف السنة، حيث يشهد كل إقليم الدراسة من ارتفاع في نسب عدم الرفاهية الحرارية في الأماكن الخارجية للأنسجة العمرانية، و الزيادة البالغة في الاستهلاك الطاقوي في كل المجال المشيد خاصة السكنية منه، و شلل تام في الأشغال الخارجية في الفترة الصيفية الممتدة لأكثر من أربعة أشهر. من خلال بحثنا هذا الذي يخص رسالة الدكتوراه، نفتح قوسا لأسئلة قد تم الإجابة عليها نوعا، كما و كيفا من خلال مراحل الدراسة: كيف هو شكل مستقبل المجال المشيد الواحاتي، و كيف هي علاقته بواحات النخيل التي تعتبر القلب النابض له؟ ما مستوى الاختلال في الرفاهية الحرارية داخل الأنسجة المشيدة في المناطق الواحاتية ؟ كيف يمكن أن يكون الإصلاح المجالي لهاته المؤسسات البشرية في ظل السياسة العمرانية غير المدروسة و التي شغلها الشاغل الكم قبل الكيف ؟

الكلمات المفتاحية:

المناطق الحارة، المجال الواحاتي، النسيج العمراني، الاستدامة، الرفاهية الحرارية الخارجية، التكميم الرقمي، التغير المناخي، التوقعات المستقبلية، مدينة طولقة.

Glossary

AALO (En)	Access to Agricultural Land Ownership
ANAAT (Fr)	Agence Nationale d’Attractivité et d’Aménagement du Territoire
APFA (Fr)	Accession à la Propriété Foncière Agricole
AR4	Fourth Assessment Report
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CFD	Computational Fluid Dynamics
DPWT (En)	Development Plan for the Wilaya* Territory
EPW	EnergyPlus Weather file
GCMs	Global Climate Models
INCT (Fr)	Institut National de Cartographie et de la Télédétection
IPCC	Intergovernmental Panel on Climate Change
MBE	Mean Bias Error
MPDUP (En)	Master Plan for Development and Urban Planning
NAATP (En)	National Agency for Attractions and Territorial Planning
NADP (En)	National Agricultural Development Plan
NICRS (En)	National Institute of Cartography and Remote Sensing
NMO (En)	National Meteorological Office
NSPS (En)	National Spatial Planning Scheme
ONM (Fr)	Office national de Météorologie
PATW (Fr)	Plan d’Aménagement du Territoire de Wilaya
PDAU (Fr)	Plan Directeur d’Aménagement et d’Urbanisme
PET	Physiologically Equivalent Temperature
PT	Perceived Temperature
PNDA (Fr)	Plan National du Développement Agricole
R_H	Relative humidity
RMSE	Root Mean Square Error
SNAT (Fr)	Schéma national d’Aménagement du Territoire
SVF	Sky View Factor
Ta	Air temperature
Tmrt	Mean Radiant Temperature
TMY	Typical Meteorological Year
Ts	Surface temperature
Va	Wind velocity

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1. CHAPTER ONE : GENERAL INTRODUCTION

1.1 Introduction: Urban centres and climate change

Nowadays, population inside the urban areas are exposed to urban sprawl consqueneces and to the impact of climate change known as global warming. According to the 2007 Intergovernmental Panel on Climate Change (IPCC) report (AR4), among the twentieth century the average global air temperature increased by 0.76 °C, and the global warming trend over the last 50 years which was nearly lined compared to last 100 years. This trend of rising in global air temperature is likely continued for the future (IPCC, 2007). Based on relevant literature review, the study of Alcoforado and Andrade.,2008, concluded that the impact of global warming including its affect on human well-being and health may be exacerbated in urban centres areas. Altough, the global and the regional warming can aggravate urban warming during summer months (Fujibe et al., 2009) and may increase the elevation of air temperature in urban areas and extends the duration of heat waves, which are very remarkable as well as reponsive in worldwide arid regions (Golden, 2004).

The cities are growing within a natural context which is constantly interacts. The climate is inseparable from this environment and, while in the past, their construction of buildings and, their expansions, cities were often built with an adapted view in their environment. Furthermore, empirical and scientific approaches had made it possible to respond in large part about the human needs in safety and well-being, depending to climate change patterns (Colombert et al., 2012). In fact, it has been found that cities have being influenced stronly by the climate change, in the other hand, cities also have a closely impact on the immediate microclimate and could modify their parameters. The built environment presents the main modifying factor of the human thermal quality, which is appearing in the temperature elevations, aerodynamic effects, and generating several daytime, noontime and nightime thermal disturbances. The study of the urban climate is much more complex, this is not easy to separate the action of the city as entity versus the people where live and work, on creating all pollution's types, whose release of dust, gas, aerosols... and could modify consequentely the weather conditions (Escourrou, 1981).

Futhermore, cities are often accused for developing several microclimatic issues in their urban centres. This accelerated increase in temperatures, compared to the required ones in nearby rural areas, lead to fluctuations in terms of thermal comfort, energy consumption (air conditioning) and different pollution's nuisances. The mineralisation of surfaces, by replacing vegetation and wetlands with concrete and asphalt, provides these thermal stress. The capacity of the urban landscape to take action on thermal heat eleveation is thus reduced. This observation leads us to try to better understand how the urban space is affected by long-term of climate change and in the contrast how it affects on it. Numerous solutions defined previously in the basis on vernacular and empirical strategies which had been proposed and corresponded relatively well to reasoned or adjusted to urbanisation in relation to weather conditions (Vinet, 2001). In fact, the situation has seriously changed when the multiplication of mineral or glazed surfaces, throughout cities and human activities had been considerably evolved, making common sense recommendations unsuitable. Compensation or regulation policies are therefore required, and a work of understanding, demonstration and information is then necessary. Otherwise, the microclimatic pattern in urban centres is only interesting when the quantification of the impact is significant, where improvements in the liveable environment and thermal comfort conditions can be expected, and where energy savings can be calculated. In this framework of the current research, we are not moving as far as these analysis' levels, however we try to seek through some key realities that will eventually allow us to reach our objectives.

1.2 Oases settlements and contextual adaptation strategies - overview

People working in the field of vernacular architecture located in arid zones acknowledge that these settlements have developed urban and architectural morphologies well adapted to the extreme physical environment. They identify adaptive features in urban and architectural patterns, cohesive social structure, and finally, adaptive behaviors derived from an indigenous 'know-how'. The indigenous people of the Sahara retain specific knowledge concerning resilient eco-systems. Thus, it is recognized that this indigenous knowledge plays a significant role in maintaining local socio-ecologic systems which contribute to socially responsible resilience toward sustainability. (Daoudi et al., 2019).

In fact, according to (Alkama, 1995) study, the oasis urban patterns is characterized by compactness and irregularity and the narrowness of their streets, strongly adapted through the surrounding palm groves, in which the urban unity is formed by scattered entities. Moreover, streets are winding and narrow, and implemented through the old houses' locations as well as the water layouts which are the main generating elements of the oasis urban patterns. Furthermore, the ancient urban block was identified in horizontal housing groupings with various sizes, depending on the built environment area, as well as the water layouts throughout the oasis settlement. Otherwise, in the external reading of the buildings's patterns, we could distinguish several diversities in the treatment of facade which was generally in blind surfaces related to the climate conditions and society customs. Accordingly, the existence of these verncaular urban forms inside the palm grove, is imperatively related to the logic of linearity, making the oasis urban patterns as a large mass protected from the aggressiveness of arid climate, notably the hot and sandy winds, and solar radiation effects which present the main weather parameters in these lands (Matallah, 2015; Alkama and Tacherift, 2001).

- ***Oases settlements urban system - characterization***

The oasis settlement demonstrates the livelihood pattern in the arid lands, is a formula of three inseparable components : water, palm grove, and 'ksar' built environment (Côte, 2012), shaped by a set of context-related factors: topographical and bioclimatic conditions, situation-specific factors: trade roads and other factors related to the diversity of the oasis structure itself such as: water mobilization patterns, agrarian form, social hierarchy and the integration into the immediate context (Kouzmine, 2007). The oasis functionality system focuses on four modes of productivity that influence the life cycle of the oasis system such as: agricultural function, territorial function, tourism function, and symbolic function (Kassah, 2010). The model demonstrated by the oasis urban system within the Ziban region in Biskra province, analyses the particular and narrow attachement of these characteristics, when the water presents the liveability factor of the oasis system fed the entire territory through the springs scattered along the edges of all oases. Additinnaly, the second factor which is the palm grove (cultivated area) chain's item of oases, the density of palm trees, the phoeinicultural productivity and its attachment to oasis settlements clearly illustrated the close human dependence on agriculture (Bouzaher and Alkama, 2012), as well as the micro-regions of Tolga Oases Complex 'Zab Dahraoui' (Figure 1.1) defined a famous path of the agricultural approach of palm trees and dates's fruits (Bouammar, 2010). Futhermore, the built-up in permanent changeover or even knowledges borrowed in the past, which took into account the conditions of the context and the hostile climate of the region. Ksourian or ksar (ancient oases' urban shapes) defines the old model of the oasis urban concentration flanked in the middle of the palm groves (Nesson, 1973), while it has changed into new urban shape of oasis settlements as a result of recent urban planning policies that seek to shelter the demographic explosion within the region and elsewhere, and which is far from being integrated into the social and the environmental aspects of the arid lands. The last factor that makes up the generating element of the transformations is the population, this one is in temporal dynamics and places the urban oasis system in transformations. Despite, the large definitions of the oasis components and ecosystem, there is not a specific knowledge about the oasis urban system, overall the literature review, oasis concerns the human grouping throughout Saharan regions.

- ***Strenght of thermal adaptation strategies***

Thermal adaptation is an old bioclimatic design element that was found in the vernacular and the traditional patterns. Instead of installing a mechanical system for heating or cooling, occupants and the buildings acted as the thermal system. Thermal adaptation is a design principle that involves two main strategies. The first strategy involves spatial thermal zoning; in other words, compartmentalization, whose the second strategy involves occupant behavioral changes and traditions (Attia, 2020). Accordingly, vernacular techniques reveal an excellent and strong application of thermal adaptation means. Architectural and urban strategies look forward for the adaptation of technologies and policies in the local built environment especially throughout arid regions. Overall, architects and urban planners are mandatory engaged for energy issues and thermal adaptation.

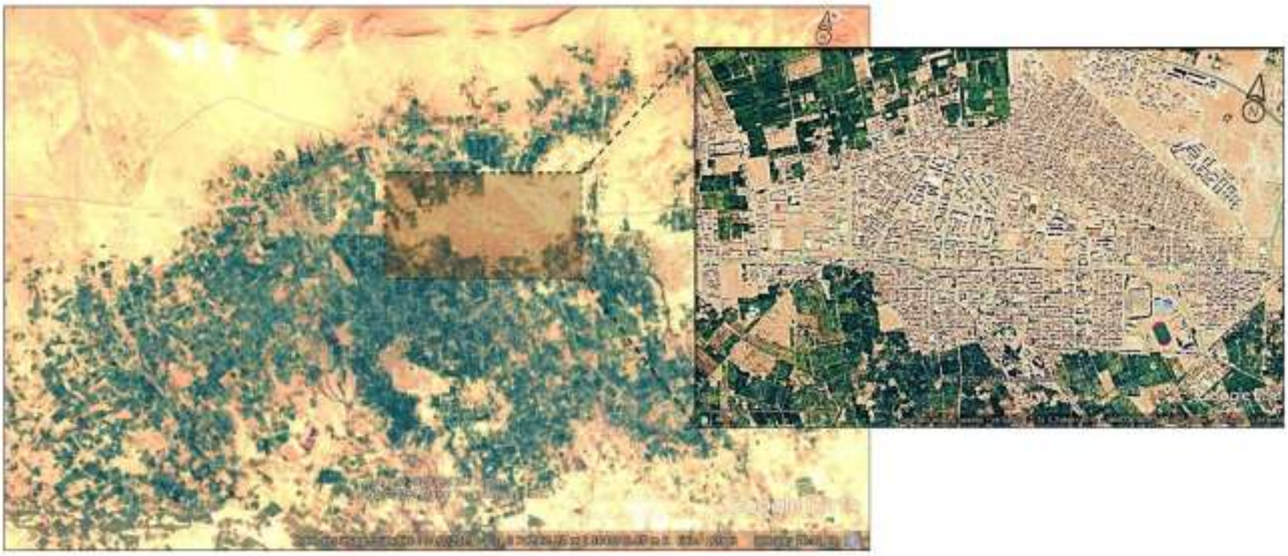


Figure 1.1: *Tolga Oases Territory map: morphogenesis of the oases structure*

Source: *Matallah et al., 2021*

1.3 Research problems

The built environment presents a source of multi-factors such as radiative, energy, dynamic and hydric variables that modify sensitively the cities' urban climate. Therefore, the surface layer of soil, with the presence of more or less important cultiveated and irrigated surfaces, as well as the human activities which induce heating impacts and pollution, and the urban morphology, endowed with heavy building materials and different architectural patterns and densities, reveal the main factors of the heat stress rise. Besides, the oases settlements located in the middle of Sahara are the most affected lands by unadptable urban sprawl policies and climate change consequences, pushing people to leave these areas to another weather context, as well as being a critical subject to increase rate of morbidity and mortality especially during the overheating period. We should note that our thesis is conducted within Tolga Oases Complex territory in Biskra province southern Algeria, which presents one of the largest oases settlements in North Africa (Figure 1.1).

Novel conditions of life incorporated within the oases settlements is quite different, under many factors from the insertion of exogenous architectural archetypes, also a new building materials foreign to the traditional building practice (Bouzaher, 2015), as well as the large abandunce of the traditional urban shapes by their current owners, which had chosen a different housing typlogies that offers in their credits more security and comfort. Contrary, urban density, compactness, healthy materials, and the glorious palm groves' areas draw the crucial key of human well-being by preserving many ingenious simple knowledges demonstrated by merey actions. Accordingly, it has been the time to revalorise the morphology aspects inside the oases settlements, enhancing the emphasis on the external formal and spatial aspect, on the housing patterns which are inseparable from its oasis system, on the cladding which imperatively conveys the microclimate of the oasis territory, as well as on the perfect harmony founded between built environment and cultiveated and irrigated surfaces, while to promote a coherent definition of sustainability for these vulnerable lands. In the other hand, the oasis urban system identifies a specific thermal microclimate affecting by hostile environment and extreme weather conditions, needs to be deeply evaluated. We believe that future weather conditions will be more critical face-to-face long-term patterns of the outdoor thermal comfort inside the oases settlements.

Thermal comfort assessment within oases settlements has not been deeply involved, despite the number of worldwide studies and projects throughout thermal comfort and urban adaptation. As a results of the lack of research in this topic, there are several evident research gaps as listed below:

1. A lack of identification and characterization of oases settlements specifically in Algeria, as well as the analysis about main components of the oasis urban system.
2. A lack of knowledges about the oases settlements' spatial configuration and their urban system development over the time.
3. A lack of the outdoor thermal comfort quantification studies throughtout an existant oases settlement complex, in short-term, medium-term and long-term.

4. No simplified thermal predictions for long-term within the oases settlements, and climate change consequences on human well-being in arid regions.

5. No connection between Algerian urban policies which are used for the improvement and cities' sustainability notably for the oases territories and recent strategies.

1.4 Research questions

Accordingly, there are four main questions raised in this research process, which are listed as follows:

(1) How to characterise the oases settlements urban forms and their urban system components?

(2) Which criteria are imperative for the spatial sustainability of the oases settlements in the Algerian arid lands?

(3) What are the correlation levels between these oases settlements and outdoor thermal comfort variations in short-term and long-term?

(4) How to achieve for a long-term predictions patterns of the outdoor thermal comfort inside the oases settlements territory?

1.5 Aim and objectives

The aim of the current research is to allow a new quantitative approache for the spatial configuration inside the Algerian oases settlements, as well as to provide an experimental method for quantifying the thermal comfort variations within oases urban forms in long-term period. Therefore, it is necessary to focus on a list of objectives which are as follow:

(1) A territorial reading (mapping) of Tolga Oases Settlements spatial and demographic development, using GIS tools (Qgis model).

(2) Searching about the sustainability criteria for the oases settlements to improve the rule of Algerian urban policies and startegies' proposals .

(3) Develop an experimental approache for the microclimatic measurements and their analysis, through several oases forms in long-term period. As well as to planify a workflow for urban climate investigations conducted by Algerian researchers especially in arid regions.

(4) In-depth, making a deep assessment of the outdoor thermal comfort throughout oases settlements during extreme hot season long-term. Chosen methods, parameters and indices are conclude on the basis of the most relevant and recent studies on same field.

(5) A contribution to establish a predicted scenarios of outdoor thermal comfort variations throughout the oases territory, as well as to attach the oasis urban system to extreme weather conditions. Accordingly, scenarios are:2020, and A1B, A2, B1 for the years 2050 and 2080 respectively.

1.6 Thesis outline

This thesis consists five core chapters in addition to an introduction and conclusion chapters. A discussion section is added after each core chapter, thus there is no discussion chapter in this thesis, all discussion's sections are included across chapters. Otherwise, due to the lack of relevant studies on oases settlements especially in Algeria, this research handles this topic from different scales (i.e. territorial and urban scale), as illustrated in Figure 1.2.

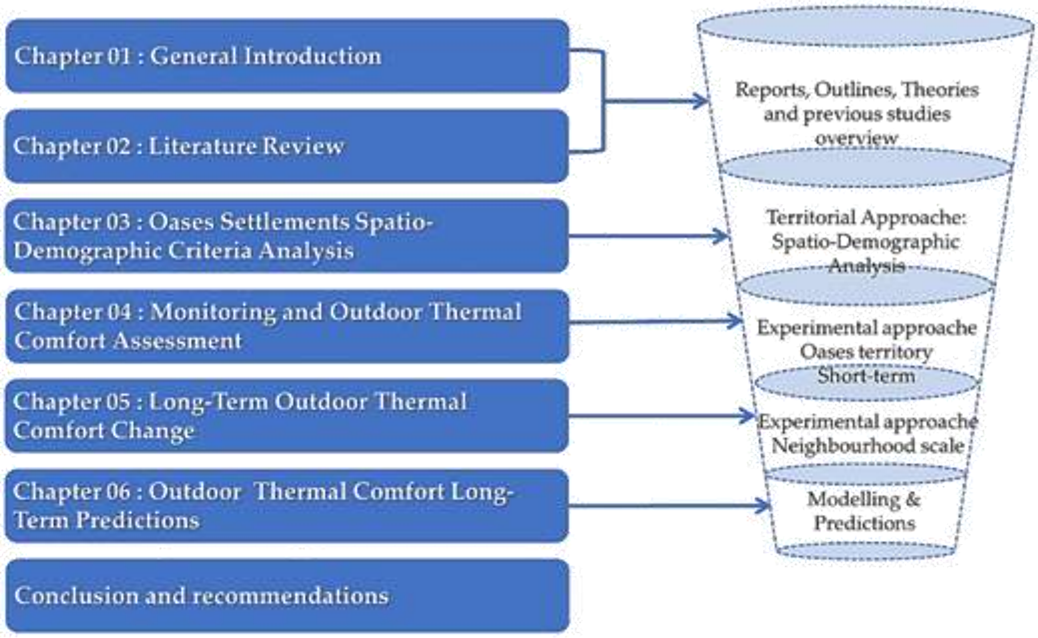


Figure 1.2: *Thesis Outline*

Source: *Author, 2018*

The part I, which gives on a theorical insights of the oasis ecosystem, such as thermal comfort worldwide field studies. Although, this first step aims to across groups of studies relied to several scientific works, including overall the defenitions that have relationship with the research’s topic, and combining between spatial factors, outdoor thermal comfort parameters and modelling tools. This section contains the general introduction (chapter 1) which represents the research scope and methodologie outlines, additionally to the literature review chapter (chapter 2), which performing several relevant theory and studies on the oases settlements and the thermal behavior through their urban fabrics.

the part II is highlighting the practical (investigations) sections which contains the study process of all questions involved in the current research. It is mandatory to note that the thesis is made up of a series of articles that have been published, or under review to peer-reviewed journals. For this reason some overlap may occur between the various chapters. Therefore, the territorial analysis of the spatial configuration through the context of Tolga Oases settlements is discussed on the chapter 3, including two main criteria such as spatial and demography throught the context study. The Assessment of the outdoor thermal comfort inside Tolga Oases Settlements is carried in the chapter 4, comparing between five diffrenet sites and which containing on 12 measured points. This chapter, clarify the methodology process for an outdoor microclimatic measurements that are used to quantify the outdoor thermal comfort levels during summer in short-term period. Moreover, the quantification of the outdoor thermal comfort in long-term period (30 years) is conducted in the chapter 5, whose three typical oases urban fabrics are comparing during three decades. Numerical assessment is added to the study process including two numerical software: ENVI-met and RayMane model. Chapter 6 is aimed to develop the outdoor thermal comfort predictions patterns for the typical multifamily residential archetype, as well as to amplify future scenarios versus worldwide climate change, in addition a greedy algorithm development for the future thermal predictions in the study conetxt. Finally, chapter 7 presents the conclusion and recommandations of the current thesis.

1.7 Research scope

As shown previously in sections 1.2 and 1.3, there are several factors and aspects involved when considering outdoor thermal comfort within oases settlements. However, it is never possible to include all aspects within a limited time and effort of doctoral thesis research work. Therefore, multi-approaches are developed to amplify the study’s robustness, following several research studies, and making some proposal of guideline parameters. However, it is out of the scope of this research to quantify their effect notably about the parameters for improvement of the oases territories sustainability, it is rather aimed to have those aspects well defined and taken in consideration.

Afterwards, quantitative research methods based on numerical simulations for precise and well defined design objectives have been employed. The scope of the developed methodology focuses on each of (1) improvement of urban instruments for decision-makers, in terms of quantitative applications, (2) oases microclimatic conditions , in terms of microclimatic vulnerability, and (3) the added long-term predictions, in terms of arid future strategies.

1.8 List of publications

Peer-reviewed journal articles

- Chapter 3 is based on:

Matallah, M. E., Alkama, D., Teller,J. (2021). Spatial and Demographic Criteria for The Improvement of Sustainability of The Oasis Network. Frontiers of Architectural Research Journal. Under submission.

- Chapter 4 is based on:

Matallah, M. E., Alkama, D., Ahriz, A., & Attia, S. (2020). Assessment of the Outdoor Thermal Comfort in Oases Settlements. Atmosphere, 11(2), 185; https://doi.org/10.3390/atmos11020185

- Chapter 5 is based on:

Matallah, M. E., Alkama, D., Teller, J., Ahriz, A., & Attia, S. (2021). Quantification of the Outdoor Thermal Comfort Within Different Oases Urban Fabrics. *Sustainability* 2021, *13*(6), 3051; https://doi.org/10.3390/su13063051

- Chapter 6 is based on:

Matallah, M. E., Mahar, W. A., Bughio, M., Alkama, D., Ahriz, A., & Bouzaher, S. (2021). Prediction of Climate Change Effect on Outdoor Thermal Comfort in Arid Region. Energies, 14(16), 4730; https://doi.org/10.3390/en14164730

refereed technical report

Matallah, M. E., Ahriz, A., & Attia, S. (2020). Quantification of the Outdoor Thermal Comfort Process: Simulation & Calculation data (No. 01/2020). Sustainable Building Design Lab. https://orbi.uliege.be/handle/2268/250205

4. CHAPTER FOUR : MONITORING AND OUTDOOR THERMAL COMFORT ASSESSMENT [1]

Facing the climate change impacts on the livelihood qualities and human well-being inside cities, studies conducted on the thermal comfort became imperative to adapt the built environment to climate conditions. However, the assessment of the outdoor thermal comfort throughout the arid regions was not enlarged among scientific works such as other climate zones in the world. Accordingly, few experiences and studies were conducted to explore the thermal balance inside an oasis territory but none of these works is taken in consideration the complex system and components of an oasis settlement. Throughout this chapter we conducted an empirical approache to evalute the outdoor thermal comfort levels inside Tolga Oases Complex, during the hot season. A list of 12 sites was investigated, where microclimatics set are monitored five times at the concerned days between July and August 2018. We believe that the current chapter gives a new methodology about outdoor thermal comfort assessment within the oases settlements and identifies new realities about impacts of the oases surroundings on the heat stress levels during the hot season as well as their influences on outdoor human's production. The chapter aims to promote a clear metholdogy for the evaluation of the outdoor thermal comfort combining between monitoring data and numerical calculations on the basis of RayMan model.

The outcomes of this chapter draws the line for the future researchers to more focusing on the microclimatic monitoring in site, especially for the oases lands. Although, for the understanding of the oasis effect we need to seek inside different oases urban forms, not only through a limited area such as caltivated surface.

[1] This chapter is based on this article: Matallah, M. E., Alkama, D., Ahriz, A., & Attia, S. (2020). Assessment of the Outdoor Thermal Comfort in Oases Settlements. Atmosphere, 11(2), 185.

4.1 Introduction

The African Sahara oases are increasingly urbanized, and their future will not be shaped in the surrounding desert but in the dense vibrant palm groves of Ghardaia (Algeria), Siwa (Egypt), Awjila (Libya), Tafilalt, (Morroco), Timia (Niger), and Tozeur (Tunisia). An oasis is the combination of a human settlement and a cultivated area in a desert or semi-desert environment. The oasis is also a socio-spatial settlement in the middle of the desert, with a cultural identity characteristic to a particular human settlement. Urban settlements around oases are growing increasingly, with enormous implications on cooling energy needs, lifestyle, tourism, economy, governance and public services; as well as rising risks if urban growth is poorly managed. According to the World Bank, urbanization and climate change are the two most important transformations the Saharan oases will undergo this century. In the same time, the outdoor environment is deteriorating in many oases settlements, where most of human activities take place. People cannot find shade in the middle of the day and excessive heat build-up during the day results in shifting the human activities to the night and halting any economic activity during summer. The influence of heat stress limits productivity and forces a large part of oasis population to migrate to cooler areas during the summer, replicating the older tradition of nomadism in a modern way. Every summer, across the Saharan desert oases, several families leave their home seeking cooler cities, in their countries. However, this modern seasonal nomadism, which is mainly due to heat stress, is not sustainable and many families find it more and more difficult to maintain. Therefore, there is a need to assess the outdoor thermal comfort in oases settlements and investigate the means to provide livable urban environments for their inhabitants. In this study, we investigated outdoor urban comfort in an oasis defined as a fertile spot in a desert, where water is found with more than 1 000 000 date palm trees. The scale of our study and its findings confirm the need to define oases and their thermal oasis effects. The research questions corresponding to the research objective are:

- What are the outdoor thermal comfort conditions in oases settlements during summer?
- How far is the oasis effect beneficial for improving thermal comfort conditions in oases settlements during summer?
- How to improve outdoor spaces design and relieve heat stress in the urban oasis Complex of Tolga, one of the largest oasis complexes of the Saharan Desert in North Africa and Algeria?

Our comparative approach allowed answering the questions above and testing several assumptions and refuting the presence of the 'oasis effect' during the months of July and August. The study shows a common similarity of the heat stress levels (PET index) in the oases settlements fabrics and Palm Grove in August 2018: Δ PET $_{\text{urban fabric.August}}$ = 36.3 °C; Δ PET $_{\text{palm grove.August}}$ = 36.2 °C. The heat stress level (PET index), evaluated in July, is slightly higher in the Palm Grove than in the oases settlements fabrics: Δ PET $_{\text{palm grove.July}}$ = 41.7 °C; Δ PET $_{\text{urban fabric.July}}$ = 40.9 °C. However, our study measurements are limited to daytime hours and should be extended to cover nighttime hours and other seasons of the year. The 'oasis effect' might be present in other climatic conditions and under other humidity, solar radiation and temperature thresholds.

In this chapter, we present the results of a research that was designed to assess thermal comfort in four oases settlements in Tolga Oases Network and compare it with thermal comfort in a palm grove. More specifically, the study tested the validity of the 'oasis effect' following a comparative field measurement and calculation approach.

4.2 Study methodology

In this research, we used field measurements and modeling. In order to assess the oasis effect on the outdoor thermal comfort we followed an empirical methodological approach. Figure 4.1 illustrates the major methodological stages from data collection to data processing and modeling until the final step of output visualization. The following subsections explain in detail the methodology.

Accordingly, a literature review is conducted including recent publications that aimed to assess outdoor thermal comfort in desert regions worldwide. The publications include scientific manuscripts that focus on the thermal effects of oasis in desert climates. Our initial Scopus and Web of Science research resulted in more than 40 publications. To narrow and concentrate the scope of our study, the publications are under three categories: outdoor thermal comfort in hot climate, outdoor thermal comfort assessment methods, oasis urban climate. In addition, recent studies conducted in Algeria, are reviewed to improve our knowledge uptake regarding the local context.

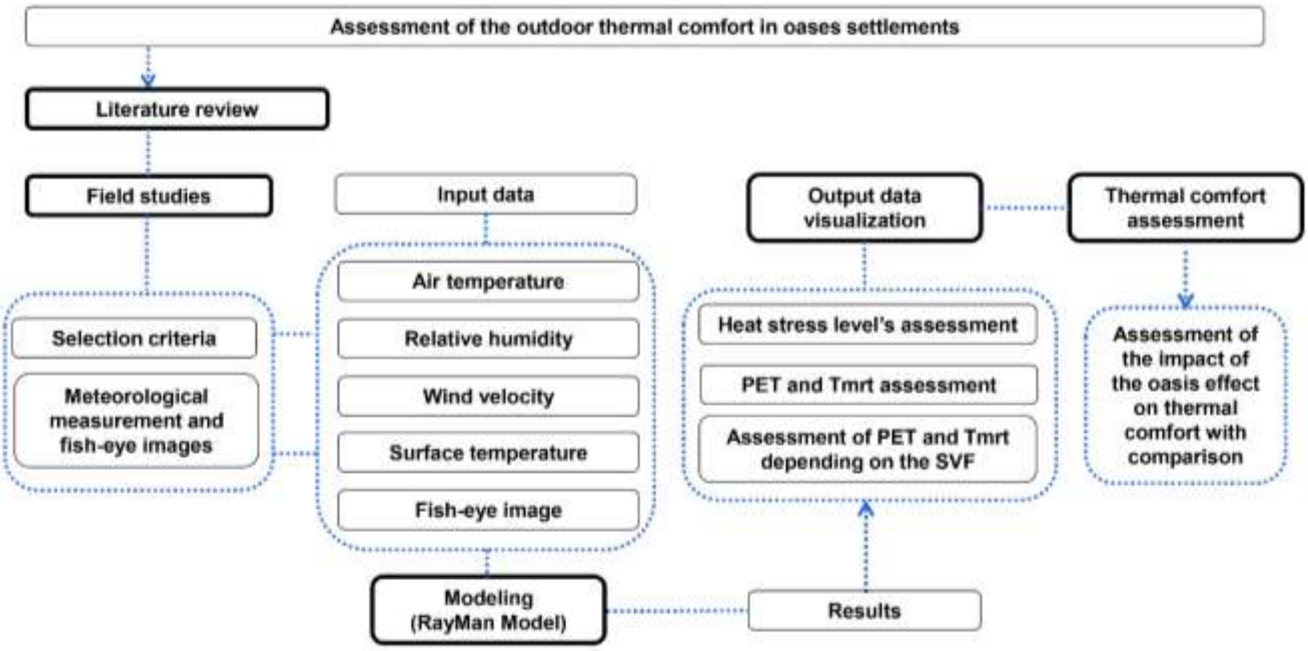


Figure 4.1: *Study Conceptual Framework*

Source: *Matallah et al., 2020*

4.3 Oases settlements characteristics

The context of this study is a complex of oasis settlements in Biskra Province, situated in the South of Algeria. The study area is Tolga city (34° 43′ 00″ N and 5° 23′ 0″ E) positioned within a six oasis Complex, situated at elevation 147 m above sea level and located in south-east Algeria, 363 km south of the capital Algiers.

Overall, five sites are selected to conduct a measurement campaign in order to assess outdoor thermal comfort and investigate the oasis effect on urban climate (Figure 4.2). The selection of the five sites is based on four main criteria: (i) level of vegetation and oases settlement fabric, (ii) the age of the oases settlement fabric, (iii) the size of the built-up settlement, and (iv) the relation between the built-up settlement and the Palm Grove. The differences between the old and new urban fabrics are mainly related to the urban form and the connection with palm grove. Most of old oasis settlements have an irregular urban form and close to the palm grove (<100 m). Thus, the urban density is high (<15 ha), streets are narrow (<4 m). In contrary, the new oasis settlements have regular urban form, far from the Palm Grove (>1000 m), with a large built area (>20 ha). The urban characteristics of the old settlements (Old Lichana, Old Tolga, and Old Farfar) are showed on the irregular urban form, streets are between 2.20-4.00 m, and occupancy of built-up area is around 0.80. Building materials are generally with local materials (stone, lime, and palm trunk), no asphalt inside streets. Old settlements are closer to the palm grove than the new ones (<100 m). In the other hand, the new settlements (New Tolga Downtown), the urban form has a regular geometry, streets are wider >3.20, urban occupancy is <0.60, and farther from the palm grove (>1000 m). Thus, the housing materials are modern; houses are built on brick, concrete, with a reflective color. Inside the most of the new settlements we can see some little green areas: grass, Ficus rubiginosa.

After applying all these criteria, on the Oases Network of Tolga, five different oases settlements are identified as case studies: (1) Old Tolga, (2) Old Lichana, (3) New Tolga Downtown, (4) Old Farfar, and (5) a Palm Grove, as a reference point.

Accordingly, for the second criterion, the size of built-up space, four different sizes are selected: (a) tiny size, less than 3.0 ha, (b) small size, between 3.0 ha and 10.0 ha, (c) medium size, between 10.0 ha and 20.0 ha, and finally, (d) large size, over 20.0 ha. The selected oases settlements are reported respectively: (a) New Tolga Downtown (22 ha), (b) Old Tolga (14 ha), (c) Old Lichana (4.2 ha) and finally, (d) Old Farfar with 2.5 ha.

For the third criterion, the age of the oases settlement fabric is distinguished through two different vintages: Old settlements, built before 1900 (Old Tolga, Old Lichana, Old Farfar), and new settlements built after 1980 (New Tolga Downtown).

For the fourth criterion, the relation between the built-up settlement and the Palm Grove, two different relations are established: (a) the heart of the Palm Grove (reference point), and (b) the distance between Palm Grove peripheries and the oases settlement fabric border.

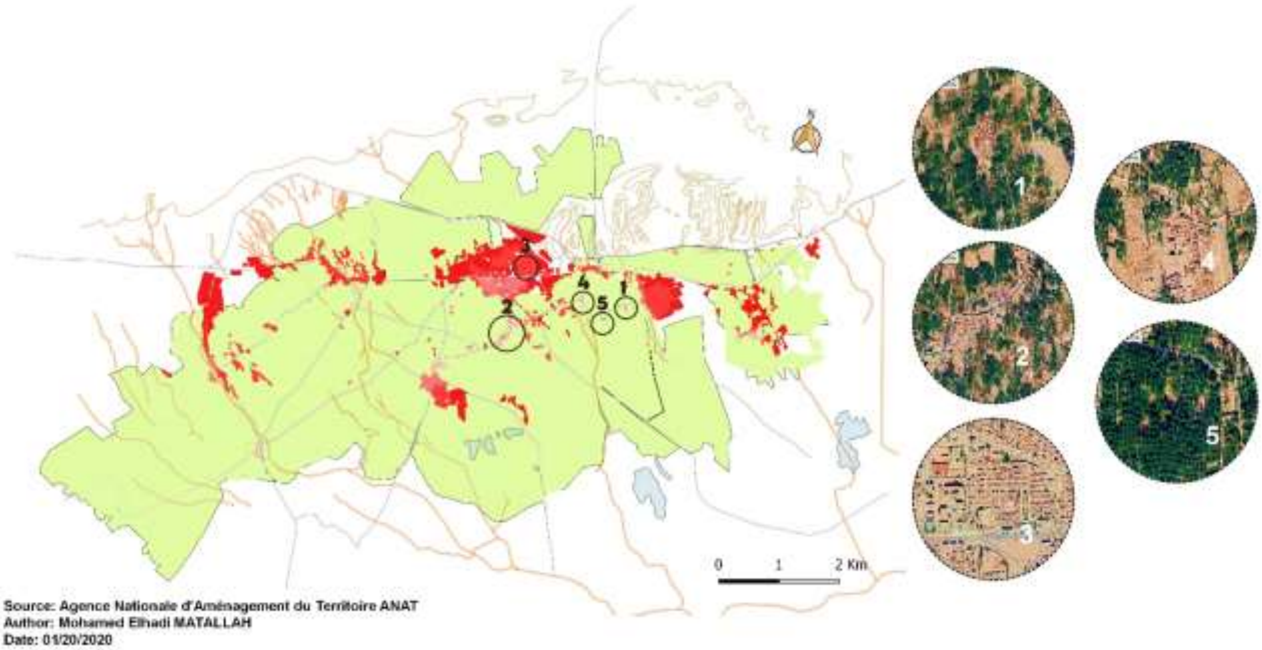


Figure 4.2: *Map of the selected sites throug Tolga Oases Network*

Source: *Matallah et al., 2020*

The four selected oases settlement comprise several residential individual buildings. The old neighborhoods 1, 2 and 4 are ancient and unplanned settlements, while Old Tolga is entirely rebuilt by its inhabitants, after 1990. The new oases settlement (3), in the downtown, represents a planned urban settlement. The buildings in the selected neighborhoods are characterized mainly as low-rise developments with two storeys housing units (G+1), which is the most common residential urban typology in Southern Algeria. A details' overview is illustrated in the Table 4.1.

To assess the oasis effect, measurement of several outdoor climate parameters was done simultaneously together with fish-eye images. In total, twelve measurement points were selected as showed in the Figure 4.3:

- Three points in Old Lichana (1, 2, 3),
- Three points in Old Tolga (4, 5, 6),
- Three points in New Tolga Downtown (7, 8, 9),
- Two points in Old Farfar (10, 11), and
- A reference point, inside the Palm Grove (12).

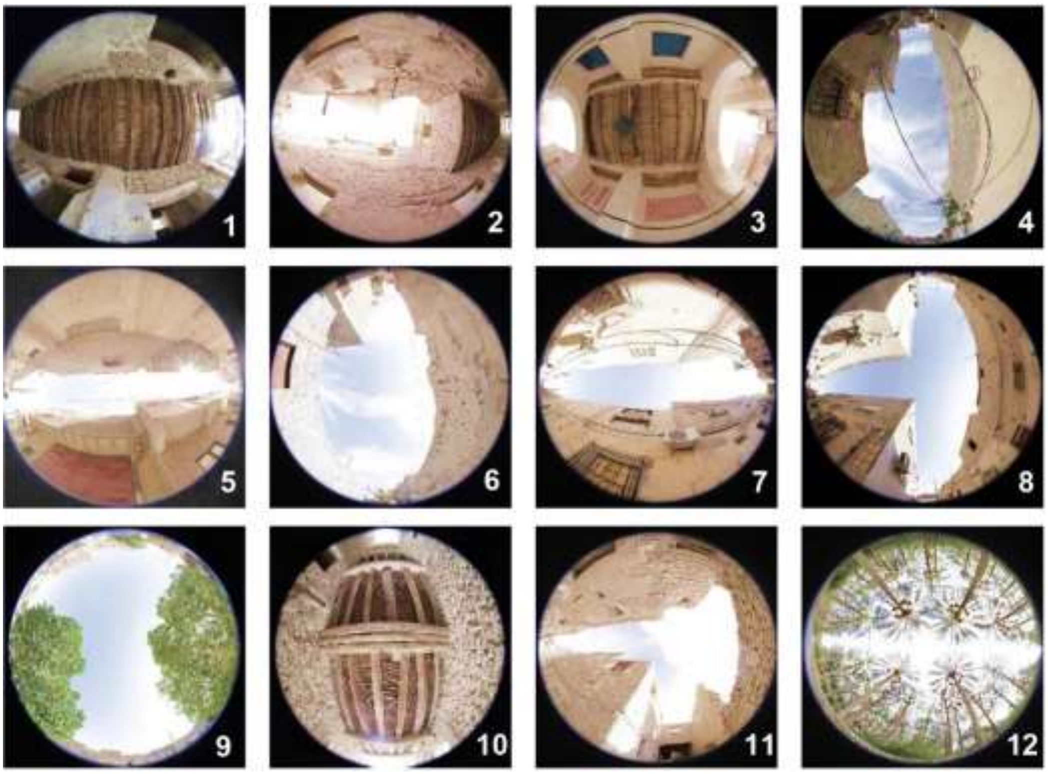


Figure 4.3: *Fish-eye images of 12 studied points: (1, 2, 3) Old Lichana; (4, 5, 6) Old Tolga; (7, 8, 9) New Tolga Downtown; (10, 11) Old Farfar; (12) Palm Grove.*

Source: *Matallah et al., 2020*

Table 4.1: *Morphological characteristics of sites and measurement points in Tolga Oases Network, July and August 2018*

Source: *Matallah et al., 2020*

Sites	Area (ha)	Location	SVF	Street direction	Width of streets (m)	Height of streets (m)
		1	0.02	E-W	2.20	3.20
Old Lichana	4.20	2	0.07	E-W	3.70	3.50
		3	0.27	N-S	3.50	5.75
		4	0.32	N-S	3.40	3.70
Old Tolga	14	5	0.18	E-W	3.15	7.10
		6	0.56	N-S	4.20	3.00
New Tolga		7	0.39	E-W	3.20	6.40
Downtown	22	8	0.42	N-S	4.10	6.40
		9	0.67	-	-	-
Old Farfar	2.50	10	0.05	N-S	2.30	3.10
		11	0.34	E-W	2.75	6.20
Palm Grove	-	12	0.37	-	-	-

4.4 Monitoring of outdoor microclimate

The parameters measured during the study are: air temperature (T_a), relative humidity (R_H), air velocity (V_a), and surface temperature (T_s). The measurements were taken using the Testo 480 measurement station, which is a reliable and validated instrument for data acquisition (Table 4.2). The sensors were kept at 1.40 m height from the ground to avoid the effect of surface contact. The fish-eye images are picked by using Canon EOS 6D camera at each measurement point. The fish-eye images took the degree of the opening to sky inside the street, in consideration. The camera was oriented to the sky.

Table 4.2: *Instruments used for the data measurement*

Source: *Matallah et al., 2020*

Meteorological data parameters					
Variable	**Device**	**Probe reference**	**Unit**	**Accuracy**	**Method of storage**
Air temperature (T_a)	Testo 480 0563 4800	12 Φ 0636 9743	°C	± 0.5 °C	Automatic
Relative humidity (R_H)		12 Φ 0636 9743	%	± 1.0 %	Automatic
Wind velocity (V_a)		Helix 100 Φ mm 0635 9343	m/s	± 0.1 m/s	Automatic
Surface temperature (T_s)		12 Φ (200 mm) 0635 1543	°C	± 0.5 °C	Automatic
Fish-eye images parameters					
Camera	**Focal length**	**Resolution**	**Dimensions**		**Colors representation**
Canon EOS 6D	8 mm	72 ppp	5472 x 3648		sRGB

The meteorological measurements which are: air temperature, relative humidity, wind velocity also to the surface temperature, this one is necessary to calculate Tmrt. The measurements are performed between July, 20th to 29th (except 27th) and August, 10th to 17th, 2018, which represent the hottest period of the year (Table 4.3). This period was selected to estimate the impact of the oasis effect on the outdoor thermal comfort during extreme hot days of the year, which is the main aim of this study. The measurements were taken at 05:00 a.m., 09:00 a.m., 01:00 p.m., 05:00 p.m., and 09:00 p.m. following the study of (Sebti et al., 2013) in Ouargla city in the South of Algeria. In the study measurements, we should mention that the air temperature extremes, are taken at 1:00 p.m., with $T_{air\ max\text{-}July}$ = 45.9°C and $T_{air\ max\text{-}August}$ = 40.4 °C. Thus, daily means are $\Delta T_{air\text{-}July}$ = 37 °C and $\Delta T_{air\text{-}August}$ = 33.3 °C. Moreover, the relative humidity values were swept between $H_{R\ max}$ = 64.8% in August in the point (12) inside the Palm Grove, and $H_{R\ min}$ = 13.1% in July in the point (10).

Table 4.3: *Summary of meteorological parameters taken throughout the twelve points*

Source: *Matallah et al., 2020*

meteorological data	Unit	Month	Old Lichana			Old Tolga			New Tolga Downtown			Old Farfar		Palm Grove
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
T_a 05:00 AM	°C	July	30.7	31.8	31.8	30	30.2	29.8	30.9	30.8	30	35.3	35.3	29.2
T_a 09:00 AM			34.8	36	39.6	34	33.8	36	32.5	34.4	33.6	37.5	37.5	37
T_a 01:00 PM			40.1	42.4	45.9	41.9	39.2	40.6	38.7	37.6	39.5	41.4	41.5	43.9
T_a 05:00 PM			42.3	43	43.9	42.4	40.2	40.8	38.2	38.8	39	42.2	42.8	39.8
T_a 09:00 PM			36.6	38.2	38.1	33.7	34.5	34.6	35.5	35.3	34.9	38.9	39.1	34.4
T_a 05:00 AM	°C	August	28.1	28.4	27.6	27.8	26.9	27.8	30.3	28.4	28.6	28.1	27.7	27.2
T_a 09:00 AM			31.7	32.2	33.1	31.5	30.3	31.7	33.7	32.2	32.8	30.8	30.6	33.1
T_a 01:00 PM			35	35.8	36.2	34.1	32.6	35.2	38.2	40	38.7	34.4	34.3	33.8
T_a 05:00 PM			33.6	34.1	34.6	33.1	33	34.5	39.5	39.3	39.3	31.7	31.1	33.4
T_a 09:00 PM			30	30.8	30.3	29.2	29.1	30.1	34.6	35	34.1	29.7	29.4	28.8
R_H 05:00 AM	%	July	35.4	33.2	29.8	32.8	30.7	29.6	26.9	27.4	28.4	20.5	21.7	45.8
R_H 09:00 AM			32.3	30	22	26.9	26.6	24.9	33.1	31.2	31.6	19.5	20	33.9
R_H 01:00 PM			20.9	18.2	15.2	17.6	19.6	19	23.4	23.2	23.2	16.3	16.2	21.4
R_H 05:00 PM			19.9	17	14.4	17.8	18.6	21.4	20.6	20.9	20.3	14.5	14	35.8
R_H 09:00 PM			22.8	20.1	19.1	28.7	26.5	23.9	24	24.7	24.7	17	16.8	35.9
R_H 05:00 AM	%	August	55.3	53.9	57	48.5	50.2	50.7	42	47.1	46.4	57.3	59.4	60.8
R_H 09:00 AM			47.8	47.1	45.4	51.8	53.3	50.8	36.5	38.2	38.1	54.4	53.1	47.3
R_H 01:00 PM			39	36.4	36.8	42.7	46.8	41.3	24.8	23	24.2	38.7	36.4	45.4
R_H 05:00 PM			40.8	41.2	40.3	41.3	43.8	41.1	18.3	17.9	18.4	33.1	36.7	48.4
R_H 09:00 PM			52.1	49.2	49.8	48.9	47.7	44.4	28.9	29.1	30.1	40.9	43.1	60.1
Va 05:00 AM	m/s	July	0.75	0.65	0.0	0.20	1.1	0.0	1.15	1.35	0.4	0.7	0.2	0.0
Va 09:00 AM			0.95	0.85	0.5	0.95	1.7	0.4	0.85	0.8	0.45	2.25	0.25	0.55
Va 01:00 PM			0.45	0.3	1.5	0.85	0.65	0.4	1.15	1.3	0.4	0.5	0.0	0.15
Va 05:00 PM			0.25	0.00	0.0	0.0	0.15	0.0	0.8	1.1	0.5	0.0	0.0	0.0
Va 09:00 PM			0.25	0.4	0.0	0.75	0.55	0.5	0.0	0.8	0.2	1.0	0.7	0.0
Va 05:00 AM	m/s	August	0.65	0.95	0.6	0.3	0.5	0.3	0.65	0.45	0.25	0.0	0.0	0.35
Va 09:00 AM			1.2	0.2	0.45	0.6	0.6	0.5	0.95	1.65	0.5	0.2	0.25	0.7
Va 01:00 PM			0.65	0.2	0.2	0.7	1.3	0.5	1.3	1.55	0.4	1.05	0.35	0.25
Va 05:00 PM			0.4	0.3	0.2	0.75	0.25	0.0	1.3	1.95	0.25	0.9	0.55	0.6
Va 09:00 PM			0.75	0.4	0.6	0.25	0.45	0.0	0.55	0.8	0.25	0.2	0.25	0.0
Ts 05:00 AM	°C	July	32.8	33.2	33	31.3	32.3	30.6	32.4	31.3	32	35.9	35.5	32.5
Ts 09:00 AM			34.7	36	38	33.1	33.3	35.3	32	34.4	31.9	36.4	36.8	34.5
Ts 01:00 PM			39.1	40.9	45.9	42.7	37.4	43.4	38.1	40.7	37.5	38.6	39.8	38.8
Ts 05:00 PM			40.4	42.7	43.9	42.1	39.2	40.7	40.6	39.5	40	39.4	40.9	40
Ts 09:00 PM			38	38.9	38.1	35.8	35.4	35.9	35.9	35.3	35.5	38.6	38.6	37.9
Ts 05:00 AM	°C	August	29	29.8	28	28.3	28.4	29.3	30.4	29.3	31.3	28.6	28.1	30
Ts 09:00 AM			31.2	31.8	33.7	32.4	31.1	33	31.7	31.7	32	29.7	30	31
Ts 01:00 PM			33.9	35	37	34.4	30.5	37.4	36.3	39.7	36	32	32.7	33.4
Ts 05:00 PM			32.9	33.9	35	35.6	32.4	38	43.7	39	39	31.1	30.8	30.2
Ts 09:00 PM			30.5	31.6	31.1	30.4	29.2	31	35	34.8	34.2	30.3	30.3	29.5

4.5 Outdoor thermal comfort levels and heat stress

For the assessment of the outdoor thermal comfort, we used RayMan Pro 3.1 Beta software which is a micro-scale model developed for environmental meteorology. The program is used to calculate the mean radiant temperature (Tmrt) and Physiologically Equivalent Temperature (PET) thermal comfort index at the twelve studied points. GIMP 2.10 (GNU Image Manipulation Program) developed for the image's manipulation, is used for processing of the fish-eye images, which are modelled on a square shape. For the SVF calculation it's necessary to process the fish-eye image with the GIMP on square shape with high resolution (300 dpi) and transfer it into the RayMan software. All the studied meteorological and fish-eye images are inserted in RayMan model (Input data) to calculate Tmrt, PET, and SVF indices. PET and SVF values are performed in RayMan output data tables. Simultaneously, to the meteorological measurements and fish-eye images, other geographical data is used in this study as: longitude (°E) 4°56′, the latitude (°N) 34°38′, the altitude (m) 147, and the time zone (UTC + h) 1.0. The RayMan output data are visualized in tables (data tables).

