

**LEARNING FROM THE PAST, DESIGNING FOR THE FUTURE:  
SUSTAINABILITY OF THE MEDITERRANEAN VERNACULAR**

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My inspiration for choosing this topic is my interest in the importance of the environment in every aspect and especially architecture. This interest started during my graduation project which was an environmentally friendly educational and awareness centre near a bird reserve. Even after the growing awareness about the environment and the birth of the term “Sustainable Architecture” and “LEED” programs, I knew that technology wasn’t the best and only way of creating an environmentally friendly building. The brilliance of vernacular architecture and the way man adapted to his surroundings fascinated me and inspired me to do further and detailed research on the Sustainable Characteristics of the Vernacular Cities of the Mediterranean.

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# 1

## Introduction

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*“I have run across the Spanish land and learnt, in all its corners, what an anonymous architecture could teach me. I have filled my eyes with all what man makes for oneself, with the wisdom of necessity supported by the tradition of the place. Going from surprise to surprise, I have learnt to guess the measure and the function of the spaces that man built to shelter his life and his work, and how he set up an environment for social life. So were born and were made the villages and small towns that I admire and from which I learnt the hidden laws of spontaneous organization” (Del Amo 1995, p.77).*

## 1.1. Architecture without Architects: Sustainable by Adaptation

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Those were the words that came from Spanish architect Jose Luis Fernandez del Amo who cherished his homeland and valued the beautiful traditional architecture of the Mediterranean. Where, for centuries, it had been a cradle of commercial exchange and cultural transmissions. On its shores, ancient historical civilizations flowered – including Egyptian, Cretan-Mycenaean, Phoenician, and Greek-and on its waters the first empires were founded – Carthaginian, Roman, Byzantine, and Islamic. Many affinities of climate, traditions, topography, and even ethnic traits are visible along the coastlines of countries facing the Mediterranean (Gravagnuolo 2010, p.15) What best preserves the signs of a civilization? Mediterranean vernacular architecture is an expression of the sustainable techniques created by cultures of living that settled over the course of centuries.

The uniqueness of the Mediterranean vernacular owes to the diversity of cultures which shared climate and water. They are the things which forced man to invent and create ways to adapt and protect himself from his natural surroundings. Bernard Rudofsky spoke of the “untutored builders” in his book *Architecture without Architects* saying:

*“instead of trying to conquer nature, as we do, they welcome the vagaries of climate, and the challenge of topography”* (Rudofsky 1964).

In the past, people had a sophisticated understanding of the ecology of their habitat, and they behaved according to its rules in order to nurture its growth and harvest its produce. This adaptation and environmental harmony is found in traditional architecture all over the world. In the early 1930s, architect Michelucci Giovanni wrote about the design of the Pompeian house and how it was based on a humanist sense of scale.

*“As man felt the need for shelter, he created an environment that responded to his needs. Humanist principles of design are the key to a Pompeian architecture”* (Sabatino 2010, p.51).

Gio Ponti wrote in the magazine *Domus* about the traditional Catalan rural architecture:

*“At times, thinking back to Ibiza and Benicarlo, I ponder with some affliction how difficult it is for us architects, in spite of all our theoretical and polemical baggage ... to achieve a result as natural as that “architecture without architects”, that farmers and men of sea have always built with content unawareness”* (Lejeune 2010, p. 85).

Many structures nowadays are erected without any consideration for the local climate or natural surroundings. For example, in the Arab houses of the Middle East, the courtyards which were home of the natural cool air, the fountains and daily activities, were replaced by street facing balconies home of heat, dust and noise. The modern architect installed mechanical equipment which cost more than the building shell itself and lead to unforeseen dangers to the environment. Preindustrial builders lacked these sources of technology that allows them to ignore the importance of climate in their designs, so they could not take the same direction as present day architects. Amos Rapoport praises indigenous builders’ love and respect for nature while referring to mechanical systems;”: *“In light of their attitude to nature, it is doubtful that they would use such tools even if they were available to them”* (Rapoport 1969, p.84).

## **1.2. Aims and Objectives: Architecture by Architects: Sustainable by Design**

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The aim of this research is to show how vernacular architecture can become a guide for designing modern dwellings which are suitable for the local climate of the Mediterranean coastal cities and islands. Consequently, comfortable living conditions are achieved reducing the need for high-tech systems and saving energy. Modern architecture can be designed in an innovative but sustainable way by learning from the Mediterranean vernacular and its passive design strategies. Integrating these strategies and elements into modern design will contribute to saving energy and protecting the environment. Modern Mediterranean architecture was greatly influenced by vernacular architecture but it was during a time before the environmental movement when the deteriorating environment was not an issue or at least was not visible. That is why this influence was more aesthetical than it was sustainable.

### **Research Question and Hypotheses:**

How can we learn from the Mediterranean vernacular to design sustainable modern dwellings which reduce the energy demand?

Which passive design strategies used in vernacular architecture can be implemented in modern dwellings?

How can we innovate new methods which meet modern demands based on vernacular methods?

To answer these questions, we must start by:

#### **1. Understanding vernacular architecture.**

One of the main problems facing vernacular architecture is its unchanging and outdated status. The vernacular is usually defined as a category of traditional buildings that are in danger of losing their authenticity and integrity when confronted with the impacts of modernity. Consequently, buildings are protected for their historical and aesthetical value but seldom are they studied for their sustainable and environmentally friendly features in order to integrate these features into modern design.

#### **2. Innovation not Imitation.**

Everyday, people's needs and demands are changing and increasing. Life involves interaction and development. Progress brings change, but change does not mean a disregard for the past, or a disregard for the vernacular builders and the environmentally appropriate buildings they produced. The ecological approach is about taking past technologies and principles and translating them within the context of modern needs. We must show that studying the past enables the active implementation of vernacular principles and guidelines within a contemporary context. We cannot repeat vernacular structures, for we have new demands, new social orders, and new technology that demands new creativity. However, what will remain are the simple needs no matter how far technology advances. They are the need for shelter, for storage, for privacy. Therefore, after studying the sustainable features of the Mediterranean vernacular, we must create a module for innovation rather than a module of imitation. With that, we can create innovative approaches for new buildings without imitating the local vernacular.

### **3. Passive design**

The most important role of this innovative approach is the integration of the passive sustainable systems of vernacular buildings into the design of new buildings in order to reduce the energy consumption caused by high-tech systems. The thermal gain and loss of a building caused by the sun and wind are important factors contributing to the energy consumption of a building and the need for high-tech systems. That is why the more passive design strategies integrated into a modern settlement, the less energy is needed to provide thermal comfort. These strategies include settlement orientation, building orientation and form, thermal mass and thermal regulating spaces in the dwellings. When considering passive design from the beginning of the design phase, one can find that saving energy through simple ways is feasible and has positive results.

The expected outcome of this analysis is that the simple passive design strategies of the urban structure and architecture of the modern case studies chosen result in a better thermal comfort level considering the non existence of high-tech systems. These case studies were inspired by vernacular architecture and their success encourages improving the application of the passive design strategies and the application of the PSPW guide to achieving the innovative sustainable design approach.

### 1.3. Definitions

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It is important to define the most important terms in the context of the thesis in order to fully understand the purpose of the research and the steps which were taken to achieve it.

#### **Vernacular**

The linguistic root of the term vernacular comes from the latin root *vernaculus* which refers to a native language or dialect and it stands in contrast to the language of a society which is oriented towards global communication (Health 2009, p.6). “*The Vernacular is anything considered native or unique to a specific place, produced without the need for imported components and processes, and possibly built by the individuals who occupy it*” (Alsayed 2005, p.xvii).

This applies to vernacular buildings and vernacular landscapes as well. Vernacular buildings “*tell what is indigenous, common and shared in a community or region*” (Bronner 2005, p.23). Paul Oliver also defines vernacular architecture as an architecture built by the community: “*Vernacular architecture comprises the dwellings and other buildings of the people. Related to their environmental contexts and available resources, they are customarily owner- or community-built, utilizing traditional technologies. All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of living of the cultures that produce them*” (Oliver 1997b: xxiii).

In a book by V.I. Atroshenko and Milton Grundy documenting Mediterranean vernacular Architecture, Architect Neil Parkyn defines the vernacular as “*community architecture, constructed by the community to meet the community’s needs. It is not imposed on the community by an individual designer or a town planning department*” (Parkyn 1991, p.184).

As an example of an architecture to meet specific needs, Mediterranean vernacular architecture can be defined by its characteristics and practical aspects: the whitewash which protected against disease and reflected the summer heat off the walls, the hillside which provided drainage (Atroshenko and Grundy 1991, p.8), preserved agriculture and offered defensive advantages, its narrow and irregular streets and the courtyard houses which had many advantages in terms of privacy and thermal regulation (Atroshenko and Grundy 1991, p.14).

#### **Sustainability**

Sustainability can be defined and understood in this message: “*Man can create a society in which he can live indefinitely on earth if he imposes limits on himself and his production of material goods to achieve a state of global equilibrium with population and production in carefully selected balance*”<sup>1</sup>. This was the message of hope from the book “Limits to Growth”, a book completed by members of The Club of Rome<sup>2</sup> in 1972 which reported the results of computer simulations of five parameters for the global economy (population, agricultural production, natural resources, industrial production and pollution)<sup>3</sup>. The results predicted a major collapse of world population in the mid-twenty first century (Bartlett 2011, p.1). This got people thinking about Sustainability.