The assessment of PET shows that during the studied period there are five different thermal comfort zones: Neutral, slightly warm, warm, hot, and very hot. PET ranges were based on the study of (Cohen et al., 2019) in arid climate (BWh). Results show an increase in the PET values during the daytime and after sunrise until sunset, in all measurement points. The assessment of PET, shows a peak zone over 42 °C at the daylight hours (from 9:00 a.m. to 5:00 p.m.) causing an extreme heat stress. Minimum values of PET (<26 °C), representing the neutral zone, were obtained in the Palm Grove at 5:00 a.m. in August (point 12). Results demonstrate a close similarity of heat stress levels in almost all measurement points during July and August at daylight hours. The Table 4.4 demonstrates the cited outcomes.

Table 4.4: *Assessment of the outdoor thermal comfort level stress via PET index in the five study cases between July and August*

Source: *Matallah et al., 2020*

District	Measurement Point	PET 5:00 a.m.		PET 9:00 a.m.		PET 1:00 p.m.		PET 5:00 p.m.		PET 9:00 p.m.	
		July	August	July	August	July	August	July	August	July	August
Old Lichana	1	30	27.3	39.9	38.5	49.7	43.8	47.3	37.8	36.7	29.3
	2	31.5	27.4	44.8	41.5	52.1	45.6	48.3	38.7	38.2	31.3
	3	31.3	26.4	45.3	39.1	55.1	45.7	53	41.9	37.4	29.2
Old Tolga	4	28.8	26.7	38.6	36.7	50.6	42.7	47.5	37.5	32.8	28.3
	5	28.8	26.1	40.2	35.3	47.6	39.4	48.3	40.5	33.8	28
	6	27.6	26.2	41.5	37.3	48.9	45	49.3	43.8	32.7	28.4
New Tolga Downtown	7	28.9	28.4	40.3	40.1	46.4	45.9	46.5	47.3	33.9	33.2
	8	28.3	26.6	39.5	35.7	45.9	49.1	46.2	45.6	33.8	33.5
	9	28.1	26.7	38.8	41.1	47.6	50.6	44.3	44.1	33	32
Old Farfar	10	35.1	28.4	42.1	36.5	50.4	42	46.9	36.2	38.5	29.8
	11	33.9	26.9	46.6	39.8	50.2	43.2	50.7	37.9	38.2	28

Palm Grove	12	28.8	25.7	45.4	43.5	51.6	44.3	48.8	39.5	34	27.8

Thermal comfort stress level	17 - 26	26 - 28	28 - 37	37 - 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

The assessment of PET in July and August, shows that the July averages are higher than August during the daytime in all the measurement points with $PET_{ave.July}$ = 41 °C, $PET_{ave.August}$ = 36.2 °C. This decrease in August is mainly due to the wind velocity, which influence the level of the heat stress. PET values were similar in the three measurement points (7, 8, 9) of the downtown 11 December neighborhood between July and August during the entire daytime where $PET_{ave.July}$ = 38.8 °C, $PET_{ave.August}$ = 38.7 °C. PET values are lower in August than July in most of other measurement points (1, 2, 3, 4, 5, 6, 10, 11, 12) $PET_{ave.July}$ = 41.8 °C, $PET_{ave.August}$ = 35.4 °C.

PET averages obtained at the points (1, 2, 3, 4, 5, 6, 10, 11, 12) are higher than (7, 8, 9) points in July and lower in August. The highest value of PET, in July, was observed at the (3) point of the Old Lichana, with a PET_{max} = 55.1 °C at 1:00 p.m. The point (9) in the downtown 11 December neighbourhood, showed the highest value in August with PET_{max} = 50.6 °C at 1:00 p.m. The lowest value PET_{min} = 27.6 °C was obtained at the point (6) in Old Tolga at 5:00 a.m. in July. The PET_{min} = 25.7 °C in August was calculated at 5:00 a.m. at the point (12) inside the Palm grove.

The Tmrt values are very sensitive to the solar time, their values were too close to the air temperature (T_a) at 5:00 a.m., and 9:00 p.m. Otherwise, Tmrt values increase in the daytime (9:00 a.m., 1:00 p.m., 5:00 p.m.). The highest value of Tmrt in July was observed at the point (3), with a $Tmrt_{max}$ = 61.0 °C at 1:00 p.m. The point (9), shows the highest value in August with $Tmrt_{max}$ = 60.3 °C at 1:00 p.m.

The lowest value of $Tmrt_{min}$ = 25.5 °C was obtained at the point (6) at 5:00 a.m. in July. As well as the $Tmrt_{min}$ = 24.4 °C in August was taken at 5:00 a.m. at the point (6) and (12) point inside the Palm Grove. The (1, 2 and 10) points in old Lichana and old Farfar respectively representing the lowest SVF (< 0.1) shows a high Tmrt levels in July all the day, compared to the other points. Tmrt averages at points (1, 2, 3, 4, 5, 6, 10, 11, 12) were higher than the (7, 8, 9) in July with 45.2 °C, 42.6 °C respectively. Whereas, they were lower in August with 39.6 °C and 42.7 °C.

The assessment of PET and Tmrt depending on the SVF, is illustrated in the Figure 4.4 and Figure 4.5, there represent two distinguished thermal periods of the day. The first period was observed during sunrise and sunset time (5:00 a.m. and 9:00 p.m.), and the second period was in daylight hours (9:00 a.m., 1:00 p.m., 5:00 p.m.). PET and Tmrt values were too close in the first period (5:00 a.m. and 9:00 p.m.) in July and August, the curves were approximately superposed.

Overall the meseared points Tmrt was very sensitive under the degree of insolation (solar radiation hours), which is related to the less shading surfaces inside the investigated sites. Consequentely, the high rate of Tmrt values is influencing directly the heat stress levels specifically during the daytime hours. In other hand, results show a common similarity on heat stress level (PET index) in daytime between July and August. Otherwise, the heat stress levels of the studied sites surrounded by the palm groves were decreased slightly in August.

Otherwise, the temperature deacrese is supported by the responsive increase on the relative humidity is almost the ‘oasis effect’ phenomenon was more registred in August than July which has not a significant impact on the thermal comfort level in the midday time.

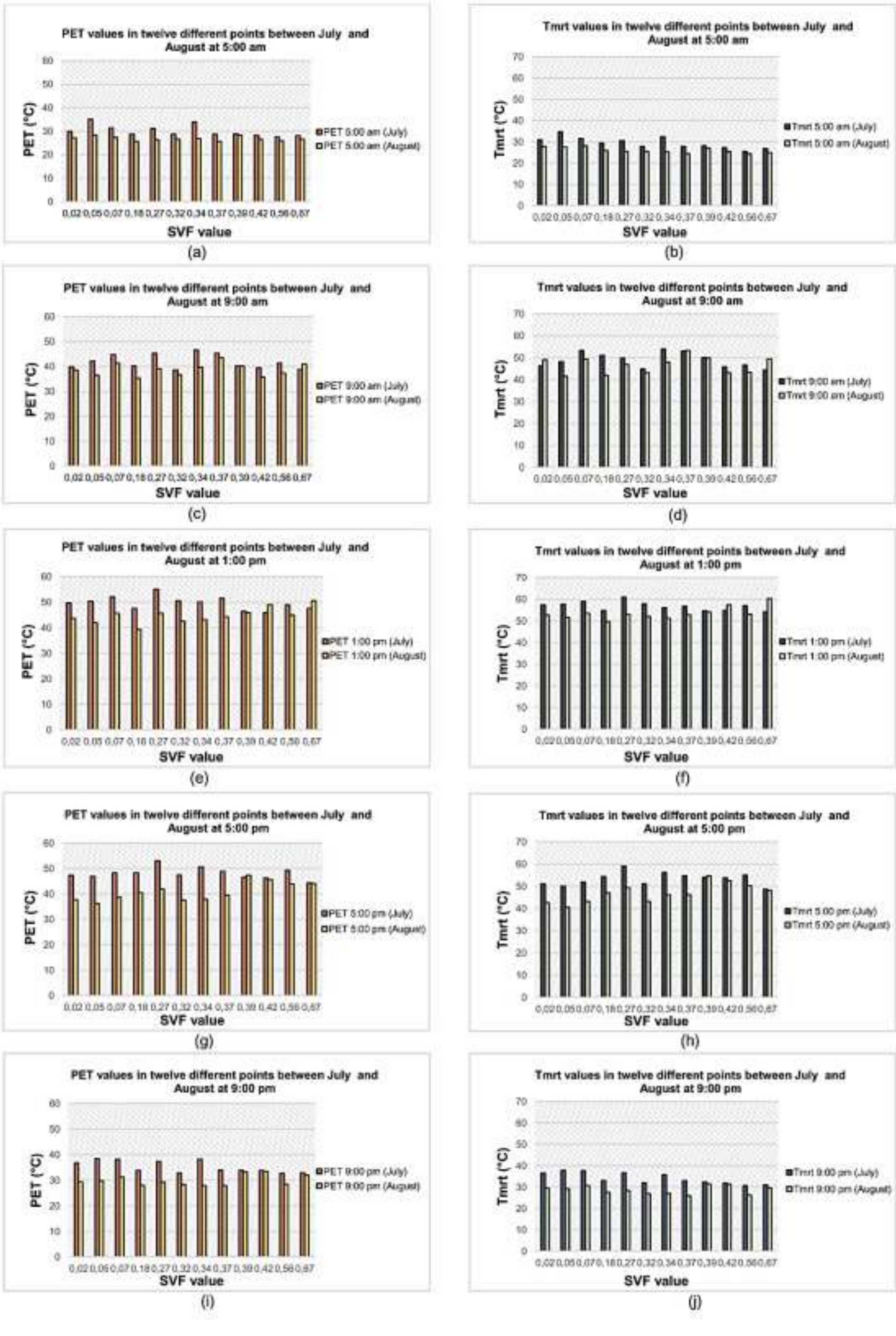


Figure 4.4: *Assessment of PET and Tmrt levels in 12 studied points during July and August 2018 at 5:00 a.m., 9:00 a.m., 1:00 p.m., 5:00 p.m., and 9:00 p.m.: (a,c,e,g,i) are PET values; (b,d,f,h,j) are Tmrt values*

Source: *Matallah et al., 2020*

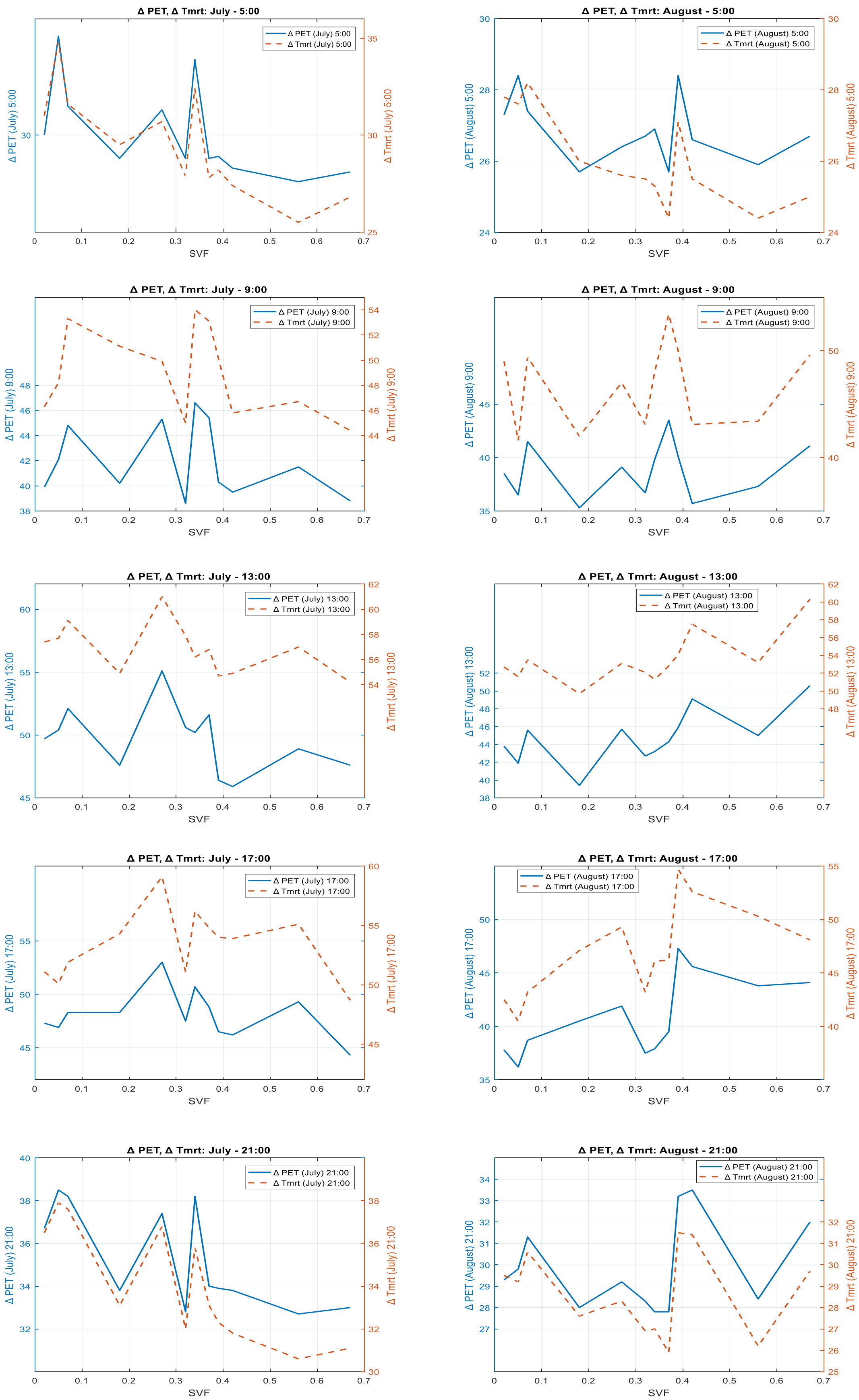


***Figure 4.5:** Variations between PET and Tmrt values depending on the SVF during July and August 2018*

***Source:** Author, 2020*

A significant difference, between PET and Tmrt values in the second period (9:00 a.m., 1:00 p.m., 5:00 p.m.) was found in July and August, relative likely to the elevation of air temperature in this period of the day. Otherwise, the curves were parallel, which means the difference is stable all the day. The average of dif. value between PET and Tmrt in July and August was negligible in the first period with $\Delta_{\text{dif. value July}}$ = 0.9 °C and $\Delta_{\text{dif. value August}}$ = − 0.75 °C. The average of dif. value between PET and Tmrt was higher in the second zone with $\Delta_{\text{dif. value July}}$ = 6.71 °C and $\Delta_{\text{dif. value July}}$ = 7.56 °C. No significant impact is observed of the SVF values on the PET and Tmrt variations all the day in July and August. These details are showed in the Table 4.5 below.

Table 4.5: *Variations between PET and Tmrt values depending on the SVF during July and August 2018*

Source: *Matallah et al., 2020*

PET. Tmrt Difference's Average	dif 5:00 a.m.		dif 9:00 a.m.		dif 1:00 p.m.		dif 5:00 p.m.		dif 9:00 p.m.	
	July	August	July	August	July	August	July	August	July	August
∆ dif max (°C)	1.00	0.80	10.9	10.5	9.00	10.3	7.70	8.20	−0.20	0.20
∆ dif min (°C)	−2.10	−1.70	4.60	5.10	5.20	7.40	3.20	4.00	−2.40	2.30
Average (°C)	−0.63	−0.81	7.08	7.88	7.14	8.73	5.27	6.08	−1.20	−1.23

4.6 Thermal comfort analysis and influences

The study shows a common similarity of the heat stress levels (PET index) in the oases settlements fabrics and Palm Grove in August $\Delta\ PET_{\text{urban fabric.August}}$ = 36.3 °C, $\Delta\ PET_{\text{palm grove.August}}$ = 36.2 °C. The heat stress level (PET index), evaluated in July, is slightly higher in the Palm Grove than in the oases settlements fabrics, $\Delta\ PET_{\text{palm grove.July}}$ = 41.7 °C, $\Delta\ PET_{\text{urban fabric.July}}$ = 40.9 °C. The difference is mainly caused by the shading factor, which is higher in the oases settlements fabrics, and slightly due to the variation of wind velocity between sites, which the $\Delta\ V_{\text{air urban fabric.July}}$ = 0.6 m/s, $\Delta\ V_{\text{air Palm Grove .July}}$ = 0.1 m/s. In the same time-peroid, the Palm Grove is more influenced by the increase of diurnal solar direct radiation $\Delta\ Tmrt_{\text{urban fabric.July}}$ = 44.5 °C, $\Delta\ Tmrt_{\text{palm grove.July}}$ = 45.1 °C, which causes a warming-effect.

Surprisingly, the influence of the urban fabric on the PET was insignificant. Despite the significant difference between the old and new oases settlement fabrics, our measurements and calculation did not identify any noticeable variation of urban thermal comfort. We processed the housing materials (albedo parameters of surroundings) in all the study period additionally to the SVF, which is the streets level's opening to the sky. The SVF values indicate that the street is wide or narrow, and how much the street is shaded or exposed to sun radiation (its ranges are from 0 to 1, where

0 means that the sky is totally covered by terrain or obstacles, while 1 stands for a free sky). RayMan took all these parameters to calculate Tmrt, and PET index, which makes it very sensitive to surrounding conditions (meteorological and thermophysical). RayMan represents current relevant software for the urban climate assessment. No significant impact of the SVF on the thermal heat stress was found. More surprisingly, the ‘oasis effect’ on the outdoor thermal comfort was insignificant (during the study period).

We refer to the insignificant correlation between the PET and SVF in the study period to illuminate three factors: (a) most of the measurement points are similar to neighborhoods in the Tolga Oases Network content, with air conditioners practically in each house, which participate as heat sources inside the streets; (b) the building materials used by the inhabitants were not used rationally; (c) certainly there are a climatic thresholds like air temperature, relative humidity, and wind velocity thresholds which influence the oasis effect, and have an impact on the thermal stress. The SVF will be connected to thermal balance (PET) in limited climatic thresholds.

This study identified the impact of the oasis on the outdoor thermal comfort during summer in Tolga Oases Network. Based on our findings, we advise urban planners and landscape architects to not overestimate the passive cooling effect of the oasis palm grove. Therefore, urban designers and city planners should assure shading in public spaces and prepare the outdoor spaces to host people during extreme heat stress conditions in oases urban settlements. Natural ventilation or increasing the air flow and providing outdoor shading are an essential design element in oasis urban fabric. The reflectivity of ground and facade surfaces should be considered too. Glare is another important aspect that needs to be avoided increasing the satisfaction of people with the perceived temperature.

Future research should focus on investigating outdoor thermal comfort on an annual basis. The cooling effect might be mostly effective outside the extreme hot summer months. Additionally, the urban outdoor thermal perception should be investigated through field surveys to assess the local comfort. The authors are aware that behavioral and psychological adaptations have proven to have a big impact on thermal perception. This approach can add several recommendations for developing an adaptive urban oasis model in oasis zone of Algeria.

4.7 Conclusion of the chapter

An empirical investigation of thermal comfort in four urban fabrics and an oasis palm grove was performed and compared between July and August 2018. The monitored data: T_a, R_H, V_a, T_s and fish-eye images were taken in several times in the day. The modeling and calculation was based on three principal parameters namely, SVF, Tmrt, and PET index with the help of RayMan model. The study shows a common similarity of heat stress levels (PET index), during daytime in August, between the oasis urban fabric and palm grove Δ PET $_{\text{urban fabric.August}}$ = 36.3 °C, Δ PET $_{\text{palm grove.August}}$ = 36.2 °C. The heat stress level (PET index) evaluated in July is slightly higher in the palm grove than in the urban fabric Δ PET $_{\text{urban fabric. July}}$ = 40.9 °C, Δ PET $_{\text{palm grove.July}}$ = 41.7 °C. The difference is related to higher shaded area in the urban fabric compared to the palm grove. No significant impact of SVF on the thermal heat stress was found. Additionally, the ‘oasis effect’ on the outdoor thermal comfort was insignificant (during the study period). Furthermore, PET values are more sensitive at midday due to high insolation. Finally, all findings and results of this study apply to the summer season, especially in the warmest months of the year (July and August). Future studies should further investigate the heat stress level in other seasons and months of the year in urban oasis settlements.

5. CHAPTER FIVE : LONG-TERM OUTDOOR THERMAL COMFORT CHANGE [2, 3]

Regarding the outdoor thermal comfort evaluation throughout the oases settlements, we need to remind that we deeply investigated the thermal environment quality during summer in 12 stations among Tolga Oases Complex in limited duration, which followed an empirical approache at first to achieve a quantitative assessment of the heat stress levels. The current chapter identifies a continuity of the outdoor thermal comfort assessment critically discussed in the previous chapter, which was throughout different oases' urban forms. Furthermore, this chapter shows an assessment in long-term (30 years) of the heat stress variations on the basis of the Typical Meteorolgical Year (TMY). Thus, TMY file includes weather datasets measured in different meteorological stations in the world. In order, the study is based on three different TMY files which are: TMY2, TMY3, and TMYx refered to 1986, 2001, and 2016 respectively and present the study periods. We should to indicate that we chosed three different urban fabrics, whereas two of them are performed in the chapter 4 such as: old neighborhood, and the invidual housing neighborhood, in order we added the multifamily neighborhood to cover a multi-urban forms within the oases settlements. The methodology of this stage is based on empirical and numerical approaches following most relevant and recent studies for this research's topic. So far, the study coupled between two numerical models: ENVI-met CFD software and RayMan calculation model, most used software for the urban climate simulations' studies. Although, for the study context definition it is necessary to have common details through the previous chapter specifically for this section.

Otherwise, the study results direct architects, urban planners and climatologists to include urban climate variations during long-term within the urban planning stages in the Saharan Oases.

[2] This chapter is based on this article: Matallah, M. E., Alkama, D., Teller, J., Ahriz, A., & Attia, S. (2021). Quantification of the Outdoor Thermal Comfort Within Different Oases Urban Fabrics. *Sustainability* 2021, *13*(6), 3051.

[3] This chapter is based on this technical report: Matallah, M. E., Ahriz, A., & Attia, S. (2020). Quantification of the Outdoor Thermal Comfort Process: Simulation & Calculation data (No. 01/2020). Sustainable Building Design Lab.

5.1 Introduction

Nowadays, urbanization in the Sahara context compares many challenges in terms of surrounding environment and climate conditions. Oases settlements are the most frequently shape in these areas, which represents a combination between human settlement and cultivated area in the desert environment (V. Batesi, 2005). Since centuries, the urban design strategies were adapted to the local conditions that were found in the vernacular and traditional architecture (S. Attia, 2020). The link between the cultivated area in particular the palm grove area and the built area was often respected through Sahara's region of North Africa, and represents the key model to the environmental adaptation (M. Cote, 2005). Thermal adaptation is the main urban design principle to allow a favorite microclimate for occupants, especially during hot season. Thermal adaptation involves shading strategies, ventilation systems, and implementation of local building materials which help people to adapt their occupancy patterns and comfort expectations depending on the season (S. Attia, 2020). Today, the new generation of urban typologies have taken different forms mostly and only built for the inhabitants' needs without respecting context characteristics. At the same time, these regions knew an enormous challenge versus two important factors: urbanization and climate change. During the last thirty years, climate became more changeable, when temperature thresholds are higher and making oases settlements suffering of discomfort during hot seasons and more stressful (Ahriz et al, 2020). Consequently, the outdoor thermal comfort through oases settlements registered an elevation on heat stress through the urban area and limits population's life, particularly during the hot season. In the current study, we investigated the outdoor thermal comfort throughout three different neighborhoods in Tolga Oases Complex, which is one of the biggest oases settlement in North Africa surrounded by over 1.000.000 palm trees, that during thirty years (Matallah et al, 2020). The research questions corresponding to the research objectives are:

- What are the variation levels of outdoor thermal comfort in oases settlements in summer for long-term?
- How severe is the impact of climate change on the outdoor thermal comfort during summer?
- Which urban fabric could be more influenced by long-term change and provides a high heat stress level in the case of Tolga oases settlements?

Therefore, this study aims to promote a comparative approach through an assessment of the outdoor thermal comfort for thirty years. Additionally, the paper provides a combination of an empirical and numerical approaches to allow a new method in that type of studies. The objectives of the current study are quantification of outdoor thermal comfort inside the oases settlements following an empirical approach; assessment of heat stress variation during long-term throughout several oases urban forms.

5.2 Literature review

The importance of outdoor thermal comfort studies is growing and become mandatory for the improvement on the urban design strategies. The purpose of this study is to understand the variation levels of thermal comfort through different urban forms of oases settlements in long-term, and to ensure thermal comfort, especially during the hot season (Figure 5.1). Our literature review included over 120 publications, found on Scopus and the Web of Science, relevant to the field of outdoor thermal comfort. However, we selected the most relevant publications and classified them into groups using two main categories, which are described in the following paragraphs.

The first group of studies regarding urban warming and outdoor thermal comfort contains worldwide studies that relief urban heat island to its impact on the thermal comfort and provide recommendations to designers. Potchter et al. (2013) investigated the urban warming elevation in the desert city of Beer Sheva (Israel) during forty years, by combining two phenomenon urban warming and global warming effects using both of PET and Discomfort index (DI) indices to conclude on a noticeable impact at daytime summer season. In other logic, few years ago Johansson et al. (2006) investigated the outdoor thermal comfort in summer season with PET index in the city of Fez, Morocco, by selecting several urban forms which are classified into old neighborhood and new neighborhood, results show that the deep canyon is fairly comfortable whereas the shallow is extremely uncomfortable. Bourbia and Awbi. (2004) focused towards finding the interaction between urban canyon geometry and incident solar radiation in the city of El-Oued, Algeria, their study shown that the street canyon orientation (and not only the H/W ratio) has a considerable effect on solar shading and urban microclimate. In other area of investigation, Berardi et al. (2016) in Toronto, Canada, investigated how new constructions will affect the urban microclimate, and to propose strategies to mitigate possible UHI effects, following empirical approaches and the numerical model of ENVI-met. Shanshan et al. (2017) did an experimental study focusing on the impact of urban morphology on the urban heat island (UHI) intensity, as well as microclimate conditions and thermal comfort in a newly-developed urban area in Tianjin city, China. In other hand, the study of Ahmed Mahmoud et al. (2011) demonstrated that variations in PET index values due likely to the difference in sky view factor (SVF) through a park, in a hot and dry climate of Cairo, Egypt. Similarly, Venhari et al. (2019) presented a significant correlation between SVF and variations on PET and Tmrt in arid climate, and the study showed the effect of urban street greenery type and arrangements on thermal comfort and heat stress in summer. Middel et al. (2016) highlighted the importance of active solar access and shading management in hot urban areas to reduce thermal stress. Although Balogun et al. (2019) investigated the outdoor thermal comfort condition of Akure city, Nigeria, where four locations within the city (Airport, Ijapo, Alagbaka and Oja Oba) with varying urban settings were assessed. Also, the emphasis of the work of Karakounos et al. (2017) is to analyze how mitigation techniques in a dense urban environment affect microclimate parameters and outdoor thermal comfort in Greece. For thermal comfort ranges, studies of Cohen et al. (2019) and Elnabawi et al. (2016) showed ranges of 17°C and 26°C (arid climate) and 23 and 32◦C respectively on PET index comfort zone. Otherwise, in the Algerian studies Boukhabla et al. (2012), evaluated the heat flow exchanged between the soil, with two different types (soil in concrete and soil in asphalt), and the urban environment on a street of open shape in Biskra city, Algeria. Masmoudi and Mazouz. (2004), years ago showed that the thermal regulation of the urban microclimate, in hot and dry climate areas is possible by judicious choices of the orientation of the place, space form, size and provision and importance of the vegetable masses.

The second group of studies regarding numerical assessment of outdoor thermal comfort mainly focuses on most common microclimatic models and software used on urban scale to assess thermal comfort levels and provide recommendations for designers. Despite the advancement of worldwide numerical models, two software have been selected: ENVI-met (Bruse et al. 1998, 2004), RayMan (Matzarakis et al. 2007, 2010) which identify most relevant models in urban climate numerical design. Tsoka et al. (2018) ensured that ENVI-met model is one of the most widely employed dynamic simulation tools, this study aimed to perform a meta-analysis of the reported evaluation results, reflecting the capability of the model to accurate calculations of microclimatic variables. Thus, the study conducted by Sharmin et al. (2017) to show the variation in microclimatic conditions of tropical warm-humid context in Dhaka, Bangladesh, inside several urban geometry (traditional and new geometries), aimed to make a specific comparison between measured and simulated data by using ENVI-met software. Most relevant similar topic studies in Algeria were researches of Ali-Toudert and Meyer. (2006) which were an investigation of the microclimatic changes within urban environments in a high spatial and temporal resolution, in a hot and dry climate of Ghardaia, Algeria, based on three-dimensional model by ENVI-met, when the outdoor thermal comfort was assessed with PET index. Other case study, Sadoudi et al. (2018) investigated the impact of spatial configuration of a green area on the level of the cooling effect, using 25 idealized scenarios numerically designed and simulated on ENVI-met software, when the human thermal comfort of each scenario is calculated by means of physiologically equivalent temperature (PET) using RayMan model. Similarly, Qunshan et al. (2018) simulated a real neighborhood with current tree arrangement with ENVI-met, and validated the reliability of ENVI-met models by comparing the simulated results with systematic temperature collection transects. In other hand, the study of Bergovic et al. (2012) investigated also an enclosed courtyard which has been studied numerically by the three-dimensional prognostic microclimate model ENVI-met. Furthermore, studies conducted by Ambrosini et al. (2014) and Acero et al. (2018) searched on the possibility of formation of an UHI and its magnitude through a small city context, carried out with the ENVI-met software, and an assessment of diurnal evolution of meteorological variables measured in four urban spaces compared with the results provided by ENVI-met, respectively. Otherwise, local studies have not containing comprehensive knowledge in the study topic. Boukhabla and Alkama. (2012) tried to know the real impact of vegetation on air temperature in Biskra city, Algeria, for a typical summer day based on newly developed ENVI-met. Although Boukhelkhal and Bourbia. (2016) aimed to discuss and assess the impact of the geometry and shade trees on the open spaces in Ghardaia (hot and dry climate), Algeria using a numerical model: ENVI-met. However, none of the previous studies assessed the overall outdoor urban comfort in oases urban settlements in long-term period. Also, all similar studies minimized the running simulation time, which is mandatory to validate the numerical model, thus, for the accuracy of results.

5.3 Study context characteristics

The study is conducted in Tolga city (34°43'00" N and 5°23'00" E), in Biskra region (Berkouk et al, 2020), and 363 km the south-east of the capital Algiers; it represents the most significant Tolga Oasis Complex territory in Algeria (Cote et al, 2012). The Oasis Complex is composed of 6 oases cities polarized by Tolga city, which presents the biggest urban area of the Oasis Complex. The study area has a hot arid climate (Köppen-Geiger BWh) with a variation between summer and winter temperatures. Since 1995, Tolga Oasis Complex has registered significantly less rainfall quantity with a yearly average of 126 mm. According to the meteorological station WMO 605265, the heating degree days estimated during the last five years (2016-2020) were 293 HDD. However the cooling degree days were greater with 1113 CDD. Otherwise, the highest temperature registered during the last decade is 46 °C in July, when the lowest is 3.0 °C in January (Matallah et al, 2020). These last weather data indicate the climactic nature of the territory, which is hot and arid. Furthermore, Tolga Oasis Complex's population reached 150,036 in 2017, where 50% of the total population is concentrated in the Tolga city area. Since 1987, Tolga city demography has been growing five times more than the surrounding cities' communes, reflecting the attractiveness of the living facilities provided in the city. Additionally, the Oasis Complex's urban landscape shows a strong integration into the rural world and the urban area's attachment to the Palm Grove (Alkama et al, 2001). Overall, Tolga Oasis Complex is surrounded by 1,006,600 palm trees, 'Phoenix Dactylifera' where 31% of them are situated in Tolga city land's limit.

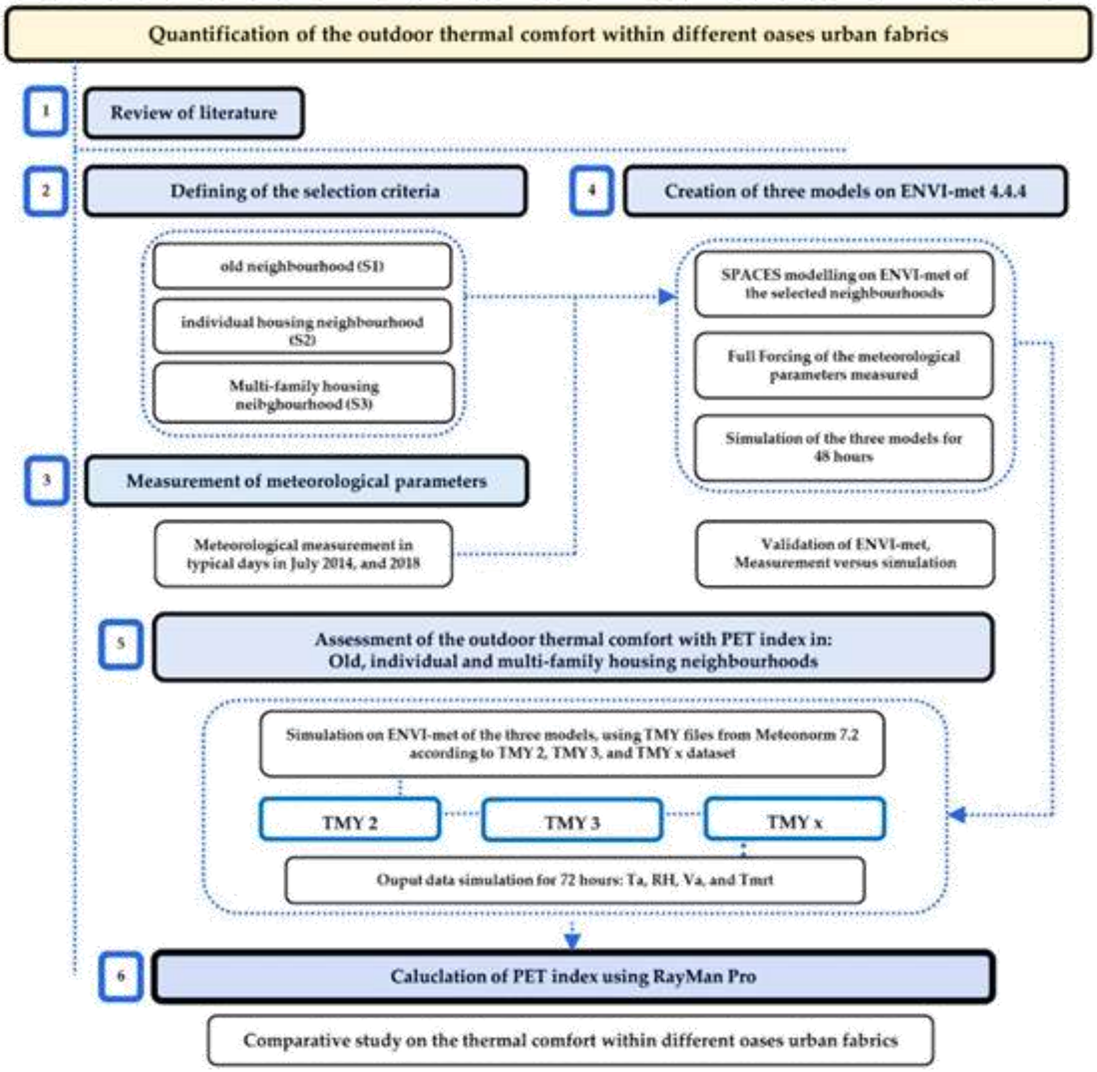


Figure 5.1: *Study conceptual framework - third research process*

Source: *Matallah et al., 2021*

5.3.1 Selection criteria

In this research, three urban fabrics are selected to be assessed in terms of outdoor thermal comfort in the arid climate southern Algeria. The investigated urban fabrics are chosen from Tolga Oasis Settlements, and represent three different typologies of housing: Old neighbourhood (S1), Individual Housing neighbourhood (S2), and Multifamily Housing neighbourhood (S3) (Figure 5.2). As well as, we named the selected neighbourhoods by sites (S) to facilitate the description of the three numerical models into the second methodology step. Regarding The selection criteria, we were specifically based on: (i) age of the urban fabric 'built-up history', (ii) urban fabric typology, and (iii) urban geometry characteristics.

5.3.1.1 Old neighborhood (S1)

As first site, the Old neighborhood (S1) is an ancient settlement built before 1900, represents the first urban fabric in Tolga Oasis Complex. Moreover, (S1) is characterized by a compact built environment, high density: 82 % of built-up occupancy, winding street pattern (< 4m) and variable building height: 3 m < H < 7.10 m. Thus, the (S1) is located inside the Palm Grove area, which is totally surrounding by palm trees 'Phoenix Dactylifera'.

5.3.1.2 Individual Housing neighborhood (S2)

Secondly, the individual housing neighborhood (S2) is situated inside the new Tolga downtown, it has a regular geometry with an arranged and narrow street with variable widths: 3.60 m < W < 3.90 m, mean density: 60%, and a uniform building height: H = 6.40 m (Table 01).

5.3.1.3 Multifamily Housing neighborhood (S3)

The Multifamily housing neighborhood (S3) is also located in the new Tolga downtown, it has a typical geometry with separated blocs, endowed uniform height: H= 12.50 m ranging of four stroyes, with low compacity, and a very low density of built-up occupancy: 18% (Semahi et al., 2020).

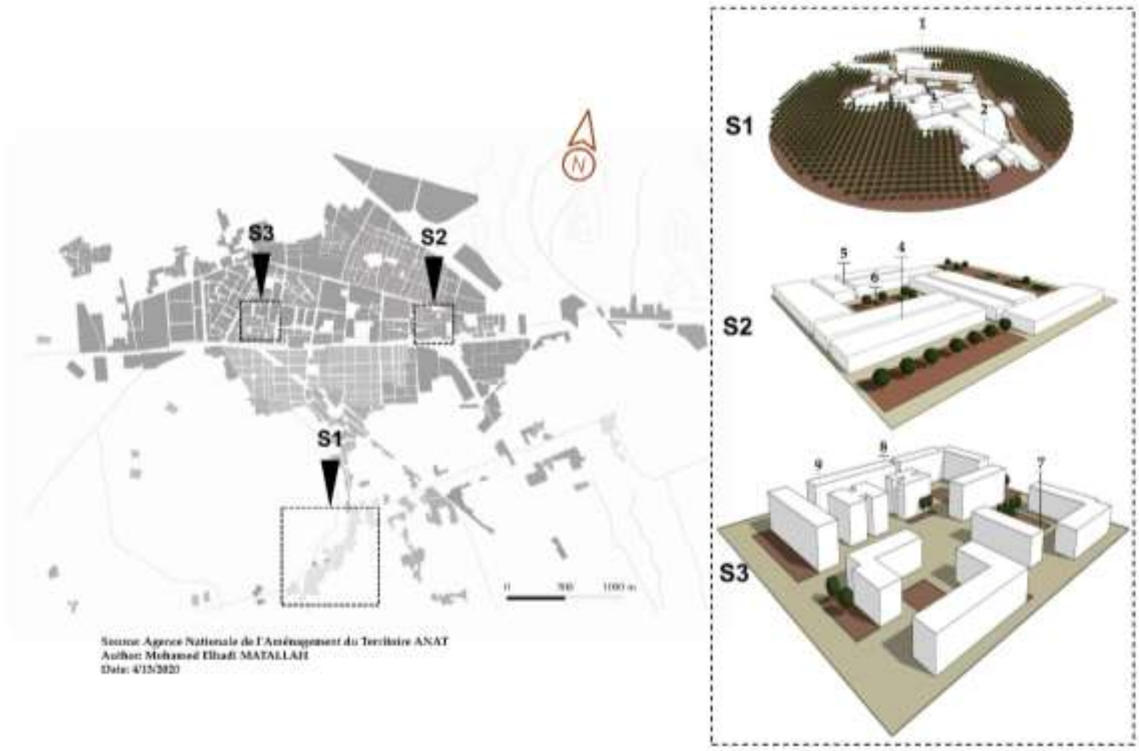


Figure 5.2: *Study sites in Tolga oasis city; S1: old neighborhood. S2: individual housing neighborhood, S3: multifamily housing neighborhood*

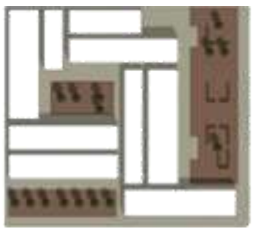
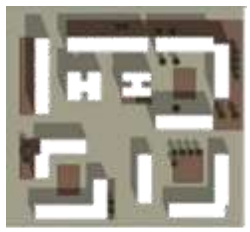
Source: *Matallah et al., 2021*

Overall, it is remarkable throughout the individual and the multifamily housing neighbourhoods that are missing the urban vegetation arrangements, we only can observe small green surfaces 'grass' and few trees spontaneously implanted. Otherwise, the three neighbourhoods contain practically the same number of houses with 150 dwellings. The three selected neighbourhoods compromise several residential individual buildings. Dimensions in (S1) are variable from a house to another, however (S2) and (S3) their house's dimensions are similar with a typical architecture design. All these details are in the Table 5.1.

In the study case, it is necessary to indicate that the distance between neighborhoods and Palm Grove, is important. (S1) is considered the closer to the Palm Grove with a distance (< 100 m), while the (S2) and (S3) are further (> 1000m) (Matallah et al., 2020).

Table 5.1: *Morphological parameters of the selected sites in Tolga Oasis city*

Source: *Matallah et al., 2021*

Morphological parameters	**Old neighbourhood (S1)**			**Individual Housing neighbourhood (S2)**			**Multifamily Housing neighbourhood (S3)**		
Urban grids									
Built-up area (m²)	14 000			22 000			28 000		
Measurement points	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Length (m)	50.35	150.00	58.70	72.20	40.00	56.10	45.70	56.00	75.00
Height (m)	3.70	7.10	3.00	6.40	6.40	-	12.50	12.50	12.50
Width (m)	3.40	3.15	4.00	3.20	3.90	-	-	12.50	14.00
H/W	1.09	2.25	0.75	2.00	1.64	-	-	1	0.89
Street orientation	N-S	E-W	N-S	E-W	N-S	-	-	N-S	E-W
Sky View Factor (SVF)	0.32	0.18	0.56	0.39	0.42	0.67	0.87	0.78	0.64
Fish-eye									
Tree specie	Phoenix dactylifera - Grass			Ficus rubiginosa - Grass			Ficus rubiginosa - Grass		

After the selection of the study sites, to quantify the outdoor thermal comfort we have followed several steps:

1 - Measurement of meteorological parameters in the selected sites,

2 - Creation of the sites numerical models using ENVI-met software (https://www.envi-met.com/),

3 - Validation of the numerical models on the basis of measured parameters through RMSE and MBE error indices (ASHRAE 14-2002).

4 - Running simulation to provide the main microclimatic parameters for the quantification of the outdoor thermal comfort through PET index.

5 - Calculation of PET index using RayMan model based on the simulated data.

5.4 Measurement of meteorological parameters

For the quantification of the outdoor thermal comfort, several microclimatic parameters were monitored simultaneously gathering to fish-eye images within the three neighbourhoods. Overall, nine points were selected for the measurements according to their SVF variations:

- Old neighbourhood (S1): (1, 2, 3),
- Individual Housing neighbourhood (S2): (4, 5, 6),
- Multifamily Housing neighbourhood (S3): (7, 8, 9),

In this case of studies, it was necessary to multiply the number of measured points to see clearly the correlation between SVF and outdoor thermal comfort variations (Venhari et al., 2019).

Furthermore, meteorological measurements were conducted for two days in July 2014 (15th, 16th), and four days in July 2018 (25th, 26th, 28th, and 29th). The field measurements included: air temperature (T_a), relative humidity (R_H), wind velocity (V_a), which were taken during 48 hours (Matallah Study Report, 2020). Otherwise, measurements were taken a 1.4 m height and at least 1 m distant from the nearby buildings in the street, to avoid data distortion due to the radiation from the soil and walls (Ali-Toudert, 2006). Table 5.2 lists the name, the range and accuracy used in the study monitoring.

Table 5.2: *instruments used for the meteorological measurements*

Source: *Matallah et al., 2021*

Meteorological data parameters					
Variable	**Device**	**Probe reference**	**Unit**	**Accuracy**	**Range**
Air temperature (T_a)	Testo 480 0563 4800	12 Φ 0636 9743	°C	± 0.5 °C	- 20 to + 70 °C
	Kimo HD 100	13 Φ lg. 110 mm	°C	± 0.3 °C	- 20 to + 80 °C
	Testo 480 0563 4800	12 Φ 0636 9743	%	± 1.0 %	0 to 100 %

Relative humidity (R_H)	Kimo HD 100	13 Φ lg. 110 mm	%	± 1.8 %	5 to 95 %
Wind velocity (V_a)	Testo 480 0563 4800	Helix 100 Φ mm 0635 9343	m/s	± 0.1 m/s	0.1 to 15 m/s
	Kimo LV 100	Helix 100 Φ mm lg. 310 mm	m/s	± 0.1 m/s ± 0.2 m/s	0.2 to 3 m/s 3.1 to 35 m/s

Fish-eye images parameters

Camera	Focal length	Resolution	Dimensions	Colors representation
Canon EOS 6D	8 mm	72 ppp	5472 x 3648	sRGB

5.5 Numerical assessment: calculation models, and software

5.5.1 Creation of the three models on ENVI-met 4.4.4

ENVI-met software is CFD microclimatic model designed to simulate the interactions between building, pavement and natural surfaces in a virtual environment by reproducing the major atmospheric process (Bruse, 1998, 2004). The generated output contains the main four thermal comfort parameters: air temperature, relative humidity, air velocity and mean radiant temperature (Taleghani et al., 2014); this involves a sequence of mathematical calculations established by the laws of fluid dynamics and thermodynamics which govern the atmospheric motions. It is a non-hydrostatic. RANS model with a typical horizontal resolution from 0.5 to 10 m. a time frame of 24–48 h and a time-step of 1–5 s (Taleghani et al., 2014). Moreover, the high resolution is particularly helpful for identifying pedestrian comfort issues and interactions between individual buildings, surfaces, and plants. As far as mathematical computation is concerned, it is very complicated to carry out a full three-dimensional calculation of microclimatic dynamics of a large urban area (Ratti et al., 2005).

ENVI-met is adopting a holistic approach to compute fine details at an urban scale, it is not surprising that the computation time and computer power are substantial. Despite the fact that ENVI-met has one of the highest spatial resolutions available for microclimatic modelling, a compromise has to be made to reduce the computation time. As a consequence, even with fairly high resolutions like 2 m ×2 m, many detailed morphological aspects are disregarded which has significant consequences on solar exposure and thus affecting the radiation budget (Sharmin et al., 2017). Also, and despite such limitations, ENVI-met is a reputable model that is widely validated and used for urban microclimate assessment, and the only one that has features and capabilities necessary for the study in hand (Sharmin et al., 2017). Otherwise, the calculation of Tmrt by ENVI-met takes into account the direct and diffuse short-wave irradiances as well as the long-wave radiation fluxes originating from the ground, building surfaces and the free atmosphere (Ali-Toudert, 2007).

5.5.2 SPACES modelling on ENVI-met of all the selected sites

By using the SPACES configuration in ENVI-met, the three studied sites were modelled. The 2D drawings were done on the basis of existing plans on bmp formats. All the geographic coordinates, and north orientation's degree were added in the Edit area interface (Table 5.3). Additionally, building materials, type of vegetation and soil were chosen according to the existing materials.

5.5.3 Full forcing of the meteorological parameters measured

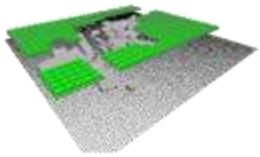
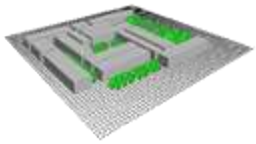
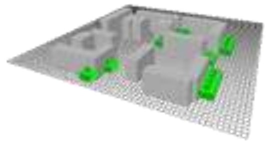
Regarding the microclimatic parameters, our simulations were set on two periods according to the measured data days: (S1), (S2) on 25th/ 26th, and 28th/ 29th July 2018 respectively and (S3) on 15th/ 16th July 2014.

the meteorological data were used on the basis of CSV files according to WMO 605265 dataset, and entered on the full forcing manager settings on ENVI-met. We should indicate that CSV data files contained all meteorological parameters measured in sites, however Tmrt is taken from the simulations results.

Table 5.3: *Input data for the case-study models in the validation step*

Source: *Matallah et al., 2021*

	Old neighbourhood (S1)			Individual housing neighbourhood (S2)			Multi-family housing neighbourhood (S3)		
Street orientation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	N-S	E-W	N-S	E-W	N-S	-	-	N-S	E-W
Model area									
Main Model Area Grid size in meter	240 m x 240 m			120 m x 120 m			120 m x 120 m		
D_x = size of X grid	d_x= 2			d_x= 2			d_x= 2		
D_y = size of Y grid	d_y= 2			d_y= 2			d_y= 2		
D_z = size of Z grid	d_z= 2			d_z= 1			d_z= 1		
Construction material									
Building material	Wall: brick wall (burned). Roof: light weight concrete			Wall: cast dense concrete. Roof: light weight concrete			Wall: brick wall (aerated). Roof: light weight concrete		
Soil	Road: asphalt. Natural surfaces: loamy soil			Road: asphalt. Pavement: concrete pavement grey. pavement concrete used/dirty. Natural surfaces: loamy soil			Road: asphalt. Pavement: concrete pavement grey. Natural surfaces: loamy soil		
Vegetation	Palm Trees: Palm, large trunk, dense, medium (15m); Grass: 50 cm aver. dense			New deciduous Trees: spherical (small trunk. sparse. small (5m)); Grass: 50 cm aver. dense			New deciduous Trees: spherical (small trunk. sparse. small (5m)); Grass: 50 cm aver. dense		

3D model			
Position			
Longitude (°)	34.93	same	same
Latitude (°)	5.13	same	same
Start and duration of the model			
Date of simulation	07/28-29/2018	07/25-26/2018	07/15-16/2014
Start time	00:00	same	same
Total simulation time (h)	48	48	48
Initial meteorological conditions			
Full forcing	CSV data	same	same

5.6 Simulation and validation of the cases study

5.6.1 Validation of ENVI-met, measurement versus simulation

The accuracy of the ENVI-met model simulation was validated through a comparison between the measured and simulated data. This step focused on how closely are the simulated data from the measured data. The validation is an essential step to create a reliable numerical model. For the validation of the neighbourhood's models, we followed ASHRAE 14 guidelines, using two indices: 1) mean bias error (MBE). and 2) root-mean-square error (RMSE) (ASHRAE 14-2002). The MBE is a nondimensional measure of the overall bias error between the measured and simulated data with a known time resolution. The (RMSE) indicates how well the simulation model describes the variability in the measured data (Semahi et al., 2019). Moreover, for the validation's step, simulation was running for 48 hours, because we considered the time of running as sufficient duration for the model's validations (Figure 5.3).

We confirm that 99 % of the outdoor thermal comfort studies in the validation's step they use only one parameter which is air temperature.

The accuracy of the numerical model is always done based on RMSE and MBE indices (ASHRAE 14 - 2002). Moreover, many studies validated their numerical models only for 24 hours running simulation. We did 48 hours running simulation for the models' validation. However, this methodological step is almost missing in many local studies which were investigating urban climate in different context, within the two operations: validation's equations and running simulation time.

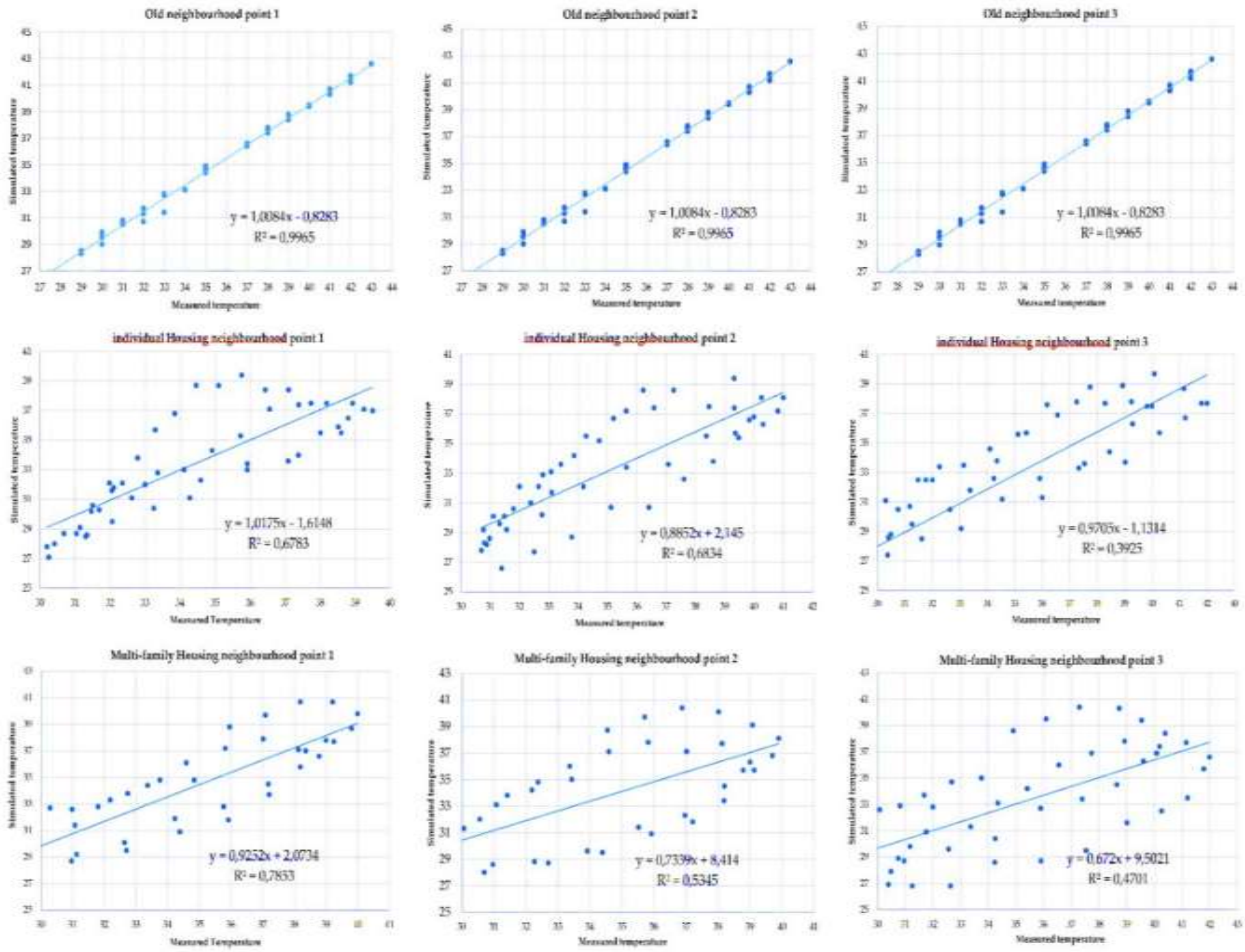


Figure 5.3: *Comparison between simulated and measured outdoor temperature during the monitored period in: (S1), (S2) and (S3)*

Source: *Matallah et al., 2021*

We should indicate that only few studies validated their numerical models. Although, same studies validated only with 20 hours (Sharmin et al., 2017), 28 hours (Taleghani et al., 2014). In our study, we followed the studies of Sadoudi et al, (Sadoudi et al., 2018) and Hien et al (Hien et al., 2012) which the validation was done with 48 hours simulation running. For their models' validation, all these studies used only the air temperature for the comparison between the simulated and measured data.

Table 5-4: *Summary of the validation of the simulated models (S1), (S2) and (S3)*

Source: *Matallah et al., 2021*

Sample	Indices	Point 1		Point 2		Point 3	
S1	RMSE	0.69	1.93 %	0.76	2.12 %	0.60	1.67 %
	MBE	- 0.62	1.74 %	- 0.69	1.93 %	- 0.53	1.48 %
S2	RMSE	2.22	6.44 %	2.77	7.88 %	2.46	6.99 %
	MBE	- 1.01	2.94 %	- 1.89	5.37 %	- 1.50	4.26 %

S3	RMSE	2.92	8.75 %	2.98	8.96 %	3.75	10.70 %
	MBE	- 0.36	1.08 %	- 0.44	1.31 %	- 1.99	5.67 %

Notably, it appears that the accuracy of simulated data is shown after the first four hours, so it is recommended by the ENVI-met team to display the simulation time in order to have accurate results.

5.7 Simulation analysis in long-term

5.7.1 Assessment of the outdoor thermal comfort with PET index

5.7.1.1 Simulation on ENVI-met of three models, using EPW data according to TMY2, TMY3 and TMYx files

On the current step, we simulate the three models on the basis of the Typical Meteorological Year (TMY) files with Epw format: TMY2 (1981-1990), TMY3 (1991-2005) taken from Meteonorm 7.2 database (https://meteonorm.com/en/), and TMYx (2003-2017) (Figure 5.4); while the last meteorological file is taken from (http://climate.onebuilding.org/) which is validated on the study of (Semahi et al, 2019) and it shows a high quality database.

5.7.1.2 Output data simulation for 72 hours: Ta. RH. Va. Tmrt

Secondly, simulation running time covered 72 hours, equivalent of three respectively days of assessment. In this step we carried four principal parameters of outdoor thermal comfort: air temperature, relative humidity, air velocity and the mean radiant temperature; all the values are reported in the (Matallah Study Report, 2020). Thus, the assessment of outdoor thermal comfort in the three models is based on the PET index, which is one of the most indices used to evaluate the thermal comfort on urban scale (Potchter et al, 2018).

5.7.2 Calculation of PET index using RayMan Pro

Thirdly, the calculation of PET index is done with RayMan Pro 3.1 Beta Software, which needs essentially the four microclimatic parameters. RayMan Pro 3.1 Software is a micro-scale model developed for environmental meteorology (Matzarakis et al. 2007; 2010). In our study, it is used to calculate the Physiologically Equivalent Temperature (PET) as a thermal comfort index at the nine studied points. Furthermore, GIMP 2.10 (GNU Image Manipulation Program) is developed for the image's manipulation, and used for processing of the fish-eye images which are modelled on a square shape (Matzarakis et al. 2007; 2010).

All the meteorological parameters and fish-eye images are inputted in RayMan model to calculate PET, and SVF values. Simultaneously to the meteorological measurements and fish-eye images, other geographical data are used in this study as: “longitude (°E) 5°23’, the latitude (°N) 34°43’, the altitude (m) 147, and the time zone (UTC + h) 1.0.

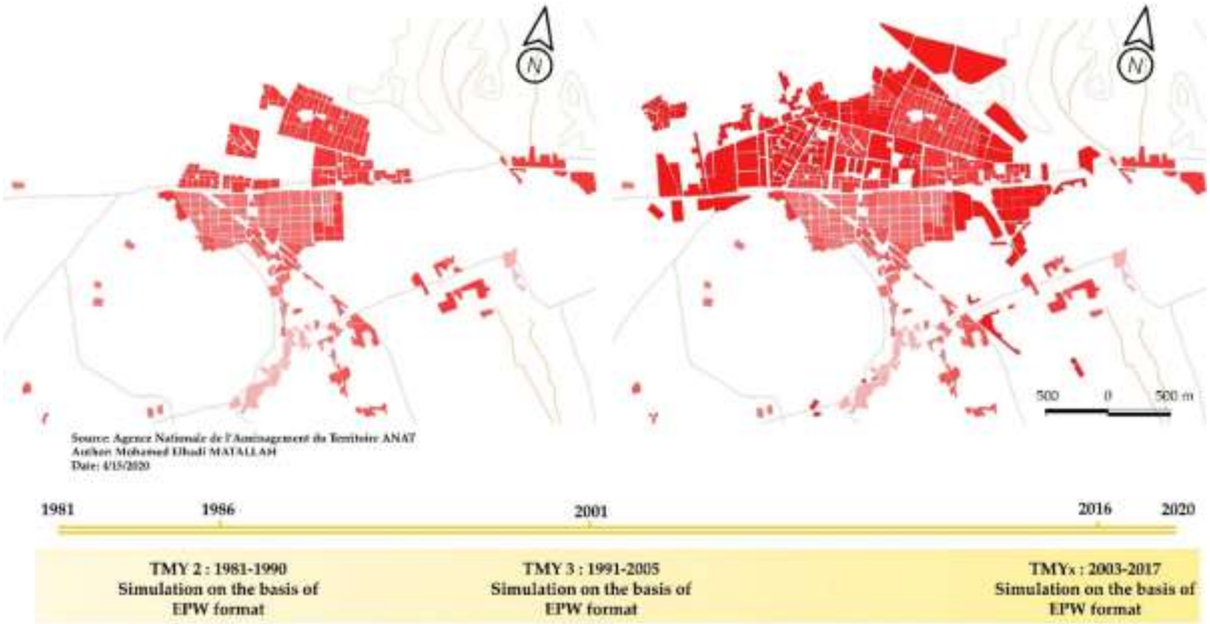


Figure 5.4: *Simulation's periods of the three case-study models according to TMY2, TMY3 and TMYx*

Source: *Matallah et al., 2021*

5.8 Comparative study

As explained, the three models were simulated for three consecutive days during July (15th, 16th, and 17th) in three different periods: TMY2 (1986), TMY3 (2001), and TMYx (2016). In this section, all PET maximums, minimums and averages are reported through the total values of PET which are detailed on the (Matallah Study Report, 2020); while, only the July 15th is demonstrated in this chapter to summarize the results reading.

We should indicate in this section, we demonstrate only one carried day 15th July, whereas the other days are all illustrated in Matallah Study Report., 2020 (Appendix). Otherwise, all the presented results through the current section are mainly performed on the basis of the three simulated days.

Furthermore, we need to indicate that TMY2 and TMY3 present the summary of the Typical Meteorolgical Year based on monitored datasets, in the other hand the TMYx is partially based on predicted datasets according to *climate.onebuilding.com* website which contains most relevant worldwide weather data used by thansands of studies in different climate zones.

Initially, TMY2: table 5.5 shows the variation of PET values which are balanced between a minimum PET_{min} = 17.2°C carried in S1, and maximum PET_{max} = 47.2°C carried in S2. Furthermore, the PET average value within the three sites is equal to PET_{ave} = 29.4 °C.

Table 5.5: *Summary of the PET values of the simulated models in July 15th 1986*

Source: *Matallah et al., 2021*

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
15.07.1986	**00:00**	20.2	20.2	20.5	19.2	18.8	19.7	19.7	19.7	19.1
	01:00	19.7	19.4	19.5	19	18.6	19.1	19.2	19.1	18.4
	02:00	18.8	18.8	18.8	18.4	18.6	18.5	18.5	18.5	18.1
	03:00	18.4	18.3	18.3	17.8	18.1	18	17.9	17.8	17.6
	04:00	17.9	17.9	18	17.1	17.6	17.3	17.1	17.1	17.5
	05:00	17.7	17.9	17.9	17.4	17.4	17.9	17.1	17.1	17.3
	06:00	17.6	17.2	17.4	17.5	17.2	17.9	17	17.2	17.1
	07:00	20.3	20.7	20.3	19.8	18.8	22	20	18.7	18.9
	08:00	25	25	24.9	23.2	23.6	29.9	23.9	23.8	23.3
	09:00	29.5	29.4	29.3	34.9	35.4	33.8	27.8	27.8	26.9
	10:00	32.6	32.5	32.6	38.7	35.1	34.9	36.5	29.4	29.2
	11:00	35.1	35.3	35.4	40.6	37.7	36.5	39.1	32.6	31.9
	12:00	41.4	41.5	41.6	38.1	40.1	36.4	37.2	38.9	39.8
	13:00	41.5	41.8	41.9	34.5	39.5	36.2	38.7	39.4	40.9
	14:00	44.8	45.1	45.1	36.7	36.7	40.4	40.2	42.1	37.1
	15:00	39.2	39.3	39.6	36.5	36.4	40	42.1	36.2	35.6
	16:00	39.4	39.6	39.6	36.4	44.6	39.1	43.7	37.3	36.5
	17:00	37.5	37.8	38	43.9	35.9	38.9	35.3	35.9	36.2
	18:00	35.5	35.5	35.5	41.9	33.8	35.6	33.7	33.9	33.5
	19:00	32.3	32.5	32.3	30.8	30.2	30.4	30.5	30.3	30.5
	20:00	27.5	27.4	27.4	27.1	25.7	25.1	26	26	26
	21:00	24.8	24.8	24.9	22.9	23.3	23	23.5	23.6	23.6
	22:00	23.6	23.4	23.5	21.4	21.8	22.1	22.1	22.4	22.3
	23:00	22.4	22.3	22.3	20.8	20.5	21	21.2	21.5	21.2

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

Secondly, TMY3 as presented in the Table 5.6 shows the PET values which are balanced between a minimum PET_{min} = 17.3°C carried in S1, and maximum PET_{max} = 50.5°C carried in S3, while the PET average value between the three sites is equal to PET_{ave} = 30.5 °C. Apparentely, the obtained results for the TMY3 are close to the previous period TMY2, maximums, minimums and averages are reported in Matallah Study Report, 2020.

Table 5.6: *Summary of the PET values of the simulated models in July 15th 2001*

Source: *Matallah et al., 2021*

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
15.07.2001	00:00	20.3	20.4	20.3	20.1	19.8	20.6	20.8	20.7	20.3
	01:00	19.7	19.5	19.5	19.8	19.5	20.3	20.1	20	19.7
	02:00	18.9	18.8	18.8	19.2	18.9	19.6	19.6	19.5	19.4
	03:00	18.4	18.4	18.4	18.6	18.6	19.1	19	18.8	18.9
	04:00	18	17.9	18	17.8	18	18.8	18.3	18.3	18.8
	05:00	18	18	18	18.4	17.7	18.5	18.2	17.9	18
	06:00	17.6	17.3	17.3	17.8	18.2	18.7	18.1	18.2	18.5
	07:00	20.3	20.9	20.9	20.8	19.6	20.9	21.1	20.3	20.3
	08:00	25	25.1	24.9	24.6	24.5	30.8	26	25.1	24.7
	09:00	29.5	29.5	29.4	35.8	35.8	35.1	36.5	29.5	28.8
	10:00	32.6	32.4	32.6	39.2	37	36.4	37.9	31.9	31.2
	11:00	35.5	35.3	35.4	41.1	39.3	38	40.5	34.6	33.9
	12:00	41.6	41.5	41.6	39.8	41	41.4	41.8	36.9	42
	13:00	41.7	41.9	41.9	36.5	40.6	41.6	41.8	42.4	43.2
	14:00	45	45.2	45.2	38.5	38.5	43.7	44.3	43.8	43.8
	15:00	46	39.5	39.6	38.4	38.4	44.9	47.5	45	37.7
	16:00	39.6	39.6	39.6	44.6	38.4	46.5	48.7	38.6	38.6
	17:00	37.6	38	38	45.4	37.6	47.9	45	37.8	37.8
	18:00	35.6	35.6	35.6	43.2	35.5	46.2	35.5	35.7	35.4
	19:00	32.4	32.6	32.3	32.3	32	32.4	32.1	32.2	32.1
	20:00	27.3	27.7	27.4	27.6	27.4	26.8	27.1	27.7	27.7
	21:00	24.9	25.1	24.9	25.1	24.9	24.8	25	25.2	25.3
	22:00	23.6	23.5	23.5	23.4	23.5	23.8	23.7	24.2	24
	23:00	22.4	22.4	22.3	22.4	22.5	22.7	22.9	23.2	23.1

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

Thirdly, TMYx, Table 5.7 shows an increase of PET values which are balanced between a minimum PET_{min} = 21.5°C, and maximum PET_{max} = 59.7°C carried in S1 both. Otherwise, the PET average value taken in the three sites is equal to PET_{ave} = 36.0 °C.

In summary, between 1986 till 2016, the PET_{min} values were founded in point 2 (S1); however, PETmax values were established in point 7 (S3). The PET. index ranges obtained between 1986 - 2016 show an increase of (+ 5.8°C) in S1, (+ 6.7°C) in S2, and (+ 7.2°C) in S3, with a difference reaches 1.4°C between S1 and S3. Thus, the growing of thermal stress zone is more remarkable in TMYx within the three sites. As a holistic reading on tables: 15-5, 16-5, and 17-5, we found that S2 and S3 showed closely the same microclimatic changes, unlike the S1 undergo different compared modifications to them.

Table 5.7: *Summary of the PET values of the simulated models in July 15th 2016*

Source: *Matallah et al., 2021*

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
15.07.2016	00:00	25.7	25.6	25.7	25.6	26	26.5	26.4	26.8	26.4
	01:00	25.7	25.1	25.6	24.8	25	25.9	25.6	26.5	25.8
	02:00	25	24.7	24.9	24.3	24.2	25.6	25.5	25.8	25.4
	03:00	24.7	24.3	24.7	24.6	24.3	25.4	25.5	25.4	25.5
	04:00	23	22.7	22.8	23.6	23.5	24	23.4	23.7	23.7
	05:00	22.7	23	23.2	23.2	22.9	24.1	23.5	23.3	23.6
	06:00	25.1	25.3	25.5	25.1	24.6	26	25.9	25.4	24.7
	07:00	30.3	30.3	30.3	29	29.5	33	30.7	30.3	29.6
	08:00	34.5	34.8	34.8	33	34.5	35.8	34.4	34.4	34.4
	09:00	39.6	39.7	39.6	44.3	39.4	44.2	39.2	39.2	39.3
	10:00	43.4	43.2	43	46.3	42.6	48	46.9	42.2	42.2
	11:00	47.4	47.2	47	49.7	45.5	50.8	49.7	45.9	45.2
	12:00	52.6	52.3	52.9	51	49	53.4	51.6	51.6	51.9
	13:00	54.1	54.9	54.5	49.7	52.8	54.9	54.3	54.6	55
	14:00	59.5	59.2	59.7	52	51.3	55.8	58.2	57.9	53.7
	15:00	52.3	52.6	52.5	51.4	50.7	54.9	57.9	58	52.1
	16:00	52	52	51.9	57.2	51.7	55	58	52.4	52.1
	17:00	49	49	49	53.5	49.5	51.6	52.5	49.3	49.2
	18:00	44.8	44.8	44.7	46.4	44.5	45.1	47.1	45.1	45.1
	19:00	40.4	40.6	40.4	40.6	42.5	40	41.8	41.7	42.5
	20:00	37.9	37.8	37.9	38.7	39	39.1	38.3	38.5	39.6
	21:00	36.6	36.6	36.7	38.5	36.6	38.7	37.6	37.6	38
	22:00	33.6	33.7	33.7	35	33.7	35.1	34.7	34.3	34.2
	23:00	31.5	31.5	31.5	31.3	31.9	33.2	32.5	32.6	32.4

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

Summarizing these data, in long-term analysis from 1986 till 2016 the PET_{min} values were founded in point 2 (S1), however PET_{max} values were founded in point 7 (S3). The PET index ranges obtained between 1986 - 2016 show an increase of (+ 5.8°C) in S1, (+ 6.7°C) in S2, and (+ 7.2°C) in S3, with a difference reaches 1.4°C between S1 and S3. Thus, the growing of thermal stress zone is more remarkable in TMY x within the three sites. As a holistic reading on tables: 5.5, 5.6, and 5.7 we found that S2 and S3 showed closely the same microclimatic changes unlike the S1 undergo differently changes compared to them. Otherwise, the examination of PET index during the month of July in long-term 1986 - 2016 showed a variation on the diurnal and nocturnal stress levels: neutral, slightly warm, warm, hot, and very hot. Firstly, PET averages show that in long-term, in July which represents the hottest period of the year, the thermal stress's assessment was always in the warm thermal zone. Neutral zone generally occupied the nocturnal daytime hours; in contrast the stress thermal zone occupied practically all the daylight hours. Whereas, the neutral zone represented an average of 46 % and 43 % respectively in 1986, 2001 equal to 10 hours of daytime and mostly been after the sunset to sunrise, and has been decrease to 24 % in 2016 equal to 7 hours of daytime between 0:00 a.m. to 6:00 a.m. (Tables: 5.5, 5.6, 5.7). Moreover, the daytime's thermal stress duration includes four levels: slightly warm, warm, hot, and very hot, showed averages higher than neutral zone with values: 54 % in 1986, 57 % in 2001 which are equal to 14 hours of daytime. Thus, 2016 represents 76 % equal to 17 hours of daytime (Tables: 5.5, 5.6, 5.7).

Otherwise, in long-term since 1986 till 2016, the neutral zone within the three sites decreased from 46 % to 24 % i.e. 10 hours to 7 hours of daytime, however the very hot zone increased from 11 % to 34 % i.e. three hours to 8 hours of daytime. Therefore, the most increasing of thermal stress zone was founded in S3 with 79 % in 2016 versus 72 % in S1, this last one represents all time the minimum percentages during the three periods (Tables: 5.5, 5.6, 5.7).

For TMY 2 period the results show that about the half of summer season is under the thermal neutral zone with close results 48% and 47 % in S2 and S3 respectively, while S1 is slightly less with 44%. Otherwise, the very hot zone represents an average of 10% with a minimum of 9% at the S1 and 12% as a maximum in the S3 (Table 5.8). For the TMY 3 period the results show also that about the half of summer season is under the thermal neutral zone with similar results for the three sites with 43%. Otherwise, the very hot zone is slightly increasing around 13% in average with a minimum of 10% at the S1 and 16% as a maximum in the S3 (Table 5.8). Finally, For the TMY x period the results show that only 25% as average of summer season is under the thermal neutral zone with a minimum of 21% in S3 and 28% as a maximum in S1. Otherwise, the very hot zone became more important with an average of 34% where we found a minimum of 31% in S1 and 38% as a maximum in S2 (Table 5.8).

In other reading we found that the neutral zone was major in the TMY2 period with an average of 46%, slightly decreasing in TMY3 giving a similar value in all sites with an average of 43%. However, at TMY x results show a remarkable decrease of the neutral zone with more than 50% of its precedent value to be at a level of 24% as average.

Additionally, in long-term, we found that the very hot zone was the smallest one with averages of 11% and 13% in TMY 2 and TMY 3 periods respectively, while, it jumps to double reaching 34% in TMY x period.

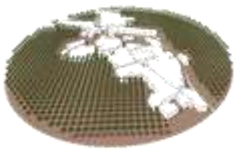
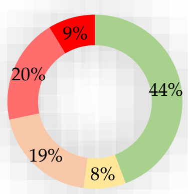
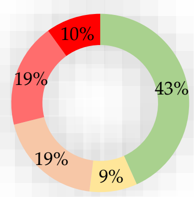
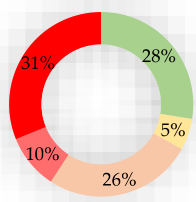
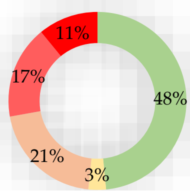
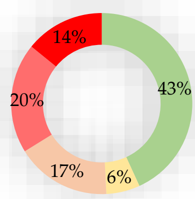
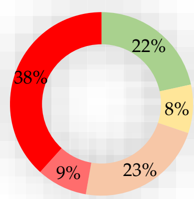
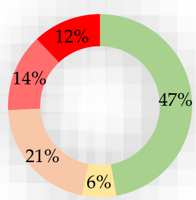
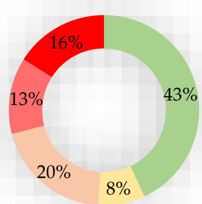
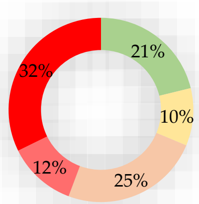
In 1986, points 1, 2, 3 and 9 show a PET maximum at 1:00 p.m. practically at the same hour, however other points show their maximums after 2:00 p.m. From 1986 to 2016, all points represent a close similarity on thermal stress level during nighttime. TMY 3 was the period showed a close value from 6:00 p.m. to 6:00 a.m. through all points. In addition, TMY x shows an extended overheating time zone comparing to TMY 2 and TMY 3, where points 1, 2, and 3 are faster refreshed when are specially observed on TMY 3 and TMY x. Finally, PET maximum values in long-term are registered in points 7 and 6 with $PET_{max.ave}$ 51.9°C and 50.7°C respectively, while the minimum values are taken in point 2 and 1 with PETmin.ave 17.2°C and 18.9°C in order, PET values are increased from 1986 to 2016, and more observed between 11:00 a.m. to 6:00 p.m. when the thermal stress becomes higher in all sites point.

During the simulation's time, there was a significant variation in PET values throughout the three sites. In long-term points: 1, 2 and 3 indicate a slowly overheating during summer daytime comparing to all other points. Furthermore, point 4 shows less values versus all points from 12:00 p.m. to 3:00 p.m. and become higher after 4:00 p.m. till sunset (Figure 5.5). During all periods, point 4 shows always a decrease on PET index values between 12:00 p.m. to 3:00 p.m. in contrast of all points presenting an increase of PET values at the same duration. In addition, no clearly correlation founded among PET values' variations and the SVF of all points during simulation's time. Close similarity is mostly observed between all measured points (Figure 5.5). Otherwise, PET values are continuously increasing over time within all measured points, while the last evaluated 15 years (TMYx) presents the most critical period.

Summarizing these results, PET values of TMY 2 show an urban warming phenomenon in PET ranges in all points varying between 0.1°C to 6.2°C. Otherwise, Old neighborhood (S1) is the least affected by the urban warming with 0.6°C as a max value recorded in point 3 and with 0.37°C as a maximum average. Secondly, PET values of TMY 3 indicate that the individual housing (S2) and the multifamily housing (S3) neighbourhoods show the same reading with an urban warming in the afternoon reaching 3°C in PET ranges and reach 6.2°C in a punctual record. Finally, as a spatiotemporal reading we found that the real urban warming phenomenon begins at last morning times 10:00 a.m. to 11:00 a.m. and reach its maximum values in the afternoon, while some records present a max warming at 8:00 p.m. till 10:00 p.m. Consequently, as a reading between the SVF and the PET ranges on TMY2 and TMY3 respectively we found a correlation between the measurement point of the same site.

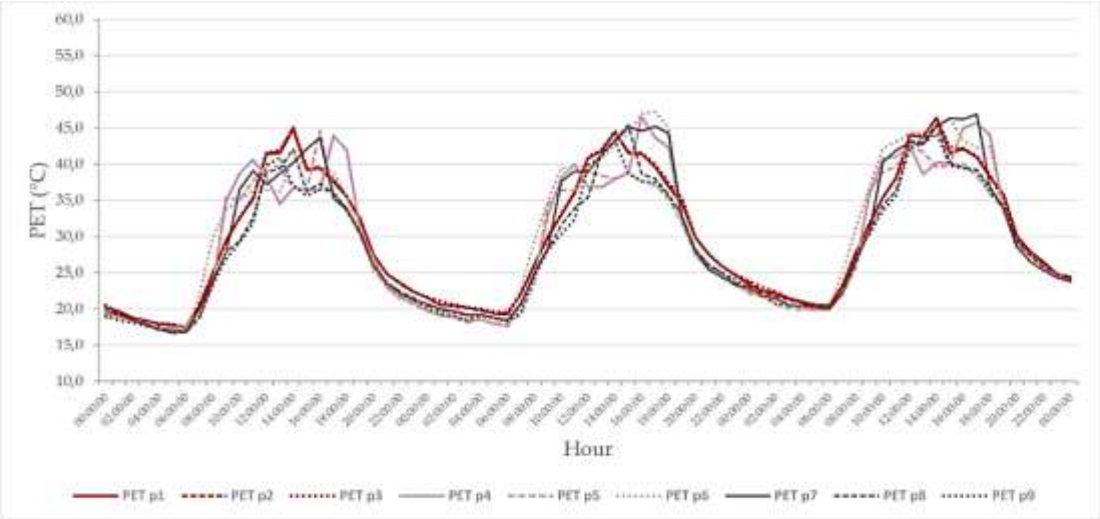
Table 5.8: *Evolution of heat stress levels within the sites during the three periods TMY2, TMY3, and TMYx*

Source: *Matallah et al., 2021*

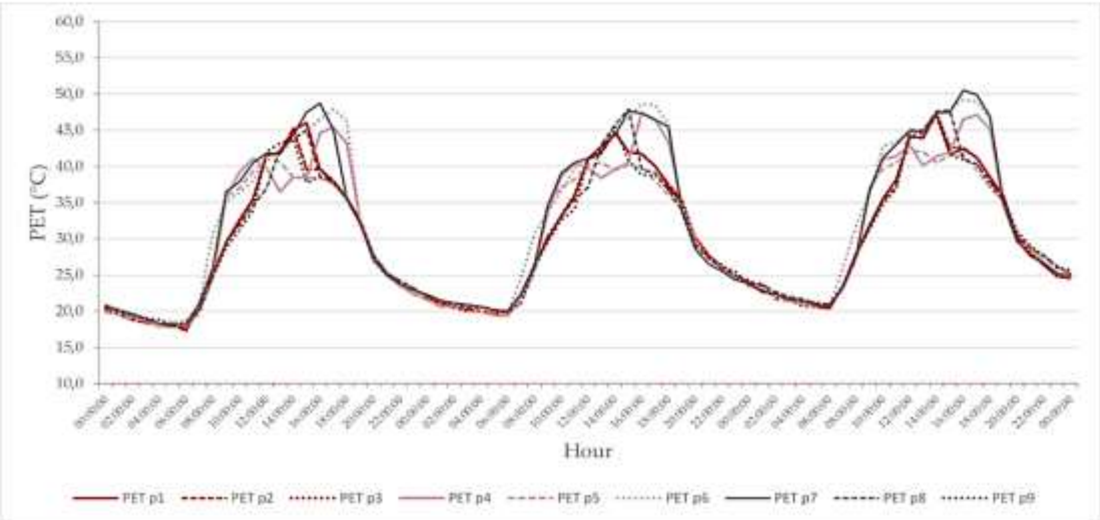
<table>
<tr><th>Sites</th><th>TMY 2</th><th>TMY 3</th><th>TMY x</th></tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td rowspan="3">Thermal comfort stress level</td>
<td colspan="3">17 - 26 | 26 -28 | 28 - 37 | 37 - 42 | > 42</td>
</tr>
<tr><td colspan="3">Neutral | Slightly warm | Warm | Hot | Very hot</td></tr>
<tr><td colspan="3">No thermal stress | Slight heat stress | Moderate heat stress | Strong heat stress | Extreme heat stress</td></tr>
</table>

In this research stage as the previous one, we had resulted that relationship between SVF and PET index were very low during daytime hours as well as nighttime hours under the extreme weather conditions. Results showed that under the severe overheating waves there is no impact of SVF on the thermal heat stress, might be very weak but the sensitivity was very low. However, PET index values are closely related to the spatial configuration once the weather conditions were in moderate levels.

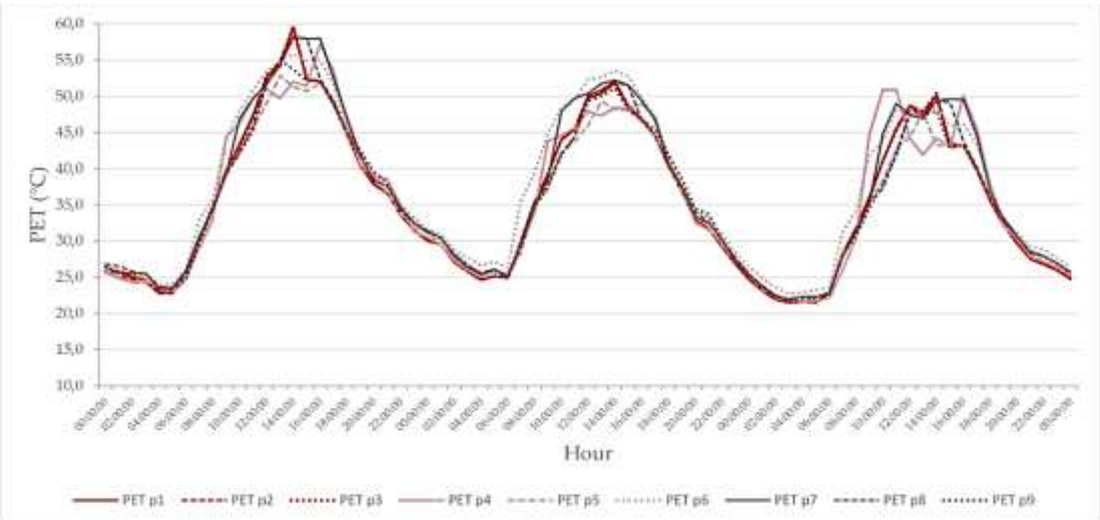
Moreover, the oasis effect could be evaluated basically of simple monitored microclimatic parameters such as air temperature and relative humidity, however in this research the oasis effect phenomenon is strongly attached to thermal stress. In order, oasis effect in two research stages has no significance appearance among extreme heat during summer days, as well as no correclations were founded between SVF and oasis effect trace.



(a)



(b)



(c)

Figure 5.5: *Variation of PET index values throughout the study points during TMY2, TMY3, and TMYx: (a) TMY2; (b) TMY3; (c) TMYx*

Source: *Matallah et al., 2021*

5.9 Discussion

At this stage, we performed a microclimatic analysis of three oasis urban fabrics in Tolga city 'Tolga Oasis Complex' in three different periods, to assess the outdoor thermal comfort variations over 30 years. Initially, we applied a simulation models, using three typical Meteorological Year (TMY) files - TMY2 (1981-1990), TMY3 (1991-2005), and TMYx (2003-2017) -, to enlarge the assessment of the outdoor thermal comfort duration, and to analyze the thermal stress changing during time. Thus, TMY hourly weather files can improve and reinforce studies investigating the long-term outdoor thermal comfort's assessment as well as for the future microclimate's prediction. Moreover, this study is based on two numerical software: CFD ENVI-met for the validation and the simulation of the models, and RayMan for the PET index calculation. To summarize the simulation readings, we list the significant findings of the analysis of the outdoor thermal comfort:

5.9.1 Findings and recommendations

Our study indicates that in the '80s (TMY2 period), the heat stress level was moderate (slightly above 50 %) and the outdoor thermal comfort levels were identical, when the neutral zone represented 46 %. Slight variation on thermal comfort level occurred during the '90s (TMY3 period). The models showed the same percentage of the neutral zone of 43 %. In parallel, a barely increase in the heat stress zone (+ 3% comparing to the precedent duration). The third-period TMYx (2003-2017) represents a significant microclimatic change, causing a high and accelerated heat stress level from 57% to 76%, which is related to the urban warming and built environment's development. The neutral zone registered a retreat from 43% to 24%, and this variation is due to the remarkable global warming intensity during the last 15 years. The last period, is considered very critical to human body health and causes a significant impact on inhabitants' well-being. Additionally, climate change and the frequently heat waves in the arid regions can be a serious cause to increase the rate of morbidity and mortality.

Results show an urban warming-effect (Oke, 2002) on PET ranges within all points varying between 0.1°C to 6.2°C, where the Old neighborhood (S1) is the least affected by the warming-effect with 0.6°C as maximum value recorded in point 3 and 0.4°C as max average. Although, (S1) represents the site where is surrounded by the palm trees' Phoenix Dactylifera' has benefited from the oasis cooling-effect (Boudjellal, 2018) due to irrigated area especially at nighttime hours, however the (S2) and (S3) are more affected by the UHI (Taleghani, 2018).

Notably, (S1) is quickly cool down after sunset in all periods comparing to (S2), and (S3), which is likely due to the oasis cooling-effect phenomenon (Potchter et al. 2008). We should indicate that the oasis cooling-effect registered in (S1) has been decreased during the last period (TMYx) comparing to the precedent periods, might due to global warming increase (Potchter et al., 2013).

From the spatiotemporal reading, we found that the real warming-effect phenomenon begins at last morning from 11:00 a.m. and reaches its maximum values in the afternoon. At the same time, some records represent a max warming-effect value at 8:00 p.m. till 10:00 p.m. In comparison between PET index values throughout the different SVF of sites points, results showed a similarity of PET index values of the measured points between 0:00 a.m. to 6:00 a.m. this is likely due to homogeneity of building materials in all sites, and their thermal aspects at nighttime. The last 15 years (2001 - 2016) witnessed a remarkable change of the microclimatic parameters, including air temperature increase and relative humidity decrease. Thus, outdoor thermal comfort levels declined and most probably will continue to decline in the future, on the short-term and long-term.

Therefore, results can instruct architects, urban planners and climatologists to pay more attention to climate change effects caused by urban development in oases lands. Adapted urban climate strategies should be implemented in the arid climate, thus moderating the potential increase in air humidity. In desert cities, irrigated surfaces can cause long-term thermal heat stress growth, especially in summer daytime hours. However, deciduous trees can create shading and protect spaces from direct sun, which is most remarkable on the cooldown temperature time. Moreover, it is mandatory on the urban planning stage to know what kind and type of vegetation arrangement must be implanted on the oasis urban area in the earlier urban planning stages. All of these strategies should follow a quantitative approach such as PET index calculation and shading areas estimation.

5.9.2 Strength and limitations

The strength of the study relates the combination between an empirical approach and simulation models analysis. The study is based on high-quality real-time data extracted from climatic dataset of Algerian meteorological stations. The study presents new and unique findings for outdoor thermal comfort assessment of oasis settlements during several periods based on different TMY files. Previous studies were based only on recent climatic dataset, i.e., for a short-term (days). Therefore, this study provides an accurate and long-term (30 years) quantification of the outdoor thermal comfort in Algeria's oases settlements. In contrast to previous research focused only on a limited geographical areas and short time assessment periods. Worldwide few studies assessed outdoor thermal comfort for long-term, analyzing the evolution of climate change and the urban form's impact on outdoor thermal stress sensation.

This study is technically based on the simulation model's validation as the first stage, which needs 150 hours only for validation's step on software, then more than 1000 hours of running simulations. We should indicate that we carried around 7776 microclimatic data include: air temperature, relative humidity, air velocity, and mean radiant temperature, which is equal to 2592 data per period. For the outdoor thermal comfort assessment, we needed to calculate 648 PET values at the three Typical Meteorological Year in the three studied sites. Methodologically, we need for coupling between two most usable software on urban climate studies: ENVI-met (CFD) and RayMan as calculation model.

This study might be considered a vital step for a future urban climate research; it could provide for the outdoor thermal comfort predictions in the oasis settlements based on the Intergovernmental Panel on Climate Change (IPCC) scenarios (Rogelj et al., 2012). Moreover, the study represents a new path of Algerian studies on urban climate, especially in the hot environments.

On the other hand, this study has several limitations. The work does not consider the buildings' shell details; i.e., doors, windows, roofs, and façade details, which can impact outdoor thermal comfort. The study focused only on the hot period, which could have benefited from a more extended monitoring period (one year or more), to use the annual hourly data for the validation and calibration if necessary, and to assess the thermal comfort during the cold period. Even more, for the Tmrt parameter, this one could be calculated mathematically on the basis of air temperature, air velocity and globe temperature, while this last needs a specific monitoring instrument which was unavailable for the current study.

5.9.3 Implication on practice and research

This study identified levels of the outdoor thermal comfort in the oasis urban fabrics, through several periods. Thus, future urban design in Algeria must be according on the basis of urban climate studies and should follow the long-term predictions. We believe that this study can guide decision makers, architects and urban planners to apply our findings in the early design stages to improve the outdoor thermal comfort depending to the urban design. Additionally, we believe that not architects or urban experts are only the concerned by this study, climate scientists and specially the Meteorological domains can have benefited from our outcomes to analyse the curve of climate change and to predict for the short and long-term future.

5.10 Conclusion of the chapter

This study is focused on the assessment of the outdoor thermal comfort within three different oasis urban fabrics which can elaborate a strong guideline for landscape and urban designers who want to build thermally comfortable outdoor climates for these specific lands. The study investigated the evolution of the heat stress level by the quantification of the outdoor thermal comfort in the urban fabric of Tolga oasis city during 30 years, on the basis of PET index which is most appropriate to evaluate the human thermal stress in arid climate, and based on Typical Meteorological Year (TMY) as time variable.

The research methodology combined between empirical approach and numerical modelling running simulations within three oasis urban fabric typologies within three different periods. Moreover, the research methodology reflects a new approach of the urban climate analysis based on monitoring, CFD and meteorological calculation's modelling. The outcomes of this paper showed that climate change and the accumulated effect of urban climate modification induced a significantly heat stress values in long-term. Thus, heat stress levels were quite increased in the last 15 years in all studied urban fabrics. Regarding the different oases urban forms and their effect on the outdoor thermal comfort, it is difficult to specify the most influenced form or orientation among the three models. However, PET index values, showed a less decrease in the Old neighbourhood (S1) comparing to other neighbourhoods, this is may due to Palm Grove surrounding the (S1). Furthermore, results suggest architects, urban planners and climatologists to pay more attention on climate change effects what can be caused by urban development on the oases lands. Although, urban strategies should put an adapted oases urban model attached to a sustainable green area and more adapted to the arid climate, thus moderating the potential increasing on air humidity. In the case of a desert city, irrigated surfaces can cause in long-term an increase heat thermal stress specially in summer daytime hours, however deciduous trees can create shading and protect spaces from direct sun, which is mostly remarkable on the cooldown temperature time. Moreover, it is mandatory on urban planning stage to know what kind and type of vegetation arrangement that must be implanted on the oasis urban area in the earlier stages of urban planning.

6. CHAPTER SIX : OUTDOOR THERMAL COMFORT LONG-TERM PREDICTIONS [3, 4]

Patterns of future climate and expected extreme conditions are pushing design limits as recognition of climate change and its implication for the built environment increases. There are several methods of estimating future climate projections and creating weather files. This chapter aims to answer two research questions : how can be the climate change and the future weather conditions' impact on the outdoor thermal quality in the arid regions ? does a method or an algorithm of generating predictions of the thermal heat stress levels in short-term, medium-term and long-term ? to answer to these two questions, the current chapter provides an overview of the major approaches and studies conducted to seek about the future weather predictions' datasets. We believe that the use of the IPCC emission scenarios are strongly enlarged through building simulations studies', in contrast only few knowledges on the urban scale were developed. Regarding the generated algorithm, we need to reveal that is developing only as pilot study, whereas the main purpose is to diffuse the followed methodology into different climate zones in Algeria to achieve a total thermal predictions throughout all the country. According to the results, all the methods provide enough information to study the long-term impacts of climate change on average. However, results also revealed that assessing the heat stress levels inside oases settlements only under typical future conditions is not sufficient. The chapter explores the outdoor thermal comfort through the Perceived Temperature index, which is the most relevant and adapted for the long-term predictions against other different thermal indices such as Phyisological Equivalent Temperature (PET) which is used in the previous two chapters, and the Universal Thermal Comfort Index (UTCI).