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<sup>1</sup> <https://www.clubofrome.org/report/the-limits-to-growth/>

<sup>2</sup> The Club of Rome is an organisation of individuals who share a common concern for the future of humanity and strive to make a difference. Its members are notable scientists, economists, businessmen and women, high level civil servants and former heads of state from around the world. <https://www.clubofrome.org/about-us/>. The members who completed the book “Limits to Growth” were a systems analysis group at MIT.

<sup>3</sup> This was done for the period of time from 1900 to 1970 and then the computer-generated values of these parameters were projected for the period from 1970 to 2100 (Bartlett 2011, p.1).



Sustainability as a term is commonly defined in the following definition of sustainable development which is found in the report of the Brundtland Commission of the United Nations: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland 1987).

Sustainability in architecture is how the development influences the environment (nature and habitat) finance (equity) and people (society and culture). A very important step in sustainable design is studying the environmental atmosphere of a place, the culture and the economic stability. That way we can remove rather than contribute stress from systems. That includes land use, social and cultural design, site ecology and water use, energy generation, materials and construction, light and air, and most important waste.

In an article entitled *Naturalness as a Pre-Condition* written by Javier Cenicacelaya & Jose Baganha, the writers argue how sustainability is not only preserving the local environment: “Sustainability requires consensus, harmony, respect to the environment, identification with the place, endeavours in common, etc.” (Cenicacelaya and Baganha 2005, p.2) Sustainability is primarily achieved when the architecture is in harmony with the local climatic and geographical surroundings. As James Ayres notes, “Before houses were ‘designed’ they evolved, with a sensitivity towards their environment that may be seen as truly organic. It is such values that we have lost today and thus it is, that we so cherish them.” (Noble 2007, p.12). The influence of the environment is made even more critical by Barry Dawson and John Gillow with their statement: “traditional architecture is a product of its environment; each regional variant develops in response to the conditions and materials determined by the local climate and vegetation.” (Noble 2007, p.12).

Sustainability in this research refers to adapting the buildings to the local environment by utilizing passive design strategies which result in the decrease of the energy demand of buildings. The Mediterranean Region is rich in examples of such architecture which can be defined as “Sustainable”.

### **Passive Design**

The innovative concepts behind the movement of passive building design originated in the United States and Canada following the oil embargo of 1973, leading a group of engineers and architects from the University of Illinois to design the Lo-Cal house in 1976<sup>4</sup>. In 1982, American physicist William Shurcliff published his book “The Saunders-Shrewsbury House,” in which the label “passive house” is first used for the concepts of superinsulation and passive solar. By the late 1980s, Germany took the rein and German physicist Wolfgang Feist improved the efficiency of the passive house design by developing a passive house with an annual heating demand of 15 kilowatt-hours per square meter of living space. He then founded the Passivhaus Institute (PHI) and created the Passivhaus performance standard, which is considered the most rigorous standard in energy efficiency today (Vaughan 2017). The definition of passive design in the mentioned context is a physical and technical one based on installing different technologies such as windows, insulation and a ventilation system which result in heating and cooling related energy savings of up to 90% compared with typical building stock and over 75% compared with average new buildings.

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<sup>4</sup> The Lo-Cal house consumed 60% less energy than the most efficient buildings of the time by using the principle of a highly insulated envelope (Vaughan 2017).

In contrast, Passive design strategies in the context of this research can be defined as strategies which use ambient energy sources instead of purchased energy like electricity or natural gas. These strategies include daylighting, natural ventilation, and solar energy. In the past, when electricity was limited or nonexistent, man was forced to use these passive strategies to achieve thermal comfort in dwellings.

In this research, passive design strategies are extended to the site and settlement in addition to the dwelling itself. Many factors were taken into consideration such as site characteristics like distance from water, amount of vegetation, and topography. In addition to the urban structure of the settlement, the orientation of the streets and the design of the dwelling in terms of orientation and form, which help utilize the maximum possible amount of passive design strategies in a particular climate.

### **The Architectural Identity of a Place**

Vernacular architecture reflects local traditions, religion, and the environment of a place and therefore it reflects its identity. These unchanging traditions are passed on from generation to generation and speak about the people and their customs. The only way to preserve the identity of a place is to protect these traditions from being neglected by studying the factors which contributed to the harmony we find in a vernacular place.

First, the social factor is important to understand the societies, their needs and relationships. The second factor is Culture and Religion. Culture was first defined by the nineteenth century British anthropologist Edward Burnett Tylor, who gave the following definition: ‘*Culture is that complex whole which includes knowledge, art, morals, law, custom, and any other capabilities acquired by man as a member of society*’ (Tylor 1871). Religion also affects the form, plan, spatial arrangements, and orientation of the house, and therefore affects the architectural identity as a whole (Rapoport 1969, p.41). Third, the Structural factor depends on the characteristics of a site like local materials, soil qualities, topography, and the urban regulations of the area. This affects the methods, tools and materials used for building. Another factor affecting identity is the Relationship with nature. The land-building connection affects the identity of a place and gives the panorama a sense of harmony. Josef Hoffman wrote about the Architecture of Capri in the magazine “Der Architekt” describing the simplicity of vernacular architecture and harmony with nature: “*Nature is rich in organization, in diversity of tree kinds, in colors and forms, which means that the simple straight, or decent curved lines of our buildings can gently contrast with that same harmony*” (Hoffman 1897, p.13). Finally, a very important factor affecting architectural identity is the Climate. People achieve sustainability by creating ways to adapt themselves to their environmental surroundings. The form, direction and materials of buildings are chosen to achieve the highest level of comfort in the interior and exterior of a building using local and available resources according to the local climate.

The architectural identity of the Mediterranean region is affected socially by the closeness of the people revealed by the narrow streets and connected roofs and terraces. Religion is seen through the courtyard dwellings which provide privacy. The Structural factor is revealed through the use of the local limestone and whitewash. The land-building connection is revealed through the hillside villages which follow the local topography and finally the climate. The Mediterranean identity is seen through the whitewash buildings, the courtyard house and the narrow streets all which contribute to the thermal comfort of the area.

### **The Mediterranean as a Region of Study**

The Mediterranean region in the context of this research can be defined and limited as the coastal cities and islands. These areas have similar climate because they all face the Mediterranean Sea. As a result of the similar climate, many Mediterranean coastal cities and islands have common vernacular qualities, urban and architectural, like the dense urban fabric and the widely spread courtyard house.

## 1.4. State of Research

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After studying the interest of the vernacular and the debate of regionalism, the love for the Mediterranean region and its vernacular, the environmental movement and the growing interest in sustainability and energy saving, we can conclude that there is still a gap in the existing research which combines all of these aspects and aid in designing a sustainable energy-saving architecture inspired by the Mediterranean vernacular architecture and suitable for the time and place. Paul Oliver whose name is linked directly to vernacular architecture greatly contributed to its research, but sustainability in the vernacular was not his focus. The same case was for Amos Rapoport and Marcel Vellinga who specialized in the research about vernacular architecture. The Mediterranean Vernacular was also studied in projects and seminars, but seldom referred to its sustainable characteristics. Finally, sustainable architecture and passive design are topics of extensive research some applied on modern architecture and others on vernacular architecture such as Hassan Fathy, however the Mediterranean area was not their focused region of study.

### 1.4.1. The Vernacular

It is important to start by displaying the emergence and evolution of the interest of vernacular architecture and how this interest evolved into theories, exhibitions and literature by very famous architects and researchers.

#### a. Emergence and Evolution of the Vernacular:

In Europe, interest in vernacular architecture was awakened in the mid-18th century, in reaction to baroque. It was accompanied by an interest in reason, an attraction to nature and all that was natural. According to many philosophers of that time, like Laugier, Rousseau and Newton, contact with nature was considered purifying. That is why the aristocrats and nobility were influenced by these philosophers fascination with nature and built rural villages and cottages in the gardens of their palaces<sup>5</sup>. Architects who traveled to Italy were also inspired by the beauty of the rural houses there and tried to copy them in their own countries (Cenicacelaya and Baganha 2004, p.9). Voyages to the Mediterranean for centuries have been part of any artistic education and included the grand tour to Italy. Gradually, from the end of 18th century onwards, the curiosity of the voyager changed from famous and well-known monuments to the “anonymous” architecture of small towns and villages (Guarneri 2010, p. 232).

In the mid-19<sup>th</sup> century, followers of architects and theorists like Pugin and John Ruskin began taking interest in the characteristics of local architecture, not only on the crafts and the design elements, but in the inheritance of this architecture and what makes it belong to its surroundings. From then onwards, the genuine interest in vernacular architecture began owing to the passion for affirmation of self and individuality which resulted in a growing interest in the unique architectural characteristics of each country (Cenicacelaya and Baganha 2004, p.10). This interest in architectural identity and individuality, however, still had not awakened the importance of sustainability which is found in vernacular architecture and the indirect way that this architecture achieves energy saving.

In 1964, Bernard Rudofsky held a very famous exhibition entitled *Architecture without Architects: An Introduction to Non pedigreed Architecture* which spread awareness about vernacular architecture, an area that has become neglected and belongs only to a hidden field of academic

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<sup>5</sup> One example is a village inhabited by peasants that Marie Antoinette of commissioned in the gardens Versailles in 1783. It was a real village with a farm, a dairy, a chicken run, a dovecote, and a mill, etc. It was in that village where Louis XVI and Marie Antoinette spent their leisure time, doing peasants' work (Cenicacelaya and Baganha 2004, p.9).

architectural research<sup>6</sup>. It opened in the Museum of Modern Art in New York in 1964 which was a time when progress and Americanization was in control and dealing with spontaneous architecture was considered indecent (Guarneri 2010, p.246). Suddenly, buildings that were only the interest of human geographers, folklorists, anthropologists and architectural scholars became a subject of architectural interest to a wider group of the public (Ozkan 2005, p.99). Examples of vernacular dwellings from all over the world were displayed in the exhibition and its catalogue showing their cultural and historical value<sup>7</sup>.

During the 20<sup>th</sup> century, the reaction to Modernism never subsided and created a debate which distinguished vernacular architecture from regional architecture. Regionalism in the view of Kenneth Frampton lies between two positions of post-modernity: the neo-Historicists who feel that no choice remains but to abandon the apparatus of Avante Garde and return to tradition, and the neo-Avant Gardists who welcome the continuing escalation of modernization as an inevitable process. He defined regionalism as:

*“a contemporary architecture of resistance – that is, a culture of dissent free from fashionable stylistic conventions, an architecture of place rather than space, and a way of building sensitive to the vicissitudes of time and climate”* (Frampton 2007, p.385).

From Critical Regionalism, however, it is defined in French philosopher Paul Ricoeur’s question: *“How to be modern and to return to sources, how to revive an old dormant civilization, and take part in universal civilization.”* (Ricoeur 1961, p.276).

As for Kenneth Frampton, critical regionalism in his opinion should not be identified with the vernacular. In his essay *Towards a Critical Regionalism*, he states:

*“It is necessary to distinguish between Critical Regionalism and simple-minded attempts to revive the hypothetical forms of a lost vernacular”* (Frampton 1983, p.21).

He also notes that the fundamental strategy of Critical Regionalism is:

*“to mediate the impact of universal civilization with elements derived indirectly from the peculiarities of a particular place”* (Frampton 1983, p.21).

Another case of Regionalism is the well-known phenomenon in the 1950s and 1960s when a small group of European and North American architects, Team X, developed an interest for the urban and rural settlements of the Mediterranean side of the African continent<sup>8</sup>. For them Africa became a “laboratory of experimentation” where they tested the most modern architectural and urban concepts throughout the colonial territories and even after independence (Avermaete 2010, p.251). This interest was also depicted as an expectation from the architects to find solutions for their modern problems from the African vernacular architecture, while the Dutch, French and English architects were designing large and sophisticated architectural and urban projects in their rapidly modernizing countries. In 1953, they altered the course of the ninth CIAM<sup>9</sup> meeting which usually presented a modern design for a new urban neighbourhood. Instead they chose to focus on a completely different urban environment: the shanty-towns in Casablanca and Algiers (Avermaete 2010, p.252). The CIAM-Morocco and CIAM-Algiers groups both presented sketches, photographs and detailed studies documenting the living conditions and problems in the

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<sup>6</sup> Rudofsky’s interest in vernacular architecture had started in 1931 when he exhibited photographs in Santorini in the *Deutsche Bauausstellung Berlin*. The idea for Architecture without Architects was first suggested in 1941 (Guarneri 2010, p.246).

<sup>7</sup> The show circulated among eighty-four venues for twelve consecutive years and its catalogue was translated in seven different languages and sold more than one hundred thousand copies in the first twenty years in the United States alone (Guarneri 2010, p.246).

<sup>8</sup> Some of these architects were Alison and Peter Smithson, Aldo van Eyke, Jacob Bakema, George Candilis and Shadrach Woods (Avermaete 2010, p.251).

<sup>9</sup> (CIAM) is the Congres Internationaux d’Architecture Moderne a large international meeting which was a very important propeller of the new interest in African architecture. Team X were members of CIAM (Avermaete 2010, p.251).

shantytowns, as well as renovation schemes and design proposals for new housing units (Avermaete 2010, p.253). These grids displayed no reference to pure forms, appealing aesthetics, and rich architectural traditions, but referred to the messy everyday environment that emerges from poverty and necessity. Although some of the old guard CIAM architects considered this presentation a negative deviation from the original goal of CIAM, which was to portray modern and universal design solutions, but to Team X, this “deviation” was the introduction to a new path for the modern movement (Avermaete 2010, p.253).

## **b. The Vernacular: Research and Literature**

A very important researcher of vernacular architecture is Paul Oliver<sup>10</sup>. For him, vernacular architecture, “*embraces the entire field of tribal, folk, peasant, popular and informal sector urban building*” (Oliver 2006, p.109). After borrowing the term ‘vernacular’ from linguistics, Paul Oliver opened a vast field of exploration. In his first book *Shelter and Society* (1969), he placed vernacular architecture into the history of architectural theory. The subject attracted a wide spectrum of interest to worldwide researchers who followed his path. Thanks to Oliver and his followers, research on vernacular since the 1970s has developed into a respectable academic field and filled the biggest gap in architectural theory. This gap was the lack of laboratory work in architectural theory which prevented the discipline from gaining valid knowledge from cases and field studies (Ozkan 2005, p.99). The book *Shelter and Society* also led to the growing interest in the environmental and social context in which vernacular buildings were built, rather than emphasizing their beauty and aesthetical values.

Oliver dedicated his growing interest in vernacular architecture to publishing a three volume encyclopedia *The Encyclopedia of Vernacular Architecture of the World* (1997). He was the leading editor for a valuable encyclopedia containing entries from more than 750 specialists from over 80 countries around the world (Oliver 2006, p.28). The encyclopedia discusses the architecture of more than 1300 cultures (Oliver 2006, p.35), it covers cultural, geographical, climatic and environmental aspects of traditional buildings, and gives a complete image of a phenomenon greatly neglected by the disciplines of architecture as well as ethnology. The aim of this encyclopedia, he states, is not merely to ‘*Save the vernacular heritage*’ and to ‘*document disappearing building g traditions*’, but to display ‘*the continued involvement of cultures in shaping their own environments, and the study and understanding of existing traditions, failing or thriving*’ (Oliver 2006, p.42). Oliver continues to speak of the importance of vernacular to achieve sustainability: “*In a period when ‘sustainability’ is prominent in much architectural discourse, much can be learned from the most sustained of all forms of architecture: the vernacular traditions*” (Oliver 2006, p.42). Oliver's encyclopedia opens the awareness, that architecture has long been restricted on samples of historical architecture selected for aesthetic reasons (such as pyramids, temples, palaces and cathedrals) thus greatly neglecting a rich variety of traditional architectural forms diffused over centuries all over the world.

Another book by Paul Oliver which focused on vernacular architecture is *Built to Meet Needs: Cultural Issues in Vernacular Architecture* (2006). In this book, Paul Oliver brings together previously unpublished papers in one volume to form a reference for students and professional architects, as well as all those involved with planning housing schemes in their home countries and overseas. It covers a wide range of issues relating to vernacular architecture from all around

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<sup>10</sup> Paul Oliver (1927) is an art historian who graduated from the University of London in 1955. From the early 1960s onwards he documented and studied vernacular architecture traditions in many parts of the world. He is an Honorary Fellow of the RIBA and received a life time achievement award from the International Association for the Study of Traditional Environments (IASTE) in 2002 (<http://architecture.brookes.ac.uk/research/pci/poval.html>).

the world including economies, technologies, inherited skills, social and family structures, physical needs, belief systems and symbolism. This book contributed many thoughts about the importance of vernacular architecture and the cultural symbolism of each form of dwelling. The book *Dwellings: The Vernacular House Worldwide (1987)* is about the vast range of types of vernacular houses around the world. He estimates that 90 percent of the world's buildings are vernacular, making it consist of approximately 800 million dwellings (Asquith 2005, p.128). The book documents the form of traditional buildings that are self-built by their owner-occupiers or built by members of a community, recording the methods of construction and decoration of different cultures. It shows how diverse communities cope with issues of climate, migration, mass development and how this brings symbolic and cultural meaning to architecture.

Another name linked to vernacular architecture is Amos Rapoport<sup>11</sup> who wrote many theories on the vernacular in the book *House, Form and Culture (1969)*. In this book, the author presents different hypotheses for the origin of the house form and questions whether they are a result of climate, technological constraints, influence of place, defense, economics and religion. He concludes that the form of the house is a result of not one single factor but a whole range of socio-cultural factors in their broadest terms. The chapter about the climate shows how the form of the house is a result of the local climate and affects its environmental adaptation to its surroundings. Among the many books describing the various forms of vernacular architecture around the world and their cultural and historical value, this book focuses on the theoretical approach of vernacular architecture which helps in finding solutions for the challenges facing the global community in terms of the environment, disasters and housing.

The names of the famous researchers mentioned above are joined in one book entitled *Vernacular Architecture in the 21st Century (2006)*, edited by Lindsay Asquith and Marcel Vellinga who are also both researchers in the field of vernacular architecture. This book was a tribute to Paul Oliver whom the editors worked with for a number of years. Their aim in producing this book was to further the debate on the importance of vernacular architecture studies now and throughout the twenty-first century, not as a study of past traditions, but as a contribution to new methods and solutions. It also aims to credit anyone involved in the field, whose integrated and dynamic approaches will ensure that the vernacular does not stand still, but continues to influence and enhance the world we live in.