In order, the chapter is divided into six sections, performing the weather's future scenarios and the thermal comfort assessment, and it presents in detail the algorithm development steps. Results and discussion sections are combined, to present all the datasets extracted and to show the algorithm methodology. Thermal predictions allow future designers to better react to climate change and think the best fit for climate adaptations, strategies and solutions to design and implement comfortable and efficient urban planning designs.

[3] This chapter is based on this technical report: Matallah, M. E., Ahriz, A., & Attia, S. (2020). Quantification of the Outdoor Thermal Comfort Process: Simulation & Calculation data (No. 01/2020). Sustainable Building Design Lab.

[4] This chapter is based on this article: Matallah, M. E., Mahar, W. A., Bughio, M., Alkama, D., Ahriz, A., & Bouzaher, S. (2021). Prediction of Climate Change Effect on Outdoor Thermal Comfort in Arid Region. Energies, 14(16), 4730.

6.1 Introduction

Nowadays, urbanization has been rapidly increasing as a large part of the world population is migrating from rural to urban areas (Gholamreza et al., 2020). Thus, city-induced climate change has severe consequences for public health, tourism, and outdoor activities. Researchers have been increasingly interested in studying the adverse effects of urbanization on thermal sensation and conditions in cities (Jamei et al., 2016; Roshan et al., 2020). Otherwise, oases settlements which are the most frequently urban patterns in the Sahara's regions in North Africa are facing a large urban sprawl during the last decades, when these regions showed a high reclamation on thermal qualities throughout the cities especially during summer. Many centuries ago, urban design strategies were adapted to the local conditions that were found in the vernacular and traditional architecture (Attia, 2020). In contrary, on a recent summer's days, the thermal context can lead to lethargy and people preferring to remain indoors, and only venture outside for key activities such as commuting or commercial tasks. At the same time, non-compulsory activities such as walking, sightseeing or socializing become less favorable (Elnabawi and Neveen, 2020). Despite the use of developed building's means and new materials' generation, the current urban strategies implemented within local authorities are mostly unadaptable to climate change and are main factor on increase the thermal discomfort inside the oases settlements, and occupants claim more to thermal stress during the hot season. Consequently, thermal adaptation patterns are taking in consideration climate change fluctuations for short-term, medium-term and long-term variations, as well as to adapt cities the weather and environment conditions specifically in the arid regions. The Intergovernmental Panel for Climate Change (IPCC) created a number of possible scenarios of future anthropogenic greenhouse gas emissions based on given socio-economic storylines, to project future changes in climate for impact and adaptation assessment (Moazami et al., 2019).

Therefore, this study aims to promote long-term predictions for outdoor thermal comfort through a unique urban multifamily residential typology, specifically inside the oases settlements in southern Algeria, that can yield valuable insights for various urban planning strategies. We used state-of-the-art urban climate modelling tools to assess outdoor thermal comfort levels through the study context. Moreover, the findings of this research can allow architects and urban planners, authorities, and programmers to benefit from environmental and urban strategies. In the Saharan urban environments, outdoor thermal comfort assessment is imperative to understand people's well-being and reduce negative impacts during extreme events, such as heatwaves and heat stress. Therefore, this paper aimed to quantify outdoor thermal comfort under current and future weather projections from 2020 until 2080 and generate an algorithm for thermal stress predictions. More specifically, the following questions are answered:

- What are the outdoor thermal comfort levels inside a multifamily residential neighbourhood concerning IPCC emission scenarios?
- How severe will be the impact of climate change on outdoor thermal comfort during summer by 2080?
- How to generate an algorithm for hourly and yearly predictions of outdoor thermal comfort thresholds through similar spatial-climate conditions?

The main objectives are to quantify the outdoor thermal comfort inside a most common urban archetype across the oases territories following an empirical approach and investigate the long-term heat stress patterns under the climate change conditions. A background, as well as an introduction of the study context highlights the objectives and the obtained results which were presented through the study. Moreover, numerical modelling, measurements in site, literature review, and a reference case excerpt have been largely demonstrated. A comparison of seven different weather data projections was made to stand by the future patterns of outdoor thermal comfort in Algerian arid lands settlements. Levels of heat stress are analysed, and the results are used to generate an algorithm for the outdoor thermal comfort predictions. Finally, recommendations for future work are outlined.

6.2 Literature review

The current article presents a definition framework based on reviewing various of studies, including climate change scenarios (Hamstead et al., 2021), outdoor thermal comfort evaluation (Coccolo et al., 2016), and urban climate modelling (Palme et al., 2021). One of the challenges of this study is to provide thermal comfort predictions in urban scale beyond what is present in literature, which mainly addresses the definition of thermal comfort predictions on building scale. Most of the studies we reviewed investigated relationships among ‘‘climate change” and “thermal heat stress” through urban livability (Kenawy et al., 2021) for short-term and long-term durations. Otherwise, majority of the future weather files used to predict the impacts of climate change are performed on building performance, we cited most relevant works on this having been published (Moazami et al., 2016, 2019; Tootkaboni et al., 2021; Nematoucha et al.; 2018; Yau and Hasbi, 2013; Jiang et al, 2017; de Wilde, 2012; Berger et al., 2014; Guan, 2009, Roetzel and Tsangrassoulis., 2012).

The adaptive comfort model (Nicol and Humphreys, 2002) considers that people’s thermal sensation depends mainly on microclimatic parameters, i.e., air temperature, humidity, radiant temperature, wind, and solar radiation, among others, and individual characteristics and situations, such as age, gender, clothing, activity, and subjective issues, such as behavior, expectations, and acclimatization (Palme et al., 2021). Accordingly, outdoor thermal comfort studies were performed during long years and developed several methods, as well as indices to quantify the thermal comfort levels against climate change and urban phenomena such as Urban Heat Island (UHI). In the earlier studies, Yaglou and Minard., 1957, developed the 'wet-bulb globe thermometer' index, which was based on the total heat stress imposed by physical training, temperature, radiation, humidity, and wind on men in three military camps. Their work was followed by the developing of the 'Discomfort index' (DI) by Thom, 1959. And so on, the thermal comfort is already peroformed by the developing of several thermal indices such as the 'Physiologically Equivalent Temperature' (PET) by Hoppe, 1999. PET 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. Moreover, the 'Perceived Temperature' (PT) defined as human biometeorological parameter that describes the thermal perception of an individual, by the use of the air temperature of a reference environment (Staiger et al., 2011; Matzarakis et al., 2007, 2010). The thermo-physiological modelling of (PT) index is based on the Klima Michel model (KMM) (Jindertzky et al., 1974, 1990; Gosling et al., 2014). In another context, in their study Dae-Guen el al., 2010 investigated relationship between (PT) index variations and the daily excess mortality in Seoul, South Korea between 1991 to 2005. Although, Wang and Zhu., 2019 explored the impact of global warming on the perceived temperature (PT), which is considered by authors as the most relevant thermal index for the outdoor thermal comfort quantification under extreme climate changing.

On the other hand, only limited studies were investigated climate change impacts on the outdoor heat stress levels such as the study conducted by Fang et al. 2020 in Guangzhou, China, results indicated that air temperature has the most significant effect on thermal sensation. In colder or warmer conditions, the mean thermal sensation vote increases with the increase in clothing insulation. Differently approaches, Liu et al., 2016 demonstrated that CFD simulation of wind conditions can be used to assess outdoor thermal comfort in the future planning stage without being coupled with thermal simulation. Additionally, in the study of Nazarian et al., 2017, researchers tried to introduce an improved methodology of predicting outdoor thermal comfort and its spatial variability in urban streets. Otherwise, Kariminia et al., 2011 searched to establish the thermal acceptable temperature range applicable for an urban context in temperate and dry climate zone on basis on thermal index.

We need to refer that, the literature review includes most recent and relevant publications aimed to assess the outdoor thermal comfort and its predictions on the basis of simulation in worldwide. On the other hand, to narrow and to concentrate the scope of our study, we divided the publications under two categories: multifamily housing archetype; thermal comfort long-term predictions. Eventually, the added value of this work is not only to address long-term thermal issues in arid regions but to extend results to several climate zones in Algeria for further studies.

The following subsections explain deeply the study hierarchy (Figure 6.1).

6.3 Methodology

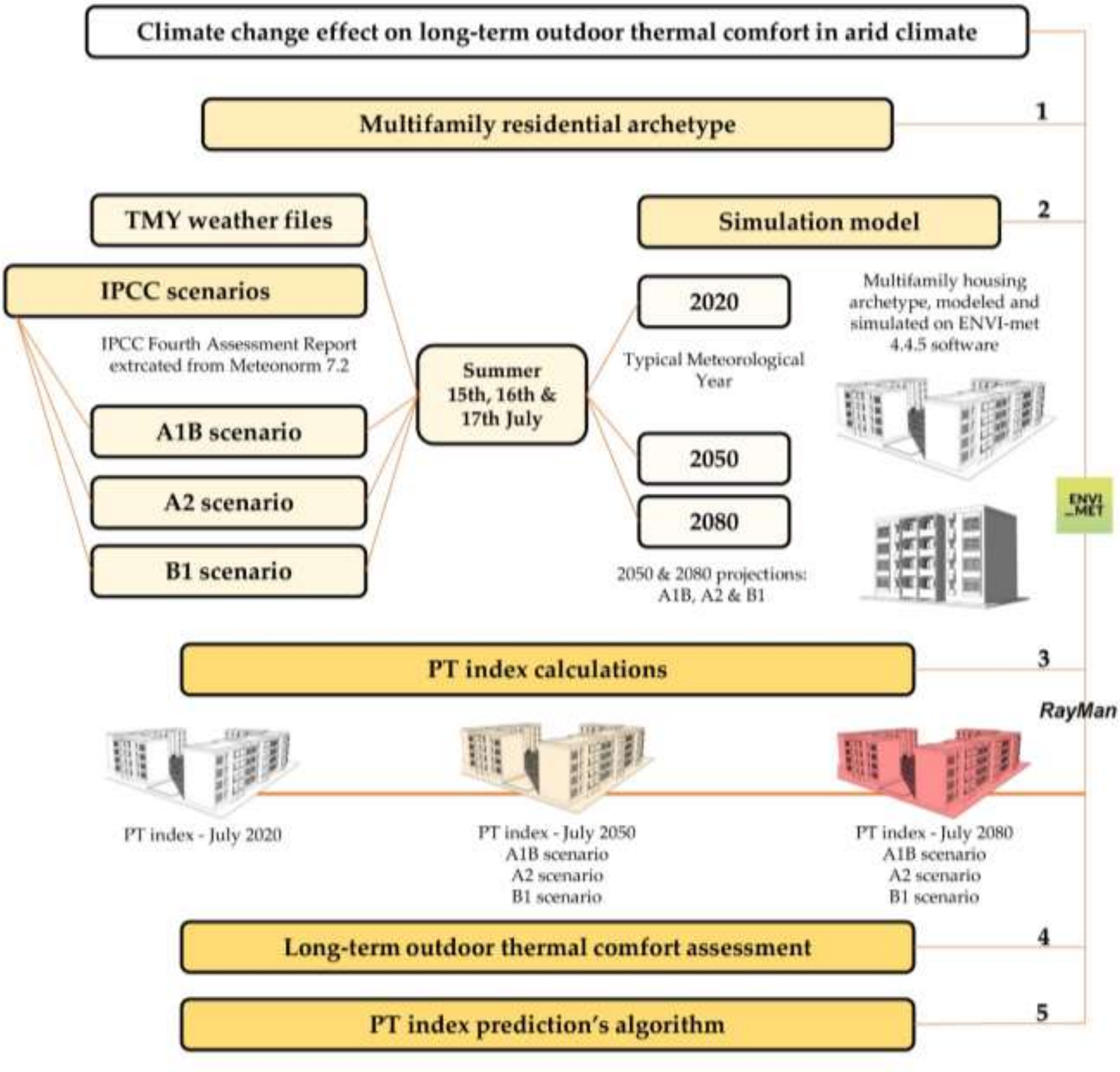


Figure 6.1: *Study Conceptual Framework*

Source: *Matallah et al., 2021*

6.3.1 Multifamily residential sector

The multifamily housing sector presents the large housing's pattern in Algeria. According to Semahi et al. (2020), the Algerian residential sector is composed of two main typologies: (i) multifamily housing which presents 51% of the total residential sector, and (ii) single-family houses which presents 49% of the residential sector.

There are several categories of the apartment building type, regarding the multifamily housing typologies depending on the contract type that reflects the inhabitants' income (Public rental housing, participatory public housing, rental-ownership housing and free promotional housing) (Semahi et al., 2020).

The social residential buildings category (Public rental housing) represents the central part (31%) in the multifamily housing. The number of dwellings in the social housing building category has been increased every year. The Algerian Ministry of Housing, Urbanism and the City launched a program to construct 800,000 dwellings between 2009-2014 and 800,000 dwellings between 2015 and 2019.

This study aims to evaluate the outdoor thermal comfort levels' quality depending on climate change within a multifamily housing neighbourhood, which presents the most common archetype residential's typology in Algeria.

6.3.2 IPCC scenarios and simulation model

Following several studies looking into climate change, this study focuses on methods and approaches related to the long-term pattern in climate change. The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental organization of the United Nations, which was established in 1988 by the World Meteorological Organization (WMO). IPCC provides the world with an objective, scientific information to understand the scientific factors of the risk of human-induced climate change, its economic and natural political impacts and risks, and potential response options (Lee, 2007; Houghton, 1996). Furthermore, IPCC established long-term emission scenarios which have been widely adopted in the study of potential climate change, its impacts, and opportunities to reduce climate change (Nakicenovic et al., 2000). The methods estimating the evolution of climate change within the Global Climate Models (GCMs) are numerical models of the physical processes that characterise the global climate system, comprising the atmosphere, oceans, cryosphere and land surface. Conferring to the Fourth Assessment Report of the IPCC (AR4) (Bernstien et al., 2008), the buildings sector has the most significant potential for climate change mitigation, and the development of mitigation when the adaptation strategies become a key challenge for building professionals (Roetzel & Tsangrassoulis, 2012; Bughio et al., 2021; Mahar et al., 2020; Mahar et al., 2021). The current work explores

the IPCC emission based on the Meteonorm database (Remund et al., 2010), which presents a stochastic weather data generator and a spatial interpolation tool. Therefore, the study is based on EPW -files for representing Typical Meteorological Year (TMY) (Crawley & Lawrie, 2015), and three IPCC emission scenarios which are: A1B, A2, B1, reveal the three projection's weather files available on Meteonorm 7.2 and used in the current study. Among several climate change studies, Calvin Cheung and Hart, 2014; Richter, 2016; Carter, 2018; Moazami et al., 2019; Nematchoua et al., 2019 and other researchers used in their work the emission scenarios for the climate change adaptation models.
Based on the literature review, it is identified that a limited number of studies investigated the impact of climate change on outdoor thermal comfort based on future weather projections. On the other hand, many similar studies were carried based on the building scale extreme weather adaptation. Meteonorm as a weather generator tool applies the GCMs of the IPCC fourth assessment report (AR4) and the climate data recorded in typical weather files (TMY). And, it generates different formats of future weather files for ten years' time period between 2010 and 2100. The three used projections were generated for the years 2050 and 2080, depending on the study area's context and geographical coordinates. These scenarios are based on a specific storyline highlighting the main relationships, characteristics, and dynamics, between the key driving forces: population, land use, agriculture, economy, energy, and technology.
The storylines represent various demographic, social, economic, technological and environmental developments (Nakicenovic et al., 2007; Roetzel & Tsangrassoulis, 2012). The main characteristics of all different scenarios and storylines are explained in Table 6.1.

Table 6.1: *IPCC climate change scenarios and storylines*

Source: *Nakicenovic et al., 2000, reproducted by author, 2021*

Storyline	characteristics
A1 A1F1, A1T, A1B	• An accelerated economic development • Important rise of the world population which reaches its peak in mid-century and relapses after that • Fast establishment of developed strategies and more effective technologies • The principal themes are convergence towards regional actions, building capacity, enhanced cultural and social interactions • A1 family scenario occurs into three groups that describe alternative trends of technological development in the energy system: A1F1 (fossil intensive), A1T (non-fossil sources) and A1B (balanced across all energy sources)

A2	• Very heterogenous world • The principal theme is self-sustenance and maintenance of local identities • Regional fertility patterns converge very slowly • World population is continuously increasing • The economic development is strongly aligned towards regional actions • The economic development and technological change are more dispersed and slower compared to other storylines
B1	• Converging world • Rise of the global population which peaks in mid-century and lower after that • A significant economic orientation towards a service and information economy • The use of clean and resource efficient technologies versus the decrease in material intensity • Worldwide solutions to economic, social, and environmental sustainability contributing improved equity, without adaptation of climate strategies
B2	• World in which the fundamental focus is on local economic, social, and environmental sustainability solutions • The global population is continuously augmented at a rate lower than A2 storyline • Economic development at medium level • Slower and more diverse technological development comparing to the B1 and A1 scenarios • Oriented toward social equity and environmental control and management • Special attention toward regional and local level development

Firstly, the work aimed to compare the current thermal stress (2020) based on (TMY) and the future projections in 2050 and 2080 (A1B, A2, B1). The study was performed exclusively in summer season, when the assessment's days was on 15th, 16th, and 17th July during each evaluated period.

Furthermore, the assessment of the outdoor thermal comfort was performed on the basis of the perceived temperature index (PT) (Staiger et al., 2012) (Table 6.2).

Table 6.2: *The thermo-physiological meaning of PT results*

Source: *Staiger et al., 2012*

PT (°C)	Thermal Perception	Thermo-physiological stress
≥ +38	Very Hot	Extreme heat stress
+32 – +38	Hot	Great heat stress
+26 – + 32	Warm	Moderate heat stress
+20 – +26	Slightly warm	Slight heat stress
0 – +20	Comfortable	Comfort possible
-13 – 0	Slightly cool	Slight cold stress
-26 – -13	Cool	Moderate cold stress
-39 – -26	Cold	Great cold stress
< -39	Very cold	Extreme cold stress

Otherwise, the purpose is to formulate a mathematical equation (algorithm) for the future yearly predictions of PT index values for (BWh) climate conditions.

As identified by Guan (Guan, 2009), the projections of temperatures have highest confidence among all the climatic variables, whereas the level of uncertainty is higher for humidity, solar radiation and wind.

6.3.3 Neighborhood context

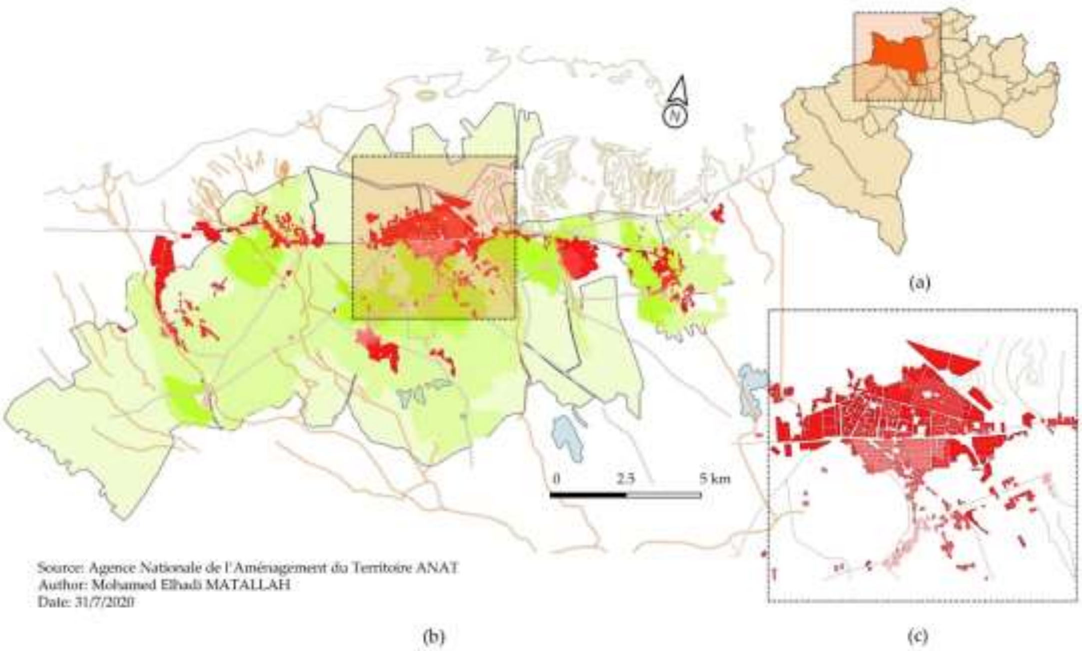


Figure 6.2: *Location of the study area: (a) Biskra Province; (b) Tolga Oases Complex; (c) Tolga city*

Source: *Matallah et al., 2021*

The work is conducted throughout the Tolga Oases Complex territory located in Biskra Province, southern Algeria (Matallah et al., 2020; 2021). Moreover, the chosen multifamily housing neighbourhood represents a typical social residential building, which was taken as a representative model for this study (Table 6.3).

The selected apartment building consists of four storeys. Each level is subdivided into two dwellings with an area of 64 m² approximately for a single family dwelling. The neighbourhood includes, 150 dwellings divided in 11 separate building blocks.

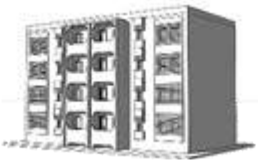
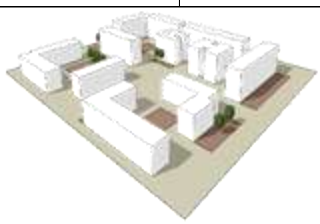
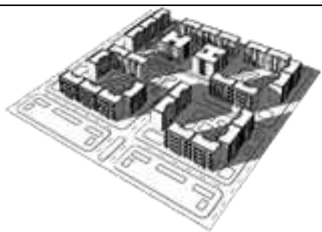
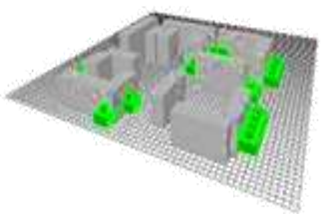
The neighbourhood is located in the centre of Tolga city. It has a typical geometry with separated blocks, endowed uniform height (H = 12.50 m), with a moderate compacity, and a very low built occupancy: 18% (Matallah et al., 2021). The multifamily neighborhood presents a total similarity between shapes, dwellings, and building materials.

It is essential to mention that the site is missing urban vegetation arrangements, where small green surfaces 'grass' and few trees 'Ficus rubiginosa' are spontaneously planted.

The building design has a rectangular form with a close similarity in design proprieties throughout the dwellings' blocks. It is necessary to indicate that the current study focuses specifically on the neighbourhood's spatial configuration than the parametric characteristics and building materials.

Table 6.3: *studied multifamily housing neighborhood urban's configuration*

Source: *Matallah et al., 2021*

Multifamily building's configuration						
Ground plan						
Configuration's model			Buildings are composed of three floors, with a similar hight of 12.50 m 20 % of the building's mass presents the open surfaces 'windows and doors' Built-up occupancy is equal to 18 % compared to the total unbuilt surface			
Building materials properties	Wall		Hollow brick, mortar, plaster		Concrete, mortar	
	Roof		Concrete slab, mortar, polystyrene, plaster			
	Thermal conductivity (W.m²°C)		Hollow brick: 0.48; Concrete: 1.75; plaster: 0.35; mortar: 1.15			
						
		SVF = 0.87		SVF = 0.78		SVF = 0.64
		-		H/W = 1		H/W = 0.89
		SDmax = 15: 30 h		SDmax = 15: 30 h		SDmax = 15: 30 h
ENVI-met modelling parameters	Building	Brick wall (aerated), light wight concrete				
	Soil	Asphalt, Pavement : concrete pavement grey, Natural surface : loamy soil				
	Vegetation	spherical (small trunk. sparse. small (5m)); Grass: 50 cm aver. dense				
3D model						
	Block model (ArchiCAD 22 software)		Architectural model (ArchiCAD 22 software)		Simulation model (ENVI-met 4.4.5 software)	

The conducted site is endowed with several building's shapes (figure 6.3). The building is equivalent to 06 residential blocks (M_1) (including two dwellings in each level). Overall, the multifamily housing neighbourhood includes several adjacent modules that leading to other modules' composition (M_2) (two adjacent buildings).

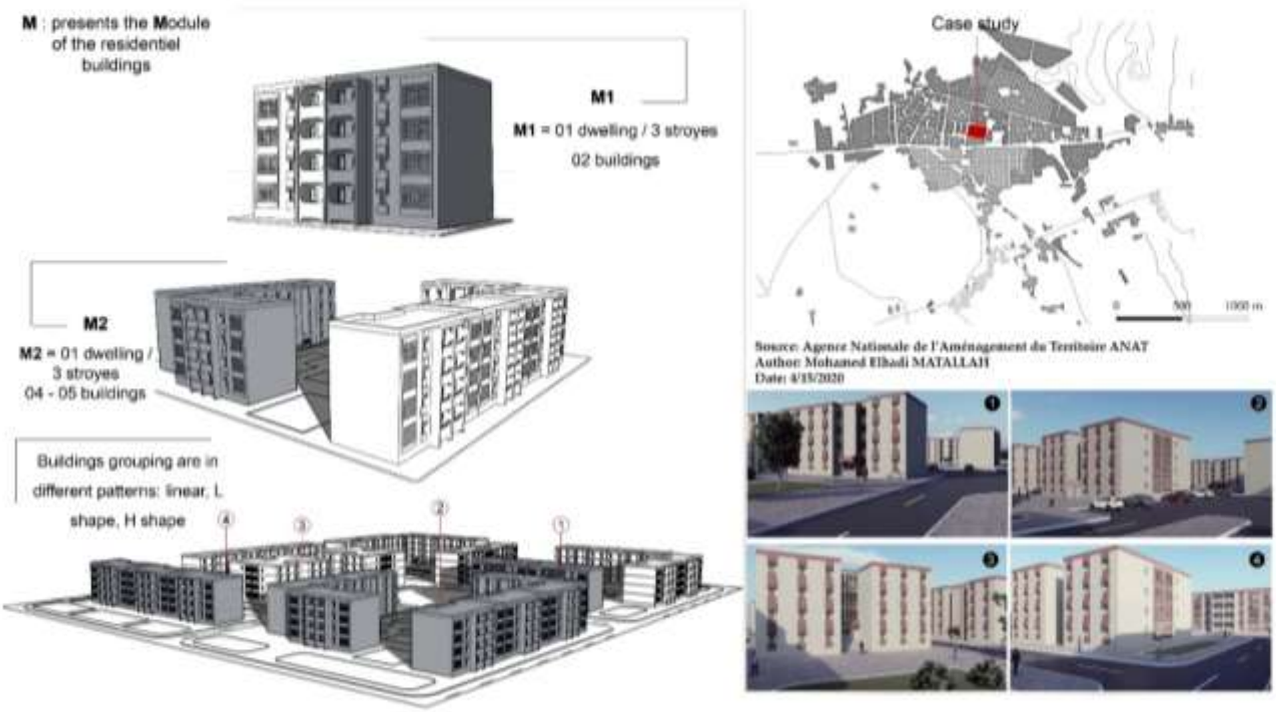


Figure 6.3: *The multifamily housing neighborhood building's shapes and configuration*

Source: *Matallah et al., 2021*

The module or (M)'s items are only illustrated to clarify the spatial configuration throughout the investigated site. As presented, the site represents a common urban geometry for the residential sector specifically for the multifamily housing design in Algeria.

However, building materials are not included in the current study, as well as the contruction details such as doors, windows, claddings, and ledges which could influencing the thermal quality around conducted buildings. It is necessary to indicate that the used building meterials for such neighborhoods' typologies are showing among the lowest thermal efficiency materials, this is implemented by the Algerian urban strategies for the social multifamily housing types.

Furthermore, the construction strategies used materials, shading, and technical systems depend strongly on the national or local context, availability and prices of materials, and climate, traditions, and national building legislation (Roetzel and Tsangrassoulis, 2012).

6.3.4 Simulation model and Outdoor thermal comfort assessment

Possibly the most important input for urban climate simulation in the context of climate change is the choice of weather data.

The current research is based on epw-files generated by Meteonorm 7.2 database (https://meteonorm.com/en/) for TMY weather files and future projections to the year 2080, which were taken from the World Meteorological Organization (WMO) (Moazami et al., 2019).

Meteonorm 7.2 database uses the IPCC Fourth Assessment Report (AR4) as a model to allow the climate change projections. Meteonorm is limited only to three scenarios: A1B, A2, and B1. Meteonorm is widely used for climate change studies. Instead of climate values, the results of IPCC (AR4) results are used as input. The anomalies of parameters temperature, precipitation and global radiation and the three scenarios A1B, A2 and B1 have been included. With the combination of Meteonorm’s current database 1961-1990, the interpolation algorithms and the stochastic generation typical years can be calculated for any site, for different scenarios, between 2010 and 2100 (Remund et al., 2010).

The study outputs are determined using simulation model created in ENVI-met 4.4.5 software (Bruse, 1998, 2004) and RayMan 3.1 Beta (Matzarakis et al., 2007; 2010) calculation model to calculate PT index. The simulated model is calibrated based on monitored data root mean square error (RMSE) and mean bias error (MBE) indices were used to validate the calibration (ASHRAE 14-2014).

The validated model focused on how closely the simulated results match the monitored data. The monitoring was done on 15th and 16th July 2014.

Moreover, for the model’s validation, the simulation needed was running for 48 hours throughout the three measured points inside the conducted site (Table 6.4). The validation was done based on hourly data.

$$\mathrm{RMSE} = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} (\mathrm{Sim}_i - \mathrm{Obs}_i)^2} \qquad \text{(b)}$$

$$\mathrm{MBE} = \frac{1}{n} \cdot \sum_{i=1}^{n} (\mathrm{Sim}_i - \mathrm{Obs}_i) \qquad \text{(c)}$$

We coupled ENVI-met 4.4.5 and RayMan 3.1 Beta to have an accurate calculation of the PT thermal index.

The requested microclimatic outputs are air temperature (T_{air}), relative humidity (R_H), air velocity (V_{air}), and the mean radiant temperature (Tmrt) throughout the three conducted days 15th, 16th, and 17th July. Therefore, only microclimatic outputs of future scenarios were taken, while the TMY outputs were evaluated in the study of Matallah et al. (2021) and mentioned in the (Matallah study report, 2020).

Table 6.4: *Summary of validation of the simulated model in ENVI-met software*

Source: *Matallah et al., 2021*

Neighborhood	Indices	Point 1		Point 2		Point 3	
Multifamily housing	RMSE	2.92	8.75 %	2.98	8.96 %	3.75	10.70 %
	MBE	- 0.36	1.08 %	- 0.44	1.31 %	- 1.99	5.67 %

On the other hand, projections for future weather data induces limitations regarding the level of confidence in the predictions of different climatic variables used in building simulation. It is necessary to indicate that the current study seeks to develop an algorithm (greedy algorithm) (Vince, 2002; Edmonds, 1971) for PT index predictions.

Additionally, the searched algorithm refers only to similar housing typologies, similar climate conditions, same lands (Tolga Oases Complex or Biskra province) and summer season. The different spatial configuration or climate zones will be not able for the application of the generated algorithm.

Accordingly, the algorithm could be used to improve urban design management under extreme weather conditions due to global climate change, notably during the summer season through the arid lands.

Moreover, the algorithm presents a simple equation of variables such as the predictions' years and hours. The algorithm could be applied under programming method in climate software such as ENVI-met, and EnergyPlus databases.

6.4 Results and discussion

This section tried to combine two parts of the analyzed datasets between results and their interpretations. Moreover, results include in particular, the elaboration process of the PT index prediction's algorithm, when the data analysis in these sections shows the points (Tables: 6.5, 6.6, and 6.7) results, where the two other points have the same analysis methods. The final equation of the algorithm is based on all data throughout the three monitored points in the site, and covers the total simulated time.

Therefore, the results and discussion section are divided in two parts: section 3.1 presents the data analysis according to the simulations running and describes all the data obtained within different studied weather scenarios. Section 3.2 focuses on developing the PT index prediction algorithm through a variety of steps: PT index averages analysis, PT index trends' forms, validation of equations, elaboration of the final shape of the algorithm.

6.4.1 Perceived Temperature (PT) index values for the points 01, 02 and 03

Table 6.5: *PT index values in point 01 among three periods: 2020, 2050, and 2080*

Source: *Matallah et al., 2021*

Time	TMY 2020			A1B Scenario 2050			A1B Scenario 2080			A2 Scenario 2050			A2 Scenario 2080			B1 Scenario 2050			B1 Scenario 2080		
	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th
00:00	19.2	21.1	21.2	25.7	26.8	30.3	28	28.4	33.4	24.9	26.6	29.7	27.5	28.9	34.2	23.3	25.5	29.3	24.9	26.3	30.6
01:00	18.6	20.5	20.1	24.3	27.5	29.9	26.2	29.6	33	23.8	27.1	27.9	26.1	29.9	32.3	22.5	25.9	27.1	23.6	26.8	28.3
02:00	18.6	20.1	19.9	23.2	26.8	26.5	27.1	28.6	28	22.8	26	26.2	24.9	29.4	28.7	21.5	24.9	25.2	22.6	26	25.9
03:00	18.2	20.0	19.1	23.4	25.9	27	23.4	28.1	29.7	22.7	25.6	25.2	25.5	28.3	29.5	21.7	24.2	24.8	22.8	25.3	26.3
04:00	17.5	19.4	19.0	22.9	25.5	26.1	24.7	27.3	29	22.4	25.2	25.1	25.1	27.5	28.4	21.5	24	24.2	22.5	25.1	25.6
05:00	17.5	19.2	18.5	21.3	26.7	25.2	22.6	29.4	27.8	21.1	26.8	24.4	23	29	27.8	20.1	24.9	23.6	21	26.1	24.9
06:00	17.8	19.1	18.5	21.8	27.4	24.8	23	29.4	27.2	21	26.8	24.2	23.1	30.1	27.2	20.1	25.7	23.5	21	27	24.5
07:00	19.4	20.7	20.3	21.9	28.4	25.7	22.7	31	27.5	21.6	27.8	24.9	23.2	31.8	28.1	20.8	26.9	24.2	21.6	28.4	25.2
08:00	22.8	23.4	23.1	25.2	29.7	27.6	26.7	32	29.2	24.9	29.6	27.2	26.7	32.4	29.6	24	28.3	26.7	24.7	29.4	27.5
09:00	29.5	28.1	28.3	29.2	33.8	36.6	30.7	35.7	37.6	29.4	33	35.6	30.9	35.6	38.3	28.5	31.5	34.9	29.2	32.8	36
10:00	29.7	30.1	30.5	33.9	34.1	38.2	33.9	36.7	39.7	32.6	34.5	37.1	34.5	36.8	39.2	31.7	33	36.5	32.5	33.9	37.3
11:00	31.0	30.7	31.4	34.4	36.8	39.1	36.2	38.5	41.1	34.3	36	37.9	36	38.1	40.1	32.7	34	37.5	33.5	36.5	38.1
12:00	32.0	31.1	32.2	37.3	37.8	38.2	39.2	39.2	40.5	37	37.7	38.3	38.9	39.2	39.2	36.2	35.7	36.6	36.3	36.6	37.4
13:00	32.6	31.6	32.8	39.2	38.8	39.9	40.6	40.9	40.8	39	37.9	39.5	41.1	39.4	40.1	37.3	36.2	37.5	38.5	37.1	38.2
14:00	34.2	32.2	33.6	38.1	38.5	41	38.9	40.1	42.7	36.7	37.2	40.9	39.5	40.7	41.1	35.1	36.4	38.8	35.9	37.3	39.4
15:00	34.6	33.5	34.3	38.4	38.1	49	40.1	40.4	50.9	38	36.8	46.5	39.7	39.2	49.8	36.6	36.1	45.8	37.4	36.8	46.7
16:00	34.6	33.6	35.2	35.4	43	45.2	35.7	42.7	45.1	34.9	39.5	43.6	36.1	41.8	45.4	33.5	38.5	42	34.2	39.4	42.7
17:00	33.4	32.9	34.5	37	39.6	41.8	40.8	41.4	40.9	36.5	38	41	39.1	40.1	42	35.1	36.7	39.3	36.2	38.2	39.5
18:00	28.4	32.6	33.3	34.5	41	37.7	35.2	38.8	40.4	32.1	38.9	37	33.8	41.6	37.9	30.6	38.1	35.2	30.8	41.4	37.9
19:00	26.9	26.8	27.1	31.9	35.4	32.8	34.5	35.6	34.3	31	34.1	32.6	33.4	36.9	33.4	29.4	33.3	30.9	30.6	34.4	31.6
20:00	23.6	24.0	24.7	29.1	35.7	30.8	29.5	36.1	31.3	28.6	33.9	30.8	30	37.1	32	26.8	32.8	29.4	27.9	33.7	30
21:00	22.5	23.3	24.1	28.2	34.4	32.6	29.7	34.9	35	28.2	33.5	31.9	30	37.3	33.9	26.7	32.4	30.5	27.8	33.9	31.4
22:00	22.1	22.3	23.5	30.4	31.4	31.1	32.7	33.3	31.9	30.1	30.4	30.7	33.3	33.3	31.5	28.5	29.4	29.2	29.8	29.8	30.2
23:00	21.6	21.3	22.7	29.5	31.4	28.1	31.2	34.2	29.4	28.5	30.1	27.8	31.4	33.2	29	27.3	28.9	26.5	28.4	30	27.2

PT (°C)	0 - 20	20 - 26	26 - 32	32 - 38	≥ 38
Thermal perception	Comfortable	Slightly warm	Warm	Hot	Very Hot
Thermo-physiological stress	Comfort possible	Slight heat stress	Moderate heat stress	Great heat stress	Extreme heat stress

PT index values during 2050 showed 05 different thermal zones depending on the human's body thermal perception, which is presenting from the lowest thermal stress to highest respectively: comfortable, slightly warm, warm, hot, and very hot zones.

The three 2050 scenarios presented a close similarity in PT index values averages with: $PT_{2050.ave}$ = 31.6°C; when $PT_{A1B\text{-}2050.ave}$ = 32.6°C, $PT_{A2\text{-}2050.ave}$ = 31.8°C, $PT_{B1\text{-}2050.ave}$ = 30.4°C, hot and warm thermal zones respectively. Otherwise, 2020 average: $PT_{2020\ ave}$ = 25.7°C in the slightly warm thermal zone.

PT index values maximums through all scenarios were: $PT_{2020.max}$ = 35.2°C, $PT_{A1B\text{-}2050.max}$ = 49°C, $PT_{A2\text{-}2050.max}$ = 46.5°C, $PT_{B1\text{-}2050.max}$ = 45.8°C. All of the PT index maximums were registered in point 1, while PTmax.2050 was in the hot thermal zone and $PT_{max.2050}$ was in the very hot thermal zone.

Table 6.6: *PT index values in point 02 among three periods: 2020, 2050, and 2080*

Source: *Matallah et al., 2021*

Time	TMY 2020			A1B Scenario 2050			A1B Scenario 2080			A2 Scenario 2050			A2 Scenario 2080			B1 Scenario 2050			B1 Scenario 2080		
	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th
00:00	19.2	20.9	21.0	25.1	26.6	30.9	27.3	28.5	33.9	24.4	26.3	29.3	26.9	28.6	33.6	22.9	25.2	28.7	24.3	26.7	30
01:00	18.5	20.2	20.9	24.4	27.3	30.4	25.8	29.5	33.5	24	26.6	27.9	26.3	29.4	32.7	22.6	25.4	27.5	23.8	26.6	29.2
02:00	18.4	20.0	20.1	23.2	26.5	27.4	25.4	29.1	29.8	22.7	26	27.7	24.9	28.7	29.7	21.5	24.9	25.2	22.6	25.9	26.4
03:00	17.8	19.5	19.3	23.3	26.4	27.2	25.6	29.2	29.2	23	26	27.2	25.8	29.2	29.1	21.9	24.6	24.7	23.1	26.1	26
04:00	17.3	19.4	19.2	23.3	25.6	26.8	25.7	26.9	28.6	22.7	25.1	27.1	25.5	27.5	29.1	21.6	24	24.5	22.9	25.1	25.7
05:00	16.8	19.2	18.6	21.3	26.3	25.8	22.9	28.6	27.9	20.9	25.7	26.1	23.1	28.8	28.1	19.9	24.5	24	20.9	25.7	25.2
06:00	17.9	19.0	18.5	21.7	26.4	25.3	23.5	28.8	27.8	21.2	26	25.1	23.5	29.1	28.1	20.3	24.7	23.6	21.3	26.2	24.9
07:00	18.9	20.7	20.0	21.6	28.6	26.5	22.9	31.4	28.7	21.2	27.9	25.5	23.3	31.1	29	20.3	26.7	24.7	21.2	28.3	26
08:00	22.5	23.2	23.1	25.1	31	28.2	26.2	32	30.1	25	29.6	27.9	26.5	32.4	30.5	24.1	28.2	26.9	24.9	29.4	28
09:00	25.3	25.4	25.5	29.6	32.3	37.5	31.1	34.3	39	29.2	32.1	34.6	30.9	34.9	38.7	28.1	31.1	35.2	29	32.1	36.2
10:00	26.4	27.1	27.3	33	35.1	38.4	34.9	37.8	39.1	32.6	35.3	41.5	34.5	38	38.4	31.2	33.8	36	32.1	34.8	36.8
11:00	27.7	28.2	28.8	34	37.4	41	35.5	39.5	43	33.1	35.9	40.8	35.8	38.5	40.1	32.1	34.8	39	33.8	36.1	39.9
12:00	29.2	29.1	32.5	34.8	37.6	40.8	36.7	38.6	41.8	35.3	36.5	43.2	36.9	38	40.8	33.7	35.1	38.7	34.8	36	40
13:00	32.8	31.7	32.7	38.4	39.5	41.1	40.8	41.5	41	37.4	39.3	43.9	39.7	40.8	42.2	35.8	37.4	39.2	37	38.4	40
14:00	33.9	32.7	33.7	39.5	38.5	43.2	41.5	40.3	42.7	39	37	45.5	40.9	39.4	43.4	37.3	36.4	40.5	37.8	37.3	41.2
15:00	34.1	33.6	34.4	40.4	37.8	47.7	42.3	39.1	49.6	39.6	36.8	43.4	42.3	38	47.4	38.1	34.9	43.7	39.1	35.8	45.3
16:00	30.3	30.0	32.3	34.5	42	43.7	35.1	41.9	46.7	35.6	39.5	43.5	36.4	42.3	46.6	33.7	39.3	42.3	34.5	40.5	45.1
17:00	29.8	29.8	30.6	37	38.6	41.9	39.2	38.7	41.3	35.3	37	41.7	38.1	39.4	42.9	33.7	36.4	39.8	34.8	37.3	40.5
18:00	28.2	28.5	29.4	31.6	39	40	33.5	41.3	42.2	30.7	37	43.1	32.2	38.4	40.1	29.3	35.1	36.7	30.2	36.1	37.6
19:00	27.3	26.8	27.8	32.7	34.6	34	36	36.2	34.2	32	33.1	34	34.8	34.5	33.9	30.2	31.3	31.3	31.4	32.3	32.1
20:00	24.2	24.3	25.3	30.1	36	31.9	32.3	39.1	32.5	29.6	34.8	31.8	31.5	38.3	32.6	27.8	33.6	29.8	29.4	34.7	30.5
21:00	22.9	23.5	24.9	29.2	33.5	35	31.5	35.6	38.6	28.6	34.5	34.7	30.7	38.8	37.5	27.1	33.6	33.1	28.2	35.6	34.4
22:00	22.6	22.3	24.5	31	31	32.4	33.3	32.5	34.3	29.9	30.2	33.3	33.2	32.3	32.5	28.7	28.6	30.1	30	29.8	31.2
23:00	21.8	21.7	23.3	29.3	31.7	29.6	31.1	33.3	31.3	28.3	30.8	30	31.2	34.1	30.3	27.1	29.3	27.4	28.2	30.7	28.2

PT (°C)	0 - 20	20 - 26	26 - 32	32 - 38	≥ 38
Thermal perception	Comfortable	Slightly warm	Warm	Hot	Very Hot
Thermo-physiological stress	Comfort possible	Slight heat stress	Moderate heat stress	Great heat stress	Extreme heat stress

PT index values minimums during all scenarios were: $PT_{2020.min}$ = 16.8°C in point 2, $PT_{A1B\text{-}2050.min}$ = 21.2°C, $PT_{A2\text{-}2050.min}$ = 20.9°C, and $PT_{B1\text{-}2050.min}$ = 19.9°C in point 3. While, $PT_{min.2020}$

and $PT_{min.B1-2050}$ presented a comfortable thermal zone, otherwise, $PT_{min-2050}$ for A1B and A2 scenarios are in the slightly warm thermal zones.

The variation in thermal zones' duration was significant and apparently through 2020 and 2050 scenarios, where the comfortable thermal was between 0:00 a.m. to 7:00 a.m. in 2020, however, 2050 showed one hour of comfort zone in 5:00 a.m. for one day exclusively in B1 scenario. Furthermore, the heat stress zones occupied all conducted days' hours in 2050, which are balanced between slightly warm, warm, hot and very hot thermal zones. The very hot thermal zone was registered among daytime hours between 10:00 a.m. to 6:00 p.m. however, 2020 has not a very hot thermal zone.

Table 6.7: *PT index values in point 03 among three periods: 2020, 2050, and 2080*

Source: *Matallah et al., 2021*

Time	TMY 2020			A1B Scenario 2050			A1B Scenario 2080			A2 Scenario 2050			A2 Scenario 2080			B1 Scenario 2050			B1 Scenario 2080		
	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th	15th	16th	17th
00:00	18.9	20.7	20.8	27.1	27	29.9	28.8	29.5	32.4	25.6	26.6	29.3	28.8	29.2	32.4	23.6	25.3	28	25.4	26.4	29.2
01:00	18.2	20.2	21.2	26.1	26.9	28.4	29	28.8	31.2	25.7	26.3	27.9	29.1	29.1	30.7	24	25.2	26.4	25.5	26.2	27.7
02:00	18.3	19.6	19.5	24.1	27.6	28.7	26.5	30.5	31.9	23.5	27.3	27.7	26.3	30.7	32.1	22.2	26.1	26.5	23	27.2	28.1
03:00	18.1	19.2	19.4	24.7	27.2	28.6	26.7	30	31.3	24.2	26.7	27.2	27	30.4	31.6	22.8	25.1	26	24.2	26.7	28
04:00	18.0	19.4	19.0	23.9	25.4	28.2	25.9	26.9	30.7	23.4	25.1	27.1	26.3	27.4	31.8	22.5	23.9	26	23.3	25.1	27.2
05:00	17.0	19.1	18.7	21.2	25.9	27.3	22.8	28.1	29.8	20.9	25.3	26.1	23.1	28.2	30.7	19.9	24.1	25.2	20.9	25.2	26.6
06:00	18.1	18.8	18.5	22.1	26.2	25.5	23.9	28.6	27.2	21.9	25.6	25.1	24	28.7	27.4	21.1	24.6	24.1	22	25.8	24.9
07:00	18.9	19.9	20.3	21.6	29.7	26	22.8	33.5	27.6	21.3	29.3	25.5	23.2	34	27.8	20.4	28	24.5	21.3	29.2	25.5
08:00	22.0	23.2	23.0	25.1	31	27.8	26.9	34.6	29.4	25.1	30.6	27.9	27.2	35	29.7	24	29.6	26.9	24.9	30.5	27.7
09:00	24.8	25.4	25.6	29.7	33.5	39	31.7	36	41	28.4	32.8	34.6	30.8	35.2	38.4	27.4	31	32.2	28.3	32.3	35
10:00	26.4	27.7	27.7	35.8	37.7	42.7	38.2	40.8	44.2	34.2	37	41.5	37.4	40.5	41.4	32.6	35.6	36.9	33.2	36.2	38.4
11:00	27.9	28.2	29.4	38.4	41.3	44.3	41	44.2	44.6	36.8	40	40.8	39.6	43.7	44.2	34.9	37.7	39.7	36.1	39.3	40.9
12:00	31.7	31.0	32.7	34.8	38.3	45	36.5	40.4	47.3	34.5	37.5	43.2	35.7	39.2	46.6	32.9	35.7	42.5	33.8	36.6	43.6
13:00	32.8	31.5	33.4	36.7	42.2	44.6	38.5	46.2	46.7	36.3	40.3	43.9	38	44.7	45.7	34.7	40.5	41.8	35.9	40.2	41.6
14:00	33.6	32.6	34.1	39.7	39.2	46.2	41.9	40.9	46.7	39.4	37.4	45.5	41.4	38.6	47.3	37.6	37.5	43.2	38.2	37.3	44.1
15:00	30.3	30.7	32.3	39.7	38.1	44.3	42.9	40.2	46.3	40.3	37.5	43.4	41.4	38.9	44.6	37.5	35.5	41.2	39.6	35.2	42.3
16:00	30.3	30.2	31.8	35	43.9	43.5	36.9	46.3	46.7	34.8	42	43.5	36.1	45.6	45.3	33	41	41.6	33.5	42.3	42.6
17:00	29.8	29.8	31.3	35.4	39.9	42.6	37.6	42.3	44.6	35.2	37.6	41.7	36.7	40.6	43.2	33.1	36.8	39.6	34.2	38.1	39.2
18:00	28.7	28.5	30.0	34.8	36.9	44	37.2	38.8	46.5	34	37	43.1	36.7	38.4	45.7	32.2	35.1	40.7	33.3	36.1	42.1
19:00	27.2	27.4	28.3	34.4	33.6	34.3	37.3	35.2	34.6	33.2	33.1	34	36	34.5	34.9	31.4	31.3	32.2	32.6	32.3	33
20:00	24.4	24.7	25.8	31.1	38.7	32.1	32.4	41.8	32.8	30.4	36.9	31.8	33.1	40.9	33.5	28.6	35.5	30.2	29.2	36.9	30.9
21:00	23.0	23.9	25.2	29.7	37.3	36.4	31.9	41.4	39.2	29.1	36.1	34.7	31.5	40.6	38.4	27.5	35.2	33.9	28.9	35.9	35.1
22:00	22.3	22.8	24.7	29.2	31.7	33.9	32	33.9	35.9	28.5	31.4	33.3	31.5	34.5	35.4	27.2	29.8	31.5	28.7	30.3	33
23:00	21.7	22.3	23.0	28	34	30.4	30.2	37	32.3	27.4	33	30	29.9	37.4	31.6	25.9	31.3	28.3	27.3	32.4	29.2

PT (°C)	0 - 20	20 - 26	26 - 32	32 - 38	≥ 38
Thermal perception	Comfortable	Slightly warm	Warm	Hot	Very Hot
Thermo-physiological stress	Comfort possible	Slight heat stress	Moderate heat stress	Great heat stress	Extreme heat stress

Results showed a significant elevation on PT averages between 2020 and 2050, with a difference of (+ 5.9°C). Apparently, the A1B presented the hottest period across all scenarios, where point 1 was all time the thermal stressful place.