#### **1.4.2. The Mediterranean Vernacular**

The Mediterranean vernacular architecture had a huge influence on modernist architects of the 20<sup>th</sup> century. A very important book which describes this influence is *Modern Architecture and the Mediterranean*<sup>12</sup>, edited by Jean-Francois Lejeune and Michelangelo Sabatino. Modern architects in the 20<sup>th</sup> century from 1920 to 1980, were fascinated by Mediterranean vernacular architecture and they reflected their experiences and knowledge in their designs. Modernist architects can be categorized into many groups each with a different vision towards modernism. Mediterranean Modernism is a complex cultural and architectural phenomenon promoted by many architects like Josep Coderch, Sedad Eldem, Le Corbusier, Aris Kostantinidis, Adalberto Libera, Dimitris

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<sup>11</sup> Amos Rapoport (1929, Warsaw) is an architect with a Bachelor of Architecture degree from the University of Melbourne (1955) and an MA from Rice University (1957). He is one of the founders of Environment-Behavior Studies (EBS) and the author of over 200 academic publications and books in this field that have been translated into many languages (Rapoport 1990, p.80).

<sup>12</sup> This book has two origins, the first are the lectures from the seminar *The Other Modern-On the Influence of the Vernacular on the Architecture and the City of the Twentieth Century*. It was held by the University of Miami School of Architecture in Capri in 1998 and directed by Professor Jean-Francois Lejeune. The second origin was the 2005 encounter between the two book editors Lejeune and Sabatino at the museum Wolfsonian-FIU in Miami. This meeting was the genuine starting point for the book (Bergdoll 2010, p.xi).

Pikionis, Luigi Cosenza, Alvaro Siza, Fernand Pouillon and Josep Lluís Sert. These architects were influenced by the Mediterranean vernacular and were committed to culture and climate-specific modern architecture, which has been referred to as ‘modern regionalism’. Another group are the architects of non-Mediterranean countries who travelled and occasionally practised in the Mediterranean include Erik Gunnar Asplund, Erich Mendelsohn, Bernard Rudofsky, Bruno Taut, Aldo Van Eyck, Herman Hertzberger, Roland Rainer, Paul Schultz-Naumburg and Jorn Utzon.

This inspiration caused by the Mediterranean vernacular led to a number of projects and seminars. Two projects were done by the Euromed Heritage Programme, Corpus and Corpus Levant. Corpus was an inventory of vernacular buildings throughout the Mediterranean. It aimed to raise awareness and knowledge of vernacular buildings and construction techniques and this was done after buildings were identified and categorised. Corpus Levant was an extension of Corpus in Syria and Lebanon. It contributed to preserve the local vernacular architecture and aimed to improve the living conditions of the population by assisting in maintenance and rehabilitation. The result of the Corpus project was the book *Traditional Mediterranean Architecture*. It provides a study of the architectural heritage of the Mediterranean region, as a place for living, its housing typologies and shapes, and the building techniques.

Another project devoted to display the architecture of the Mediterranean region is *The Mediterranean Medina: International Seminar* which took place in the School of Architecture at Pescara in June of 2004. The seminar aimed at the study of the particular physical characters and the transformation of the Mediterranean city. The proceedings of the seminar were published into a volume with the same title and edited by Ludovico Micara, Ettore Vadini and Attilio Petruccioli.

### **1.4.3. Sustainable Architecture and Passive Design**

The rise of the Environmental Movement began the 1960s and 1970s in the United States following a series of environmental disasters such as oil spills and lake fires. This resulted in increased awareness for the preservation of Americas wilderness in addition to the impact of environmental damage to the human population (Gordon 2012, p.1).

It became apparent that global populations, rates of resource use and environmental degradation were all increasing so rapidly that these increases would soon reach the limits imposed by the finite productivity of the global ecosphere and the geological availability of mineral and fossil fuel resources (Bartlett 2012, p.1).

This led to the formation of The Club of Rome in 1968, “*an organisation of individuals who share a common concern for the future of humanity and strive to make a difference. Our members are notable scientists, economists, businessmen and businesswomen, high level civil servants and former heads of state from around the world. Our mission is to promote understanding of the global challenges facing humanity and to propose solutions through scientific analysis, communication and advocacy*”<sup>13</sup>.

The first report carried out by this organization is the book “The Limits to Growth” (1972) which is the nontechnical report of the results of a computer simulation study done by an international team of researchers at the Massachusetts Institute of Technology in 1970. The simulation recorded the five basic factors that determine and limit growth on this planet for the period of time from 1900 to 1970. The parameters were: population increase, agricultural production, non-renewable resource depletion, industrial output, and pollution generation. The MIT team then tested the behavior of the model under several sets of assumptions to determine alternative patterns for

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<sup>13</sup> <https://www.clubofrome.org/>



mankind's future<sup>14</sup>. Some of these assumptions predicted a world wide collapse of world population in the mid 21<sup>st</sup> century (Bartlett 2012, p.1).

Following the 1983 World Commission on Environment and Development (WCED), chaired by Gro Harlem Brundtland, a report named 'Our Common Future' was published in 1987, highlighting three fundamental components to sustainable development: environmental protection, economic growth and social equity. The concept of sustainable development focused on finding strategies to promote economic and social advancement in ways that avoid environmental degradation, over-exploitation or pollution, and sidelined the importance of development and the environment as one single issue<sup>15</sup>.

After 1990, the concept of Sustainability became more and more popular, and new organizations, such as the US Green Building Council, appeared. USGBC is a private, membership-based non-profit organization that promotes sustainability in building design, construction, and operation. It is best known for its development of a green building rating system (LEED), Leadership in Energy and Environmental Design and its annual Greenbuild International Conference and Expo, the world's largest green building conference and expo<sup>16</sup>.

Other organizations for promoting sustainability in building design and construction include The International Solar Energy Society (ISES) with roots dating back to 1954. ISES is a global organization for promoting the development and utilisation of renewable energy. One of their publications is the Renewable Energy Focus journal which aims to publish applied research on commercially-feasible renewable energy technology development across all vertical technology industries<sup>17</sup>.

PLEA - Passive Low Energy Architecture, is a global network that has led a worldwide discourse on sustainable architecture and urban design through its conferences, workshops and publications since 1982. Thousands of professionals, academics and students from over 40 countries are members of this network<sup>18</sup>. In the 23<sup>rd</sup> PLEA conference in Geneva 2006, proceedings entitled "Lessons from Traditional Architecture" were presented by a wide range of scholars and these proceedings were published in a book "*Learning from Traditional Architecture: Achieving Climatic Buildings by Studying the Past*", edited by Simos Yannas and Willi Weber. The topic was the lessons that can be learned directly from vernacular architecture from around the world and they are offered to the reader as guidance and inspiration for designing new sustainable buildings. Case studies from around the world focus on environmental design aspects of vernacular architecture in a broad range of climatic conditions and building types, one of them the courtyard house.

Beginning in 2000, The Sustainable Built Environment (SBE) is a series of conferences including four international organizations as co-owners<sup>19</sup>:

- International Council for Research and Innovation in Building and Construction
- International Initiative for a Sustainable Built Environment
- United Nations Environment Programme
- International Federation of Consulting Engineers

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<sup>14</sup> <https://www.clubofrome.org/report/the-limits-to-growth/>

<sup>15</sup> <https://www.sustainabledevelopment2015.org/AdvocacyToolkit/index.php/earth-summit-history/historical-documents/92-our-common-future>

<sup>16</sup> [https://en.wikipedia.org/wiki/U.S.\\_Green\\_Building\\_Council](https://en.wikipedia.org/wiki/U.S._Green_Building_Council)

<sup>17</sup> <https://www.ises.org/what-we-do/publications/re-focus-journal>

<sup>18</sup> <http://www.plea-arch.org/index.php/>

<sup>19</sup> <http://www.sbe-series.org/the-sbe-series/overview/>

The SBE series is held on a 3-year cycle<sup>20</sup> and its main objective is to distribute innovative policies and developments in the field of sustainable urban environment to a broad international audience specializing in design, construction and operation of buildings and infrastructure<sup>21</sup>.

The Passivehaus Institute (PHI)<sup>22</sup> was founded in 1996 by German physicist Wolfgang Feist. Dating back to the energy crisis in the United States in 1976, the idea of the passive house was first interpreted. The crisis led to the emergence of the LO-Cal house which consumed 60% less energy than the most efficient buildings of the time, using the principle of a highly insulated envelope<sup>23</sup> (Vaughan 2017). The term “passive house” emerged in 1982, in a book by American physicist William Shurcliff “The Saunders-Shrewsbury House,” as label for the concepts of superinsulation and passive solar (Vaughan 2017).

By the late 1980s, a full passive house movement had launched in North America, but Germany took the reins when German physicist Wolfgang Feist improved the efficiency of the passive house design and developed a passive house with an annual heating demand of 15 kilowatt-hours per square meter of living space. Feist then founded the Passivhaus Institute (PHI) in 1996 and created the Passivhaus performance standard (Vaughan 2017).

The first architect to pioneer passive solar design is George F. Keck, who created an all-glass house named “The House of Tomorrow” in 1933. Although this house failed due to the stress on the air conditioning system, it became an inspiration for the design of other passive solar houses. A “solar house” movement boomed in the 1940s and Frank Lloyd Wright became the next architect to use solar design for his buildings (Neiley 2016).