In comparison to all PT index values in the previous periods, 2080 scenarios showed four different thermal zones, which were: slightly warm, warm, hot and very hot thermal zones.

PT index averages were more elevated versus 2050 scenarios, when $PT_{2080.ave}$ = 33.4°C; $PT_{A1B\text{-}2080.ave}$ = 34.5°C, $PT_{A2\text{-}2080.ave}$ = 34.2°C in the hot thermal zone, and $PT_{B1\text{-}2080.ave}$ = 31.5°C in the warm thermal zone.

On the other hand, the PT index maximums of the 2080s three scenarios presented a slight elevation comparing to 2050 scenarios (+ 1.9°C) and a significant elevation to 2020 (+ 15.7°C), while $PT_{A1B\text{-}2080.max}$ = 50.9°C, $PT_{A2\text{-}2080.max}$ = 49.8°C, and $PT_{B1\text{-}2080.max}$ = 46.7°C, all the values were registered in point 1 included in the very hot thermal zone.

Otherwise, PT index minimums were: $PT_{A1B\text{-}2080.min}$ = 22.6°C in point 1, $PT_{A2\text{-}2080.min}$ = 23°C in point 1, and $PT_{B1\text{-}2080.min}$ = 20.9°C in points 2, 3, which were in the slightly warm thermal stress. Thus, $PT_{2080.min}$ does not show any comfort thermal's zone.

The elevation of the thermal heat stress levels was significant through the 2080 scenarios. It appeared with a long duration of warm, hot, and very hot thermal zones among the day hours, while this last was concentrated in a large duration of midday hours between 9:00 a.m. to 6:00 p.m. Moreover, A1B and A2 scenarios showed the heat stressful periods compared to the B1 scenario (figure 6.4).

Therefore, the difference on the PT index averages obtained significantly enlarged comparably to the 2020 period (+ 7.7°C) and slightly to 2050 (+ 1.8°C), where point 1 was the highest heat stressful place.

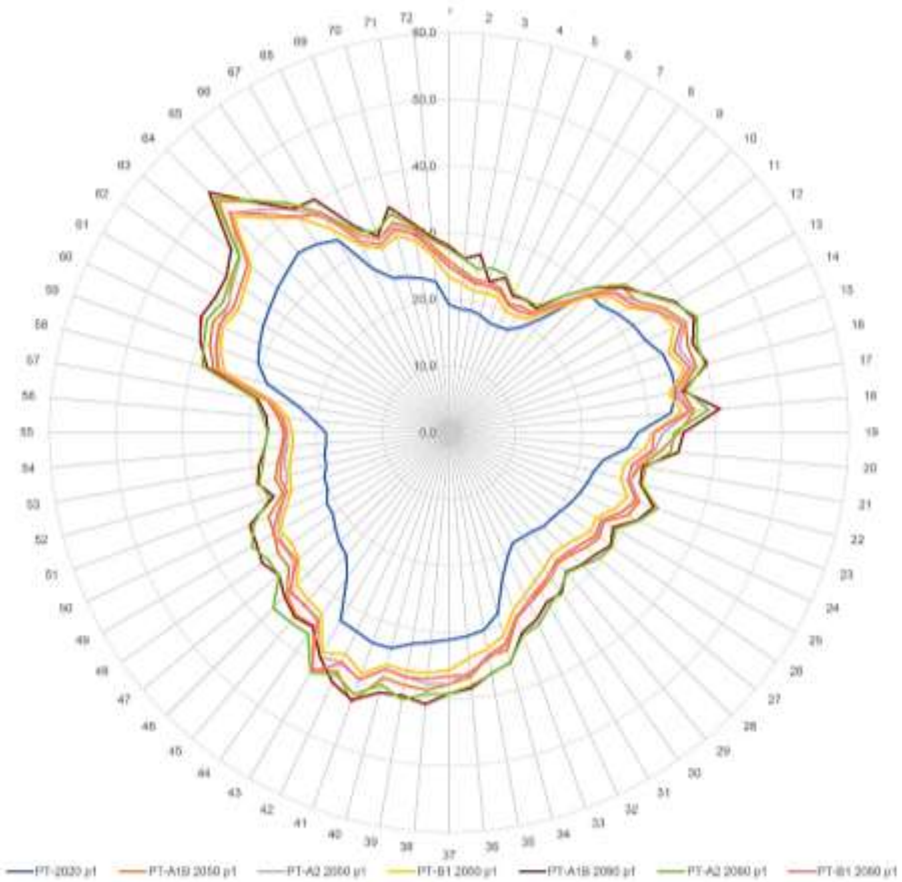


Figure 6.4: *PT index values evolution during all the studied periods*

Source: *Matallah et al., 2021*

Algorithm process datasets

In these insights, we allowed to formulate a type of hourly-yearly predictions' equation (P-eq) of PT index according to the specific measured days, and basically performed on simulated results. Thus, mainly based on PT index averages in all periods' scenarios 2020, 2050 and 2080 within the three points, the equation is built within several stages deeply explained in the recurring sections' steps (figure 6.5):

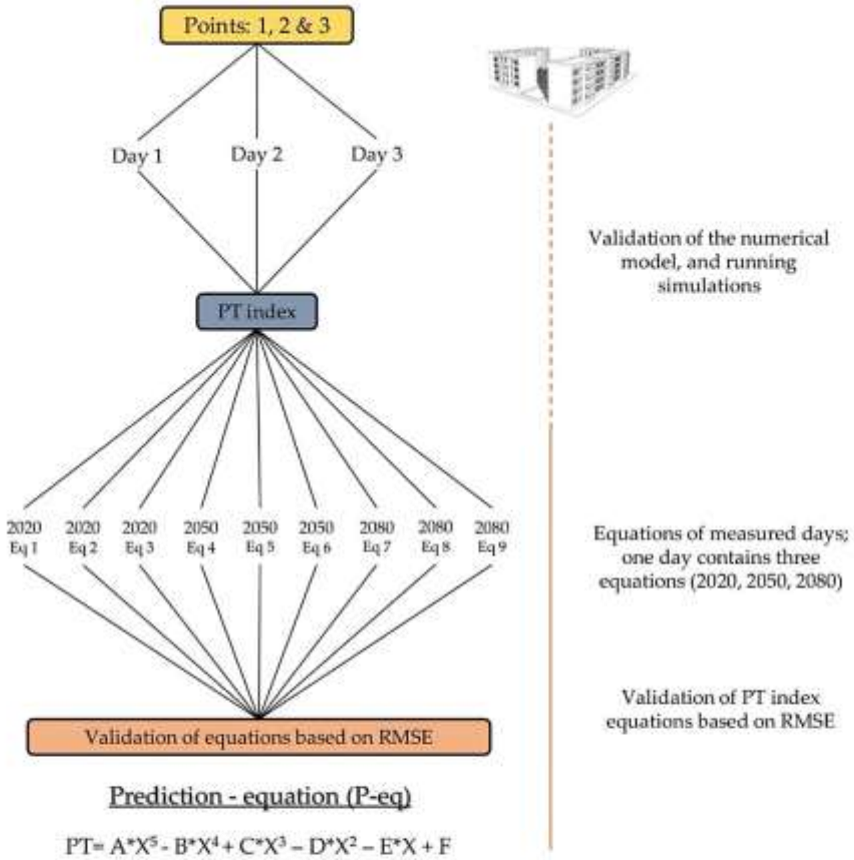


Figure 6.5: *Workflow steps of the PT thermal index predictions algorithm*

Source: *Matallah et al., 2021*

Firstly, we calculated PT averages for 2020, 2050 and 2080 of all scenarios (A1B, A2, B1) based on the data simulation process. Otherwise, for the next presenting data are only for the first point (15^{th} 16^{th} and 17^{th} July) to be related to previous data. (Figure 6.6) and (Table 6.8) presents PT averages' curves of each period separately in point 1, where 2020: S1, 2050: S2, and 2080: S3.

Table 6.8: *PT index averages in point 01 for three days among three periods: 2020, 2050, and 2080*

Source: *Matallah et al., 2021*

Time	2020 July 15^{th}	2050 July 15^{th}	2080 July 15^{th}	2020 July 16^{th}	2050 July 16^{th}	2080 July 16^{th}	2020 July 17^{th}	2050 July 17^{th}	2080 July 17^{th}
0 :00	19.2	24.6	26.8	21.1	26.3	27.9	21.2	29.8	32.7
1 :00	18.6	23.5	25.3	20.5	26.8	28.8	20.1	28.3	31.2
2 :00	18.6	22.5	24.9	20.1	25.9	28.0	19.9	26.0	27.5
3 :00	18.2	22.6	23.9	20.0	25.2	27.2	19.1	25.7	28.5
4 :00	17.5	22.3	24.1	19.4	24.9	26.6	19.0	25.1	27.7
5 :00	17.5	20.8	22.2	19.2	26.1	28.2	18.5	24.4	26.8

6 :00	17.8	21.0	22.4	19.1	26.6	28.8	18.5	24.2	26.3
7 :00	19.4	21.4	22.5	20.7	27.7	30.4	20.3	24.9	26.9
8 :00	22.8	24.7	26.0	23.4	29.2	31.3	23.1	27.2	28.8
9 :00	29.5	29.0	30.3	28.1	32.8	34.7	28.3	35.7	37.3
10 :00	29.7	32.7	33.6	30.1	33.9	35.8	30.5	37.3	38.7
11 :00	31.0	33.8	35.2	30.7	35.6	37.7	31.4	38.2	39.8
12 :00	32.0	36.8	38.1	31.1	37.1	38.3	32.2	37.7	39.0
13 :00	32.6	38.5	40.1	31.6	37.6	39.1	32.8	39.0	39.7
14 :00	34.2	36.6	38.1	32.2	37.4	39.4	33.6	40.2	41.1
15 :00	34.6	37.7	39.1	33.5	37.0	38.8	34.3	47.1	49.1
16 :00	34.6	34.6	35.3	33.6	40.3	41.3	35.2	43.6	44.4
17 :00	33.4	36.2	38.7	32.9	38.1	39.9	34.5	40.7	40.8
18 :00	28.4	32.4	33.3	32.6	39.3	40.6	33.3	36.6	38.7
19 :00	26.9	30.8	32.8	26.8	34.3	35.6	27.1	32.1	33.1
20 :00	23.6	28.2	29.1	24.0	34.1	35.6	24.7	30.3	31.1
21 :00	22.5	27.7	29.2	23.3	33.4	35.4	24.1	31.7	33.4
22 :00	22.1	29.7	31.9	22.3	30.4	32.1	23.5	30.3	31.2
23 :00	21.6	28.4	30.3	21.3	30.1	32.5	22.7	27.5	28.5

The trend curves of each period indicated a significant increase on PT index averages during time; however, the early morning hours showed a common resemblance on PT values. In the basis of the trend curves of the first day, the regression's equation R^2 of periods was extracted separately, which defined a long duration time enlarged between 9:00 a.m. to 7:00 p.m (Figure 6.6).

In other hand, the obtained differences (diff) on PT index values from 2020 to 2080 were progressively elevated over time (Table 6.9). The highest difference registered between 2020 and 2050 was PT_{diff} = 8.7°C specifically in the point 03 at 17th July, whereas this difference was more higher between 2020 and 2080 with PT_{diff} = 10.6°C in the same point and same conducted day. Otherwise, the point 01 showed the minimum values of PT_{diff} with: 3.8°C and 5.3°C at 15th July between 2020-2050 and 2020-2080 respectively. The elevation on PT index differences refered to the impact level of climate change on the outdoor thermal comfort in the study context in summer which was very significant elevaltion.

Table 6.9: *Difference values of PT index between 2020 - 2050 and 2020 - 2080 for days 15th, 16th and 17th July*

Source: *Matallah et al., 2021*

Points & days	P1D1	P1D2	P1D3	P2D1	P2D2	P2D3	P3D1	P3D2	P3D3
$PT_{diff\ 2020\text{-}2050}$ (°C)	3.8	6.4	6.5	4.6	7.0	7.8	5.2	8.0	8.7
$PT_{diff\ 2020\text{-}2080}$ (°C)	5.3	8.2	8.1	6.4	8.9	9.5	7.0	10.2	10.6

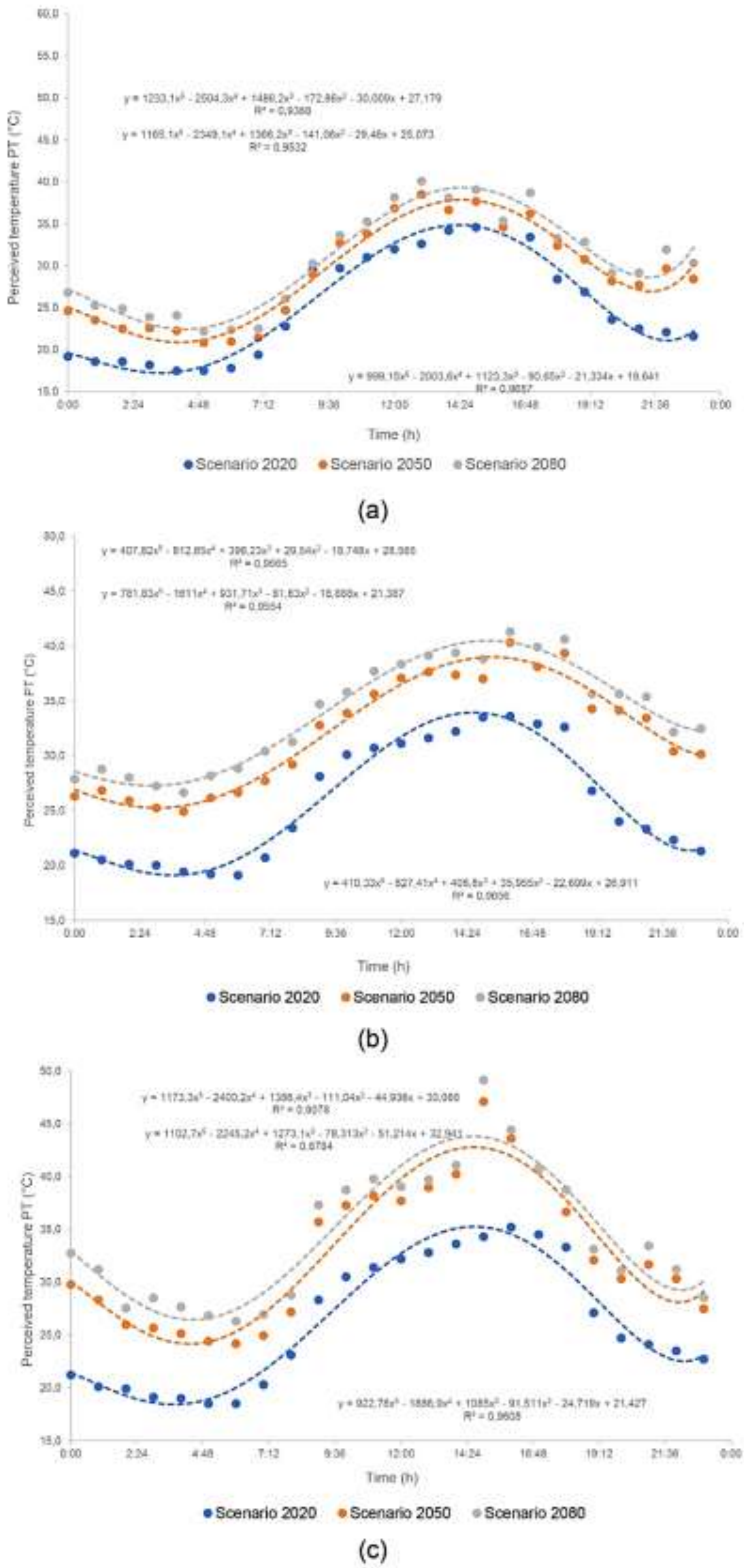


Figure 6.6: *PT index averages' variations during three days among: 2020, 2050 and 2080 in point 01: (a) 15th July; (b) 16th July; (c) 17th July*

Source: *Matallah et al., 2021*

15th July 2020- eq:

$$Y = 999.15 \cdot X^5 - 2003.6 \cdot X^4 + 1123.3 \cdot X^3 - 90.65 \cdot X^2 - 21.334 \cdot X + 19.641 \quad (1)$$

$$R^2 = 0.9657$$

16th July 2020-eq:

$$Y = 781.83 \cdot X^5 - 1611 \cdot X^4 + 931.71 \cdot X^3 - 81.63 \cdot X^2 - 18.888 \cdot X + 21.387 \quad (2)$$

$$R^2 = 0.9554$$

17th July 2020-eq:

$$Y = 922.78 \cdot X^5 - 1886.9 \cdot X^4 + 1085 \cdot X^3 - 91.511 \cdot X^2 - 24.719 \cdot X + 21.427 \quad (3)$$

$$R^2 = 0.9608$$

Where (Y) are the PT index values, and (x) is the assessed hour. Even more, this operation is proceeded similarly for all the measured days (July 15th, 16th and 17th), and for the other monitored points.

Trends for 2020 in the three days showed a complex diurnal increase between 9:00 a.m. to 7:00 p.m. (equations: 1, 2, 3), where the highest regression was obtained on day 1 (Figure 6.6). Furthermore, trends for 2050, and 2080 scenarios for the three assessed days differed marginally depending on day hour (Figure 6.6), and indicated an increase in PT values comparing to the previous period of 2020 (equations: 4, 5, 6, 7, 8, 9).

15th July 2050-eq:

$$Y = 1165.1 \cdot X^5 - 2349.1 \cdot X^4 + 1366.2 \cdot X^3 - 141.06 \cdot X^2 - 29.46 \cdot X + 25.073 \quad (4)$$

$$R^2 = 0.9532$$

16th July 2050-eq:

$$Y = 410.33 \cdot X^5 - 827.41 \cdot X^4 + 406.8 \cdot X^3 + 35.955 \cdot X^2 - 22.699 \cdot X + 26.911 \quad (5)$$

$$R^2 = 0.9656$$

17th July 2050-eq:

$$Y = 1173.3 \cdot X^5 - 2400.2 \cdot X^4 + 1386.4 \cdot X^3 - 111.04 \cdot X^2 - 44.936 \cdot X + 30.068 \quad (6)$$

$$R^2 = 0.9078$$

15th July 2080-eq:

$$Y = 1233.1 \cdot X^5 - 2504.3 \cdot X^4 + 1486.2 \cdot X^3 - 172.89 \cdot X^2 - 30.009 \cdot X + 27.179 \quad (7)$$

$$R^2 = 0.9368$$

16th July 2080-eq:

$$Y = 407.82 \cdot X^5 - 812.85 \cdot X^4 + 398.23 \cdot X^3 + 29.54 \cdot X^2 - 18.748 \cdot X + 28.565 \quad (8)$$

$$R^2 = 0.9665$$

17th July 2080-eq:

$$Y = 1102.7 \cdot X^5 - 2245.2 \cdot X^4 + 1273.1 \cdot X^3 - 78.313 \cdot X^2 - 51.214 \cdot X + 32.941 \quad (9)$$

$$R^2 = 0.8784$$

In order, based on equations from the precedent section of all scenarios we needed to search about equations which includes new form of variables (correction factors) and gathered all the previous equations' scenarios, so far to create a unique equation for the total equations of the prediction's formula. Therefore, we are presenting only the first day (15th July) an example in this study, however the final prediction's equation is enlarged within the three studied days which are typical days for summer season.

Furthermore, the implemented correction factors: A, B, C, D, E, F, are named for the regression equation of the prediction's equation. All the previous regression equations need to be formulated similarly as the equation (10). Thus, the formulas of the correction factors were extracted below :

$$A = 2.3395 \cdot y - 3663.5 \quad (10)$$

$$B = 5.007 \cdot y - 7978.7 \quad (11)$$

$$C = 3.6291 \cdot y - 6114.2 \quad (12)$$

$$D = 0.8221 \cdot y - 1550.4 \quad (13)$$

$$E = 0.0867 \cdot y - 150.9 \quad (14)$$

$$F = 0.0754 \cdot y - 130.56 \quad (15)$$

Where (y) presents the prediction's year.

Accordingly, the prediction's equation of the PT index for the first day (15th July) through the point 01 was formulated within the equation :

$$PT = A \cdot X^5 - B \cdot X^5 + C \cdot X^3 - D \cdot X^2 - E \cdot X^1 + F \quad (16)$$

Where (X) presents the predictions hour.

In order, we needed in total 27 prediction's equation for three days throughout three points for all different scenarios 2020, 2050, and 2080. We validated the accurate prediction's equation on the basis of RMSE, which present the first equation's scenarios for point 01 as the favourite formula for the total predictions within different emission scenarios (Table 6.10). Therefore, the algorithm is mathematically generated based on the selected predictions' equation among the validation method.

Table 6.10: *Summary of the validation of PT index equations based on RMSE*

Source: *Matallah et al., 2021*

Points and days	RMSE
P1-Day1	1.423
P1-Day2	1.457
P2-Day1	1.475
P2-Day2	1.579
P3-Day1	1.680
P3-Day2	2.092
P2-Day3	2.108
P1-Day3	2.111
P3-Day3	3.001

Accordingly, an accurate validation equation that presents the lowest RMSE value was taken from the first prediction's equation in point 01 during the first day (15^{th} July). It is necessary to refer that the PT index prediction's algorithm is generated for specific conditions: climate zone (BWh), period (July: extreme heat month), typical housing neighborhoods (multifamily housing) to provide a close hourly-yearly predictions of PT index in the study area.

It is imperative in this stage to draw a workflow for the numerical algorithm obtaining under the following of several steps which should be added to any numerical database. The process is containing intputs sets such as the hour and the predicted year, otherwise the outputs which are the PT index values are merely calculated (Figure 6.7). Futhermore, prediction's algorithm will be able only for same climate zone, same urban form, and same duration, in the other hand the generated algorithm will be enable to predict PT index. Otherwise, the algorithm can be enlarged for different climate zones, on the basis on new simulations depending to climate conditions.

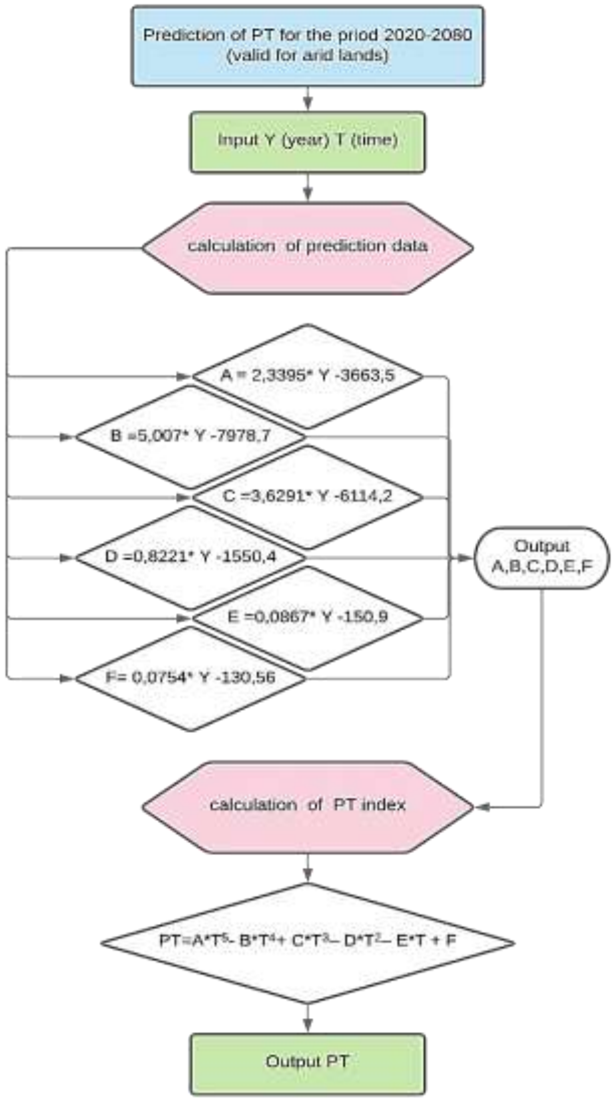


Figure 6.7: *Framework of PT index predictions algorithm from inputs to outputs*

Source: *Matallah et al., 2021*

6.5 Findings and recommendations

The study shows a gradual increase in PT index values, beginning from 2020 and progressively elevated to 2080 during the hot season, and refers to an extreme thermal heat stress level.

The difference in PT index averages at the hot season between 2020 and 2050 was (+5.9°C), and 2080 (+7.7°C), which means a change from the slightly warm thermal stress zone to warm and hot thermal stress zones respectively, due notably to the predicted climate change according to (AR4).

Surprisingly, no comfortable thermal stress zone was found during the 2080 period. However, only one comfortable hour was found at 2050 within two points 02 and 03, otherwise, the comfortable thermal zone represented 25% of the daily thermal stress level during the hot season in 2020. The thermal stress elevation is likely due to climate changes and their significant impact on arid lands.

As expected, climate change has an important impact on thermal stress through outdoor places without shading arrangements or spaces with big SVF degrees. Most unfavourable places are exposed for a long time to sun. Otherwise, the multifamily housing is representing a vulnerable urban form against climate changes in the long-term.

Interestingly, the highest increase in future thermal heat stress was found by A1B scenario which is characterized by rapid demography and a balance on the energy sources use. This increase is occurred inside different spatial configurations of the multifamily housing categories.

Moreover, in the summer season the hot thermal stress zone is enlarged during the day from 8:00 a.m. to midnight, while the very hot thermal stress zone is more enlarged during the daytime hours for 09 hours between 9:00 a.m. till 6:00 p.m. Otherwise, no very hot thermal stress zone was showed in the first period of 2020, whereas the hot thermal stress zone presented 05 hours in the daytime from 12:00 p.m. to 5:00 p.m.

It is also interesting to develop a greedy algorithm for the PT thermal index predictions, typically for the multifamily housing sector, whereas the outputs related to the algorithm are required hourly-yearly values in the same time.

6.5.1 Strength and limitations

The strength of this study is mainly due to its combination between empirical and numerical approaches to quantify the outdoor thermal comfort within an oasis territory in the arid lands. Furthermore, the current study provides new findings of outdoor thermal comfort predictions in the arid climate, basically on long-term evaluation within current time and future climate change scenarios.

None of the previous studies have investigated the predictions of outdoor thermal comfort or long-term weather patterns, specifically inside the oases settlements in arid climate using TMY and (AR4) datasets.

Consequentially, the study outcomes are considered key findings for outdoor thermal comfort predictions and redevelop them to cover all climate zones in the country. Findings are basically related to the study context but could be strongly enlarged following the same methods and approaches for different climate and urban forms.

The long-term overheating in arid lands is critical to the human body and has a significant impact on resident’s well-being, productivity, and satisfaction. Despite with climate change and the recurring heatwaves, human health in oases settlements can be subject to increases in morbidity and mortality.

This study focused on quantifying the physical heat by measuring and modelling urban thermal comfort during extreme summer climatic conditions. We hope that our findings can be coupled to epidemiological analysis to estimate the socio-economic impact of heat stress on oases inhabitant and tourism activities. The outcomes indicate the urgency of providing an integrated outdoor spaces design procedure to relieve heat stress in arid lands the long-term.

The algorithm allows numerical software used for urban climate studies several thermal stress scenarios on the basis of PT index for short and long-term patterns. Thus, it is necessary to indicate that the generated algorithm is mathematically able to be applied in different software's databases such as ENVI-met, Grasshopper, EnergyPlus.

On the other hand, our study has few limitations. The most important limitation is the use of only one urban housing archetype. Even though the used multifamily housing archetype represents Algeria's dominant household typologies, single-family households represent a large part of the residential building stock.

Moreover, the study focused only on the hot period, otherwise the research could have benefited from a longer monitoring period (one year or more) to assess the thermal comfort changes all the year, also to predict the heat stress overall seasons. The predictions are limited only on one climate zone (BWh), one geographical context (Tolga Oases Complex, Biskra province) or similar area, which means that the generated algorithm cannot be applied for other climate zones as well as different regions.

In fact, we should indicate that at the begining of the predictions we carried two thermal indices: PT index and PET index, however this last has given us wrong thermal readings as well as no correlations was founded to generate the algorithm. We supposed that PET index values are not suitable at this time by the use of IPCC projections (2050 and 2080 scenarios) which are simulated under ENVI-met software. In the other hand, on the basis of the same simulated datasets PT index has provided an encouraging outcomes in terms of values and correlations. Further predictions studies must mathematically improve thermal indices' calculations using TMY future weather data to allow multi-possibilities of long-term weather patterns investigations.

6.5.2 Implication on practice and research

This study allows urban climate researchers, architects, designers and urban planners several insights into predicted climate circumstances and their impacts on outdoor thermal comfort for the long-term under extreme weather conditions. Furthermore, the predicted results should be considered according to the large value on thermal stress changes within the following years. Natural ventilation or increasing the airflow, and improving outdoor shading are essential in the oasis urban fabric. Thermal predictions allow future designers to react to climate change better and think the best fit for climate adaptations, strategies, and solutions to design and implement comfortable and efficient urban planning designs.

We believe that numerous solutions attempt for heat stress reduction and cooling energy savings were developed through the worldwide arid regions. Such as, the incorporation of PCMs in the built environment especially among the residential sector (Sovetova et al., 2019; Wahid et al., 2017). This method can reduce the indoor temperature during the summer months by up to 2.04°C and cooling energy savings up to 40.43 kWh (Memon, 2014), which could be beneficial for the external spaces as well. Hence, the utilization of PCM must be supported by dense external shading to benefit from the outdoor thermal heat stress balance and the cooling energy savings as well (Nematchoua et al., 2020). In this case, for future urban projects, the buildings' orientation is crucial, and representative buildings' shells composition should be chosen to reach the optimum PCM (Wahid et al., 2017).

The Human thermal indices need to be improved and applied in microclimatic predictions. This study highlights the biometeorological studies to promote a new process of outdoor thermal comfort long-term predictions among the worldwide climate zones and inside different urban contexts.

The Algerian government, especially the Ministry of Urban Planning and Housing as well as the Ministry of Environment, may do an in-depth review regarding the built environment and the future strategies in urban housing against extreme weather conditions changing, notably in the arid lands, which became more and more vulnerable during the time. Additionally, we believe that not architects or urban experts are only concerned by this study climate scientists and especially for the meteorological fields. We can enormously benefit from our key findings to see beyond the climate change impacts and predict the short and long-term conditions.

6.6 Conclusion of the chapter

In this study, the predictions of the outdoor thermal comfort through an urban housing archetype in the Tolga Oases Complex were investigated during different weather conditions (TMY) and (AR4) scenarios. These were used to better understand in predicting the impact of urban housing archetypes on the outdoor thermal comfort in arid climate for the long-term.

Although, the study investigated the evolution of the heat stress levels in the middle of an urban housing neighbourhood which is representative of the most urban residential typology in Algeria. The outdoor thermal comfort assessment is done in a long-term period (60 years), and basically using PT thermal index.

According to the results, climate change has a large impact on the outdoor thermal quality for upcoming years, and PT index values show a high elevation on heat stress during the hot season when the comfortable thermal zone is decreasing from 25% in 2020 to 1% in 2050 and 0% in 2080.

The suite of the study was the generation of an algorithm essentially for the PT index predictions in the near-term, medium-term and long-term future for extreme conditions in relation to the investigated climate zone, urban housing archetype, and the conducted period. Accordingly, the algorithm could be enlarged to cover several climate zones, during all seasons and for multi-urban forms.

The focus of this paper was on the impacts of future long-term climate change conditions on the outdoor thermal comfort within a multifamily residential neighbourhood. Future work should be undertaken using different climate zones in Algeria, as well as all seasons to study the thermal stress upon cities' inhabitants in all the country over the year.

Otherwise, our research provided further evidence that proper weather datasets based on high-resolution data from climate models and climate scenarios are required to empower urban planners and architects to test their design solutions under future climate uncertainties, especially in the arid climate.

Furthermore, outcomes present guidelines for landscape and urban designers who want to build thermally comfortable outdoor climates for these specific lands.

On the other hand, findings suggest architects, urban planners and climatologists to pay more attention to climate change effects in the long-term in relation to urban growth. Even more, urban strategies should involve an urban model adapted to oases territories, proper to a sustainable green area and arid climate, as well as moderating the potential increase on air humidity.

7. CONCLUSION AND RECOMMENDATIONS

This thesis aimed to draw a new research line for the urban climate studies throughout arid regions based on different approaches, theories and applications as well as to promote the thinking on urban resilience facing extreme weather conditions notably during hot seasons. Beside climate change, urbanization is widely acknowledged to be one of the major causes of a substantial increase in the frequency and magnitude of thermal heat stress across the globe, specifically through the arid lands. Consequently, there is a large need to monitor urban development versus the outdoor thermal qualities to support efficient planning policies and strategies within the Saharan settlements. This thesis sought to understand and mitigate the potential impact of urbanization in the oases territories southern Algeria on the thermal comfort up to 2080. In doing so, four scientific challenges considered as research questions in this thesis. Tolga Oases Complex territory (Algeria) was selected as a case study. Tolga Oases Complex represents many challenges in terms of urbanization modeling: urban sprawl, oasis ecosyetm sustainability, and thermal heat stress variations. As well as, the study context is considred as one of the largest oases territories in North Africa since centries. Many worldwide arid regions, especially in Middle East, North Africa and USA, are characterized by sprawl expansion and urban resilience challenges against climate change. Having low rate of empirical urban studies in the arid lands means having less information to evaluate the heat stress over wide range.

In this chapter, the research hypothesis are revisited and the findings, strength and limitations are discussed, with an eye to future work.

7.1 Summary of the main findings

In search of the thermal comfort levels inside the oases settlements, Tolga Oases territory has been chosen as a case study which is presenting one of the most largest Algerian oasis territory. Through the application and the searching of a developed methodology that determines quantitatively the impact of the oases complex on the outdoor thermal comfort variations' levels, the following findings have been concluded:

- Answering our first research question which sought about the spatial sustainability criteria for oases settlements, the quantitative approach could be a main tool for the policies and strategies adopted by the Algerian Government such as NSPS, and DPWT, to enhance a sustainable territorial development, specifically in the arid regions. Otherwise, these lands comprise the oasis system in the large geographical part of the country. This approach focuses closely on the spatial-demographic dimension, which is mentioned principally in the second part of the DWPT orientations for the Horizon of 2030 (Report of the Biskra wilaya development plan by NAATP, 2018). Our framework is to quantify the level of the spatio-demographic sustainability throughout the Tolga Oases Settlements which are undergoing several factors of change such as : climate change, demography explosion, and local agrarian development, taking advantage of the parameters acting on its sustainability of the system : palm grove, population, built environment, and connection inside the territory. Accordingly, the main purpose of this step is to enhance territorial strategies especially for the spatial and demographic criteria regarding the oases regions and which present 84 % of the southern Algeria lands.
- In addition, a theoretical indicators were proposed to accommodate more spatial sustainability through the oases lands, provided that the urban planning regulations must be likely attached to the cultivated area, as well as the number of palm trees, and inhabitants progression at the same time.
- The conservation of the urban oasis system is a crucial thinking on the strategies and policies which highlighted the territorial development in Algeria. The insertion of the demographic-spatial dimension to preserve or to restore this system is essential, even the strong correlation between components of the oasis urban ecosystem. Altough, the main indicators (ratios) were performed through a quantitative approach to be integrated into three obtained ratios: 'UA.PGA', 'Distance.Peremiter' and 'Palm Tree. Population' which could be applied exclusively in the Algeria urban doucments. It was found through the third chapter, that these correlations are essential for the improvement of the sustainability of an oasis urban system. Consequentely, the significance of these correlations is summarized as following:

- The surface of the built-up area (urbanized area) must equals to 5% of the cultivated area (palm grove), to avoid an ecosystem unbalance that maintains the oasis formula. Secondly, the distance between future urban expansion which is highlighting generaly by land use policies, should be quantified during the early stages of the policies elaboation. Therefore, this is very necessary for the drafting stage in order to locate the urban area for the future implementation. In our cas, the distance must be linked to centre (polygonal centroid) of the city of Tolga (urban area), to maintain the distance and connection of the oasis territory. Thirdly, keeping the balance of palm trees quantity is imperative for the maintenance of the oasis urban system. The future number of palm trees should correspond to the future number of inhabitants which are together strongly attached. Population numbers' projections should be attached to palm projections in the reports of urban planning instruments prepared by the local authorities. In order, the prediction formula is using for the maintenance of the correlation between these two components of the oasis urban system.

Afterwards, in the fourth chapter we tried to provide a new approach to achieve the real evaluation of the thermal comfort through the oases settlements in short-term. We should note that, pratically all the previous studies does not quantify the thermal comfort within an empirical approache through a real oasis settlement. Accordingly, this methodology facilitates and provides an informed assessment of the thermal comfort quality for a large part of Tolga Oases Settlements.

- The oasis effect (decreasing of diurnal air temperature and increasing of relative humidity) which is more observed in August than July had no significant impact on the thermal comfort level in the midday period.
- The palm grove area was more influenced by elevation of diurnal air temperature than an urban area, generating a warming-effect in daytime. Moreover, based on PET index the current research shows a common similarity on the thermal heat stress level in daytime hours during the hot season inside the oases territory.
- Thermal heat stress is higher in the palm groves places in July at daytime than urban fabrics, likely due to the warming effect cleared from the palm groves. The decreasing of the heat stress level in these points surrounded by palm trees, might indicate a kind of air temperature thresholds could affect on the oasis effect (air temperature and relative humidity). Otherwise, the peak hour still always 1:00 p.m. which showed a very hot thermal zone.
- No significant impact of SVF on the thermal heat stress during summer, when PET values became more responsive to insolation's degrees. The thermal heat stress inside the 'Phoenix Dactylifera' represents a high level in July in comparison to 'Ficus

Rubigionosa'. Accordingly, Phoenix Dactylifera $PET_{moy.July}$ = 41.7°C, Ficus Rubigionosa $PET_{moy.July}$ = 38.4°C. The thermal heat stress in the 'Phoenix Dactylifera' grove decreased slightly in August than the 'Ficus Rubigionosa'. Estimated results could be used for the improvement of the outdoor thermal comfort balance inside the urban area in the arid region, based on the relationship between urban morphology and the palm grove area.

Otherwise, the current study aimed to assess the outdoor thermal comfort in long-term through the oases settlements. The evaluation was performed in long duration to provide an accurate reading of thermal perception variations, and to amplify the consequences of climate change on these regions. Morever, we should note that overall the previous studies, very less knowledges and works were conducted for the long-term evaluation within an empirical approache. The methodology developed in this part of the research allows a robust experience for future scientific studies. Therefore, results are explained as following:

- The current study was focused on the quantification of the outdoor thermal comfort within several oases urban typologies which can elaborate a strong guideline for landscape and urban designers who want to build thermally comfortable outdoor climates for these specific lands. The research evaluated of the heat stress level within a group of urban fabrics in Tolga oasis city during a period 30 years (from 1986 till 2016), on the basis of PET index which is most appropriate to evaluate the human thermal stress in arid climate, as well as the Typical Meteorological Year (TMY) as time variable. The research methodology combined between empirical approach and numerical modelling within cited oases urban fabrics in three different periods. Moreover, the research methodology revealed to a new approach of the urban climate analysis based on monitoring, CFD and meteorological calculation's modelling.
- The outcomes of this research stage showed that climate change and the accumulated impacts of the Urban Heat Island (UHI) induced a significantly heat stress values in long-term during hot seasons. Although, the heat stress levels were significantly increased during the last 15 years. Regarding the different oases urban forms and their effect on the outdoor thermal comfort, it is difficult to specify the most influenced typology or orientation among the investigated sites. However, PET index values, showed merely a little decrease inside the old settlement comparing to other new neighborhoods, this is may due to palm grove adjacent. Furthermore, results suggest architects, urban planners and climatologists to pay more attention on climate change effects and how can be caused by urban development on the arid lands. Furthermore, urban strategies should put an adapted oases urban model attached to a sustainable

green area and more adapted to the arid climate, thus moderating the potential increasing on air humidity.

- In the other hand, for the case of a desert city, irrigated surfaces can cause in long-term an increase heat thermal stress specially in summer daytime hours, however deciduous trees can create shading and protect spaces from direct sun, which is mostly remarkable on the cooldown temperature time. Moreover, it is mandatory on urban planning stage to know what kind and type of vegetation arrangement that must be implanted on the oasis urban area in the earlier stages of urban planning.

Afterwards, the sixth chapter aimed to draw a line for the outdoor thermal comfort predictions in long-term up to 2080 within the oases settlements specifically the multifamily housing archetype. The methodology was based on climate change scenarios basically on IPCC (AR4), as well as elaboration of an algorithm for the thermal heat stress predictions. Therefore, this stage based on the Perceived Temperature (PT) index which is the most relevant thermal index used in thermal predictions cases. However, we should note that urban climate predictions present a challenge relative to the little knowledges and studies about this topic. Results, are explained as following:

- By quantification, differences founded in PT index averages at the hot season among 2020 and 2050 was (+5.9°C), when 2080 (+7.7°C) which means a progressively elevation from the slightly warm thermal zone to the warm and hot thermal zones respectively, following the IPCC report (AR4).
- In order, no comfortable thermal stress zone was found during 2080 scenarios. However only one comfortable hour was found at 2050 overall scenarios. Thus, the comfortable thermal zone represented only 25% of the daily thermal stress level during the hot season in 2020. The thermal heat stress is elevating mainly due to climate changes effects and its significant impact on the arid lands, as well as it depends to the urban form quality.
- Consequently, climate change has a significant impact on thermal stress through outdoor spaces without shading arrangements or spaces with important SVF degrees, which are more affected on solar radiance. Most unfavorable places are exposed for long time to sun, such as the multifamily housing are representing a vulnerable urban form against climate changes in long-term, notably in the arid regions. In fact, the multifamily housing typologies are not suitable forms for the urban strategies in the oases lands in arid climate, otherwise these neighborhoods need more reflection about their master plans and urban design.

7.2 Innovations and limitations of the thesis

The thesis proposes several interventions and innovations in the field of urban climate throughout the oases settlements. However, there are also several limitations that have been encountered which are evident in several aspects as following:

7.2.1 Strengths

- The current study could be implemented into several acts of national plans and schemes (NSPS, DPWT) to the Horizon 2030. Particulary, in the second orientation's document to enhance dynamics of territorial rebalancing (the main orientations of NSPS), which can be used by decision-makers and authorities as urban planning tools merely to establish balance sheets and to provide the future development perspectives: demographic, agricultural (palm grove), and spatial (urban expansion), to better managing the oasis ecosystem resources, territorial equity. In fact, this research focused on a single oases territory Tolga Oases Settlements, located in Biskra province and identifies the country's largest oases territory, however the use of the research outcomes is adequate overall the country 'Saharan' oasis territories (84% of Algeria's surface). Therefore, obtained results (ratios and equation) present the first experience of quantification approach of the components inisde the urban oasis system, which could enlarge for possible studies through arid environments for the oasis urban system sustainability.
- Moreover, this study provides valuable insights for urban oases networks, as well as their population and their correlation through three important dimensions: 'UA.PGA', 'Distance.Peremiter' and 'Palm Tree. Population'. These findings can exclusively be applied for other oasis network in Algeria as well as in other countries after having all the local aspects such as: geographical, political, economical, socio-cultural etc.
- The current study is mainly due to its empirical and comparative approach to assess urban thermal comfort in an oasis Complex. None of the previously published studies compared urban thermal comfort in a large-scale palm grove community, in North Africa. Therefore, this study provides a quantification of outdoor thermal conditions inside and outside a palm grove area during summer, in the arid climate of Algeria.
- This study presents a main path in the assessment of outdoor thermal comfort and overheating conditions in a hot arid climate oasis Complex. Unfortunately, across the reviewed literature there is a large confusion and wrong understanding of the definition of an oasis, which is essentially associated with lower temperatures and higher relative humidity regardless of the context.

- With climate change and the recurring heat waves, human health in oases settlements can be subject to increases in morbidity and mortality. Although, as explained in the fourth chapter, there is strong evidence linking extreme heat with excesses in mortality, there is less literature describing the impact on morbidity, including the impacts on specific age groups in oases communities during heat waves. We are focusing on quantifying the physical heat by measuring and modeling urban thermal comfort during extreme summer climatic conditions. We hope that our findings can be coupled to epidemiological analysis to estimate the socio-economic impact of heat stress on oases inhabitant and tourism activities. Our findings indicate the urgency of providing an integrated outdoor spaces design procedure to relieve heat stress in oases settlements.
- This study presents a first framework for the outdoor thermal comfort assessment in long-term periods throughout the Algerian oases' settlements, based on TMY files as variable. Furthermore, many previous studies were based only on current weather datasets for short-term, whereas our research investigates and seeks for the quantification of the outdoor thermal comfort during 30 years, in contrast to previous research that focused only on limited area and short time. Although, less studies take on consideration the outdoor thermal comfort evaluation for long-term, which is imperative to analyse the climate change consequences and urban forms impact on the heat stress levels.
- As previously explained, our study indicates that in 80's the heat stress level was moderate (slightly above 50 %) and the heat stress levels were similar, when the neutral zone represented 46 %. Therefore, slight variation on heat stress level during the 90's, when thermal comfort quantification showed the same rate of the thermal neutral zone with 43 %, in parallel a barely increase in the heat stress zone (+ 3% comparing to the precedent duration). Otherwise, the third period at the last 15 years presents a significant thermal variations, affected a high and accelerated elevation on heat stress levels from 57% to 76%. Thus, the neutral thermal zone registered a responsive recoil from 43% to 24%, this change is due to the remarkable global warming intensity during the last 15 years.
- This work is considered as finding key for the nearly and long-term urban climate studies, it could promote for the outdoor thermal comfort predictions' scenarios in the oasis settlements based on multi-approaches and under extreme weather conditions.
- Moreover, the study outcomes are considering as key findings for outdoor thermal comfort predictions and to redevelop them covering all climate zones in the country. Findings are basically related to the study context but could be strongly enlarged

following same methods and approaches for different climate and urban forms. Although, the long-term overheating in arid lands is critical to the human body and has a significant impact on resident's well-being, productivity, and satisfaction. Despite, with climate change and the recurring heat waves, human health in oases settlements can be subject to increases in morbidity and mortality.

- None of the previously studies were investigated the predictions of outdoor thermal comfort or long-term weather patterns specifically inside the oases settlements in arid climate using TMY and (AR4) datasets.
- The generated greedy algorithm allows on numerical software used for urban climate studies several thermal stress calculations on the basis of PT index for short-term and long-term respectively. Thus, it is necessary to indicate that the generated algorithm is mathematically adequate to be applied in different software's databases such as ENVI-met, Grasshopper, EnergyPlus.

7.2.2 Limitations

In fact as presenting above, our reseach revealed to several key findings in different aspects, notably about thermal comfort patterns and their predictions. However, there are also several limitations that have been encountered which are evident in several aspects as following:

- The limits of the first step of the research are presenting on: water management in oasis environments which is considered as main factor for the sustainability or vulnerability of oases' ecosystem in the arid regions; this factor could be addressed in a future research, whereas aspects : resources, systems, constraints, issues, and strategies highlighted by the urban documents, particularly in the NSPS guidelines.
- The second limitation is identified on the economic aspect of the oasis territory, and the role of economic-agricultural development for the sustainability of the oasis system. This factor is also strongly linked to the socio-cultural aspect, which could opens a margin for research on the three components : (i) economic 'economic and agricultural development policy', (ii) social 'social distribution, function's hierarchy', (iii) 'cultural dimension and the nature of rurality in oasis environments'.
- Additionnaly, the study should benefited for longer monitoring period (cold season and hot season together) to assess deeply the microclimatic thresholds for the triggering of an oasis effect and its direct impact on the outdoor thermal comfort. The outdoor thermal comfort variations could be more understanding if the study includes the winter period, to cover all weather conditions during the 12 months. We believe that abroad the hot season we will reveal different reflection about the oasis effect especially inside settelements attached to palm grove and irrigated surfaces. The study scale should be

larger to cover multi urban forms throughout oases settlements and to have multi datasets for the microclimatics measurements. However we conducted our study using the best available data. Further works will cover more weather conditions and more urban forms, as well as more arid regions in Algeria to enhance the research results' quality.

- The current research does not take account the buildings shell details such as doors, windows, roofs and façade details, which could generating a serious impact on the outdoor thermal comfort. In order, predictions datasets are basically related to weather conditions, monitoring data, and built environment characteristics which are likely limited in some stages. The use of long-term monitored data and acquisition will make the predictions' models more reliable. Thus, predicted models depend on the accuracy of carried data through investigations.
- Furthermore, our research does not envolve to a qualitative approches such as surveys and interviews which could enhancing the study results. However, we claim that the current research is following strongly the most relevant experiences and studies done among this theme in worldwide arid regions. Further researches will imperatively take the human aspects, and activities as variables.
- No relationships were achieved between the spatial sustainability ratios (chapter three) and the outdoor themal comfort (rest of chapters). Accrodingly, the thermal patterns should be attached to the spatial criteria overall the oases territory not only inside the urban fabrics. Impacts of future weather might depend to the totality of territory including all the oasis components. In the other hand, the oases spatial criteria must be carried in the current reserach to identify the complexity of real urban oasis system in arid lands. We believe that obtained results promote further researches to build a new framework seeks about the existing oasis system and thermal comfort patterns in long-term.

7.3 Recommandations for further research

- This study identified the impact of the oasis on the outdoor thermal comfort during summer in Tolga Oases Complex. Based on our findings, we advise urban planners and landscape architects to not overestimate the passive cooling effect of the oasis palm grove. Therefore, urban designers and city planners should assure shading in public spaces and prepare the outdoor spaces to host people during extreme heat stress conditions in oases urban settlements. Natural ventilation or increasing the air flow and providing outdoor shading are an essential design element in oasis urban fabric. The reflectivity of ground and facade surfaces should be considered too. Glare is another important aspect that needs to be avoided increasing the satisfaction of people with the perceived temperature. Future research should focus on investigating outdoor thermal comfort on an annual basis. The cooling effect might be mostly effective outside the extreme hot summer months.

- Additionally, the urban outdoor thermal perception should be investigated through field surveys to assess the local comfort. The authors are aware that behavioral and psychological adaptations have proven to have a remarkable impact on thermal perception. This approach can add several recommendations for developing an adaptive urban oasis model and bioclimatic design recommendations in oasis zone of Algeria.
- This research identified levels of the outdoor thermal comfort in the oases urban fabrics, through several periods. Thus, future urban design in Algeria must be according basically to urban climate studies and should follow a long-term predictions. We believe that this research could be as guideline for decision makers, architects and urban planners to apply our findings in the early design stages to improve the outdoor thermal comfort depending to the urban design.
- Additionally, we believe that not architects or urban experts are only the concerned by this study, climate scientists and specially the Meteorological domains can have benefited from our outcomes to analyse the curve of climate change and to predict for the short and long-term future.
- Algerian government, especially the ministry of urban planning and housing as well as the ministry of environment should make a deep review regarding the built environment and the future strategies in urban housing against extreme weather conditions changing, notably in the arid lands which became more and more vulnerable during time. The current research presents the best support for a favourite start.
- The next study will aim for a conceptual dimension that seeks to be state-based. Rationalisation or legislation of a set of recommendations that will make it possible to make it easier for stakeholders or specialists to have the right approach for the similar objective.

References

Aboelata, A., & Sodoudi, S. (2020). Evaluating the effect of trees on UHI mitigation and reduction of energy usage in different built up areas in Cairo. Building and Environment, 168, 106490.

Acero, J. A., & Arrizabalaga, J. (2018). Evaluating the performance of ENVI-met model in diurnal cycles for different meteorological conditions. Theoretical and applied climatology, 131(1), 455-469.

Ahriz, A., Fezzai, S., & Mady AA, M. (2019). Predicting the limits of the oasis effect as a cooling phenomenon in hot deserts. Desert, 24(2), 255-266.

Alcoforado, M. J., & Andrade, H. (2008). Global warming and the urban heat island. In Urban ecology (pp. 249-262). Springer, Boston, MA.

Ali-Toudert, F., Djenane, M., Bensalem, R., & Mayer, H. (2005). Outdoor thermal comfort in the old desert city of Beni-Isguen, Algeria. Climate research, 28(3), 243-256.

Ali-Toudert, F., & Mayer, H. (2007). Effects of asymmetry, galleries, overhanging facades and vegetation on thermal comfort in urban street canyons. Solar energy, 81(6), 742-754.

Ali-Toudert, F., & Mayer, H. (2006). Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Building and environment, 41(2), 94-108.

Aljawabra, F., & Nikolopoulou, M. (2010). Influence of hot arid climate on the use of outdoor urban spaces and thermal comfort. Int. J. Intelligent Buildings International, 2, 00-00.

Alkama, D. (2005). Pour une nouvelle approche d'urbanisation dans les zones arides, cas du bas Sahara - les Ziban, le Souf et l'Oued Righ, Thèse de doctorat, 2005, Université de Biskra.

ALKAMA, D., & TACHERIFT, A. (2001). Essai d'analyse typo-morphologique des noyaux urbains traditionnels dans la région des Ziban.

Ambrosini, D., Galli, G., Mancini, B., Nardi, I., & Sfarra, S. (2014). Evaluating mitigation effects of urban heat islands in a historical small center with the ENVI-Met® climate model. Sustainability, 6(10), 7013-7029.

Aroua, N., & Berezowska-Azzag, E. (2013). Le risque intrinsèque à la gestion locale des risques liés à l'eau en Algérie. Revue Géographique de l'Est, 53(1-2).

Arrouf, A. (2000). Apprendre du passé : une stratégie alternative. Cas des ksour sahariens, in Actes du séminaire international, Espace saharien et développement durable, Biskra (Algérie), CRSTRA, 14-16 novembre, pp. 217-233.

ASHRAE. (2014). ASHRAE Guideline 14–2014, Measurement of Energy, Demand, and Water Savings.

Atef, A., Noureddine, Z., & Soufiane, F. (2015). SPUCAL_mrt as a new model for estimating the mean radiant temperature in arid lands. Energy Procedia, 74, 273-280.

Attia, S. (2009). The Bioclimatic Zones Concept Landscape Design Strategy for site planning in hot arid climates. In Proceedings of the 3rd CIB International Conference on Smart and Sustainable Built Environment. SASBE-TUD.

Attia, S., & Duchhart, I. (2011, July). Bioclimatic landscape design in extremely hot and arid climates. In Proceedings of 27th Conference of Passive and Low Energy Architecture (PLEA) 2011. PLEA.

Attia, S. (2020). Spatial and Behavioral Thermal Adaptation in Net Zero Energy Buildings: An Exploratory Investigation. Sustainability, 12(19), 7961.

Ruck, N. C. (1989). Building design and human performance.

Baker, N., & Steemers, K. (2003). Energy and environment in architecture: a technical design guide. Taylor & Francis.

Balogun, I. A., & Daramola, M. T. (2019). The outdoor thermal comfort assessment of different urban configurations within Akure City, Nigeria. Urban Climate, 29, 100489.

Baruti, M. M., Johansson, E., & Yahia, M. W. (2020). Urbanites' outdoor thermal comfort in the informal urban fabric of warm-humid Dar es Salaam, Tanzania. Sustainable Cities and Society, 62, 102380.

Baruti, M. M., Johansson, E., & Åstrand, J. (2019). Review of studies on outdoor thermal comfort in warm humid climates: Challenges of informal urban fabric. International journal of biometeorology, 63(10), 1449-1462.

Battesti, V. (2000). Les échelles temporelles des oasis du Jérid tunisien. Anthropos, 419-432.

Battesti, V. (2005). Jardins au désert: évolution des pratiques et savoirs oasiens: Jérid tunisien. IRD éditions.

Belguidoum, S. (2002). Urbanisation et urbanité au Sahara. Méditerranée: revue géographique des pays méditerranéens, 99, 53-64.

Benziouche, S. (2012). Analysis of the dates sector in Algeria, observations and prospects of development . A case study of the Daira Tolga. Thesis PhD, ENSA Algeria, p 465.

Berardi, U. (2016). The outdoor microclimate benefits and energy saving resulting from green roofs retrofits. Energy and Buildings, 121, 217-229.

Berkouk, D., Bouzir, T. A. K., Maffei, L., & Masullo, M. (2020). Examining the Associations between Oases Soundscape Components and Walking Speed: Correlation or Causation?. Sustainability, 12(11), 4619.

Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R., Davidson, O., ... & Yobe, G. (2008). Climate Change 2007 Synthesis Report. Intergovernmental Panel on Climate Change.

Binarti, F., Koerniawan, M. D., Triyadi, S., Utami, S. S., & Matzarakis, A. (2020). A review of outdoor thermal comfort indices and neutral ranges for hot-humid regions. Urban Climate, 31, 100531.

Biqaraz, B., Fayaz, R., & Naeeni, G. H. (2019). A comparison of outdoor thermal comfort in historical and contemporary urban fabrics of Lar City. Urban Climate, 27, 212-226.

Bisson, J. (1993). Développement et mutations au Sahara maghrébin. Ministère de l'Education Nationale, Centre Régional de Documentation Pédagogique, Acad. d'Orléans-Tours.

Bisson, J. (2003). Mythes et réalités d'un désert convoité: le Sahara. Editions L'Harmattan.

born Bouzaher, L., & Alkama, D. (2012). Palm trees reuses as sustainable element in the Sahara. The case of Ziban, as self-sustainable urban units. Energy Procedia, 18, 1076-1085.

born Bouzaher, S. L., & Alkama, D. (2013). The requalification of the palm trees of Ziban as a tool for sustainable planning. Procedia-Social and Behavioral Sciences, 102, 508-519.

Bosselmann, P., Dake, K., Fountain, M., Kraus, L., Lin, K. T., & Harris, A. (1988). Sun, Wind, and Comfort: A Field Study of Thermal Comfort in San Francisco. No. CEDR-06-88). Berkeley, CA: Center for Environmental Design Research, University of California, Berkeley.

BOUAMMAR, B. (2010). Le développement agricole dans les régions sahariennes Etude de cas de la région de Ouargla et de la région de Biskra (2006-2008) (Doctoral dissertation, Université de Ouargla-Kasdi Merbah).

Bouchair, A., & Dupagne, A. (2003). Building traditions of Mzab facing the challenges of re-shaping of its built form and society. Building and environment, 38(11), 1345-1364.

Bouchair, A. (2004). Decline of urban ecosystem of Mzab valley. Building and Environment, 39(6), 719-732.

Bouchair, A., Tebbouche, H., Hammouni, A., Lehtihet, M. C., & Blibli, M. (2013). Compact cities as a response to the challenging local environmental constraints in hot arid lands of Algeria. Energy Procedia, 42, 493-502.

Boudjellal, L., & Bourbia, F. (2018). An evaluation of the cooling effect efficiency of the oasis structure in a Saharan town through remotely sensed data. International Journal of Environmental Studies, 75(2), 309-320.

Boukhabl, M., & Alkam, D. (2012). Impact of vegetation on thermal conditions outside, Thermal modeling of urban microclimate, Case study: the street of the republic, Biskra. Energy Procedia, 18, 73-84.

Boukhelkhal, I., & Bourbia, P. F. (2016). Thermal comfort conditions in outdoor urban spaces: Hot dry climate-Ghardaia-Algeria. Procedia Engineering, 169, 207-215.

Bourbia, F., & Awbi, H. B. (2004). Building cluster and shading in urban canyon for hot dry climate: Part 1: Air and surface temperature measurements. Renewable energy, 29(2), 249-262.

Bourbia, F., & Awbi, H. B. (2004). Building cluster and shading in urban canyon for hot dry climate: Part 2: Shading simulations. Renewable Energy, 29(2), 291-301.

Bouzaher Lalouani, S. (2015). Un aménagement durable par un projet écotouristique Cas des ksour de la micro région des Ziban. Le redressement d'un circuit écotouristique (Doctoral dissertation, Université Mohamed Khider-Biskra).

Bruse, M., & Fleer, H. (1998). Simulating surface–plant–air interactions inside urban environments with a three dimensional numerical model. Environmental modelling & software, 13(3-4), 373-384.

Bruse, M. (2004). ENVI-met 3.0: updated model overview. University of Bochum. Retrieved from: www. envi-met. com.

Chalfoun, N. V. (2003, May). Sustainable Urban Design in Arid Regions; Integrating Energy and Comfort. In Collaborative Symposium: Urban Design in Arid Regions.

Chaouche-Bencherif, M., & Farhi, A. (2007). La Micro-urbanisation et la ville-oasis; une alternative à l'équilibre des zones arides pour une ville saharienne durable (Doctoral dissertation, Université Mentouri).

Coccolo, S., Kämpf, J., Scartezzini, J. L., & Pearlmutter, D. (2016). Outdoor human comfort and thermal stress: A comprehensive review on models and standards. Urban Climate, 18, 33-57.

Cohen, P., Shashua-Bar, L., Keller, R., Gil-Ad, R., Yaakov, Y., Lukyanov, V., ... & Potchter, O. (2019). Urban outdoor thermal perception in hot arid Beer Sheva, Israel: Methodological and gender aspects. Building and Environment, 160, 106169.

Côte, M. (1998). Des oasis malades de trop d'eau?. Science et changements planétaires/Sécheresse, 9(2), 123-130.

Coté, M. (Ed.). (2005). La ville et le désert: le Bas-Sahara algérien. Karthala Éditions.

Côte, M. (2012). Signatures sahariennes: terroirs & territoires vus du ciel. Méditerranée.

Crank, P. J., Sailor, D. J., Ban-Weiss, G., & Taleghani, M. (2018). Evaluating the ENVI-met microscale model for suitability in analysis of targeted urban heat mitigation strategies. Urban climate, 26, 188-197.

Crawley, D. B., & Lawrie, L. K. (2015, December). Rethinking the TMY: is the 'typical'meteorological year best for building performance simulation?. In Proceedings of the 14th Conference of International Building Performance Simulation Association BS2015 (pp. 2655-2662).

da Silveira Hirashima, S. Q., Katzschner, A., Ferreira, D. G., de Assis, E. S., & Katzschner, L. (2018). Thermal comfort comparison and evaluation in different climates. Urban Climate, 23, 219-230.

de Freitas, C. R., & Grigorieva, E. A. (2015). A comprehensive catalogue and classification of human thermal climate indices. International journal of biometeorology, 59(1), 109-120.

de Freitas, C. R., & Grigorieva, E. A. (2017). A comparison and appraisal of a comprehensive range of human thermal climate indices. International journal of biometeorology, 61(3), 487-512.

de Lartigue, L. C. (1904). Monographie de l'Aurès: Par le Lt-Colonel de Lartigue. Photographies de Neurdein... Imprimerie Marle-Audrino.

De Schiller, S. (2000, July). Sustainable cities. In Architecture, City, Environment: Proceedings of PLEA 2000: July 2000, Cambridge, United Kingdom (Vol. 2, No. 3, p. 353). Earthscan.

Djennane, A. (1990). Constat de situation des zones Sud des oasis algériennes. Revue options méditerranéennes, CIHEAM, 29-40.

Docherty, M. J., & Szokolay, S. V. (1999). Climate analysis. PLEA, Passive and Low Energy Architecture.

Dubost, D., & Larbi-Youcef, Y. (1998). Mutations agricoles dans les oasis algériennes: l'exemple des Ziban. Sécheresse (Montrouge), 9(2), 103-110.

DUPAGNE, A., & HÉGRON, G. (2002). Introduction, Architectural and Urban Ambient Environment. In First International Workshop, Nantes, France, L'Écoled'Architecture de Nantes.

Eddine, B. S., & Foued, C. (2010). La conduite du palmier dattier dans les palmeraies des Zibans (Algérie) Quelques éléments d'analyse. European Journal of Scientific Research, 42(4), 644-660.

Edmonds, J. (1971). Matroids and the greedy algorithm. Mathematical programming, 1(1), 127-136.

Elnabawi, M. H., Hamza, N., & Dudek, S. (2016). Thermal perception of outdoor urban spaces in the hot arid region of Cairo, Egypt. Sustainable cities and society, 22, 136-145.

Elnabawi, M. H., & Hamza, N. (2020). Behavioural perspectives of outdoor thermal comfort in urban areas: A critical review. Atmosphere, 11(1), 51.

Escourrou, G. (1996). Transports, contraintes climatiques et pollutions. FeniXX.

Fahmy, M., Mahdy, M., Mahmoud, S., Abdelalim, M., Ezzeldin, S., & Attia, S. (2020). Influence of urban canopy green coverage and future climate change scenarios on energy consumption of new sub-urban residential developments using coupled simulation techniques: A case study in Alexandria, Egypt. Energy Reports, 6, 638-645.

Fanger, P. O. (1970). Thermal comfort. Analysis and applications in environmental engineering. Thermal comfort. Analysis and applications in environmental engineering.

Françoise, C. H. O. A. Y. (1980). La règle et le modèle. Sur la théorie de l'architecture et de l'urbanisme. Edition du Seuil, Paris.

Fujibe, F. (2009). Detection of urban warming in recent temperature trends in Japan. International Journal of Climatology: A Journal of the Royal Meteorological Society, 29(12), 1811-1822.

Gandemer, J., & Barnaud, G. (1975). Inconfort dû au vent aux abords des bâtiments: étude aérodynamique du champ de vitesse dans les ensembles bâtis: étude complémentaire. Centre scientifique et technique du bâtiment, Établissement de Nantes.

Gandemer, J. (1976). Inconfort dû au vent aux abords des bâtiments: concepts aérodynamiques.

GhaffarianHoseini, A., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., Makaremi, N., & GhaffarianHoseini, M. (2013). Sustainable energy performances of green buildings: A review of current theories, implementations and challenges. Renewable and Sustainable Energy Reviews, 25, 1-17.

Givoni, B. (1998). Climate considerations in building and urban design. John Wiley & Sons.

Givoni, B., Noguchi, M., Saaroni, H., Pochter, O., Yaacov, Y., Feller, N., & Becker, S. (2003). Outdoor comfort research issues. Energy and buildings, 35(1), 77-86.

Golden, J. S. (2004). The built environment induced urban heat island effect in rapidly urbanizing arid regions–a sustainable urban engineering complexity. Environmental Sciences, 1(4), 321-349.

Gosling, S. N., Bryce, E. K., Dixon, P. G., Gabriel, K. M., Gosling, E. Y., Hanes, J. M., ... & Wanka, E. R. (2014). A glossary for biometeorology. International journal of biometeorology, 58(2), 277-308.

HADAGHA, F. Z., FARHI, B. E., FARHI, A., & PETRISOR, A. I. (2018). Multifunctionality of the oasis ecosystem. Case study: Biskra Oasis, Algeria. Journal Of Contemporary Urban Affairs, 2(3), 31-39.

Hammoudi, A. (2014). le patrimoine ksourien, mutation et devenir. Le cas du Zab El Gherbi–Tolga (Doctoral dissertation, Université Mohamed Khider Biskra).

Hamstead, Z. A., Iwaniec, D. M., McPhearson, T., Berbés-Blázquez, M., Cook, E. M., & Muñoz-Erickson, T. A. (2021). Resilient Urban Futures (p. 190). Springer Nature.

Hatira, A., Baccar, L., Grira, M., & Gallali, T. (2007). Analyse de sensibilité du système oasien et mesures de sauvegarde de l'oasis de Métouia (Tunisie). Revue des sciences de l'eau/Journal of Water Science, 20(1), 59-69.

He, B. J., Ding, L., & Prasad, D. (2020). Relationships among local-scale urban morphology, urban ventilation, urban heat island and outdoor thermal comfort under sea breeze influence. Sustainable Cities and Society, 60, 102289.

He, B. J., Ding, L., & Prasad, D. (2020). Outdoor thermal environment of an open space under sea breeze: A mobile experience in a coastal city of Sydney, Australia. Urban Climate, 31, 100567.

Hien, W. N., Ignatius, M., Eliza, A., Jusuf, S. K., & Samsudin, R. (2012). Comparison of STEVE and ENVI-met as temperature prediction models for Singapore context. International Journal of Sustainable Building Technology and Urban Development, 3(3), 197-209.

Hong, Z., Jian-Wei, W., Qiu-Hong, Z., & Yun-Jiang, Y. (2003). A preliminary study of oasis evolution in the Tarim Basin, Xinjiang, China. Journal of Arid Environments, 55(3), 545-553.

Höppe, P. (2002). Different aspects of assessing indoor and outdoor thermal comfort. Energy and buildings, 34(6), 661-665.

Hu, N., & Li, X. (2014). Spatial distribution of an ancient agricultural oasis in Juyan, northwestern China. Frontiers of earth science, 8(3), 338-350.

Hurabielle, J. (1899). Au Pays du bleu: Biskra et les oasis environnantes. Challamel.

Jamei, E., Rajagopalan, P., Seyedmahmoudian, M., & Jamei, Y. (2016). Review on the impact of urban geometry and pedestrian level greening on outdoor thermal comfort. Renewable and Sustainable Energy Reviews, 54, 1002-1017.

Jendritzky, G., & Nübler, W. (1981). A model analysing the urban thermal environment in physiologically significant terms. Archives for meteorology, geophysics, and bioclimatology, Series B, 29(4), 313-326.

Jendritzky, G., Staiger, H., Bucher, K., Graetz, A., & Laschewski, G. (2000). The Perceived Temperature : The Method of the Deutscher Wetterdienst for the Assessment of Cold Stress and Heat Load for the Human Body.

JENDRITZKY, G. (2003). Perceived temperature: Klima-Michel-model. The Development of Heat Stress Watch Warning Systems. Freiburg.

Jia, B., Zhang, Z., Ci, L., Ren, Y., Pan, B., & Zhang, Z. (2004). Oasis land-use dynamics and its influence on the oasis environment in Xinjiang, China. Journal of Arid Environments, 56(1), 11-26.

Johansson, E. Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. Build. Environ. 2006, 41, 1326–1338.

Kandal, H. A., Yacoub, H. A., Gerkema, M. P., & Swart, J. A. (2019). Traditional knowledge and community resilience in Wadi Allaqi, Egypt. Journal of Arid Environments, 171, 103987.

Karakounos, I., Dimoudi, A., & Zoras, S. (2018). The influence of bioclimatic urban redevelopment on outdoor thermal comfort. Energy and Buildings, 158, 1266-1274.

Kedissa, C., Outtas, S., & Belarbi, R. (2016). The impact of height/width ratio on the microclimate and thermal comfort levels of urban courtyards. International Journal of Sustainable Building Technology and Urban Development, 7(3-4), 174-183.

Kassah, A. (2009, February). Oasis et aménagement en zones arides. Enjeux, défis et stratégies. In Gestion des ressources naturelles et développement durable des systèmes oasiens du Nefzaoua (pp. 6-p). Cirad.

Kenawy, I., Lam, C. K. C., & Shooshtarian, S. (2021). Summer outdoor thermal benchmarks in Melbourne: Applications of different techniques. Building and Environment, 195, 107658.

Kouzmine, Y. (2007). Dynamiques et mutations territoriales du Sahara algérien vers de nouvelles approches fondées sur l'observation (Doctoral dissertation, Université de Franche-Comté).

Kouzmine, Y., & Avocat, H. (2007, November). L'eau et les territoires sahariens en Algérie, Mutations et enjeux. In Colloque International Eau, Ville et Environnement (p. 255p).

Kouzmine, Y., Fontaine, J., Yousfi, B. E., & Otmane, T. (2009). Etapes de la structuration d'un désert: l'espace saharien algérien entre convoitises économiques, projets politiques et aménagement du territoire. In Annales de géographie (No. 6, pp. 659-685). Armand Colin.

Labdaoui, K., Mazouz, S., Acidi, A., Cools, M., Moeinaddini, M., & Teller, J. (2021). Utilizing thermal comfort and walking facilities to propose a comfort walkability index (CWI) at the neighbourhood level. Building and Environment, 193, 107627.

Lall, S. V., Henderson, J. V., & Venables, A. J. (2017). Africa's cities: Opening doors to the world. World Bank Publications.

Lamqadem, A. A., Saber, H., & Pradhan, B. (2018). Quantitative assessment of desertification in an arid oasis using remote sensing data and spectral index techniques. Remote Sensing, 10(12), 1862.

Lee, H. (2007). Intergovernmental panel on climate change. World Merteorological Organization: Geneva, Switzerland.

Li, H., Zhou, Y., Li, X., Meng, L., Wang, X., Wu, S., & Sodoudi, S. (2018). A new method to quantify surface urban heat island intensity. Science of the total environment, 624, 262-272.

LIEBARD, A., JORIGNE, E., de Herde, A., & DEPREZ, B. (1996). Guide de l'architecture bioclimatique-Haute qualité et développementdurable. Cours fondamental: Tome 1 Connaître les bases. Systèmes solaires (Revue), (116).

Ling, H., Xu, H., Fu, J., Fan, Z., & Xu, X. (2013). Suitable oasis scale in a typical continental river basin in an arid region of China: A case study of the Manas River Basin. Quaternary International, 286, 116-125.

Lomas, K. J., & Porritt, S. M. (2017). Overheating in buildings: lessons from research.

Mahar, W. A., Verbeeck, G., Reiter, S., & Attia, S. (2020). Sensitivity analysis of passive design strategies for residential buildings in cold semi-arid climates. Sustainability, 12(3), 1091.

Mahar, W. A., Verbeeck, G., Singh, M. K., & Attia, S. (2019). An investigation of thermal comfort of houses in dry and semi-arid climates of quetta, pakistan. Sustainability, 11(19), 5203.

Mahmoud, A. H. A. (2011). Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions. Building and environment, 46(12), 2641-2656.

Masmoudi, Soraya, and Said Mazouz. 2004. "Relation of geometry, vegetation and thermal comfort around buildings in urban settings, the case of hot arid regions." Energy and Buildings no. 36 (7):710-719.

Matallah, M. E., Ahriz, A., & Attia, S. (2020). Quantification of the Outdoor Thermal Comfort Process: Simulation & Calculation data (No. 01/2020). Sustainable Building Design Lab.

Matallah, M. E., Alkama, D., Ahriz, A., & Attia, S. (2020). Assessment of the Outdoor Thermal Comfort in Oases Settlements. Atmosphere, 11(2), 185.

Matallah, M. E., Alkama, D., Teller, J., Ahriz, A., & Attia, S. (2021). Quantification of the Outdoor Thermal Comfort within Different Oases Urban Fabrics. Sustainability, 13(6), 3051.

Matallah, M. E., Mahar, W. A., Bughio, M., Alkama, D., Ahriz, A., & Bouzaher, S. (2021). Prediction of Climate Change Effect on Outdoor Thermal Comfort in Arid Region. Energies, 14(16), 4730.

Matallah, M. E. (2015). L’impact de la morphologie des tissus urbains sur le confort thermique extérieur-Cas d’étude ville de Tolga.

Matzarakis, A., Mayer, H., & Iziomon, M. G. (1999). Applications of a universal thermal index: physiological equivalent temperature. International journal of biometeorology, 43(2), 76-84.

Matzarakis, A., Rutz, F., & Mayer, H. (2007). Modelling radiation fluxes in simple and complex environments—application of the RayMan model. International journal of biometeorology, 51(4), 323-334.

Matzarakis, A., Rutz, F., & Mayer, H. (2010). Modelling radiation fluxes in simple and complex environments: basics of the RayMan model. International journal of biometeorology, 54(2), 131-139.

Memon, S. A. (2014). Phase change materials integrated in building walls: A state of the art review. Renewable and sustainable energy reviews, 31, 870-906.

Middel, A., Selover, N., Hagen, B., & Chhetri, N. (2016). Impact of shade on outdoor thermal comfort—a seasonal field study in Tempe, Arizona. International journal of biometeorology, 60(12), 1849-1861.

Moazami, A., Nik, V. M., Carlucci, S., & Geving, S. (2019). Impacts of future weather data typology on building energy performance–Investigating long-term patterns of climate change and extreme weather conditions. Applied Energy, 238, 696-720.

Moisselin, J. M., Schneider, M., & Canellas, C. (2002). Les changements climatiques en France au XXè siècle. Etude des longues séries homogénéisées de données de température et de précipitations. La météorologie.

Moufida, B., Djamel, A., Noureddine, M., & Soumia, B. (2014). The energy balance behavior in Open Street. Case study city of Biskra, Algeria. Energy Procedia, 50, 3-9.

Nakicenovic, N., Alcamo, J., Davis, G., Vries, B. D., Fenhann, J., Gaffin, S., ... & Zhou, D. (2000). Special report on emissions scenarios.

Nematchoua, M. K., Yvon, A., Kalameu, O., Asadi, S., Choudhary, R., & Reiter, S. (2019). Impact of climate change on demands for heating and cooling energy in hospitals: An in-depth case study of six islands located in the Indian Ocean region. Sustainable Cities and Society, 44, 629-645.

Nematchoua, M. K., Noelson, J. C. V., Saadi, I., Kenfack, H., Andrianaharinjaka, A. Z. F., Ngoumdoum, D. F., ... & Reiter, S. (2020). Application of phase change materials, thermal insulation, and external shading for thermal comfort improvement and cooling energy demand reduction in an office building under different coastal tropical climates. Solar Energy, 207, 458-470.

Nesson, C. (1973). OASIS DU SAHARA ALGERIEN.

Nesson, C. (1978). Recherches sur l'Algérie.

Newman, P., Beatley, T., & Boyer, H. (2009). Resilient cities: Responsing to peak oil and climate change.

Nicol, F. (1993). Thermal comfort: a handbook for field studies toward an adaptive model (pp. 1-85). London: University of East London.

Nikolopoulou, M. H. (1998). Thermal comfort in outdoor urban spaces (Doctoral dissertation, University of Cambridge).

Nikolopoulou, M., & Steemers, K. (2003). Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy and Buildings, 35(1), 95-101.

Nikolopoulou, M., Lykoudis, S., & Kikira, M. (2004). Thermal comfort models for open urban spaces. In Designing open spaces in the urban environment: a bioclimatic approach (pp. 2-6). Centre for Renewable Energy Sources, EESD, FP5.

Nikolopoulou, M. (2004). Designing open spaces in the urban environment: a bioclimatic approach. Centre for Renewable Energy Sources, EESD, FP5.

Oke, T. R. (1988). Street design and urban canopy layer climate. Energy and buildings, 11(1-3), 103-113.

Oke, T. R. (2002). Boundary layer climates. Routledge.

Okin, G. S., Gillette, D. A., & Herrick, J. E. (2006). Multi-scale controls on and consequences of aeolian processes in landscape change in arid and semi-arid environments. Journal of arid environments, 65(2), 253-275.

Olgyay, V. (2015). Design with climate: bioclimatic approach to architectural regionalism-new and expanded edition. Princeton university press.

P Tootkaboni, M., Ballarini, I., Zinzi, M., & Corrado, V. (2021). A Comparative Analysis of Different Future Weather Data for Building Energy Performance Simulation. Climate, 9(2), 37.

Palme, M., & Salvati, A. (2021). Urban Microclimate Modelling for Comfort and Energy Studies: Springer International Publishing.

Potchter, O., Goldman, D., Kadish, D., & Iluz, D. (2008). The oasis effect in an extremely hot and arid climate: The case of southern Israel. Journal of Arid Environments, 72(9), 1721-1733.

Potchter, O., & Ben-Shalom, H. I. (2013). Urban warming and global warming: Combined effect on thermal discomfort in the desert city of Beer Sheva, Israel. Journal of arid environments, 98, 113-122.

Potchter, O., Cohen, P., Lin, T. P., & Matzarakis, A. (2018). Outdoor human thermal perception in various climates: A comprehensive review of approaches, methods and quantification. Science of the Total Environment, 631, 390-406.

Potvin, A. (2000). Assessing the microclimate of urban transitional spaces. Proceedings of Passive Low Energy Architecture, 581-6.

Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. Energy and buildings, 37(7), 762-776.

Rchid, A. (2012). The effects of green spaces (Palme trees) on the microclimate in arides zones, case study: Ghardaia, Algeria. Energy Procedia, 18, 10-20.

Remund, J. S. C. M., Müller, S. C., Schilter, C., & Rihm, B. (2010, September). The use of Meteonorm weather generator for climate change studies. In 10th EMS Annual Meeting (pp. EMS2010-417).

Ribeiro, P. J. G., & Gonçalves, L. A. P. J. (2019). Urban resilience: A conceptual framework. Sustainable Cities and Society, 50, 101625.

Roetzel, A., & Tsangrassoulis, A. (2012). Impact of climate change on comfort and energy performance in offices. Building and environment, 57, 349-361.

Rogelj, J., Meinshausen, M., & Knutti, R. (2012). Global warming under old and new scenarios using IPCC climate sensitivity range estimates. Nature climate change, 2(4), 248-253.

Roshan, G., Almomenin, H. S., da Silveira Hirashima, S. Q., & Attia, S. (2019). Estimate of outdoor thermal comfort zones for different climatic regions of Iran. Urban Climate, 27, 8-23.

Roshan, G. R., Farrokhzad, M., & Attia, S. (2017). Defining thermal comfort boundaries for heating and cooling demand estimation in Iran's urban settlements. Building and Environment, 121, 168-189.

Roussel, I. (1991). G. Escourrou. 1991. Le climat et la ville. Hommes et Terres du Nord, 4(1), 260-260.

Saaroni, H., Bitan, A., Dor, E. B., & Feller, N. (2004). The mixed results concerning the 'oasis effect'in a rural settlement in the Negev Desert, Israel. Journal of Arid Environments, 58(2), 235-248.

Saidouni, M. (2000). Eléments d'introduction à l'urbanisme.

Santamouris, M. (2013). Energy and climate in the urban built environment. Routledge.

Sebti, M., Alkama, D., & Bouchair, A. (2013). Assessment of the effect of modern transformation on the traditional settlement 'Ksar'of Ouargla in southern Algeria. Frontiers of Architectural Research, 2(3), 322-337.

Sellami, M. H., & Sifaoui, M. S. (1998). Measurements of microclimatic factors inside the oasis: interception and sharing of solar radiation. Renewable energy, 13(1), 67-76.

Semahi, S., Zemmouri, N., Singh, M. K., & Attia, S. (2019). Comparative bioclimatic approach for comfort and passive heating and cooling strategies in Algeria. Building and Environment, 161, 106271.

Semahi, S., Benbouras, M. A., Mahar, W. A., Zemmouri, N., & Attia, S. (2020). Development of Spatial Distribution Maps for Energy Demand and Thermal Comfort Estimation in Algeria. Sustainability, 12(15), 6066.

Sharifi, A. (2016). A critical review of selected tools for assessing community resilience. Ecological indicators, 69, 629-647.

Sharifi, A. (2019). Resilient urban forms: A macro-scale analysis. Cities, 85, 1-14.

Sharifi, A. (2019). Resilient urban forms: A review of literature on streets and street networks. Building and Environment, 147, 171-187.

Sharmin, T., Steemers, K., & Matzarakis, A. (2015). Analysis of microclimatic diversity and outdoor thermal comfort perceptions in the tropical megacity Dhaka, Bangladesh. Building and Environment, 94, 734-750.

Sharmin, T., Steemers, K., & Matzarakis, A. (2017). Microclimatic modelling in assessing the impact of urban geometry on urban thermal environment. Sustainable cities and society, 34, 293-308.

Smithson, P. A. (1997). MICROCLIMATIC LANDSCAPE DESIGN: CREATING THERMAL COMFORT AND ENERGY EFFICIENCY. RD Brown and TJ Gillespie, John Wiley & Sons Inc.(New York), 1995. No. of pages: xi+ 193. Price:£ 29.95. ISBN 0-471-05667-7 (paperback).

Sodoudi, S., Zhang, H., Chi, X., Müller, F., & Li, H. (2018). The influence of spatial configuration of green areas on microclimate and thermal comfort. Urban Forestry & Urban Greening, 34, 85-96.

Song, W., & Zhang, Y. (2015). Expansion of agricultural oasis in the Heihe River Basin of China: Patterns, reasons and policy implications. Physics and Chemistry of the Earth, Parts A/B/C, 89, 46-55.

Sovetova, M., Memon, S. A., & Kim, J. (2019). Thermal performance and energy efficiency of building integrated with PCMs in hot desert climate region. Solar Energy, 189, 357-371.

Staiger, H., Laschewski, G., & Grätz, A. (2012). The perceived temperature–a versatile index for the assessment of the human thermal environment. Part A: scientific basics. International journal of biometeorology, 56(1), 165-176.

Staiger, H., Laschewski, G., & Matzarakis, A. (2019). Selection of appropriate thermal indices for applications in human biometeorological studies. Atmosphere, 10(1), 18.

Stone, B., Hess, J. J., & Frumkin, H. (2010). Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities?. Environmental health perspectives, 118(10), 1425-1428.

Taleghani, M., Kleerekoper, L., Tenpierik, M., & Van Den Dobbelsteen, A. (2015). Outdoor thermal comfort within five different urban forms in the Netherlands. Building and environment, 83, 65-78.

Taleghani, M. (2018). Outdoor thermal comfort by different heat mitigation strategies-A review. Renewable and Sustainable Energy Reviews, 81, 2011-2018.

Teller, J., & Azar, S. (2001). Townscope II—A computer system to support solar access decision-making. Solar energy, 70(3), 187-200.

TESTO. TESTO 480 Climate Measuring Instrument. Available online: https://static-int.testo.com/media/cf/01/ 1_8d8380280/testo-480-Instruction-manual.pdf (accessed on 30 July 2020).

Thom, E. C. (1959). The discomfort index. Weatherwise, 12(2), 57-61.

Toutain, G., Dollé, V., & Ferry, M. (1989). Situation des systèmes oasiens en régions chaudes. Les Cahiers de la recherche développement, (22), 3-14.

Tsoka, S., Tsikaloudaki, A., & Theodosiou, T. (2018). Analyzing the ENVI-met microclimate model's performance and assessing cool materials and urban vegetation applications–A review. Sustainable cities and society, 43, 55-76.

Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. Climate and development, 4(4), 311-326.

Venhari, A. A., Tenpierik, M., & Taleghani, M. (2019). The role of sky view factor and urban street greenery in human thermal comfort and heat stress in a desert climate. Journal of Arid Environments, 166, 68-76.

Vigarié, A. (1997). G. Escourou, Transports, contraintes climatiques et pollutions. In Annales de géographie (Vol. 106, No. 597, pp. 551-552). Persée-Portail des revues scientifiques en SHS.

Vince, A. (2002). A framework for the greedy algorithm. Discrete Applied Mathematics, 121(1-3), 247-260.

Vinet, J. (2000). Contribution à la modélisation thermo-aéraulique du microclimat urbain. Caractérisation de l'impact de l'eau et de la végétation sur les conditions de confort en espaces extérieurs (Doctoral dissertation, Université de Nantes).

Wahid, M. A., Hosseini, S. E., Hussen, H. M., Akeiber, H. J., Saud, S. N., & Mohammad, A. T. (2017). An overview of phase change materials for construction architecture thermal management in hot and dry climate region. Applied thermal engineering, 112, 1240-1259.

Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. Energy and Buildings, 114, 2-19.

Yang, G., Li, F., Chen, D., He, X., Xue, L., & Long, A. (2019). Assessment of changes in oasis scale and water management in the arid Manas River Basin, north western China. Science of The Total Environment, 691, 506-515.

Zella, L., & Smadhi, D. (2006). Gestion de l'eau dans les oasis Algeriennes. LARHYSS Journal P-ISSN 1112-3680/E-ISSN 2521-9782, (5).

Zhao, Q., Sailor, D. J., & Wentz, E. A. (2018). Impact of tree locations and arrangements on outdoor microclimates and human thermal comfort in an urban residential environment. Urban Forestry & Urban Greening, 32, 81-91.