Many books were published which are considered guides for sustainable planning and design. *Sol Power. The Evolution of Sustainable Architecture* (1996) by Sophia and Stephan Behling, displays different ways to achieve energy conscious buildings by promoting solar-oriented architecture. It illustrates the role of the sun in various natural cycles including sustainable ecosystems, wind patterns, ocean currents, fossil fuels and animal life cycles. It displays the different ways that people since Neolithic times have harnessed the sun’s power in different climates and adapted to life in the tundras, rainforests, savannas, deserts and in earths comfort zones<sup>24</sup>.

The book *Energy in Architecture. The European Passive Solar Handbook* (1992) by John R. Goulding, is a detailed design guide to energy-efficient and passive solar architecture. It provides the environmental response of different architectural typologies, traditional and modern, in a range of locations including coastal, plain and woodlands in European climates. It examines these in terms of passive solar heating strategies, daylighting control systems and evaluation methods<sup>25</sup>. Goulding’s other book *Energy Conscious Design. A Primer for Architects*, is an introduction to the theory and practice of designing energy-efficient passive solar buildings according to the climate and principles of energy conservation.

From an urban planning perspective, the book *Environmental site layout planning: solar access, microclimate and passive cooling in urban areas* is a guide to on site layout planning in order to improve solar access, passive cooling and microclimate. This project was jointly funded by the European Commission JOULE programme and national funding agencies and was coordinated by the University of Athens, LEMA (University of Liege) and AICIA (University of Seville). The

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<sup>20</sup> The three-year schedule is planning and preparation in year 1, national/regional conferences in year 2 and a single global event in year 3.

<sup>21</sup> <http://www.sbe-series.org/the-sbe-series/objectives/>

<sup>22</sup> <https://passivehouse.com/index.html>

<sup>23</sup> This was accomplished by a group of engineers and architects from the University of Illinois Small Homes Council 1976.

<sup>24</sup> <https://www.amazon.com/Solar-Power-Evolution-Sustainable-Architecture/dp/379132411X>

<sup>25</sup> <https://www.amazon.co.uk/ENERGY-ARCHITECTURE-European-Passive-Handbook/dp/0713469188>

aim was to enable designers to produce comfortable, energy-efficient buildings surrounded by pleasant outdoor spaces, within an urban context that minimizes energy consumption and the effects of pollution (Littlefair, Santamouris, Alvarez, Dupagne, Hall, Teller, Coronel and Papanikolaou 2000, p.iii).

When speaking about passive design and vernacular architecture, Hassan Fathy is one of the architects who studied the genius passive design methods of vernacular architecture. He is considered one of the most famous activists of regionalism. He challenged modernism and struggled against the prevalent forces of internationalism. Internationalism, in his opinion was an intrusion to the meaning of architecture<sup>26</sup> (Ozkan 2005, p.104). Hassan Fathy's book *Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates* is an essential book which presents the vernacular wisdom of indigenous architectural forms that have evolved in hot arid climates. Linking vernacular architecture to sustainability, he shows how natural energy is created in the genius design of a traditional dwelling. The survival of these traditional societies over hundreds and thousands of years indicates that they possess a great knowledge that can be used and developed for our present and future needs. Hassan Fathy adds that traditional techniques are rarely costly in terms of material and energy, and the participation of the local people in the design and construction of their houses is also essential. That leads to a triangular relationship between the local people, the architects and the builders. In that way, the design of the house not only reflects the architect's knowledge, but it reflects the people and their culture (Fathy 1986, p.xviii).

#### **1.4.4. Dense Urban Structure and Courtyard Housing**

When speaking about the chosen typology of this thesis, the dense urban structure and courtyard housing, the book *Urban Forms and Colonial Confrontations* (1997) by Zeynep Çelik is an important book about one of the case studies, Algiers. It is a detailed look at Algiers as the site of colonial policies, based on an understanding that architecture and urban forms are key players in definitions of culture and identity. For colonialism not only involved economics and politics but also was a cultural phenomenon. The author's analysis of Algiers evolves around two general themes: urban form and urban process. The approach to studying the city was based on Spiro Kostof's, an architectural historian's approach where emphasis was placed on the "physical frame of things" and the "spatial characteristics of the city." (Kostof 1992). They focus on urban form in a historical perspective, looking for specific intents (Celik, 1997, p.1-2).

Another book detailing the urban form of a vernacular city is *Sidi Bou Said, Tunisia: Structure and Form of a Mediterranean Village* (2009) by Professor Besim Hakim and a team of students who undertook a landmark analysis of the village of Sidi Bou Said located on the Mediterranean in northern Tunisia. The goal of this analysis was to show that the main elements of such a natural system are associated with the phenomenon of emergence. The configuration and form of the built environment is not known during the process of formation and have a spontaneous character. However, the result fits well and is in balance with its immediate surroundings and maintains the quality of the village as a whole (Hakim 2009, p.viii).

The book *Courtyard Housing: Past, Present and Future* edited by Brian Edwards, Magda Sibley, Mohamad Hakmi and Peter Land, is a collection of essays covering the history, the theories and

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<sup>26</sup> Hassan Fathy's mission was to create an architecture that would improve the living conditions of the poor, by using traditional methods of building. Two of his rural settlement projects were New Gourna Village and Bariz Village (Ozkan 2006, pg.104). His book *Architecture for the Poor* (2000), describes Hassan Fathy's plan for building the village of New Gourna, near Luxor, Egypt, which was designed to house 900 families (Oliver 2006, p.140). Building was undertaken without the use of expensive materials such as steel and concrete, but by using mud bricks and the native technique that Fathy learned in Nubia.

the cultural, environmental and contemporary dimensions of courtyard housing. Focusing more on the Arab courtyard houses, chapter three of this book describes the climatic aspects of the courtyard house in the hot arid region and its thermal performance. By displaying a series of case studies, this book demonstrates, through discussions on sustainability and regional identity, that courtyard housing has a future as well as a past.

### **Review of the State of Research**

It is evident that a lot of research has been done in all fields relating and contributing to this research:

In the field of Vernacular Architecture, many researchers dedicated their careers to shining the light on the value of vernacular architecture. Their literature became an important source for examples of vernacular architecture worldwide and some of them from the Mediterranean region. Their focus however, was not aimed at the climatic aspects of the vernacular dwelling but a more general description of its design and form.

In the field of Mediterranean Vernacular, its influence on modern architecture has been reflected in the architecture of many modern architects, however this inspiration has been seen in the design and form of the buildings and seldom were the elements applied for their climatic benefit. In addition, books and seminars specializing in the Mediterranean vernacular covered the whole region and did not focus on the coastal cities.

In the field of Sustainable Development and Passive Design, there are many organizations which released standards that evaluate a project for its sustainability. However, these rating standards are complicated and address many economic and social aspects. They focus on efficient modern technologies rather than simple design tools that contribute to reducing the energy use of a building. In addition, most of these standards address individual buildings without considering the location and the settlement as a whole. Books which are considered guides for passive architecture are mostly limited to passive solar design and are not focused on wind and natural ventilation.

When speaking about settlements with a dense urban structure and courtyard housing specifically, there are several pieces of literature describing the urban structure and housing of specific cities in detail without any focus on the environmental characteristics of the design and form of these cities. Books about the courtyard house display the history, evolution, shape and a few climatic aspects of the courtyard house around the world and not the Mediterranean region specifically.

As outlined, there is a lot of research specifically focused on different topics, and there are many elaborate evaluation systems, but there is a lack of easy-to-use methods available for the designing architect to test the use of passive design strategies at every stage. My research questions result from this gap.

## **1.5. Research Design**

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The design of this research played an important role in the achieving the goals and objectives. Three main steps were taken, sources relevant to the topic were chosen, methods to answer the research hypothesis were utilized and a clear and sequenced structure was designed to lead the reader to the conclusion of this research.

### **1.5.1. Sources**

Research data was collected from books, articles, journals and theses. First, information about vernacular architecture was collected from the most famous literature about the topic to show its importance and the growing interest in it. General facts about the Mediterranean and its vernacular architecture were gathered to describe the region of study, its climate, geological and architectural characteristics. Several books showed studies of vernacular dwellings from different regions which carry sustainable features and many of them from the Mediterranean region. General information was gathered about the way in which passive design strategies function in buildings in hot and dry climates and how these strategies aid in increasing thermal comfort and save energy. Any data selected referred to the vernacular architecture within the limit of the region of study (the Mediterranean coastal cities). Books specialized in the four case studies carried a description of the settlement and its houses, master plans of settlements, and plans, sections and facades of houses. Information and plans for each case study was found from multiple sources and collected to fill in all the necessary steps taken to prove the aim of research.

For the case studies chosen, all urban and architectural drawings (master plans, house plans, sections, facades and 3d drawings) were redrawn on Auto Cad by the author of this research. The re-drawings of the urban structure and houses of four case studies were used to analyse the passive design strategies in relation to the solar and wind factors according to the general information collected either about passive design or about a specific city or settlement. This analysis was displayed in matrices to show which settlement carries the most positive characteristics in terms of passive design strategies and to show how it is possible to design modern dwellings with a high comfort level by using simple vernacular methods.

### **1.5.2. Methods:**

In this section, the methods used to answer the following research questions are explained:

How can we learn from the Mediterranean vernacular to design sustainable modern dwellings?

What are the simple passive design strategies that can be applied in modern architecture and aid in the thermal comfort and energy saving of it?

How can we innovate new methods which meet modern demands based on vernacular methods?

### **Limitations:**

The region of study for the vernacular examples is the Mediterranean Coasts and Islands which share a similar climate and consequently share similar building typologies and passive design strategies in their vernacular architecture. This region was chosen due to the rich history of the Mediterranean area resulting in many vernacular settlements which are until today inhabited and well preserved.

Case studies with a dense urban structure and courtyard typology were chosen because they are spread all across the Mediterranean region and they carry many passive design characteristics. This typology until today is found in many cities around the world whether vernacular or modern

and has proved to be sustainable in every way. The selection of the case studies was based on availability of material and according to relevance in terms of the region of study. One case study, the village of Sidi Bou Said was chosen because it is a well preserved vernacular city on a steep cliff overlooking the Mediterranean Sea and carries many of the passive design characteristics, such as dense urban fabric and courtyard houses. The second case study, the Casbah of Algiers is the traditional quarter of Algiers built on a hill and slopes down towards the Mediterranean Sea. With its dense fabric and courtyard houses, it also carries many passive design strategies and is considered a good example of a historic Maghreb city with an extensive influence on town-planning in the western part of the Mediterranean and sub-Saharan Africa. The courtyard house (Dar Toumi) was chosen because many sustainable features were gathered in this house in addition to the availability of material found to cover all important aspects.

The selection of the modern case studies was due to their inspiration by the Mediterranean vernacular architecture, its simple architecture and the existence of the courtyard typology. They were also chosen due to the availability of material and data. Other than the courtyard typology, the first case study Quinta da Malagueira has a Mediterranean temperate climate similar to that of the vernacular case studies. Second, it has a compact but modern urban structure making it a good example for comparison and achieving the outcome of the research. The second case study, Fredensborg Housing is different from the first case study in terms of the cooler climate and the dispersed urban structure. The different climate shows that it is important to consider the place and local climate in order to implement passive design strategies suitable for the place. The dispersed structure is a good comparison showing its slight disadvantage due to the increased heat loss and consequent energy consumption. The selection of two different modern case studies rather than one allowed for comparison between two different climates and urban structures.

Finally, the main factors which were depended on for the analysis of the passive design strategies were the response of the site, urban structure, houses and elements to the sun and wind only. The humidity factor was mentioned only where relevant. Other sustainable features of vernacular cities like the use of local materials or water collection were not studied. The reason for this limitation is the importance of the sun and wind factors in affecting the thermal response of a settlement and its buildings and consequently the amount of energy needed to achieve thermal comfort.

Sustainability in this research refers to dwellings that demand less energy use due to the passive design strategies used in the design of the settlement and dwellings. Some tools have high influence on the energy use of dwellings, such as form, orientation, density of blocks and window size. Others have a medium effect on the energy savings of buildings like some of the thermal regulating spaces and finally there are tools with a low effect on building energy savings, but affect the thermal comfort of the streets and the pedestrians like street orientation and public spaces.

### **Qualitative Comparative Analysis:**

Four case studies, two vernacular settlements and two modern vernacular inspired settlements were analysed and compared in matrices in order to display the thermal response of vernacular urban structures and houses and the thermal response of modern urban structures and houses in order to show how it is possible to design modern houses with similar passive design strategies but at the same time achieve the modern humans' demands and comfort. The rating system in the comparative matrices depended on the personal estimates of the author of this work according to the research and analysis done in the literature.

## **The Analytical Approach:**

### **Conventional Sustainable Rating Systems**

There are many large systems of certification for sustainability of buildings such as LEED, BREEAM, HQE, CASBEE and Bewertungskriterien DGNB. When comparing with this research and evaluation of different elements, all of these systems are rather complicated with lots of additional factors like economy and social aspects. Some of them can be summarized in the following<sup>27</sup>:

Leadership in Energy and Environmental Design (LEED) rating system assesses buildings against key sustainability standards, including energy conservation, indoor air quality, use of recycled and recyclable materials, water use reduction, greenhouse gases emittance reduction and long-term sustainability. Although there is a specified LEED for Homes certification, the standards are technical and not related to simple design strategies for the use of an architect. In addition, they are not related to the site or the urban structure.

Building Research Establishment's Environmental Assessment Method (BREEAM) is an assessment standard for buildings, master-planned projects and infrastructure. It assesses the procurement, design, construction and operation of a development project against performance-based target benchmarks.

German Sustainable Building Council (DGNB) covers all aspects of sustainable development and is based on three classic columns of sustainability: ecology, economy and social aspects. Assessments are always based on the entire lifecycle of the building, with primary focus on the well-being of the building's end user. Comparing it to previous systems, DGNB is more complete as it is the younger system and was able to orientate itself according to LEED and BREEAM.

Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is designed to achieve energy and resource savings, recycling performance and other environmental-impact reductions. This system evaluates the environmental performance of buildings, including comfort and landscape considerations from a single home to a whole city.

All of these standards have a rating system where buildings can obtain a score based on their performance against a very wide and complicated list of aspects. In addition, they are not based on simple design strategies that can be done during the initial design phase. For example, LEED standards have few design based credits and is orientated more towards using efficient technologies like efficient water fixtures, HVAC and lighting. It is not based on simple design strategies that an architect can follow to create a thermally comfortable dwelling which requires the least amount of heating or cooling. The evaluation found in this research enables the architect to follow simple design methods in a settlement and dwelling where he can follow a simple checklist, collect points and obtain a score which determines a level of sustainability and energy reduction. The Passive Solar and Passive Wind (PSPW) Rating System is explained in the following section and then in more detail in the conclusion where a very simple scorecard is revealed based on the analysis which this research is based upon.

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<sup>27</sup> <https://www.prologis.com/about/sustainable-industrial-real-estate/environmental-stewardship>

### The PSPW Rating System

The analysis was first implemented in chapter 2, in the general passive design characteristics affected by the sun and wind which can be found in the Mediterranean area and their effect on the thermal response of a house and settlement and subsequently the amount of energy savings in the buildings. The humidity factor was studied in integration with the solar factor due to the relationship of the solar effect to the evaporation process. This analysis was done in the general to detailed sequence: Site, Settlement, Dwelling, Element. First, the sun and wind affect the site as a whole depending on different elements existing in and around it, like topography, vegetation and water. Second, the urban structure of the settlement determines how the building blocks and streets respond to the sun and wind. This depends on whether the settlement is compact or dispersed, the orientation of the settlement, dimensions of the building blocks and streets and the public spaces, affecting the residents on a public level. Third, the configuration of the dwelling itself (the courtyard house), reacts to the sun and wind depending on its shape, its orientation, and the distribution of spaces, and translates the more general effects in a positive or negative way. Finally, there are also significant elements found in the courtyard house which also aid in the thermal comfort of the dwellers. It is important to note that not all design tools have the same effect on energy savings of buildings, therefore, each tool was given an evaluation with a number of points depending on the influence of this tool on energy savings. The tools were assessed into 4 different categories: high influence, medium influence, low influence, no influence. For each category, a number of points was given<sup>28</sup>:

<b>CATEGORY (influence on building energy savings)</b>	<b>POINTS</b>
<b>Very high influence</b>	<b>16</b>
<b>High influence</b>	<b>12</b>
<b>Medium influence</b>	<b>8</b>
<b>Low influence</b>	<b>4</b>
<b>No influence</b>	<b>0</b>

Matrix (1.1) Evaluation according to Influence on Energy Savings

The reason for the number of points given for each tool is explained in chapter 2 (general analysis) at the end of each section (Site, Settlement, Dwelling, Element). Since each tool is assessed with its relation to the sun and wind factor, the number of points given is divided into 50% for the sun factor and 50% for the wind factor. The reason for the equal distribution is the importance of both factors in the thermal regulation of a building and their effect is of equal importance. The following example shows the SITE and SETTLEMENT matrices where all the tools are relevant with regards to the sun and wind factor:

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<sup>28</sup> It is important to note that this evaluation is a result of the estimation of the author based on the facts collected in chapter 2.



Site (SI)	Total Points	Sun 50%	Wind 50%
<b>SI 1. Topography</b>	<b>12</b>	<b>6</b>	<b>6</b>
<b>SI 2. Vegetation</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SI 3. Water Bodies</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>Total for SI Category: 44</b>			

Matrix (1.2) Evaluation of Tools in SITE Category

Settlement (SE)	Total Points	Sun 50%	Wind 50%
<b>SE 1. Compact Geometry</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 2. Block Orientation</b>	<b>12</b>	<b>6</b>	<b>6</b>
<b>SE 3. Street Orientation</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 4. Narrow Streets</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 5. Open Spaces</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 6. Vegetation</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 7. Public Fountains and Wells</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 8. Surface Materials</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>Total for SE Category: 88</b>			

Matrix (1.3) Evaluation of Tools in SETTLEMENT Category

In some cases, where the tool can not be applied for either the sun or wind, then the number of points for the N/A factor will be (0) and 50% will be given to the other applicable factor. Example: In the Dwelling category, elements like the Arcade effect the thermal comfort of the dwelling in relation to the sun only and vice versa, the Loggia is an element where the wind only is utilized.

<b>Dwelling (DW)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>DW 1. Shape and Form</b>	16	8	8
<b>DW 2. Orientation</b>	16	8	8
<b>DW 3. Dimensions</b>	12	6	6
<b>DW 4. Liwan</b>	8	4	4
<b>DW 5. Arcade</b>	8	4	N/A
<b>DW 6. Loggia</b>	8	N/A	4
<b>DW 7. Terrace/Roof</b>	8	4	4
<b>Total for DW Category: 68 (total - N/A elements)</b>			

Matrix (1.4) Evaluation of Tools in DWELLING Category

Another example is the ELEMENT category where the Malqaf is applicable only when related to the wind factor.