Appendices

Old neighbourhood (07.28-29.2018)

Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)			Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)		
		1	2	3	1	2	3			1	2	3	1	2	3
07.28.2018	**00:00**	30.7	31	30.7	30.3	30.3	30.4	07.29.2018	**00:00**	34.3	33.7	33.7	32.8	32.7	32.8
	01:00	30.7	30.9	30.5	30.3	30.3	30.5		**01:00**	33.3	32.8	32.3	32.6	32.7	32.7
	02:00	30.5	30.8	30.4	30.3	30.1	30.5		**02:00**	32	31.9	30.8	31.7	31.7	31.7
	03:00	30.4	30.4	30.4	29.3	29.3	29.6		**03:00**	31.2	31.3	30	30.8	30.7	30.8
	04:00	30.4	30.2	30.2	29.3	29.1	29.5		**04:00**	30.6	30.8	29.4	29.8	29.9	29.9
	05:00	30.3	30.1	28.9	28.3	28.3	28.5		**05:00**	30.1	30.5	29	28.5	28.6	28.5
	06:00	28	28.8	27.3	26.5	26.5	26.4		**06:00**	29.8	28.7	28.7	28.3	28.4	28.3
	07:00	29	30.2	30.2	28.2	28.2	28.4		**07:00**	29.7	30.2	28.6	29	29.2	29
	08:00	30.5	30.9	30.9	31.1	30.8	31.3		**08:00**	30.7	30.9	29.5	30.7	30.9	30.7
	09:00	32.6	32.1	32.1	33.1	32.8	33.1		**09:00**	32.2	32.1	31	33	33	33.1
	10:00	34.2	33.6	33.6	34.2	34	34.5		**10:00**	34	33.4	32.6	34.3	34.4	34.4
	11:00	36	35.1	35.1	36.1	36.1	36.4		**11:00**	35.4	34.8	34.4	36.3	36.3	36.5
	12:00	37.6	36.6	36.6	38.1	38.1	38.4		**12:00**	37.6	36.1	36.1	37.4	37.1	37.4
	13:00	39.1	37.9	37.9	39.2	38.9	39.5		**13:00**	39.3	37.3	37.7	38.4	38.1	38.4
	14:00	40.4	39	39	40.4	40.1	40.4		**14:00**	40.7	38.4	39	39.2	39.1	39.4
	15:00	41.4	39.9	39.9	41.2	40.8	41.2		**15:00**	41.7	39.1	39.8	40.3	40.2	40.3
	16:00	42	40.4	40.4	40.4	40.1	40.3		**16:00**	42.4	39.6	40.6	41.3	41.3	41.6
	17:00	42.2	40.6	40.6	41.4	41.4	41.5		**17:00**	42.6	39.8	40.8	41.5	41.3	41.5
	18:00	41.3	39.8	39.8	40.5	40.2	40.7		**18:00**	41.7	41.2	41.9	42.5	42.6	42.6
	19:00	40.2	38.9	38.9	40.6	40.5	40.6		**19:00**	40.5	40.9	40.9	41.6	41.6	41.7
	20:00	39.1	37.8	37.8	37.7	37.6	37.6		**20:00**	39.2	39.6	40.2	40.7	40.7	40.7
	21:00	37.4	36.7	36.7	36.7	36.5	36.6		**21:00**	37.9	38.6	39.2	38.8	38.7	38.8
	22:00	36.6	35.7	35.7	34.7	34.6	34.7		**22:00**	36.5	37.9	37.2	37	37.7	37.8
	23:00	35.4	34.6	34.64	34.7	34.5	34.6		**23:00**	35.3	35	35.2	34.9	34.8	34.9

Individual Housing neighbourhood (07.25-26.2018)

Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)			Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)		
		4	5	6	4	5	6			4	5	6	4	5	6
	00:00	33.1	32.4	31.5	32	31	32.5		**00:00**	32.3	32.6	32	32.1	32.1	32.5
	01:00	32	31.8	30.8	31.6	30.6	32.1		**01:00**	32	32	31.8	32.1	32.1	32.5
	02:00	31.5	31.3	30.3	30.6	29.6	31.1		**02:00**	31.7	31.5	31.2	30.3	30.1	30.7
	03:00	31	31	29.9	28.7	28.6	29.5		**03:00**	31.5	31.1	30.7	30.2	30.1	30.5
	04:00	30.7	30.8	29.7	28.7	29.2	29.5		**04:00**	31.3	30.9	30.5	28.6	28.2	28.8
	05:00	30.4	30.7	29.6	28	27.8	28.5		**05:00**	31.3	30.8	30.4	28.5	28.3	28.6
	06:00	30.2	31.4	30.4	27.1	26.6	27.4		**06:00**	32.1	31.56	31.3	29.5	29.2	29.5
	07:00	30.2	32.5	31.6	27.8	27.7	28.5		**07:00**	33.2	32.8	32.6	30.4	30.2	30.5
	08:00	31.1	33.8	33	29.1	28.7	29.2		**08:00**	34.6	34.2	34.2	32.3	32.1	32.6
	09:00	32.6	35.1	34.5	31.1	30.7	31.2		**09:00**	36	35.6	35.9	33.4	33.4	32.6
	10:00	34.3	36.4	36	31.1	30.7	31.3		**10:00**	37.1	37.1	37.5	33.6	33.6	33.6
07.25.2018	**11:00**	35.9	37.6	37.3	33	32.6	33.3	**07.26.2018**	**11:00**	38	38.4	39	35.5	35.5	33.7
	12:00	37.4	38.6	38.4	34	33.8	34.4		**12:00**	38.6	39.5	40.3	35.5	35.4	35.7
	13:00	38.5	39.3	39.3	35.9	35.7	36.3		**13:00**	38.8	40.3	41.2	36.5	36.3	36.7
	14:00	39.2	39.8	39.8	37.1	36.6	37.5		**14:00**	37.7	40.8	41.8	37.5	37.2	37.7
	15:00	39.5	40	40	37	36.8	37.5		**15:00**	37.1	41	42	38.4	38.1	37.7
	16:00	38.9	39.3	39.2	37.5	37.4	37.8		**16:00**	36.4	40.3	41.2	38.4	38.1	38.7
	17:00	38.2	38.5	38.3	37.5	37.5	37.7		**17:00**	35.8	39.3	40.1	39.4	39.4	39.7
	18:00	37.4	36.6	37.2	37.4	37.4	37.8		**18:00**	35.1	37.3	38.9	38.7	38.6	38.9
	19:00	36.6	35.6	36.2	37.1	37.2	37.6		**19:00**	34.5	36.2	37.7	38.7	38.6	38.8
	20:00	35.7	34.7	35.1	35.3	35.2	35.6		**20:00**	33.8	35.2	36.6	36.8	36.7	36.9
	21:00	34.9	33.9	34.1	34.3	34.2	34.6		**21:00**	33.3	34.3	35.4	35.7	35.5	35.7
	22:00	34.1	33.1	33.1	33	33.1	33.5		**22:00**	32.8	33.4	34.3	33.8	33.6	33.8
	23:00	33.4	32.8	32.3	32.8	32.9	33.4		**23:00**	32.1	33.1	33.3	31.8	31.7	31.8

Multifamily Housing neighbourhood (07.15-16.2014)

Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)			Date	Time	Measured air Temperature (T_a) - (°C)			Simulated air Temperature (T_a) - (°C)		
		7	8	9	7	8	9			7	8	9	7	8	9
07.15.2014	**00:00**	31	30.6	30.8	33	32	32.9	07.16.2014	**00:00**	29.2	29.2	32	32.8	32.8	32.8
	01:00	30.3	29.8	30.1	32.6	31.8	32.6		**01:00**	27.4	27.4	31.8	30.8	30.9	30.9
	02:00	29.8	29.3	29.5	32.7	31.5	31.7		**02:00**	27.3	27.2	31.2	29.9	29.9	29.8
	03:00	29.3	28.8	29	31.5	31.7	31.5		**03:00**	27.4	27.4	30.7	28.9	28.9	28.9
	04:00	29.1	28.6	28.8	28.7	28.4	28.6		**04:00**	27.1	27.1	30.5	27.8	27.9	27.9
	05:00	29	28.5	28.7	27.5	27.3	27.4		**05:00**	27	27.2	30.4	26.9	26.8	26.9
	06:00	29.8	29.3	29.6	26.4	26.3	26.8		**06:00**	29.9	29.9	31.3	26.8	26.8	26.8
	07:00	31.1	30.7	30.9	28.1	28	28.7		**07:00**	29.3	29.3	32.6	26.7	26.7	26.8
	08:00	32.6	32.3	32.6	29.2	28.8	29.6		**08:00**	30.9	30.9	34.2	28.5	28.6	28.6
	09:00	34.2	33.9	34.3	30.1	29.6	30.4		**09:00**	32.7	32.7	35.9	28.7	28.7	28.7
	10:00	35.8	35.5	35.9	31.9	31.4	32.7		**10:00**	34.4	34	37.5	29.5	29.5	29.5
	11:00	37.2	36.9	37.4	32.8	32.3	33.4		**11:00**	35.9	36.1	39	30.9	30.9	31.6
	12:00	38.4	38.2	38.6	34.5	34.5	34.5		**12:00**	37.2	37.2	40.3	31.8	31.8	32.5
	13:00	39.2	39.1	39.6	37	35.7	36.3		**13:00**	38.2	38	41.2	33.7	33.4	33.5
	14:00	39.8	39.7	40.2	37.7	36.8	37.4		**14:00**	38.8	38.8	41.8	35.8	35.7	35.7
	15:00	40	39.9	40.4	38.7	38.1	38.4		**15:00**	39	39	42	36.6	36.3	36.6
	16:00	39.2	39.1	39.5	39.8	39.1	39.4		**16:00**	38.1	38.2	41.2	37.8	37.7	37.7
	17:00	38.2	38	38.7	40.7	40.1	40.3		**17:00**	37	37.1	40.1	37.1	37.1	36.9
	18:00	37.1	36.9	37.3	40.7	40.4	40.4		**18:00**	35.8	35.8	38.9	37.9	37.8	37.8
	19:00	35.9	35.7	36.1	39.7	39.7	39.5		**19:00**	34.6	34.5	37.7	37.2	37.1	36.9
	20:00	34.8	34.5	34.9	38.8	38.7	38.6		**20:00**	33.4	33.4	36.6	36.1	36	36
	21:00	33.8	33.4	33.8	34.8	35	35		**21:00**	32.2	32.2	35.42	34.4	34.2	34.2
	22:00	32.7	32.4	32.7	34.8	34.8	34.7		**22:00**	31.1	30.9	34.35	33.3	33.1	33.1
	23:00	31.8	31.4	31.7	33.8	33.8	33.7		**23:00**	30.1	30	33.37	31.4	31.3	31.3

Old Tolga neighbourhood (07.15.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.15.1986	**00:00**	27.4	27.4	27.8	27.9	28.7	27.9	0.42	0.42	0.42	12.9	12.9	12.9
	01:00	26.7	26.4	26.5	29.8	30.4	29.8	0.33	0.33	0.33	12.6	12.5	12.5
	02:00	25.5	25.4	25.4	35.1	35.1	35.1	0.24	0.24	0.24	12.1	12.1	12.1
	03:00	24.9	24.8	24.8	37.4	37.8	37.8	0.16	0.16	0.16	11.7	11.7	11.7
	04:00	24.3	24.2	24.3	39.1	39.9	39.5	0.14	0.14	0.14	11.4	11.4	11.4
	05:00	24.1	24	24	41.1	41.1	41.1	0.18	0	0	11.1	11.1	11.1
	06:00	23.9	23.1	23.5	45.6	47.2	46.1	0.15	0.1	0.15	10.9	10.9	10.9
	07:00	24.1	23.8	24.3	41.2	41.2	41.2	0.1	0	0.13	16.4	16.4	16.4
	08:00	26.3	26.1	26.2	34.2	34.2	34.2	0.17	0.12	0.17	24.2	24.2	24.2
	09:00	28.3	28.1	28	29.4	29.4	29.8	0.16	0.16	0.16	31	31	31
	10:00	30.3	30.1	30.3	23.3	24	23.3	0.28	0.28	0.28	35.7	35.7	35.7
	11:00	32.1	31.9	32.1	19.5	20.3	19.5	0.32	0.22	0.22	38.9	38.9	38.9
	12:00	33.4	33.6	33.7	20.9	18.4	18.4	0.26	0.26	0.26	48.9	48.9	48.9
	13:00	34.1	34.6	34.8	21.9	19	19	0.36	0.36	0.36	48.9	48.9	48.9
	14:00	35.2	35.8	35.8	19.8	17.4	18.6	0.32	0.32	0.32	53.4	53.4	53.4
	15:00	35.3	35.6	35.9	18.2	15.9	17	0.53	0.53	0.53	43.6	43.6	43.6
	16:00	35.8	36.1	36.1	16.3	16.3	16.3	0.59	0.59	0.59	43.6	43.6	43.6
	17:00	34.7	35.3	35.6	19.4	15.9	15.9	0.49	0.49	0.49	40.8	40.8	40.8
	18:00	34.6	34.6	34.6	17.2	17.2	17.2	0.42	0.42	0.42	36.9	36.9	36.9
	19:00	33.3	33.6	33.2	19	17.7	19	0.32	0.32	0.32	31.8	31.8	31.8
	20:00	32.1	32.3	32.3	20.8	20.8	20.8	0.33	0.33	0.33	23.1	22.6	22.6
	21:00	30.7	30.9	31.1	24	24	24	0.28	0.28	0.28	18.9	18.6	18.6
	22:00	29.6	29.5	29.6	30.5	29.9	29.3	0.35	0.35	0.24	17.3	17.2	17.2
	23:00	28.5	28.4	28.4	32.9	32.3	32.3	0.22	0.22	0.22	16.2	16.1	16.1

Old Tolga neighbourhood (07.16.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.16.1986	**00:00**	27.6	27.8	27.9	34.3	33.3	33.3	0.32	0.32	0.32	15.3	15.3	15.1
	01:00	26.7	26.9	27.6	37.3	34.1	34.1	0.43	0.43	0.43	14.5	14.4	14.4
	02:00	27	26.8	27.2	35.3	36	34.6	0.36	0.36	0.36	14	13.9	13.9
	03:00	26.8	26.8	26.9	36.1	36.9	36.1	0.59	0.59	0.59	13.6	13.5	13.5
	04:00	26.5	26.3	26.7	34.9	33.9	33.9	0.35	0.35	0.35	13.3	13.2	13.3
	05:00	25.7	25.9	26.3	38.5	36.7	35.8	0.3	0.3	0.3	13	12.9	12.9
	06:00	25.7	26.1	26.4	38.4	36.2	36.2	0.5	0.5	0.5	12.9	12.8	12.8
	07:00	27.2	27	27.3	32.7	33.4	32.7	0.59	0.59	0.59	17.9	17.9	17.9
	08:00	28.9	28.6	28.9	27.4	27.4	27.4	0.62	0.62	0.62	25.1	25.1	25.1
	09:00	30.8	30.5	30.8	23.5	23.5	23.5	0.84	0.84	0.84	31.2	31.2	31.2
	10:00	32.7	32.4	32.7	17.9	18.8	17.9	1.28	0.86	0.86	35.5	35.5	35.5
	11:00	34.5	34.2	34.5	14.9	15.7	14.9	0.87	0.87	0.87	39	39	39
	12:00	35.8	35.8	36	12.9	12.2	12.2	1.4	1.4	1.4	48.4	48.4	48.4
	13:00	36.9	36.9	37.2	10.7	10.7	11.4	1.24	1.24	1.24	48.2	48.2	48.2
	14:00	37.9	37.9	38.1	10	10	10	1.41	1.41	1.41	52.7	52.7	52.7
	15:00	38.2	38.5	38.5	8.8	8.3	8.3	1.46	1.46	1.46	45.2	45.2	45.2
	16:00	38.5	38.5	38.7	7.9	8.5	7.9	1	1	1	44.4	44.4	44.4
	17:00	38.2	38.2	38.6	8.8	8.8	8.8	1.2	1.2	1.2	40.7	40.7	40.7
	18:00	37	37.4	37.8	9.8	9	9	1.13	1.13	1.13	36.4	36.4	36.4
	19:00	35.7	36.2	36.7	11.2	10.2	10.2	0.96	0.96	0.96	33.3	33.3	33.3
	20:00	35.1	35.1	35.4	10.6	11.3	10.6	0.87	0.87	0.87	23.1	23.1	22.5
	21:00	34	34	34.3	13.1	13.6	14.2	0.61	0.61	0.61	19.6	19.6	19.2
	22:00	33.1	33.1	33.3	14.8	14.8	14.8	0.35	0.35	0.35	18.2	18.2	17.9
	23:00	32	31.8	32	14.9	15.4	15.8	0.32	0.32	0.32	17.2	17.2	17.2

Old Tolga neighbourhood (07.17-18.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.17.1986	**00:00**	30.2	30.8	31.1	18.1	16.4	16.4	0.44	0.44	0.44	16.3	16.3	16.1
	01:00	29.3	29.3	30.2	21	19.7	17	0.53	0.53	0.53	15.6	15.6	15.4
	02:00	29.2	29.4	29.7	18.6	19.4	18.6	0.51	0.51	0.51	14.9	14.9	14.7
	03:00	28.6	28.6	28.8	17.8	19.1	17.8	0.33	0.33	0.33	14.4	14.4	14.3
	04:00	28.2	27.9	28.2	18.8	19.5	18.8	0.26	0.26	0.26	14	14	13.9
	05:00	27.7	27.6	27.9	19.8	19.8	19.4	0.13	0.13	0.13	13.7	13.7	13.6
	06:00	27.8	27.5	27.5	19.4	19.8	19.6	0.12	0	0	13.6	13.5	13.5
	07:00	28.4	28.4	28.4	19.2	19.2	19.4	0	0	0	18.6	18.6	18.6
	08:00	29.9	29.8	29.8	18.4	18.7	19.2	0	0	0	26	26	26
	09:00	32	31.9	31.9	15.9	16.5	16.5	0.45	0.3	0.3	32.6	32.6	32.6
	10:00	33.9	33.9	33.8	13.4	14.4	13.4	0.26	0.26	0.26	37.5	37.5	37.5
	11:00	35.6	35.6	35.8	12.6	14.8	12.6	0.38	0.38	0.38	41	41	41
	12:00	37.1	37.1	37.4	11.6	13.8	11.6	0.41	0.41	0.41	50.6	50.6	50.6
	13:00	37.9	37.9	38.2	11.6	12.5	11.6	0.67	0.67	0.67	49.8	49.8	49.8
	14:00	38.8	38.8	38.8	11.2	12.1	11.2	0.71	0.71	0.71	53.9	53.9	53.9
	15:00	37.7	38	39	13.8	11.3	10.5	1.01	1.01	1.01	45.6	45.6	45.6
	16:00	38.9	39.3	38.9	11.8	11	11.8	0.76	0.76	0.76	44.9	44.9	44.9
	17:00	39	39	39.4	12.1	12.1	12.1	0.78	0.78	0.78	42.1	42.1	42.1
	18:00	38.2	38.2	38.6	11.8	12.6	11.8	0.79	0.79	0.79	37.4	37.4	37.4
	19:00	37.2	37.4	37.6	13	12.6	12.6	0.24	0.24	0.24	34.6	34.6	32.3
	20:00	35.7	35.8	35.9	14.2	13.3	13.3	0.17	0.17	0.17	24.9	24.9	24.4
	21:00	34.5	34.5	34.7	17.6	17.2	17.2	0.2	0.2	0.2	21.4	21.4	21
	22:00	33.2	33.2	33.1	19.6	19.3	20.1	0.19	0.13	0.13	19.8	19.8	19.6
	23:00	32.1	32.1	32.3	21.2	21.2	21.4	0	0	0	18.7	18.7	18.6
07.18.1986	**00:00**	31.1	31.1	31.3	24.3	24.3	24.9	0.13	0.13	0.13	17.9	17.9	17.8

Individual Housing neighbourhood (07.15.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.15.1986	**00:00**	25.6	25.1	26	41.2	44.1	40.3	0.61	0.81	0.42	13.2	13.2	13.4
	01:00	24.9	24.7	25.1	44.9	48	45.9	0.17	0.49	0.33	12.8	12.8	13.1
	02:00	24	23.5	24.2	49.5	52	50.3	0.13	0	0.24	12.3	12.3	12.6
	03:00	23.5	23.2	23.6	50.7	51.5	49.2	0.17	0	0.25	11.7	11.7	12.3
	04:00	22.3	22.6	22.9	53.8	51.9	51.9	0.28	0	0.34	11.3	11.3	12
	05:00	22.4	22.2	22.5	52.4	53.2	51.7	0	0.38	0.28	11	11	11.4
	06:00	22	22.1	22.4	50.9	49.7	49.1	0.21	0	0.16	11	11	11.3
	07:00	22.3	22.9	22.3	49.7	50.7	48.7	0	0.3	0.15	15.6	15.6	22.2
	08:00	24.2	24.4	24.6	40.9	40.1	40.9	0.19	0.14	0.14	23.1	23.1	35
	09:00	26.2	26.2	26.5	33.6	32.6	34.5	0.22	0.16	0.22	43.8	43.8	41.4
	10:00	27.9	27.7	28.3	26.9	31.1	29.7	0.13	0.83	0.37	47.7	47.7	43
	11:00	29.7	29.4	30	26.1	27.6	26.2	0.11	0.64	0.22	49.1	49.1	43
	12:00	31.6	31.3	31.8	20.1	25	23.8	0.75	0.15	0.51	47.5	47.5	42.5
	13:00	32.4	32.4	32.7	18.8	21.9	20.3	1.2	0.47	1.2	39.8	47.7	43
	14:00	33	33.3	33.5	21.4	19.3	20.3	0.81	0.99	0.81	42.6	42.6	49.7
	15:00	33.2	33.4	33.6	22	19.2	18.3	1.17	1.44	0.89	42.6	42.6	48.9
	16:00	33.5	33	33.7	18.9	21.5	22.8	1.51	0.69	1.24	42.6	58.1	47.7
	17:00	33.8	33.3	33.5	19	21.5	21.5	1.12	0.92	0.72	57.7	40.4	46.2
	18:00	32.7	31.9	32.7	20.8	24.7	21.7	0.77	0.42	0.42	53.6	36.7	39.5
	19:00	31.5	31.2	31.3	26.5	25.6	24.8	0.7	1.22	0.87	31.2	31.2	31.2
	20:00	29.8	29.7	30	27.6	28.4	27.6	0.83	0.39	0.68	22.6	22.2	20.2
	21:00	28.6	28.4	28.7	32.4	33.1	31.8	0.56	0.31	0.43	17.1	18.3	17.2
	22:00	27.1	27.3	28	33.8	34.8	32.8	0.13	0.76	0.23	15.8	17.1	16.3
	23:00	26	26.2	26.7	38.1	39.2	37.1	0.11	0.7	0.21	15.6	15.8	15.4

Individual Housing neighbourhood (07.16.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.16.1986	**00:00**	25.7	25.4	25.4	37.8	39.5	38.7	0.82	0.29	0.42	14.8	14.8	14.6
	01:00	25.2	25	25.4	40.7	41.8	39.7	1.02	0.45	0.59	14	14	14.8
	02:00	24.8	24.5	25.1	43.2	45.9	42.5	0.45	0.59	0.3	13.6	13.6	13.9
	03:00	24.5	24.2	24.8	43.8	45.4	43.8	0.86	1.11	0.61	13.4	13.4	14.3
	04:00	24.4	24	24.5	44.4	46.1	45.3	0.41	0.16	0.28	13	13	13.3
	05:00	23.7	23.9	24.3	46	46.9	46	0.38	0.49	0.27	12.6	12.6	13.2
	06:00	23.8	23.6	24.2	44.7	45.7	43.6	1	0.23	0.42	12.5	12.5	13
	07:00	25.1	24.5	25.3	41.6	42.6	44.8	0.3	1.63	0.57	17.3	17.3	22.9
	08:00	26.6	26	26.7	39.1	42.5	39.1	0.56	0.82	0.56	24.4	24.4	35.2
	09:00	28.3	27.6	28.5	33.3	36.4	34.3	1.1	0.42	0.76	43.2	43.2	45.3
	10:00	30.4	29.6	30.6	25.4	30.6	25.4	0.45	0.84	0.45	47.3	47.3	49.5
	11:00	32.5	30.9	32	21	25.3	22.1	0.45	1.62	0.84	48.4	48.4	50.3
	12:00	33.4	32.9	33.6	20.2	21.6	20.9	3.13	0.7	1.31	46.9	46.9	49.9
	13:00	34.9	33.6	34.7	17.3	20.4	18.9	1.2	1.75	1.2	40.2	47.8	49.3
	14:00	35.5	34.8	35.7	16.9	18.7	17.5	1.94	0.72	1.33	42.2	42.2	52.2
	15:00	36.1	35.4	36.1	16.5	18.3	17.7	2.02	0.76	1.39	43.2	43.2	54.9
	16:00	36.2	34.6	36.5	16.1	20.8	17	0.5	1.41	0.96	56.7	42.7	59.1
	17:00	36	35	36.4	17.3	21.1	18.3	1.07	0.57	1.07	53.5	39.7	60
	18:00	35.3	34.9	35.6	20	22.1	19	1.81	0.91	0.91	53.5	35.9	56.4
	19:00	34.1	33.3	34.5	20.4	22.7	21.6	1.19	0.41	0.8	30.5	30.5	30.5
	20:00	33.1	31.8	32.7	21.9	26.2	23.6	0.44	1.22	0.83	22.6	22.6	20.4
	21:00	30.9	30.6	31.6	30.2	31.2	29.2	1.64	1.35	1.05	19.7	19.7	17.9
	22:00	31.2	30.5	30.9	27.1	29.3	28.4	0.19	0.19	0.36	18.1	18.1	17.2
	23:00	29.2	29.4	29.7	32	31.2	29.6	0.59	0.74	0.45	17.2	17.2	16.4

Individual Housing neighbourhood (07.17-18.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.17.1986	**00:00**	28.4	27.9	28.9	35.3	38.1	36.2	1.15	0.79	0.79	16.5	16.5	16
	01:00	27.6	27.8	28.3	36.1	38	36.1	0.75	1.48	1	16.1	16.1	15.3
	02:00	27.1	26.4	27.3	41.2	44.2	41.9	0.71	0.91	0.71	15.5	15.5	15
	03:00	26.3	26.1	26.8	44.2	45.2	43.2	0.16	1.06	0.46	15.1	14.6	14.8
	04:00	25.7	25.9	26.4	48	47.1	45.3	0.51	0.75	0.51	14.6	14.6	14.4
	05:00	25.5	25.5	26	51.4	50.8	50.2	0.37	0	0.37	14.2	14.2	14.5
	06:00	25.8	25.7	26.1	48	48.7	48.7	0.33	0.26	0.39	13.9	13.9	14.2
	07:00	26.5	26.1	26.7	45.1	46.6	45.9	0.25	0.3	0.3	18.4	18.4	24.2
	08:00	27.8	27.5	28.3	40.3	41.9	40.3	0.15	0.37	0.23	25.4	25.4	34.5
	09:00	29.3	29.7	30	38.4	37.1	36.5	0.62	0.48	0.75	44.8	44.8	46.9
	10:00	31.7	31.4	32	31.3	32.9	31.3	0.24	0.71	0.24	48.9	48.9	51.1
	11:00	33.5	32.8	33.7	25.4	29.4	27.4	0.45	0.81	0.45	49	49	52.7
	12:00	35.1	34.2	35.2	23.5	27.3	24.5	0.39	0.58	0.39	49.6	51.2	52.8
	13:00	35.8	35	36	21.6	25.4	23.5	1.24	0.94	0.65	42.5	50.1	53.2
	14:00	36.8	35.7	36.8	20.1	23.7	21	1.02	0.71	0.71	44.1	44.1	54.1
	15:00	36.9	36.6	37.1	19.3	20.3	18.3	1.79	2.16	1.41	44.5	44.5	58.1
	16:00	36.1	37	37.2	22	18	18.8	2.01	1.03	1.52	58.4	43.6	51
	17:00	36.7	35.7	36.4	19.8	23.7	20.8	1.93	0.92	1.26	58.6	41.3	49.9
	18:00	36.2	35.1	36.4	20.3	24.5	21.1	1.09	0.75	0.41	53.6	36.9	48
	19:00	35.4	35.2	35.5	18.9	19.9	19.4	0.1	0.63	0.28	32.2	32.2	32.2
	20:00	34	33.8	34.2	22.8	23.3	22.8	0	0.3	0.15	24.3	24.3	22.3
	21:00	32.6	32.9	32.8	28.4	27.8	28.4	0.69	0.31	0.44	21.1	21.1	20
	22:00	31.7	31.5	32.1	27.6	28.1	28.2	0.26	0.49	0.18	19.6	19.6	19.6
	23:00	30.1	30.8	31.1	32.4	31.7	31.1	0.12	0.28	0	18.6	18.6	18.1
07.18.1986	**00:00**	29.7	29.5	30.1	34	35.3	35.3	0.17	0.49	0.25	17.9	17.9	17.4

Multifamily Housing neighbourhood (07.15.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.15.1986	**00:00**	26.1	25.9	25.5	40.2	40.2	41.9	0.71	0.36	1.07	13.6	13.5	13.5
	01:00	25.2	25	24.5	44.5	45.4	48.1	0.29	0.29	0.84	13.1	13.1	13.1
	02:00	24.4	24.2	23.9	49.3	49.3	50	0.37	0.19	0.37	12.6	12.6	12.6
	03:00	23.5	23.3	23.2	50.5	51.2	51.2	0.22	0.22	0.32	12.2	12.2	12.2
	04:00	22.5	22.8	22.9	53	52.5	52	0.26	0.44	0.18	11.9	11.9	11.9
	05:00	22.5	22.4	22.3	51.6	52	52	0.17	0.44	0.38	11.6	11.4	11.6
	06:00	22.1	22.3	22.4	50.4	49.9	49.5	0.17	0.17	0.12	11.4	11.2	11.2
	07:00	22.8	22.7	23	48.2	48.2	48.2	0	0.26	0.26	15.6	15.6	15.6
	08:00	24.7	24.5	24.5	40.2	41	40.6	0.15	0.15	0.29	23.5	23.5	23.5
	09:00	26.5	26.4	26.2	32.9	33.6	33.6	0.21	0.21	0.42	30	30	30
	10:00	28.2	28.3	28.4	27.7	27.7	30	0.42	0.8	1	46.7	34.2	34.2
	11:00	30	30.2	30.2	24.5	23.2	25.9	0.24	0.47	0.92	47.8	36.8	36.8
	12:00	31.1	31.5	31.9	25.3	22.6	21.3	0.53	0.53	0.35	45.2	48.1	48.1
	13:00	31.8	32.7	33.5	23.4	21.8	20.2	0.81	0.81	0.41	48.7	48.7	48.7
	14:00	33.4	34.3	34	24.5	21.7	20.3	0.77	1.02	1.02	49.1	52.6	42.1
	15:00	33.7	34	33.4	22.7	21.6	20.4	0.44	1.7	1.7	50.8	41.1	41.1
	16:00	33.7	34	34	20.3	19	19	0.72	0.37	1.06	55.5	41	41
	17:00	32.9	33.8	33.8	23.5	20.9	20.9	0.8	0.8	0.54	39.4	39.4	39.4
	18:00	32.4	32.8	32.4	23	20.9	24	0.52	0.52	0.77	36.1	36.1	36.1
	19:00	31.2	31.4	31.6	28.1	27.2	26.4	0.6	1.19	1.19	31	31	31
	20:00	30.4	30.2	30.2	26.3	27.2	27.2	0.19	0.38	0.56	21.8	22.2	22.2
	21:00	29.3	29	28.8	30.6	31.4	32.2	0.17	0.32	0.48	17.7	18.3	18.6
	22:00	27.6	28.1	28	34.5	33	33	0.21	0.42	0.62	16.7	16.9	16.9
	23:00	26.8	27.2	27	38.2	36.5	36.5	0.23	0.23	0.69	15.7	15.9	15.9

Multifamily Housing neighbourhood (07.16.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.16.1986	**00:00**	26.4	26.1	25.9	36.3	37.2	37.2	0.17	0.17	0.34	15	15	15
	01:00	25.8	25.4	25.1	39.7	40.8	40.8	0.23	0.23	0.44	14.2	14.4	14.4
	02:00	25.4	25.2	24.8	42.9	42.9	45.5	0.23	0.23	0.65	14	14	14
	03:00	25.3	24.9	24.6	41.7	42.6	45.4	0.4	0.4	1.17	13.4	13.6	13.6
	04:00	25	25	24.8	43.7	43.7	43.7	0.21	0.21	0.21	13.3	13.4	13.3
	05:00	24.4	24.4	24.6	46.3	45.2	44.2	0.16	0.31	0.31	12.9	13.1	12.9
	06:00	24.3	24.1	23.9	44.9	43.8	44.9	0.27	0.27	0.27	12.9	12.9	12.8
	07:00	25.3	25.5	24.9	41.7	41.7	43.9	0.45	0.87	1.73	17.4	17.4	17.4
	08:00	27.1	27.1	26.4	38.7	38.7	40.7	0.47	0.47	0.47	24.4	24.4	24.4
	09:00	28.7	28.4	28.2	33.6	33.6	34.7	0.54	0.54	0.54	30	30	30
	10:00	30.8	30.6	29.9	25.5	26.5	29.6	0.58	0.58	1.14	46.6	34.4	34.4
	11:00	32.2	32.5	31.7	21.9	21.9	25	0.6	0.6	1.77	47.6	36.7	36.7
	12:00	33.6	33.6	33.8	21.1	20.3	20.3	0.79	0.79	0.79	46.3	38.7	47.9
	13:00	34.9	35.2	34.6	17.6	17.6	19.5	0.67	0.67	0.67	48.9	48.9	48.9
	14:00	35.8	36.2	36	17.6	16.3	16.9	0.74	0.74	0.74	51.6	51.6	51.6
	15:00	36.3	36.8	36.5	16.8	16.3	16.3	0.75	0.75	0.75	54.8	54.8	41.1
	16:00	36.5	36.5	35.4	18.2	17.2	20.1	1.07	0.55	1.07	54.4	40.7	40.7
	17:00	36.4	36.7	36	18.3	18.3	19.2	0.65	0.65	0.65	54.4	39.1	39.1
	18:00	35.2	35.8	35.5	20.9	19.3	19.3	0.63	0.63	0.63	54.1	35.7	35.7
	19:00	34.5	34.9	34.9	21.1	20.1	20.1	0.54	0.54	0.54	30.7	30.7	30.7
	20:00	33	33	32.3	23.9	23.9	25.8	1.02	1.02	1.02	21.3	21.8	22.8
	21:00	31.4	32	31.4	29.7	26.9	27.8	0.58	0.58	1.13	18.4	19.1	19.5
	22:00	30.9	31.4	31.1	28.7	27.2	28	0.24	0.47	0.47	17.6	17.8	18.1
	23:00	29.7	29.9	30.2	31.2	29.6	29.6	0.26	0.26	0.73	16.7	17.1	17.3

Multifamily Housing neighbourhood (07.17-18.1986)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.17.1986	**00:00**	29.1	28.5	28.8	35.7	36.7	36.7	0.51	0.51	0.26	16.4	16.6	16.6
	01:00	27.8	28.4	28.2	38.8	36.4	35.7	0.42	0.82	1.22	15.7	16	16
	02:00	27.5	27.7	26.7	40.8	40.8	44.3	0.29	0.58	1.14	15.3	15.5	15.5
	03:00	26.2	27.2	26.7	43.5	42.4	44.6	0.52	0.52	1.26	14.9	15.1	15.1
	04:00	26.2	26.7	26.5	45.8	44.7	45.8	0.3	0.3	1.12	14.6	14.6	14.8
	05:00	25.9	26.2	26.2	50.4	49.5	49.5	0.28	0.41	0.41	14.2	14.5	14.5
	06:00	25.7	26.1	26.1	49.5	48	48	0.27	0.63	0	14.1	14.1	14.1
	07:00	26.5	26.8	26.8	46.6	45.5	45.5	0.23	0.53	0	18.4	18.4	18.4
	08:00	28	28.2	27.9	41.6	40.5	40.5	0.15	0.5	0	25.8	25.8	25.8
	09:00	29.9	30.3	30.3	37.8	35.9	36.5	0.24	0.24	0.71	31.8	31.8	31.8
	10:00	32	32.2	32.2	30.5	30.5	31.4	0.3	0.3	0.88	48.2	36.6	36.6
	11:00	33.6	33.6	33.6	25.9	27	28.2	0.35	0.35	1.03	49.9	39.4	39.4
	12:00	35.2	35.4	35.2	22.9	24	25.1	0.37	0.37	0.72	50.4	50.4	50.4
	13:00	35.8	36.4	36.9	23.2	22.1	23.2	0.5	0.5	0.99	49.6	49.6	49.6
	14:00	36.9	37.2	36.6	19.7	19.7	20.7	0.52	0.52	1.03	53.3	53.3	53.3
	15:00	36.4	37.6	37.3	22.9	19.4	18.5	0.64	0.64	1.9	56.4	42.5	42.5
	16:00	37.1	37.3	37.3	20.6	18.8	18.8	0.66	0.66	1.31	55.4	41.4	41.4
	17:00	37.5	37.5	37.2	19.1	19.1	20.2	0.47	0.47	1.39	55.6	40.4	40.4
	18:00	36.7	36.7	35.7	19.7	20.7	22.6	0.5	0.5	0.98	36.4	36.4	36.4
	19:00	35.7	35.8	35.8	19.4	19.4	19.4	0.22	0.43	0.64	32	32	32
	20:00	34.1	34.4	34.1	23.1	22.4	22.8	0.22	0.29	0.43	22.9	23.9	24.3
	21:00	32.5	33	33.2	28.9	27.8	27.2	0.17	0.33	0.48	20.4	21	21.3
	22:00	31.5	31.9	32.1	28.5	27.7	27.2	0.12	0.12	0.45	19.1	19.5	19.7
	23:00	30.6	30.9	30.9	31.7	31	30.6	0	0.25	0.12	18.5	18.6	18.6
07.18.1986	**00:00**	29.8	30	30	34.7	33.7	33.7	0.12	0.12	0.33	17.7	17.9	17.9

Old Tolga neighbourhood (07.15.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.15.2001	**00:00**	27.6	27.6	27.6	27.9	28.7	27.7	0.42	0.42	0.42	12.9	12.9	12.9
	01:00	26.7	26.5	26.5	29.8	30.4	29.8	0.33	0.33	0.33	12.6	12.5	12.5
	02:00	25.7	25.5	25.5	35.1	35.1	35.1	0.24	0.24	0.24	12.1	12.1	12.1
	03:00	24.9	24.9	24.9	37.4	37.8	37.8	0.16	0.16	0.16	11.7	11.7	11.7
	04:00	24.4	24.3	24.3	39.1	39.1	39.5	0.14	0.14	0.14	11.4	11.4	11.4
	05:00	24.1	24.1	24.1	41.1	41.1	41.1	0	0	0	11.1	11.1	11.1
	06:00	23.9	23.3	23.3	45.6	47.2	46.1	0.15	0.1	0.15	10.9	10.9	10.9
	07:00	24.1	24.1	24.3	41.2	41.2	40.6	0.1	0	0	16.4	16.4	16.4
	08:00	26.3	26.3	26.2	34.2	33.9	34.2	0.17	0.12	0.17	24.2	24.2	24.2
	09:00	28.3	28.3	28.1	29.4	29.4	29.8	0.16	0.16	0.16	31	31	31
	10:00	30.4	30	30.3	23.3	24.7	23.3	0.28	0.28	0.28	35.7	35.7	35.7
	11:00	32.3	31.9	32.1	19.5	20.3	19.5	0.22	0.22	0.22	38.9	38.9	38.9
	12:00	33.7	33.6	33.7	18.4	18.4	18.4	0.26	0.26	0.26	48.9	48.9	48.9
	13:00	34.4	34.8	34.8	21.9	18.9	18.9	0.36	0.36	0.36	48.9	48.9	48.9
	14:00	35.6	36	36	19.8	17.4	17.4	0.32	0.32	0.32	53.4	53.4	53.4
	15:00	35.6	35.9	35.9	17	15.9	17	0.53	0.53	0.53	56.5	43.6	43.6
	16:00	36.1	36.1	36.1	16.3	16.3	16.3	0.59	0.59	0.59	43.6	43.6	43.6
	17:00	35	35.6	35.6	18.3	15.9	15.9	0.49	0.49	0.49	40.8	40.8	40.8
	18:00	34.8	34.8	34.8	17.2	17.2	17.2	0.42	0.42	0.42	36.9	36.9	36.9
	19:00	33.5	33.8	33.3	18.3	17.7	19.6	0.32	0.32	0.32	31.8	31.8	31.8
	20:00	32.1	32.3	32.3	20.8	20.8	20.8	0.33	0.33	0.33	22.6	23.1	22.6
	21:00	30.9	31.1	31.1	24	24	24	0.28	0.28	0.28	18.9	18.9	18.6
	22:00	29.6	29.6	29.7	29.9	29.9	29.3	0.35	0.24	0.24	17.3	17.3	17.2
	23:00	28.5	28.5	28.5	32.3	32.3	32.3	0.22	0.22	0.22	16.2	16.2	16.1

Old Tolga neighbourhood (07.16.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.16.2001	**00:00**	27.8	27.9	28.2	35.2	33.3	33.3	0.32	0.32	0.32	15.3	15.3	15.1
	01:00	26.9	27.6	27.6	36.2	34.1	34.1	0.43	0.43	0.43	14.5	14.5	14.5
	02:00	27.2	27	27.3	35.3	36	34.6	0.36	0.36	0.36	13.9	14	13.9
	03:00	26.9	26.8	26.9	36.1	37.8	36.1	0.59	0.59	0.59	13.6	13.6	13.5
	04:00	26.5	26.5	26.7	34.9	33.9	33.9	0.35	0.35	0.35	13.3	13.3	13.2
	05:00	25.9	26.3	26.5	38.5	35.8	35.8	0.3	0.3	0.3	13	13	12.9
	06:00	25.9	26.4	26.4	38.4	36.2	36.2	0.5	0.5	0.5	12.8	12.8	12.8
	07:00	27.3	27.2	27.3	32.7	34.8	32.7	0.59	0.59	0.59	17.9	17.9	17.9
	08:00	29.1	28.9	29.1	27.4	27.4	27.4	0.62	0.62	0.62	25.1	25.1	25.1
	09:00	30.8	30.8	30.8	23.5	23.5	23.5	0.84	0.84	0.84	31.2	31.8	31.8
	10:00	32.7	32.4	32.7	17.9	17.9	17.9	0.86	0.86	0.86	35.5	35.5	35.5
	11:00	34.5	34.2	34.5	14.9	15.7	14.9	1.28	0.87	0.87	39	39	39
	12:00	36	36	36	12.9	12.2	12.2	1.4	1.4	1.4	48.4	48.4	48.4
	13:00	37.2	36.9	37.2	10.7	11.4	10.7	1.24	1.24	1.24	48.2	48.2	49.5
	14:00	38.2	38.2	38.2	8.5	9.1	8.5	1.41	1.41	1.41	52.7	52.7	52.7
	15:00	38.8	38.8	38.8	8.3	8.3	8.3	1.46	1.46	1.46	45.2	45.2	45.2
	16:00	38.9	38.9	38.9	7.9	8.5	7.9	1	1	1	44.4	44.4	44.4
	17:00	38.6	38.6	38.6	8.8	8.8	8.8	1.2	1.2	1.2	40.7	40.7	40.7
	18:00	37.4	37.8	37.8	9	9	9	1.13	1.13	1.13	36.4	36.4	36.4
	19:00	36.2	36.7	36.7	10.2	10.2	10.2	0.96	0.96	0.96	33.3	33.3	33.3
	20:00	35.4	35.1	35.4	10.6	11.9	10.6	0.87	0.87	0.87	23.1	23.1	22.5
	21:00	34.3	34.3	34.3	13.1	14.2	13.6	0.61	0.61	0.61	19.6	19.6	19.2
	22:00	33.3	33.3	33.3	14.8	14.8	14.8	0.35	0.35	0.51	18.2	18.2	18.2
	23:00	32.2	31.8	32.2	15.4	15.4	15.4	0.32	0.32	0.32	17.2	17.2	17.2

Old Tolga neighbourhood (07.17-18.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.17.2001	**00:00**	30.5	31.4	31.4	18.1	16.4	16.4	0.44	0.44	0.64	16.3	16.3	16.3
	01:00	29.7	29.7	30.4	20.9	19	17	0.53	0.53	0.53	15.6	15.6	15.4
	02:00	29.4	29.4	29.7	18.6	18.6	18.6	0.51	0.51	0.51	14.9	14.9	14.7
	03:00	28.8	28.6	29	17.8	19.8	17.8	0.33	0.33	0.33	14.4	14.4	14.3
	04:00	28.4	28.2	28.4	18.8	19.5	18.8	0.26	0.26	0.26	14	14	13.1
	05:00	27.9	27.9	28	19.8	19.8	19.4	0.13	0.13	0.13	13.7	13.7	13.6
	06:00	27.9	27.8	27.8	19.4	19.6	19.6	0	0	0	13.6	13.6	13.5
	07:00	28.5	28.5	28.5	19.2	19.2	19.4	0	0	0	18.6	18.6	18.6
	08:00	30	29.9	29.9	18.4	18.7	19.2	0	0	0	26	26	26
	09:00	32.1	31.9	32	15.9	16.5	16.5	0.45	0.3	0.45	32.6	32.6	32.6
	10:00	34	34	34	13.4	13.9	13.4	0.26	0.26	0.26	37.5	37.5	37.5
	11:00	35.8	35.6	35.6	12.6	13.3	12.6	0.38	0.38	0.38	41	41	41
	12:00	37.4	37.1	37.4	11.6	13.8	11.6	0.41	0.41	0.41	50.6	50.6	50.6
	13:00	38.2	38.2	38.2	11.6	12.5	11.6	0.67	0.67	0.67	49.8	49.8	49.8
	14:00	39.1	39.1	39.1	11.2	12.1	11.2	0.71	0.71	0.71	55.3	55.3	55.3
	15:00	38	39	39.4	14.6	11.3	10.5	1.01	1.01	1.01	45.6	45.6	45.6
	16:00	39.3	39.6	39.3	11.8	10.9	11.8	0.76	0.76	0.76	44.9	44.9	44.9
	17:00	39.4	39.4	39.4	12.1	12.1	12.1	0.78	0.78	0.78	42.1	42.1	42.1
	18:00	38.6	38.6	38.6	11.8	12.6	11.8	0.79	0.79	0.79	37.4	37.4	37.4
	19:00	37.4	37.6	37.6	13	12.6	12.6	0.24	0.24	0.24	34.6	32.3	32.3
	20:00	35.8	35.9	35.9	14.2	13.3	13.3	0.17	0.17	0.17	24.9	24.9	24.4
	21:00	34.7	34.7	34.7	17.6	17.2	17.2	0.2	0.2	0.2	21.4	21.4	21.4
	22:00	33.4	33.4	33.4	19.6	19.3	20.1	0.13	0.13	0.13	19.8	19.8	19.8
	23:00	32.3	32.3	32.3	21.2	20.9	21.4	0	0	0	18.7	18.7	18.7
07.18.2001	**00:00**	31.5	31.5	31.3	24.3	24	24.9	0.13	0.13	0.13	17.9	17.9	17.8

Old Tolga neighbourhood (07.17-18.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.15.2001	**00:00**	26.9	26.4	27.4	30.1	32.9	30.1	0.81	0.81	0.42	13.6	13.6	13.8
	01:00	26.5	26	26.8	31.1	33.3	31.1	0.33	0.48	0.17	13.3	13.3	13.8
	02:00	25.7	25.1	25.7	35.5	37.2	35.5	0.24	0.24	0.24	12.8	12.8	13.7
	03:00	25	24.8	25.3	38.1	37.3	38.8	0.25	0.17	0.25	12.2	12.4	12.9
	04:00	23.9	24.2	24.6	41.9	39.9	39.9	0.35	0.22	0.35	11.9	11.9	13.4
	05:00	24.2	24	24.2	42.1	43	42.1	0	0.44	0.24	11.7	11.7	13
	06:00	23.7	23.7	24.1	46.4	45.8	45.2	0.22	0	0.16	11.7	11.7	13.1
	07:00	24	24.2	24.7	41	41	40	0	0.41	0.16	16.4	16.4	17.4
	08:00	26	26.1	26.5	35.5	34.7	33.8	0.19	0.25	0.19	23.9	23.9	35.6
	09:00	27.9	27.9	28.3	31.1	30.2	30.2	0.29	0.29	0.22	44.4	44.4	42.1
	10:00	29.7	29.7	30.2	24.6	27.3	25.9	0.25	0.83	0.37	48.4	48.4	43.8
	11:00	31.4	31.1	31.9	21.9	24.5	21.9	0.22	0.63	0.22	49.9	49.9	43.9
	12:00	33.3	33.1	33.6	19.3	23.8	21.6	0.74	0.27	0.51	48.4	48.4	50
	13:00	34.2	34.2	34.5	20.4	23.3	20.4	1.35	0.76	0.76	40.9	48.7	50.3
	14:00	34.9	35.1	35.3	21.1	19.1	20.1	0.99	1.17	0.99	43.7	43.7	54.2
	15:00	35.2	35.4	35.6	19.8	17.2	17.2	1.45	1.73	0.89	43.6	43.6	56
	16:00	35.3	34.7	35.6	17.3	22.2	18.5	1.79	0.96	1.51	59	43.6	61.6
	17:00	35.6	35.1	35.4	17.2	19.6	17.2	1.32	0.92	0.72	58.5	41.1	61.4
	18:00	34.5	34.1	34.5	17.9	21.5	18.8	0.94	0.59	0.42	54.4	37.6	57.3
	19:00	33.3	33.1	33.4	21.4	19.7	19.7	0.88	1.39	0.88	32.1	32.1	32.1
	20:00	31.7	31.5	31.8	22.6	23.3	23.3	0.83	0.68	0.68	23.4	23.4	21.4
	21:00	30.4	30.2	30.5	26.2	26.8	26.8	0.68	0.43	0.56	19.5	19.5	18.7
	22:00	28.9	29.1	29.9	30.7	31.7	30.7	0.23	0.87	0.34	17.9	17.9	17.4
	23:00	27.8	28.3	28.8	34	34	33	0.21	0.8	0.31	17	16.9	16.5

Individual Housing neighbourhood (07.16.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.16.2001	**00:00**	27.5	27.2	27.7	35.5	37.2	35.5	1.08	0.42	0.55	16.1	16.1	15.9
	01:00	26.9	26.7	27.2	37.3	38.4	36.2	1.16	0.59	0.59	15.3	15.4	15.6
	02:00	26.8	26.5	27.2	36.7	38.8	36.7	0.59	0.74	0.45	14.8	15	15.4
	03:00	26.3	26.1	26.6	39.1	41.5	38.3	1.11	1.11	0.86	14.6	14.6	15
	04:00	26.2	25.9	26.4	35.4	35.4	36.2	0.54	0.28	0.28	14.1	14.1	14.7
	05:00	25.5	25.9	26.1	38.6	38.6	37.6	0.49	0.6	0.39	13.8	13.8	14.7
	06:00	25.7	25.7	25.9	39.3	41.2	38.2	1.19	0.42	0.61	13.7	13.7	14.5
	07:00	26.8	26.6	27.1	36.1	38.4	35	0.57	1.9	0.83	18.3	18.3	24.5
	08:00	28.3	27.9	28.5	28.9	32.3	29.7	0.82	0.82	0.56	25.2	25.2	35.6
	09:00	30	29.7	30.3	25.5	28.6	25.5	1.45	0.76	1.1	43.6	43.6	41.5
	10:00	32.4	31.4	32.4	19.1	23.1	20.1	0.84	1.22	0.84	47.7	47.7	43.5
	11:00	34.1	33.1	34.4	16.5	21.6	17.5	0.84	2.01	0.84	49	49	47.2
	12:00	35.1	34.6	35.4	14.3	15.6	14.9	2.52	1.31	1.91	49	49	50.5
	13:00	36.5	35.6	36.5	13	15.2	13	1.75	1.75	1.2	41	48.5	51.4
	14:00	37.2	36.9	37.4	13	13	13	2.55	1.33	1.33	42.9	42.9	54.3
	15:00	37.8	37.3	38.1	12.5	12.5	12.5	2.65	1.39	1.39	43.7	43.7	57.3
	16:00	38.3	37.2	38.3	13.5	13.5	13.5	0.96	1.87	0.96	57.3	43.2	59.7
	17:00	38	36.8	38	13.4	13.4	13.4	1.58	1.07	1.07	57.4	39.4	60.4
	18:00	36.8	36.4	37.3	13	13	13	2.26	0.91	1.36	53.7	35.3	56.7
	19:00	36.2	35.7	36.2	13	13	13	1.59	0.8	0.8	32.5	32.5	29.9
	20:00	35	33.9	34.7	13	15.4	13	0.83	1.61	0.83	23.1	23.1	20.2
	21:00	32.4	32.8	33.6	18.4	17.5	15.7	1.94	1.64	1.35	20	20	18.3
	22:00	33.2	32.4	32.9	15.7	17.1	16.4	0.36	0.36	0.54	18.7	18.7	17.7
	23:00	30.8	31.4	31.9	19.2	17.7	17	0.74	0.74	0.45	17.8	17.8	16.9

Individual Housing neighbourhood (07.17-18.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.17.2001	**00:00**	30.2	29.6	30.5	18.9	21.5	18.9	1.32	0.61	0.97	17.1	17.1	16.1
	01:00	29.7	29.7	30.3	18.4	20.2	18.4	0.76	1.72	0.76	16.5	16.5	15.5
	02:00	28.8	28.1	29	20.4	20.4	23.2	0.91	1.1	0.71	15.8	15.8	14.9
	03:00	28.2	27.9	28.8	21.4	21.4	20.4	0.31	1.21	0.61	15.2	15.2	14.6
	04:00	27.6	28.2	27.9	22.9	22	21.1	0.52	0.88	0.52	14.8	14.8	14.2
	05:00	27.4	27.4	27.8	21.9	20.7	21.3	0.51	0.15	0.44	14.4	14.4	14
	06:00	27.7	27.5	27.7	20.2	20.8	20.8	0.39	0.39	0.39	14.3	14.3	14
	07:00	28.4	28.2	28.4	20.1	20.9	20.9	0.29	0.38	0.29	18.8	18.8	24.6
	08:00	29.7	29.4	29.9	19.5	20.3	19.5	0.2	0.43	0.2	25.9	25.9	34.4
	09:00	31.3	31.7	32	18.6	17.4	18	0.73	0.6	0.6	44.6	44.6	42.6
	10:00	33.4	33.2	33.8	16.2	16.2	15.5	0.35	0.81	0.24	48.9	48.9	51
	11:00	34.9	34.4	35.2	14.7	17.4	14.7	0.64	0.99	0.64	49.2	49.2	52.8
	12:00	36.5	35.6	36.7	12.9	16.6	14.7	0.58	0.77	0.39	49.9	49.9	52.9
	13:00	37.4	36.2	37.6	13.2	17.6	14.1	1.53	0.94	0.94	43.2	49.2	52.2
	14:00	38.1	36.9	38.4	12.8	16.1	13.6	1.33	1.02	1.02	44.8	44.8	56.3
	15:00	38.6	38.3	38.9	12.6	12.6	12.6	2.16	2.54	1.41	45	45	58.6
	16:00	37.9	38.7	38.9	15.3	13	13.8	2.5	1.52	1.52	59	44.1	61.5
	17:00	38.4	37.5	38.4	14.4	17.1	14.4	2.27	1.26	1.6	59.1	41.3	62.1
	18:00	37.9	36.9	37.6	13.1	16.1	13.1	1.43	1.09	1.09	54.1	36.6	57
	19:00	37.2	37	37.2	13	13	13	0.19	0.71	0.36	32.4	32.4	32.4
	20:00	35.9	35.7	36.1	13.6	13.6	14.1	0	0.37	0.22	25.2	25.2	23.1
	21:00	34.2	34.4	34.4	19.3	17.7	18.8	0.69	0.44	0.56	22	22	20.4
	22:00	32.8	33.1	33.6	20.3	20.3	20.9	0.26	0.64	0.26	20.5	20.5	19.6
	23:00	31.4	32.1	32.6	22	20.8	21.4	0.17	0.34	0	19.5	19.5	18.7
07.18.2001	**00:00**	30.6	31.1	31.3	25.3	25.3	25.9	0.25	0.56	0.25	18.7	18.7	18.2