<b>Element (EL)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>EL 1. Windows</b>	16	8	8
<b>EL 2. Mashrabiya</b>	12	6	6
<b>EL 3. Courtyard Vegetation</b>	16	8	8
<b>EL 4. Water Features</b>	8	4	4
<b>EL 5. Thermal Mass</b>	16	8	8
<b>EL 6. Malqaf</b>	12	N/A	6
<b>Total for DW Category: 74 (total - N/A elements)</b>			

Matrix (1.5) Evaluation of Tools in ELEMENT Category

After the general analysis and evaluating each tool and its influence on energy savings, the same approach was repeated but this time specialized in two vernacular case studies found in the region

of study (the Mediterranean coastal cities) and again repeated for two modern vernacular inspired case studies found in other areas. This was done in the same sequence as chapter 2 (Site, Settlement, Dwelling, Element), showing the way the passive design strategies affect the actual case study. The detailed analysis for each case study was always referenced to the general information in chapter two. For each case study, and at the end of each of the four sections (Site, Settlement, Dwelling, Element), a matrix displays the evaluation for each characteristic or tool in the specific case study, giving a number of points out of the total given for each tool in chapter 2. These points were also given according to categories and shown as a percentage out of the general evaluation:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (1.6) Evaluation for Existing Situation of Tools (EE)

After analysing the case studies and giving points for each tool, the total number of points for each category (Site, Settlement, Dwelling, Element) is added together to present a final score. This score receives a certification level as per the following:

<b>SUSTAINABILITY LEVEL</b>	<b>POINTS REQUIRED</b>
<b>Not Sustainable</b>	<b>Below 140</b>
<b>C</b>	<b>140-164</b>
<b>B</b>	<b>165-189</b>
<b>B+</b>	<b>190-214</b>
<b>A</b>	<b>215-239</b>
<b>A+</b>	<b>240-274</b>
<b>Total points</b>	<b>274</b>

Matrix (1.7) Sustainability Levels

### **1.5.3. Structure**

The structure of this research is based on 5 chapters:

#### **Chapter 1: Introduction**

This chapter describes the aim of the research, comparing between the vernacular “Architecture without architects” and the modern “Architecture by Architects” which can be sustainable by learning from the former. The research question which needs to be answered is how can we learn from this “Architecture without Architects” to design modern sustainable architecture? Understanding a few steps is needed in order to start finding answers to the question.

The key words relating to the subject were defined in order to understand the area of focus. It is important to define terms like “vernacular”, “sustainable”, “passive design” and “architectural identity” in the research context to make the research clear to the reader.

In the state of research, a summary was given describing the emergence and evolution of the interest in vernacular architecture starting from the 18<sup>th</sup> century. After that, literature, exhibitions and seminars by the most important researchers and architects was displayed on subjects like Vernacular Architecture, Regional Architecture, The Mediterranean and its vernacular architecture, and Passive Design, in order to show the existing gap where no research focused on the passive design strategies of Mediterranean vernacular architecture.

Finally, in this chapter, the research design starts with the sources used and how they were treated, either by collecting information about the relevant subjects or by redrawing the plans needed to clarify the steps leading to the outcome. Then methods and approaches taken were explained to show the way the research question is answered. Limitations to define the areas of focus were stated like the region of study, typologies, case studies, climate factors in addition to the reasons for these choices.

#### **Chapter 2: The Mediterranean**

This chapter describes the Mediterranean Basin with its unique characteristics and special identity. It carries a diversity of cultures and this diversity resulted in its unique identity. Many trade connections took place on its shores. These factors resulted in the current state of land, the people, the style of living and consequently the architecture and urban planning. All these factors in addition to the climate of the Mediterranean were summarized in this chapter, all which resulted in a unique identity which is threatened to be lost if globalization takes the lead in this region and buildings are designed without considering any local factors or sense of belonging. The diversity of the Mediterranean region results in many typologies, however, the typology chosen to be studied in the Mediterranean coastal cities is the dense urban fabric and courtyard housing. General passive design strategies in the Mediterranean area were displayed in a gradual sequence starting from the site as a whole and any elements which affect it, moving down to the dense urban fabric of the settlement itself, down to the courtyard house and its thermal regulating spaces, and finally what elements it contains which contribute to the thermal comfort of the different spaces. At the end of each section of this chapter, a general matrix gives a score for each passive design strategy depending on its contribution to energy savings. These strategies are assessed for their actual performance in the actual case studies at the end of chapter three (the vernacular case studies) and chapter four (the modern case studies) so they can be compared in chapter five (the conclusion). The same sequence is used, Site-Settlement-Dwelling-Element in this matrix.

### **Chapter 3: Mediterranean Vernacular: Site.. Settlement.. Dwelling.. Element**

This chapter displays actual case studies from the Mediterranean vernacular coastal cities: Sidi Bou Said, Tunisia and Casbah of Algiers, Algeria. The same sequence of analysis displayed in chapter two of the general passive design methods is repeated but this time analysing each case study for the effect of sun and wind on the thermal response of the settlement in Mediterranean climate. That means the effect of the sun and wind on different elements of the site, the effect of the sun and wind on a compact city and its streets, their effect on the courtyard house and its thermal regulating spaces and finally, their effect on other elements which contribute to the thermal comfort of the dwelling. At the end of this chapter, a matrix shown in chapter two is repeated but this time giving actual scores for the performance of each passive design method in the vernacular case studies and this matrix allows for a comparison between the two vernacular examples.

### **Chapter 4: Mediterranean Vernacular Inspired: Site.. Settlement.. Dwelling.. Element**

This chapter again repeats the same sequence of analysis but this time carried out on two examples from modern architecture inspired by Mediterranean vernacular architecture and designed by modern architects of the 20<sup>th</sup> and 21<sup>st</sup> centuries. These case studies are Qunita da Malagueira at Evora, Portugal by Alvaro Siza and Fredensborg Housing in Denmark, by Jorn Utzon. These examples carry some passive design strategies, one of them more than the other, especially since they were designed and implemented after the environmental movement around 1950. They are also analysed with regards to solar and wind factors using the same sequence. This chapter also ends with a matrix giving scores for each passive design method found in the actual case studies and the two Mediterranean inspired examples are compared together in this matrix to show the positive and negative factors in both examples.

### **Chapter 5: Conclusion: An Innovative Sustainable Design Approach**

This chapter introduces the PSPW (Passive Solar and Passive Wind) Rating System which is based on the analysis done from chapter 2, 3 and 4. After calculating scores of all 4 case studies, the comparison between Mediterranean vernacular settlements and Mediterranean vernacular inspired settlements is explained and reasons behind higher or lower scores are clarified. The result shows us that even though the score of the vernacular inspired case studies is less than that of the vernacular ones, the scores are close and that means that it is possible to design modern settlements by learning from the vernacular ones. We can achieve that by taking past techniques, translating them to adapt with the changes and demands of the present, and we can develop a new knowledge based on vernacular standards which have a flexibility to be intervened in any time or place. The PSPW system enables the architect to follow steps from the beginning of the design phase in order to achieve the highest possible score and highest rating. It is important to consider the place before determining any design schemes. This enables us to determine the climate of the place which is the most important factor of sustainability and it also determines the identity of the place. Next step is to integrate vernacular strategies while considering modern human demands in order to innovate a sustainable design approach for future architectural and urban interventions.

# 2

## The Mediterranean

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*“The Mediterranean is not even a single sea, but a complex of seas; and these seas are broken up by islands, interrupted by peninsulas, ringed by intricate coastlines. Its life is linked to the land, its poetry more than half-rural, its sailors may turn peasant with the seasons; it is the sea with vineyards and olive trees just as much as the sea of the long-oared galleys and the roundships of merchants and its history can no more be separated from that of the lands surrounding it than the clay can be separated from the hands of the potter who shapes it”<sup>29</sup>*

Fernand Braudel  
May, 1946

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<sup>29</sup> Quote from the preface to the first edition of “The Mediterranean and the Mediterranean World in the Age of Philip II, Volume I” by Fernand Braudel, 1946.

## 2.1. The Mediterranean: “The Liquid Continent”

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The word “Mediterranean” means “Middle of the Earth” and it lies between the three great continents of the Old World (Carrington 1971, p.13). Its waters, as Fernand Braudel states, are not a single sea, but a succession of small seas that communicate by means of wider or narrower entrances. He describes the Mediterranean as “*The narrow seas, home of history*”. Each sea has “*its own character, types of boat, customs and its own laws of history*” (Braudel 1992, p.72).

The history of the Mediterranean dates back more than 8,000 years. These years have resulted in a dense and complex history (Corpus 2002, ch.1, p.7). From this complex history, many major and minor events have triggered many historical changes in the area. If only stating the major events, it is agreed that the Mediterranean area was shaken by three large waves of civilisation. In the North West of the north-south and east-west axis is Rome, the Latin world and Christendom. Below the east-west axis, in the southern half, is the Arab-Muslim world and Islam. In the North East, is the Greek and orthodox world (Corpus 2002, ch.1, p.7). Following these events, the Islamic influence extended to the North East, the Latin world pushed South West, evolving into the Byzantine and Turk-Ottoman eras. In addition to many epochs and territories: Judaism, Germanic groups, a variety of states, kingdoms and nations, even English and Dutch influences. Clearly, many people, periods and societies have influenced the Mediterranean area (Corpus 2002, ch.1, p.7).