Multifamily Housing neighbourhood (07.15.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.15.2001	**00:00**	27.8	27.6	27.1	28.1	29	30.8	0.36	0.36	0.71	13.7	13.8	13.8
	01:00	26.9	26.7	26.2	29.7	29.7	32.4	0.29	0.29	0.56	13.3	13.5	13.5
	02:00	26.2	26	25.8	34.4	34.4	35.1	0.19	0.19	0.19	13	13	13
	03:00	25.1	24.9	24.9	37.7	38.4	38.4	0.11	0.22	0.11	12.8	12.8	12.8
	04:00	24.3	24.4	24.6	40.6	40.1	39.6	0.18	0.27	0	12.3	12.3	12.3
	05:00	24.2	24.1	24.1	41.2	41.2	41.2	0.17	0.4	0.34	12.1	12	12.1
	06:00	23.8	24	24.1	45.7	45.3	44.9	0.12	0.12	0	12	12	12
	07:00	24.6	24.6	24.6	39.3	39.3	39.3	0	0.22	0.22	16.5	16.5	16.5
	08:00	26.6	26.3	26.3	33.7	34.5	34.1	0	0.14	0.28	24.3	24.3	24.3
	09:00	28.3	28.2	28.1	29.4	29.9	29.9	0.11	0.11	0.31	43.2	30.8	30.8
	10:00	30.1	30.2	30.1	23.9	23.9	26	0.22	0.41	0.8	45.5	35.1	35.1
	11:00	31.7	31.9	31.9	21.7	20.5	22.9	0.24	0.24	0.7	48.7	37.8	37.8
	12:00	33	33.5	33.7	21.8	20.6	19.4	0.35	0.18	0.18	50.6	40.1	49.1
	13:00	33.9	34.8	35.4	23.2	21.7	20.3	0.4	0.4	0.21	49.8	49.8	49.8
	14:00	35.2	35.9	35.9	23	20.4	19.1	0.52	1.02	1.02	53.6	53.6	53.6
	15:00	35.2	35.5	35.2	19.7	18.6	17.5	0.44	1.7	1.28	59	59	41.9
	16:00	35.9	35.9	35.9	16.1	16.1	16.1	0.72	0.72	0.72	62.2	41.9	41.9
	17:00	34.7	35.7	35.7	19.2	16.8	16.8	0.54	0.54	0.54	55.7	40.3	40.3
	18:00	34.3	34.7	34.3	19.1	17.1	20	0.26	0.26	0.51	37	37	37
	19:00	32.8	33.2	33.2	22.1	21.3	20.4	0.31	0.89	1.18	31.9	31.9	31.9
	20:00	32.3	32	32	20.7	21.5	22.3	0.19	0.38	0.56	22.1	23.4	23.4
	21:00	31.3	30.9	30.7	23.1	24.6	25.3	0.17	0.32	0.48	18.9	19.5	19.8
	22:00	29.6	30.1	29.7	30.3	28.9	28.9	0.21	0.42	0.62	17.7	18.1	18.1
	23:00	28.8	29.2	29	32.9	31.4	31.4	0.24	0.24	0.7	16.9	17	17

Multifamily Housing neighbourhood (07.16.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.16.2001	**00:00**	28.4	28	27.8	33.3	34.2	34.2	0.17	0.17	0.33	16.2	16	16.2
	01:00	27.6	27.1	27.1	35.2	36.2	36.2	0.23	0.23	0.23	15.3	15.5	15.5
	02:00	27.2	27.2	26.6	35.6	35.6	38.1	0.23	0.44	0.65	14.9	15.1	15.1
	03:00	27.2	26.7	26.3	36.2	37.1	39.9	0.4	0.79	1.17	14.6	14.7	14.7
	04:00	26.9	26.9	26.8	33.9	33.9	33.9	0.21	0.21	0.21	14.3	14.3	14.4
	05:00	26.3	26.3	26.3	37.9	36.9	35.9	0.31	0.31	0.31	14	14.2	14.2
	06:00	26.1	26.1	25.9	38.5	37.4	37.4	0.27	0.27	0.27	13.9	14	13.9
	07:00	27.1	27.3	26.6	34	34	36.3	0.45	0.87	1.73	18.6	18.6	18.6
	08:00	28.9	28.9	28.4	28.5	27.5	30.5	0.47	0.47	0.47	24.9	24.9	24.9
	09:00	30.5	30.5	30.2	24.8	24.8	25.9	0.54	0.54	0.54	40.8	30.5	30.5
	10:00	32.7	32.7	32.4	18.1	19.1	23.1	0.58	0.58	1.14	47.2	34.8	34.8
	11:00	34	34.4	33.4	16.3	16.3	19.2	0.6	0.6	1.77	48.3	37.3	37.3
	12:00	35.4	35.6	35.4	14.4	13.7	13.7	0.79	0.79	0.79	48.4	39.2	48.4
	13:00	36.7	37	36	12	12	13.6	0.67	0.67	0.67	49.6	49.6	49.6
	14:00	37.4	38	37.7	10.2	10	10	0.74	0.74	0.74	52	53.9	53.9
	15:00	38.1	38.4	38.1	10	10	10	0.75	0.75	0.75	57.7	57.7	43.6
	16:00	38.2	38.2	37	10.3	10.3	12.1	1.07	0.55	1.07	57.6	40.9	40.9
	17:00	38.1	38.5	38.1	10	10	10.8	0.65	0.65	0.65	54.8	39.2	39.2
	18:00	37.1	37.4	37.4	11	10.3	10	0.63	0.63	0.63	54.4	35.7	35.7
	19:00	36.3	36.7	36.7	11	10.1	10.1	0.54	0.54	0.54	30.7	30.7	33.3
	20:00	34.6	34.6	33.8	12.7	12.7	14.4	0.52	0.52	1.02	21.7	22.9	23.4
	21:00	33	33.7	33.3	17.1	14.6	15.4	0.58	0.58	1.13	18.9	19.7	20.1
	22:00	32.9	33.2	32.9	16.5	15.1	15.8	0.24	0.24	0.47	18	18.3	18.8
	23:00	31.4	31.9	31.9	17.1	16.3	16.3	0.26	0.26	0.73	17.2	17.8	17.8

Multifamily Housing neighbourhood (07.17-18.2001)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.17.2001	**00:00**	30.7	30.4	30.4	18.4	18.4	18.4	0.51	0.51	0.26	16.6	17	17
	01:00	29.3	30.1	30.4	20.9	18.7	17.9	0.42	0.82	1.22	15.8	16.5	16.5
	02:00	29.5	29.5	28.2	19.4	18.6	22.9	0.29	0.58	1.14	15.4	15.8	15.8
	03:00	28.5	28.8	28.5	19.6	18.5	20.6	0.53	0.53	1.27	14.9	15.3	15.3
	04:00	28.4	28.7	28.1	20.6	19.5	20.6	0.3	0.3	1.13	14.5	14.8	15
	05:00	27.8	27.9	28.1	20.7	19.9	19.5	0.28	0.42	0.28	14.2	14.6	14.6
	06:00	27.6	27.9	27.9	21.4	19.9	19.5	0.18	0.61	0	14.2	14.4	14.4
	07:00	28.3	28.3	28.3	20.8	19.6	19.6	0.15	0.59	0	19	19	19
	08:00	29.7	29.9	29.7	19.6	18.8	18.8	0	0	0	25.7	25.7	25.7
	09:00	31.6	32.1	32.1	17.3	16.1	16.7	0.24	0.24	0.69	42	31.8	31.8
	10:00	33.8	34	34	13.8	13.8	14.6	0.3	0.3	0.88	48.6	37	37
	11:00	35.5	35.3	35.3	13.3	14.4	15.5	0.35	0.35	1.03	50.3	39.5	39.5
	12:00	36.9	37.1	36.9	12.1	13.1	14.1	0.37	0.37	0.72	52.3	52.3	52.3
	13:00	37.8	38.1	38.1	13.8	12.8	14.9	0.5	0.5	1	51.5	51.5	51.5
	14:00	38.6	38.9	38.6	12.4	12.4	13.4	0.52	0.52	1.03	55.6	55.6	55.6
	15:00	38	39.4	39.4	14.9	11.7	10.9	0.65	1.27	1.9	56.9	56.9	42.7
	16:00	38.7	39.1	39.1	13.9	12.4	12.4	0.66	1.95	1.3	61.8	41.6	41.6
	17:00	39.3	39.3	38.9	12	12	13	0.47	0.47	0.93	59.2	40.7	40.7
	18:00	38.5	38.5	37.4	11.9	11.9	14.5	0.5	0.5	0.98	54.6	36.7	36.7
	19:00	37.5	37.7	37.7	12.4	12.4	12.4	0.22	0.43	0.64	32.4	32.4	32.4
	20:00	35.9	36.2	36.2	13.8	13.5	13.5	0.22	0.29	0.43	23.8	24.8	25.3
	21:00	34.3	34.3	35	19	18.5	17.5	0.17	0.48	0.48	21	21.9	21.9
	22:00	33.5	33.9	33.9	20.4	19.7	20.4	0.12	0.45	0.45	20	20.4	20.4
	23:00	32.5	32.7	32.8	20.9	20.6	20.3	0	0.25	0.12	19.1	19.6	19.6
07.18.2001	**00:00**	31.6	31.8	32.1	25.2	24.3	23.9	0.12	0.12	0.33	18.5	18.7	18.7

Old Tolga neighbourhood (07.15.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.15.2016	**00:00**	33.7	33.5	33.7	15.7	16.2	15.7	0.51	0.51	0.51	16	16	16
	01:00	32.9	32.1	32.7	17.2	17.8	17.8	0.86	0.86	0.86	16.2	16.2	16.2
	02:00	32.2	31.8	32	18.9	21.1	19.5	0.67	0.67	0.67	16.2	16.2	16.2
	03:00	32.1	31.5	32.1	19.2	20.1	19.2	0.46	0.46	0.46	16.3	16.3	16.3
	04:00	30.6	30.2	30.4	21.7	22.2	21.7	0.17	0.17	0.17	15.3	15.3	15.3
	05:00	29.3	29.7	29.9	27.2	26	24.9	0.95	0.95	0.95	15.4	15.4	15.4
	06:00	29.9	30.2	30.5	24.8	24	24	0.62	0.62	0.62	20.6	20.6	20.6
	07:00	31.1	31.1	31.1	24.8	24.8	24.8	0.72	0.72	0.72	31.1	31.1	31.1
	08:00	32.2	32.5	32.5	26.9	25.8	25.8	1	1	1	39.4	39.4	39.4
	09:00	34.7	34.8	34.7	24.6	24.4	24.4	1.25	1.25	1.25	46.8	46.8	46.8
	10:00	36.4	36.1	35.9	20.9	21.4	21.4	0.94	0.94	0.94	51.7	51.7	51.7
	11:00	38.7	38.4	38.2	15.8	16.1	17.3	0.7	0.7	0.7	55.8	55.8	55.8
	12:00	41.1	40.6	40.2	15.3	15.3	15.7	0.51	0.51	0.51	62	62	63.6
	13:00	42.6	42.3	41.7	14.8	14.8	15.3	0.47	0.47	0.47	63	64.7	64.7
	14:00	45.2	44.8	45.5	15.8	13.5	15.8	0.29	0.29	0.29	69.1	69.1	69.1
	15:00	44.5	44.9	44.7	10.9	10.9	10.8	0.78	0.78	0.78	57.9	57.9	57.9
	16:00	45.6	45.6	45.6	9.1	9.1	9	0.56	0.56	0.56	55.9	55.9	55.9
	17:00	44.9	44.9	45	8.4	8.3	8.3	0.57	0.57	0.57	51	51	51
	18:00	45.5	45.5	45.4	7.8	7.7	7.8	0.31	0.31	0.31	43	43	43
	19:00	43.5	43.8	43.6	8.8	8.6	8.7	0.65	0.65	0.65	34.4	34.4	34.2
	20:00	41.3	41.1	41.3	8.4	8.4	8.3	1.05	1.05	1.05	30.4	30.4	30.4
	21:00	40.3	40.3	40.4	9.5	9.6	9.5	1.11	1.11	1.11	28.7	28.7	28.7
	22:00	37.7	37.8	37.8	12.6	12.5	12.5	0.91	0.91	0.91	26.9	26.9	26.9
	23:00	36.3	36.3	36.3	15.1	15.1	15	0.65	0.65	0.65	25.2	25.2	25.2

Old Tolga neighbourhood (07.16.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.16.2016	**00:00**	35.3	35.2	35.3	16.3	16.3	16.2	0.51	0.51	0.51	23.9	23.9	23.9
	01:00	35.4	35.3	35.4	19.3	19.4	19.3	0.4	0.4	0.4	22.7	22.7	22.7
	02:00	32	32.2	32.2	23.6	23	23	1.09	0.74	0.74	21.3	21.2	21.2
	03:00	31.3	31.4	31.3	21.4	21.1	21.4	0.55	0.55	0.55	19.9	19.9	19.9
	04:00	30.1	30.2	30.1	25.5	25.1	25.3	0.4	0.4	0.4	19	19	19
	05:00	30.9	30.9	31	30.9	30.9	30.5	0.3	0.3	0.3	19	19	19
	06:00	28.3	28.3	28.3	36.2	36.2	36.2	0	0	0	21	21	21
	07:00	29.4	29.4	29.4	36.8	36.6	36.6	0.38	0.28	0.49	31.4	31.4	31.4
	08:00	31.6	31.6	31.6	31.2	30.8	30.8	0.4	0.4	0.4	39.9	39.9	39.9
	09:00	33.1	33.1	33.2	26.6	26.1	26.2	0.5	0.5	0.5	46.3	46.3	46.3
	10:00	35	34.8	35.2	22.3	22.3	21.9	0.45	0.45	0.45	52.9	52.9	52.9
	11:00	36.4	36.4	36.4	19.7	19.4	19.7	0.86	0.86	0.86	55.5	55.5	55.5
	12:00	39.1	39.5	39.4	14.1	14.6	14.1	1.24	1.24	1.24	61.5	61.5	61.5
	13:00	40.1	40.6	40.5	11.6	12.5	12.5	1.03	1.03	1.03	60.9	60.9	60.9
	14:00	41.2	41.6	41.4	10.4	10.7	10.4	1.22	1.22	1.22	62.4	62.4	62.4
	15:00	41.2	41.4	41.3	9.8	9.8	9.8	1.04	1.04	1.04	55.2	55.2	55.2
	16:00	41.6	41.6	41.6	7.9	7.9	7.9	1.85	1.85	1.85	51	51	51
	17:00	41.7	41.7	41.7	8	8	8	1.77	1.77	1.77	44.7	44.7	44.7
	18:00	40.6	40.6	40.6	8.8	8.7	8.7	1.62	1.62	1.62	36.8	36.8	36.8
	19:00	39.8	39.8	39.8	9.5	9.5	9.5	1.24	1.24	1.24	30	30	30
	20:00	37.4	37.3	37.4	12.1	12.2	12.1	0.8	0.8	0.8	26.2	26.2	26.2
	21:00	36.4	36.3	36.4	13.7	13.7	13.7	0.91	0.91	0.91	24.8	24.8	24.8
	22:00	34.5	34.5	34.5	15.8	15.9	15.8	0.5	0.5	0.5	23.2	23.2	23.2
	23:00	32.2	32.2	32.2	18.5	18.5	18.5	0.53	0.53	0.53	21	21	21

Old Tolga neighbourhood (07.17-18.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		1	2	3	1	2	3	1	2	3	1	2	3
07.17.2016	**00:00**	30.1	30.3	30.2	22.3	21.9	22	0.35	0.35	0.35	19.5	19.5	19.5
	01:00	28.4	28.5	28.5	26.8	26.5	26.5	0.71	0.48	0.48	18.5	18.4	18.4
	02:00	27.3	27.4	27.3	28.9	28.8	29.2	0.45	0.45	0.45	17.3	17.3	17.3
	03:00	27.1	27.1	27.1	29.3	29.3	29.2	0	0	0	15.8	15.8	15.8
	04:00	27.4	27.4	27.5	30.7	30.4	30.4	0.62	0.62	0.62	16.4	16.4	16.4
	05:00	27.2	27.3	27.3	30.9	30.4	30.4	0.6	0.6	0.6	16.4	16.4	16.4
	06:00	26.3	26.4	26.4	38.9	38.2	38.2	0.49	0.49	0.49	20.7	20.7	20.7
	07:00	27.8	27.8	27.8	41.5	41.3	41.3	0.71	0.71	0.71	31.4	31.4	31.4
	08:00	28.8	28.8	28.8	42.8	42.5	42.8	1.19	1.19	1.19	39.7	39.7	39.7
	09:00	30.3	30.1	30	38.2	38.6	38.9	1.08	1.08	1.08	46.3	46.3	46.3
	10:00	32.1	31.9	31.9	31.2	32.1	32.5	0.44	0.44	0.44	50.8	50.8	50.8
	11:00	34.9	35.3	34.6	25.8	26.2	27.4	0.49	0.49	0.49	55.8	55.8	55.8
	12:00	34.6	34.6	34.6	26.4	26.4	26.4	0.74	0.74	0.74	63.7	63.7	63.7
	13:00	35.1	35.1	35.1	24.9	24.5	24.9	0.8	0.8	0.8	60.5	61.9	61.9
	14:00	36.5	36.2	36.7	21.9	22.5	21.9	0.81	0.81	0.81	64.5	64.5	64.5
	15:00	35.8	36.5	36.2	22.9	22.1	22.4	0.98	0.98	0.98	51.8	51.8	51.8
	16:00	37.1	36.8	36.9	20.8	21	21	0.71	0.71	0.71	49.8	49.8	49.8
	17:00	36.3	36.2	36.3	21.4	21.5	21.4	0.69	0.69	0.69	43.8	43.8	43.8
	18:00	35.8	35.8	35.8	21.9	21.9	21.9	0.77	0.77	0.77	35.2	35.2	35.2
	19:00	35.5	35.5	35.4	21.9	21.7	21.8	0.59	0.59	0.59	28	28	28
	20:00	34.2	34.3	34.3	22.8	22.6	22.7	0.43	0.43	0.43	24.5	24.5	24.5
	21:00	32.2	32.2	32.3	27.2	27.1	26.9	0.35	0.35	0.35	22.6	22.5	22.5
	22:00	32	31.9	32	27.5	27.5	27.5	0.28	0.28	0.28	21.3	21.3	21.3
	23:00	31.1	31.1	31.2	28.3	28.1	27.9	0.39	0.39	0.39	20.5	20.5	20.5
07.18.2016	**00:00**	30.2	30.1	30.3	30.1	30.2	29.9	0.28	0.28	0.41	19.3	19.3	19.3

Individual Housing neighbourhood (07.15.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.15.2016	**00:00**	31.9	32.5	33.1	19.1	18	16.4	1.22	1	0.79	17.5	17.5	18
	01:00	30.8	31.1	32.3	21.6	22.3	18.8	1.5	1.14	0.78	17.6	17.6	18.1
	02:00	30.9	30.7	31.9	21.5	22.7	19.7	0.32	0.32	0.6	17.5	17.5	18.5
	03:00	31.5	30.9	31.8	20	22.6	20	0.24	0.24	0.46	17.6	17.6	18.5
	04:00	30.6	30.4	30.8	21.7	22	21.5	0.34	0.34	0.26	16.3	16.3	17.1
	05:00	29.3	29.1	30	26.4	25.7	24.5	1.14	2.13	1.14	16.7	16.7	17.7
	06:00	29.7	28.7	30	22.5	28.5	25.5	1.88	0.88	1.38	21.8	21.8	23.1
	07:00	30.4	30	30.9	26.3	28.4	26.3	1.65	0.7	1.02	30.8	30.8	38.4
	08:00	31.8	31.8	32.3	27.6	28.1	27	2.6	0.77	1.13	39.3	39.3	42.4
	09:00	34.3	34.2	34.5	25.9	26.6	25.6	3.04	0.91	1.34	63.6	46.3	57.8
	10:00	35.9	36	36.3	21.7	21.7	21.7	1.33	0.67	0.67	59.8	49.9	59.8
	11:00	38.6	37.8	38.3	16.1	17.1	16.4	0.3	1.05	0.8	58.7	54.1	63.3
	12:00	40.6	40.3	40.6	14.2	14.5	14.7	0.2	0.56	0.74	58.6	56.6	65
	13:00	41.9	41.5	41.9	12.6	13.2	12.9	0.35	0.51	0.83	55.7	62.1	66.4
	14:00	44.3	43.1	43.9	12	12.5	12.3	1.57	0.31	1.06	57.2	57.2	65.9
	15:00	44.6	44.3	44.6	10.4	10.5	10.4	2.08	0.38	1.4	55	55	63.3
	16:00	45.8	45.3	45.6	10	10	10	1.18	0.9	0.61	65.9	55.4	61.7
	17:00	45.3	44.8	45.2	10	10	10	0.83	1.35	0.31	59.1	50.7	55.8
	18:00	45.2	45.4	45.6	10	10	10	0.34	0.34	0.17	46.1	42.1	44.2
	19:00	43.4	43.8	43.5	10	10	10	0.66	1.57	0.36	34.7	34.7	35.2
	20:00	40.9	40.8	41.3	8.7	8.7	8.4	1.63	2	0.87	31.4	31.4	34.1
	21:00	40.1	39.6	40.2	9.8	10.3	9.8	2.8	1.19	1.72	30	30	32.7
	22:00	37.5	37.3	37.7	12.7	13	12.6	2.34	0.81	0.81	28.2	28.2	31
	23:00	36.2	35.9	36.3	15.2	15.7	15.3	0.33	0.93	0.63	26.1	26.1	29.2

Individual Housing neighbourhood (07.16.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.16.2016	**00:00**	34.8	34.9	35.1	16.7	16.8	16.5	0.78	1.78	0.53	25	25	27.6
	01:00	35.3	34.9	35.4	19.4	20.1	19.3	0.21	0.4	0.21	23.6	23.6	26.7
	02:00	32	32.1	32.3	22.7	23.2	22.5	0.41	2.61	0.78	22.5	22.5	25.4
	03:00	30.8	31.2	31.5	22.4	21.4	21.2	1.64	0.37	1	21.2	21.2	24.1
	04:00	29.9	30.3	30.5	25.7	24.9	24.5	0.45	1.08	0.24	20.4	20.4	23
	05:00	30.7	30.9	31.1	30.8	30.6	30.4	0.5	0.62	0.5	20.6	20.6	23.4
	06:00	28	28.1	28.2	37.2	36.5	36.5	0	0	0.25	22	22	24.7
	07:00	28.7	29.1	29.5	38.3	37.9	37.2	0.14	1.1	0.4	30.7	30.7	42.8
	08:00	31.3	31.4	31.8	32.9	31.3	32.3	1	0.44	0.64	39	39	49
	09:00	32.7	32.8	33.2	27.2	27.4	26.7	0.85	1.37	0.32	57.7	45.3	55.2
	10:00	35.3	35.1	35.3	22.4	22.4	21.9	1	1	0.51	56.1	51.1	61.1
	11:00	36.7	36.5	36.9	18.7	19.3	18.9	1.84	0.75	0.75	58.3	51.6	62.7
	12:00	39.4	39.5	39.5	13.5	13.5	13.6	1.59	2.1	0.6	57.7	53.6	63.7
	13:00	40.5	40.9	40.7	10.7	10.9	10.8	1.26	1.7	0.85	54	58	63.8
	14:00	41.5	41.3	41.6	10	10.1	10	1.5	2	1	54.8	54.8	64.7
	15:00	41.3	41.5	41.6	10	10	10	0.46	1.32	0.89	54	54	63
	16:00	41.6	41.5	41.7	7.9	7.9	7.9	3.8	2.1	2.1	56.5	49.9	58.1
	17:00	41.7	41.7	41.7	7.9	7.9	7.9	2.4	1.5	1.5	51.4	44.9	51.4
	18:00	40.6	40.6	40.6	8.7	8.7	8.7	1	1.89	1.89	39.4	36.8	40.3
	19:00	39.7	39.7	39.8	9.5	9.5	9.5	1.47	0.82	0.82	31.1	31.1	33.5
	20:00	37.1	37.1	37.3	12.3	12.4	12.1	0.4	1.13	0.77	27.4	27.4	29.5
	21:00	36.2	36.1	36.4	13.8	14.1	13.8	0.45	0.88	0.88	26	26	28.7
	22:00	34.1	33.9	34.3	16.3	16.6	16.2	1.33	0.6	0.82	24.4	24.4	27
	23:00	32.1	31.9	32.3	19	18.8	18.6	0.81	0.63	0.81	22.2	22.2	24.6

Individual Housing neighbourhood (07.16.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.16.2016	**00:00**	34.8	34.9	35.1	16.7	16.8	16.5	0.78	1.78	0.53	25	25	27.6
	01:00	35.3	34.9	35.4	19.4	20.1	19.3	0.21	0.4	0.21	23.6	23.6	26.7
	02:00	32	32.1	32.3	22.7	23.2	22.5	0.41	2.61	0.78	22.5	22.5	25.4
	03:00	30.8	31.2	31.5	22.4	21.4	21.2	1.64	0.37	1	21.2	21.2	24.1
	04:00	29.9	30.3	30.5	25.7	24.9	24.5	0.45	1.08	0.24	20.4	20.4	23
	05:00	30.7	30.9	31.1	30.8	30.6	30.4	0.5	0.62	0.5	20.6	20.6	23.4
	06:00	28	28.1	28.2	37.2	36.5	36.5	0	0	0.25	22	22	24.7
	07:00	28.7	29.1	29.5	38.3	37.9	37.2	0.14	1.1	0.4	30.7	30.7	42.8
	08:00	31.3	31.4	31.8	32.9	31.3	32.3	1	0.44	0.64	39	39	49
	09:00	32.7	32.8	33.2	27.2	27.4	26.7	0.85	1.37	0.32	57.7	45.3	55.2
	10:00	35.3	35.1	35.3	22.4	22.4	21.9	1	1	0.51	56.1	51.1	61.1
	11:00	36.7	36.5	36.9	18.7	19.3	18.9	1.84	0.75	0.75	58.3	51.6	62.7
	12:00	39.4	39.5	39.5	13.5	13.5	13.6	1.59	2.1	0.6	57.7	53.6	63.7
	13:00	40.5	40.9	40.7	10.7	10.9	10.8	1.26	1.7	0.85	54	58	63.8
	14:00	41.5	41.3	41.6	10	10.1	10	1.5	2	1	54.8	54.8	64.7
	15:00	41.3	41.5	41.6	10	10	10	0.46	1.32	0.89	54	54	63
	16:00	41.6	41.5	41.7	7.9	7.9	7.9	3.8	2.1	2.1	56.5	49.9	58.1
	17:00	41.7	41.7	41.7	7.9	7.9	7.9	2.4	1.5	1.5	51.4	44.9	51.4
	18:00	40.6	40.6	40.6	8.7	8.7	8.7	1	1.89	1.89	39.4	36.8	40.3
	19:00	39.7	39.7	39.8	9.5	9.5	9.5	1.47	0.82	0.82	31.1	31.1	33.5
	20:00	37.1	37.1	37.3	12.3	12.4	12.1	0.4	1.13	0.77	27.4	27.4	29.5
	21:00	36.2	36.1	36.4	13.8	14.1	13.8	0.45	0.88	0.88	26	26	28.7
	22:00	34.1	33.9	34.3	16.3	16.6	16.2	1.33	0.6	0.82	24.4	24.4	27
	23:00	32.1	31.9	32.3	19	18.8	18.6	0.81	0.63	0.81	22.2	22.2	24.6

Individual Housing neighbourhood (07.17-18.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		4	5	6	4	5	6	4	5	6	4	5	6
07.17.2016	**00:00**	30.1	30.2	30.4	22.5	22.2	21.8	0.52	1.31	0.68	20.8	20.8	23.1
	01:00	28.4	28.4	28.7	26.5	26.6	26.1	0.32	2.2	0.63	19.9	19.9	22.1
	02:00	27.2	27.4	27.5	29.8	28.8	28.6	0.82	0.42	0.42	18.3	18.3	20.8
	03:00	26.9	26.9	27.1	29.7	29.7	29.4	0.2	0.2	0.32	17.2	17.2	19.1
	04:00	27.2	27	27.4	31.2	32	31	1.6	1	1.34	17.8	17.8	20.8
	05:00	27.2	27.1	27.4	31.2	31.7	30.9	1.1	0.3	0.8	17.7	17.7	20.7
	06:00	26.3	26.3	26.5	39	39	38.3	1.5	0.6	0.6	21.6	21.6	22.7
	07:00	27.7	27.7	27.9	42	42.2	41.9	2.2	0.33	0.62	30.6	30.6	37.6
	08:00	28.8	28.8	28.9	43.2	43.4	43	1.9	1.8	1	38.6	38.6	43.9
	09:00	30.1	30.3	30.3	38.7	38.7	38.7	0.8	1.2	0.8	62.6	45.4	56.8
	10:00	33.1	31.8	32	30.8	32.9	32.5	0.3	1.1	1.1	65.5	48.9	60
	11:00	35.6	34.5	34.9	24.4	26.3	25.8	0.3	1	0.5	63.3	53.4	60.8
	12:00	34.8	34.1	34.5	25.7	26.7	26.2	2.3	0.4	1.15	60.1	54	64.2
	13:00	35.4	35.4	35.1	24.2	24.2	24.6	2.5	0.45	1.27	53.3	59.1	63
	14:00	36.6	36.3	36.3	22	22.6	22.3	1.19	1.96	0.81	53.6	53.6	61.8
	15:00	36.6	36.1	36.1	22.2	22.5	22.5	1.49	0.84	0.51	51.2	51.2	55.4
	16:00	37.7	37.3	37.5	20.4	20.7	20.7	0.74	1.06	0.42	62.4	49.8	54
	17:00	37	36.5	36.6	21.3	21.4	21.3	0.75	1.06	0.43	54.4	44.4	49.4
	18:00	36.1	35.8	35.8	21.9	22.2	22.2	0.75	1.83	0.39	39.6	35.5	40.4
	19:00	35.4	35.4	35.5	21.9	21.9	21.8	0.35	1.29	0.35	28.2	28.2	29.7
	20:00	34.1	34.3	34.4	23	22.7	22.6	0.27	1.05	0.53	26.4	25.3	27.4
	21:00	32.1	32.3	32.4	27.3	27	26.9	0.38	0.56	0.56	23.4	23.4	25.9
	22:00	31.8	32.2	32.3	27.7	27	26.9	0.31	0.17	0.45	22.3	22.3	25.2
	23:00	31	31.1	31.3	28.4	28.1	27.9	0.41	0.59	0.41	21.7	21.7	24.1
07.18.2016	**00:00**	30.1	29.9	30.4	30.8	31.2	30.3	0.45	1.06	0.75	20.4	20.4	22.7

Multifamily Housing neighbourhood (07.15.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.15.2016	**00:00**	33.1	33.3	33.3	17	16.5	17	0.9	1.34	0.9	17.4	17.1	17.1
	01:00	31.8	32.5	31.8	19.3	18.5	20.1	1.38	2.04	2.04	17.5	17.2	17.2
	02:00	31.8	32.1	31.3	20	19.3	21.4	1.23	1.23	2.43	17.4	17.4	17.4
	03:00	31.8	31.8	31.5	20.1	20.1	20.9	1.04	1.04	2.05	17.6	17.3	17.3
	04:00	29.8	30.4	30.4	23.8	22.5	22.5	0.51	0.51	0.51	16.7	16.4	16.4
	05:00	29.7	29.5	29.7	25.4	25.4	25.4	1.16	1.16	2.29	16.7	16.7	16.7
	06:00	30.5	29.9	29.2	24.1	24.8	26.3	0.67	1	1.33	21.4	21.4	21.4
	07:00	31.3	31.1	30.7	24.8	24.8	26.1	0.86	1.28	1.71	31.8	31.8	31.8
	08:00	32.2	32.2	32.2	26.7	26.7	26.7	1.03	1.03	1.03	39.2	39.2	39.2
	09:00	34.5	34.5	34.6	24.9	25.1	24.9	1.25	1.25	1.25	46.3	46.3	46.3
	10:00	35.8	36.1	36.1	22.6	21.5	21.5	1.46	0.98	0.98	61.8	49.6	49.6
	11:00	38.2	38.4	38.4	17.5	16.1	16.1	1.49	1.49	1.49	63.6	54.9	53.1
	12:00	40.2	40.6	40.4	15.2	14.4	14.4	1.54	1.16	0.78	64.1	62.6	62.6
	13:00	42.3	42.3	42.1	13	12.4	12.6	1.42	1.07	0.71	65.9	65.9	65.9
	14:00	44.9	44.9	44.1	11.7	11.4	11.7	0.92	1.22	0.62	68.8	68.8	60.9
	15:00	44.9	44.6	44.2	10.1	10.2	10.3	1.23	0.82	0.82	68.8	68.8	57.9
	16:00	46.2	45.9	45.7	8.8	8.8	9	0.7	1.05	0.7	66.6	55.9	55.9
	17:00	45.3	45.2	45	8.3	8.3	8.3	0.86	0.86	0.86	57.2	50.7	50.7
	18:00	45.5	45.4	45.4	7.7	7.8	7.8	0.48	0.48	0.48	46.8	42.9	42.9
	19:00	43.8	43.7	43.7	8.7	8.7	8.7	1.08	1.08	1.61	35	35	35
	20:00	41.2	41.5	41.3	8.3	8.1	8.3	1.11	1.11	2.2	31.3	31.3	31.3
	21:00	40.3	40.3	40.2	9.6	9.7	9.7	1.35	1.35	2.03	30.5	30.5	30.1
	22:00	37.7	37.7	37.7	12.7	12.6	12.6	1.52	1.02	1.02	28.4	28.4	28.1
	23:00	36.2	36.3	36.1	15.3	15.1	15.3	1.18	1.18	1.18	26.5	26.5	26.5

Multifamily Housing neighbourhood (07.16.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.16.2016	**00:00**	35.2	35.3	35.2	16.4	16.3	16.4	1.06	1.06	1.58	25.4	25.4	25.4
	01:00	35.6	35.6	35.3	19.1	19	19.6	0.54	0.54	0.54	24.1	24.1	24.1
	02:00	32.3	32.5	32.5	22.9	22.5	22.5	1.35	1.35	2.65	22.6	22.6	22.6
	03:00	31.1	31.4	31.5	21.7	21.1	20.9	0.86	0.86	0.86	21.6	21.6	21.6
	04:00	30.4	30.5	30.5	24.9	24.6	24.7	0.76	0.76	0.76	20.3	20.6	20.3
	05:00	31.1	31.1	31	29.8	30.4	30.4	0.67	0.67	0.67	20.6	20.6	20.4
	06:00	28.2	28.3	28.4	36.6	36.3	36	0.16	0.16	0.47	22.3	21.9	21.9
	07:00	29.4	29.7	29.4	36.5	36	36.2	0.53	0.53	0.78	31.1	31.1	31.1
	08:00	31.5	31.7	31.7	31.9	31	30.8	0.49	0.49	0.72	39.5	39.5	39.5
	09:00	33.4	33.3	33.2	26.9	26.2	26.2	0.81	1.19	1.58	45.5	45.5	45.5
	10:00	35.8	35.5	35.3	22.5	21.7	21.7	0.77	1.14	1.14	60.9	50.8	50.8
	11:00	36.9	36.7	36.5	19.2	18.9	18.9	0.91	1.8	0.91	63.6	55.1	53.5
	12:00	39.7	39.3	39.6	13.6	13.5	13.3	1.53	1.53	3.01	62.6	62.6	62.6
	13:00	40.6	40.2	40.8	10.9	10.9	10.6	1.29	1.29	2.52	63.4	62.1	60.8
	14:00	41.6	41.3	41.6	10	10	9.9	1.53	1.53	3.02	63.2	63.2	61.9
	15:00	41.5	41.4	41.5	9.5	9.5	9.5	1.47	1.47	2.9	61.8	61.8	54.4
	16:00	41.6	41.6	41.6	7.9	7.9	7.9	2.03	3.03	3.03	57.2	50.3	50.3
	17:00	41.7	41.7	41.7	7.9	7.9	7.9	1.99	1.99	4.93	50.3	44.4	44.4
	18:00	40.6	40.6	40.6	8.7	8.7	8.7	1.82	1.82	4.53	37	37	37
	19:00	39.7	39.8	39.8	9.5	9.5	9.5	1.45	1.45	2.88	31.2	31.2	31.2
	20:00	37.3	37.3	37.3	12.1	12.2	12.2	0.83	1.62	2.02	27.2	27.2	27.7
	21:00	36.4	36.3	36.4	13.8	13.8	13.8	1.22	1.22	3.65	25.9	26.4	25.9
	22:00	34.4	34.4	34.4	16.1	16.1	16.1	1.08	1.08	1.08	24.4	24.4	24.4
	23:00	31.9	32.2	32.3	19	18.7	18.4	0.73	1.22	0.49	22.3	22.7	22.7

Multifamily Housing neighbourhood (07.17-18.2016)

Date	Time	Air Temperature (T_a) - (°C)			Relative Humidity (H_R) - (%)			Air Velocity (V_a) - (m/s)			Mean Radiant Temperature (Tmrt) - (°C)		
		7	8	9	7	8	9	7	8	9	7	8	9
07.17.2016	**00:00**	30.3	30.3	30.4	22	22	21.8	0.43	1.64	1.04	20.7	20.7	20.7
	01:00	28.6	28.8	28.7	26.3	25.9	26.1	0.96	0.96	1.91	19.8	19.8	19.8
	02:00	27.3	27.5	27.6	29.1	28.8	28.6	0.73	0.73	0.73	18.6	18.6	18.6
	03:00	27.2	27.1	26.9	29.3	29.5	29.5	0.15	0.15	0.36	17	17	17
	04:00	27.6	27.5	27.4	30.4	30.7	30.7	0.78	0.78	1.17	18.1	18.1	17.8
	05:00	27.5	27.5	27.4	30.3	30.3	30.5	0.71	0.71	0.71	18	18	17.7
	06:00	26.4	26.5	26.5	38.5	38.1	38.1	0.76	0.76	0.51	20.9	20.9	20.9
	07:00	27.8	27.8	27.8	41.5	41.5	41.5	0.82	0.82	0.82	31.1	31.1	31.1
	08:00	28.8	28.9	28.9	43.2	42.9	42.6	1.25	1.25	1.85	38.9	38.9	38.9
	09:00	30.1	30.3	30.3	39	38.3	38.2	1.13	1.13	1.68	45	45	45
	10:00	32.1	31.8	31.8	32.2	32.2	32.2	1.54	2.05	1.54	64.5	49.5	49.5
	11:00	35.4	34.8	34.5	25.3	25.7	26.1	1.04	1.56	1.56	64.9	53.1	53.1
	12:00	35.1	34.5	33.6	25.3	26.1	27.3	1.27	0.85	0.85	63.1	63.1	63.1
	13:00	35.7	35.4	34.9	23.5	24.2	24.9	1.41	0.94	0.94	61.7	61.7	61.7
	14:00	37.4	37.1	36.8	21.3	21.6	21.6	1.14	1.14	1.7	63	63	63
	15:00	36.4	35.9	36.4	22.2	22.8	22.2	0.89	0.89	1.76	63.8	63.8	52
	16:00	38	38	37.6	19.8	20	20.5	0.89	0.89	1.33	61.4	49.8	49.8
	17:00	36.9	36.9	36.6	21.2	20.9	21.3	0.9	0.9	1.34	53	43.6	43.6
	18:00	35.8	35.9	35.9	22	21.8	21.9	1.23	1.23	1.82	38.1	35.8	35.1
	19:00	35.5	35.7	35.6	21.7	21.5	21.6	1.1	1.65	1.65	28.2	28.5	28.5
	20:00	34.5	34.5	34.5	22.5	22.3	22.3	0.97	0.97	0.97	25.3	25.3	25.3
	21:00	32.4	32.6	32.5	26.6	26.5	26.6	0.9	0.9	0.9	23.5	23.8	23.8
	22:00	32.3	32.3	32.2	26.9	26.9	27	0.72	0.72	0.72	22.8	22.8	22.8
	23:00	31.4	31.4	31.4	27.7	27.5	27.5	0.89	0.89	0.89	22.1	22.1	22.1
07.18.2016	**00:00**	30.5	30.4	30.2	29.7	29.9	30.4	0.43	0.64	1.27	20.9	20.9	20.9

PET index values through the three sites during July 16th 1986

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
07.16.1986	00:00	21.5	21.6	21.6	19.7	19.9	19.7	20.7	20.5	20.2
	01:00	20.5	20.6	21.1	19	19.2	19.7	20	19.8	19.4
	02:00	20.5	20.3	20.6	19	18.7	19.4	19.7	19.6	19
	03:00	20.2	20.1	20.2	18.4	18.1	19.1	19.2	19.1	18.5
	04:00	19.9	19.7	20	18.5	18.6	18.8	19.2	19.2	19.1
	05:00	19.3	19.4	19.6	17.9	18	18.7	18.8	18.7	18.7
	06:00	19.2	19.4	19.6	17.6	18	18.4	18.5	18.4	18.3
	07:00	22.1	22	22.2	20.8	19.2	22.9	20.8	20.5	19.5
	08:00	26.2	26	26.2	24.5	23.7	29.4	25	25	24.5
	09:00	30	29.8	30	32.9	34.4	34.9	28.4	28.2	28.1
	10:00	33	33	33.2	38.1	36.4	39.4	37.6	31.6	30.4
	11:00	36.1	35.9	36.1	40	36.4	39.6	39	33.9	32.3
	12:00	40.8	40.8	41	36.9	38.9	39.8	38.9	35.4	39.8
	13:00	41.8	41.8	42	36.8	38.4	40.6	41.3	41.5	41.1
	14:00	44.4	44.4	44.6	37.9	38	42.6	43.1	43.4	43.3
	15:00	41.5	41.7	41.7	38.8	38.8	44.1	45.1	45.4	38.7
	16:00	41.4	41.4	41.6	46.5	37.6	47	44.6	38.6	37.6
	17:00	39.6	39.6	40	43.7	37.1	47.2	45.2	38	37.5
	18:00	36.9	37.2	37.5	42.3	35.2	45.1	44.3	35.8	35.6
	19:00	34.5	34.9	35.3	32.3	31.8	32.7	32.6	32.9	32.9
	20:00	29.9	29.9	29.9	28.1	27.5	27.2	28	28.2	28
	21:00	27.5	27.5	27.6	25.8	25.5	25.7	25.4	26.1	26
	22:00	25.9	25.9	25.9	24.7	24.4	24.4	24.4	25	25
	23:00	24.7	24.6	24.8	23.3	23.5	23.3	23.3	23.6	24.1

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

PET index values through the three sites during July 16th 2001

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
07.16.2001	00:00	21.6	21.6	21.8	21.5	21.5	21.7	22.3	22	22
	01:00	20.6	21.1	21.1	20.7	20.8	21.2	21.5	21.3	21.3
	02:00	20.6	20.5	20.7	20.6	20.4	21.2	21.1	21.1	20.6
	03:00	20.2	20.2	20.2	20	19.9	20.5	20.9	20.5	20
	04:00	19.9	19.9	20	19.9	19.9	20.5	20.6	20.6	20.6
	05:00	19.5	19.7	19.8	19.4	19.6	20.2	20.1	20.2	20.2
	06:00	19.3	19.6	19.6	19.3	19.6	19.9	20	20	19.8
	07:00	22.2	22.1	22.2	22	21.1	24.5	22.4	22.3	21.2
	08:00	26.4	26.2	26.4	25.7	25.4	30.7	26.3	26.3	26
	09:00	30	30.3	30.3	33.8	34.9	33.7	34.6	29.8	29.6
	10:00	33.2	33	33.2	38.6	37.1	36.6	39.1	33.2	32.6
	11:00	35.9	35.9	36.1	40.4	38.2	39.8	40.5	35.4	34.1
	12:00	41	41	41	39.7	40.2	41	41.1	37.1	41.1
	13:00	42	41.8	42.6	38.4	40.5	42.9	42.8	43	42.3
	14:00	44.7	44.7	44.7	39.6	39.5	44.9	44.3	45.7	45.5
	15:00	42	42	42	40.5	40.2	46.7	47.7	47.9	40.8
	16:00	41.7	41.8	41.7	47.4	39.8	48.6	47.3	39.6	38.8
	17:00	40	40	40	46.5	38	48.5	46.4	39.1	38.8
	18:00	37.2	37.5	37.5	43.3	36	45.8	45.5	36.7	36.7
	19:00	34.9	35.3	35.3	34.9	34.2	33.5	33.7	33.9	35.1
	20:00	30.2	30	29.9	29.9	29.5	28.5	28.6	29.1	29.2
	21:00	27.7	27.7	27.5	27.2	27.5	27.5	26.5	27.3	27.6
	22:00	26	26	26.3	26.2	25.7	25.9	25.5	25.8	26.2
	23:00	24.9	24.6	24.9	24.6	25	24.8	24.3	24.9	25.4

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress

PET index values through the three sites during July 17th-18th 2016

Date	Time	PET- S1			PET- S2			PET- S3		
		1	2	3	4	5	6	7	8	9
07.16.2016	00:00	30.1	30	30.1	30.5	31.2	31.6	31.2	31.3	31.5
	01:00	29.6	29.5	29.6	29.5	29.6	31	30.5	30.5	30.3
	02:00	27.1	27.1	27.1	27.3	27.8	28.8	27.9	28.1	28.3
	03:00	25.8	25.8	25.8	26	26.1	27.7	26.4	26.6	26.7
	04:00	24.6	24.6	24.6	25	25.3	26.6	25.4	25.6	25.4
	05:00	25.1	25.1	25.2	25.8	26	27.2	26.1	26.1	26
	06:00	24.9	24.9	24.9	25.3	25.3	26.2	25.2	25	24.8
	07:00	29.9	30.1	29.7	29.7	28.4	35.5	29.5	29.7	29.2
	08:00	35.3	35.3	35.3	33.8	34.7	39.4	34.9	35	34.6
	09:00	39.2	39.2	39.3	43.8	37.2	44.7	38.5	37.9	37.4
	10:00	44	43.9	44.1	44.6	42.1	48.5	47.9	42.1	41.9
	11:00	45.4	45.4	45.4	45.6	43.7	49.6	49.7	44.3	44.4
	12:00	49.7	50.1	50	47.9	46	52.3	50.4	50.1	49.3
	13:00	50.4	50.8	50.8	47.3	49.3	52.6	51.7	50.8	50
	14:00	51.8	52.1	52	48.4	48.2	53.5	52.2	52	51.1
	15:00	48.5	48.6	48.6	48.3	48.1	52.7	51.5	51.4	48.1
	16:00	46.9	46.9	46.9	48.9	46.4	49.8	49.4	46.8	46.8
	17:00	44.5	44.5	44.5	47.2	44.4	47.1	46.7	44.5	45.4
	18:00	40.4	40.4	40.4	41	40.6	41.8	40.6	40.6	41.9
	19:00	36.8	36.8	36.8	37.4	36.6	37.7	37.4	37.5	38.6
	20:00	32.9	32.8	32.9	32.6	33.5	34.1	33.3	34	34.5
	21:00	31.7	31.7	31.7	31.5	31.9	33.2	32.5	32.6	33.7
	22:00	29.2	29.2	29.2	30	29.4	30.9	30.2	30.2	30.2
	23:00	26.8	26.8	26.8	27.3	27.1	28.4	27.2	27.7	27.5

Thermal comfort stress level	17- 26	26 - 28	28 - 37	37- 42	> 42
	Neutral	Slightly warm	Warm	Hot	Very hot
	No thermal stress	Slight heat stress	Moderate heat stress	Strong heat stress	Extreme heat stress