### 2.1.1. Cultural Identity

Mediterranean cities have been historically characterised by the archetypal image of density, urban complexity and social diversity. In the words of Fernand Braudel, it is a “*meeting place*” of many realities; cultures, languages and ethnicities. Braudel asked the question: “*What is the Mediterranean? It is one thousand things at the same time. Not one landscape but innumerable landscapes. Not a sea but a succession of seas. Not a civilization, but civilizations amassed on top of one another. To travel within the Mediterranean is to encounter the Roman world in Lebanon, Prehistory in Sardinia, the Greek cities in Sicily, the Arab presence in Spain, Turkish Islam in Yugoslavia*” (Braudel 1977, p.7).

The Mediterranean Basin can be defined as a cultural and geographical place where the coasts and islands share the same water and similar climate. Its identity is formed by the common qualities between the cities surrounding it and is a result of the diversity of the local cultures, climate, materials and religion which take place on its coasts and islands. The relationship between them is expressed by architectural and natural symbols and these symbols create a unique atmosphere. This relationship between site, climate and building forms a shared Mediterranean heritage expressed in Gio Ponti’s vision:

“*The Mediterranean is large and its shores along the coasts of Morocco, Spain, France, Sardinia, Sicily, Italy, the Tyrrhenian and the Adriatic, Greece, Anatolia, Palestine, Egypt, Libya, and Algeria have washed over many different histories, civilizations and climates*” (Ponti 1941, p.1).

### Loss of Identity

Although the Mediterranean basin is considered one of the largest areas of cultural creativity and variety, it has also been a victim of transformations slowly taking it away from its historical, cultural, and natural contexts. This created unrecognizable places where buildings reflect no specific identity, no bond with nature and no individuality or sense of belonging.

As for the well preserved whitewashed villages of the Mediterranean, they are working communities, not museums or theme parks and they continue to be threatened by falling employment, ageing and depopulation. Many of them are vulnerable to the pressures of incoming development and it is unrealistic to preserve them in their present state in a frozen fairy tale world (Parkyn 1991, p.188). Many transformations are taking place due to the progress of technology, social changes, and the pressure to keep up with changing fashion (Noble 2007, p.290). These transformations are affecting the vernacular buildings identity which came to exist under certain cultural and environmental circumstances. In Morocco, for example, several changes in the traditional house were catalogued by Darryl Baker (1986, 153–4) and included: “*reduction of the size and number of rooms; increasing popularity of overhanging second stories; reduction in size or even disappearance of the courtyard; disappearance of the L-shaped entryway and its replacement by a hallway; greater regularity in the form of the dwelling; shift of the kitchen from the upper floors and the terrace to the ground level; and increasing specialization of function of spaces. Major social changes, including the increasing number of nuclear families, the decline of polygamy, and the reduction in number of children per couple in higher income families, have also affected domestic architecture, primarily in the decreasing size of dwellings*” (Noble 2007, p.291). These changes are not merely changes in the form of the traditional house in Morocco, but they affect valuable aspects perhaps without the awareness of modern architects. The value of traditional building is quoted by historian Charles van Ravenswaay (1977, 112): “*People everywhere seek to live in the kind of housing with which they are familiar as part of their cultural tradition. Consequently, the shape of a house and the arrangement and type of rooms and passageways are all keys to the cultural history of the people who build and live in them*” (Noble 2007, p.293).

In order to save the identity of the Mediterranean, first, we have to define what we mean by "Mediterranean", people, cultures and architecture, then find new ways to recover and benefit from the diverse resources of the Mediterranean landscapes, and utilize them to design a new sustainable architecture which meets the demands of the modern system, in the context of the cultural traditions that created these values (Scarano 2007).

### **2.1.2. Topography**

The Mediterranean coast is 46000 km long. It ranges between rocky, abrupt, steep, cut up, in addition to flat and broad littoral strips through river-scarred plains, some of which open into significant deltas (the Nile, Ebre, Pô, the Rhone...) or onto the desert (Libya, Israel...) The mountainous range littorals with valleys going in all directions, take up a good part of the coast. They define a very narrow littoral followed by an abrupt climb sometimes to altitudes exceeding 500 m. On the Mediterranean coasts, altitudes can reach as high as 1000 or 1500 m within only a few kilometres of the coast such as in Corsica, or reaching close to 3000 m in Italy or even 4138 m in Toubkal, Morocco (Corpus 2002, ch.1, p.2).

In addition to the large islands in this sea such as Cyprus, Crete, Sicily, Corsica, Sardinia or Majorca, Greece alone counts over 2000 large and small islands, only a hundred of which are inhabited (Corpus 2002, ch.1, p.2).

Two thirds of the land of the Mediterranean is made up of limestone which makes it the most widely used building material throughout the Mediterranean area (Corpus 2002, ch.1, p.2). As for the flora growing in the region, a rich, perfectly adapted variety is well adapted to the scarcity of rain and others are irrigated. They fill the atmosphere with different fragrances like thyme,



rosemary, lavender, basil, cumin, fennel, mint, jasmine, rose tree, fig tree, orange tree, apricot tree, and olive-trees (Corpus 2003, ch.1, p.2).

### 2.1.3. Climate

Despite the diversity of people and cultures in the Mediterranean region, there should be something that can impose uniformity on the landscape and way of life. It is climate, the climate of the coastal strip and islands of the Mediterranean. That is why “Mediterranean” has become an adjective describing the uniform of climate and culture at its centre (Braudel 1992, p.172) Fernand Braudel pointed to the fact that many factors are dependent on the climate and therefore the uniformity of climate results in the uniformity of the characteristics of a place and most important, dealing with the environment: shelter. He described these identical characteristics: “*Everywhere can be found the same eternal trinity: wheat, olives, and vines, born of the climate and history; in other words, an identical agricultural civilization, identical ways of dominating the environment*” (Braudel 1992, p.176). This unity gave a sense of comfort for any Mediterranean native who travelled across the sea, never feeling out of place (Braudel 1992, p.178).

Braudel describes the Mediterranean climate as a climate which separates two very important factors of life: warmth and water. It rains only in autumn, winter and spring leaving the summers dry and harsh (Braudel 1992, p.179). A Mediterranean climate is the climate typical of most of the lands in the Mediterranean Basin, and is a particular variety of subtropical climate. According to The Köppen Climate Classification System<sup>30</sup> (figure 2.1), the coastal zones bordering the Mediterranean Sea (Latitude Range: 30° - 50° N and S) is classified under the “Chaparral Biome - Mediterranean Climate (Cs)” which is characterized by being very hot and dry in summer and mild and wet in winter with temperatures about 10 °C (Csa)<sup>31</sup>. The summer is so hot and dry at 40 °C that fires and droughts are very common. The Annual Precipitation is 42 cm (17 in). Examples are the coastal cities of Andalusia like Malaga which is also under the Köppen Climate Classification system Csa. The warmest month is August with an average temperature of 25.4°C and the coolest month on average is January, with an average temperature of 11.9°C. The month with the most precipitation on average is November with 94 mm of precipitation<sup>32</sup>. The urban structure of Malaga is also characterized by density and courtyard housing typical of the Mediterranean region.

Then there is the region south of the southern Mediterranean coast which is classified under Desert Biome - Dry Tropical Climate (BW) which is characterized by hot and dry desert temperatures which range from 20 to 25° C. The extreme maximum temperature for hot desert climates ranges from 43.5 to 49° C (Bwh). Rainfall is very little and/or concentrated rainfall in short periods between long rainless periods<sup>33</sup>. Examples are the cities of southern Tunisia and Algeria like Gafsa, Tunisia which has a Köppen Climate Classification subtype "Bwh". This desert climate occurs

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<sup>30</sup> In 1884, Wladimir Köppen established a climate classification system which uses monthly temperature and precipitation to define boundaries of different climate types around the world. Since its inception, this system has been further developed and modified until 1961 after collaboration with German climatologist Rudolf Geiger resulting in the Köppen–Geiger climate classification system. The popularity of the system lies in its simplicity and power in linking climate and natural vegetation (Chen and Chen 2013, p.70).

<sup>31</sup> The Köppen climate classification scheme divides climates into five main climate groups: A (tropical), B (dry), C (temperate), D (continental), and E (polar). All the major groups (except B) are determined by temperature only. All the sub-types (except the two sub-types under E) are determined based on both seasonal temperature and precipitation. The third letter indicates the level of heat (Chen and Chen 2013, p.74).

<sup>32</sup> <http://www.weatherbase.com/weather/weather-summary.php?s=28480&cityname=M%E1laga%2C+Andalusia%2C+Spain&units=>

<sup>33</sup> Source: (<http://www.thesustainabilitycouncil.org/resources/the-koppen-climate-classification-system/>).

between 15° and 30° latitudes. The warmest month is July with an average temperature of 29.4°C and the coolest month is January, with an average temperature of 8.9°C. The month with the most precipitation on average is March with 22.9 mm of precipitation and the least precipitation on average is July with 2.5 mm. Gafsa is also characterized by densely built structures and narrow paths to decrease the intense solar exposure. The structure of the medina was built to obstruct the sand-carrying Saharan winds from the southwest<sup>34</sup>. Instead the roads constructed east-west welcome the more humid and cool winds from the sea (Cadoni and Masetto 2006, p.266). Courtyard housing is also the architectural typology in this medina.

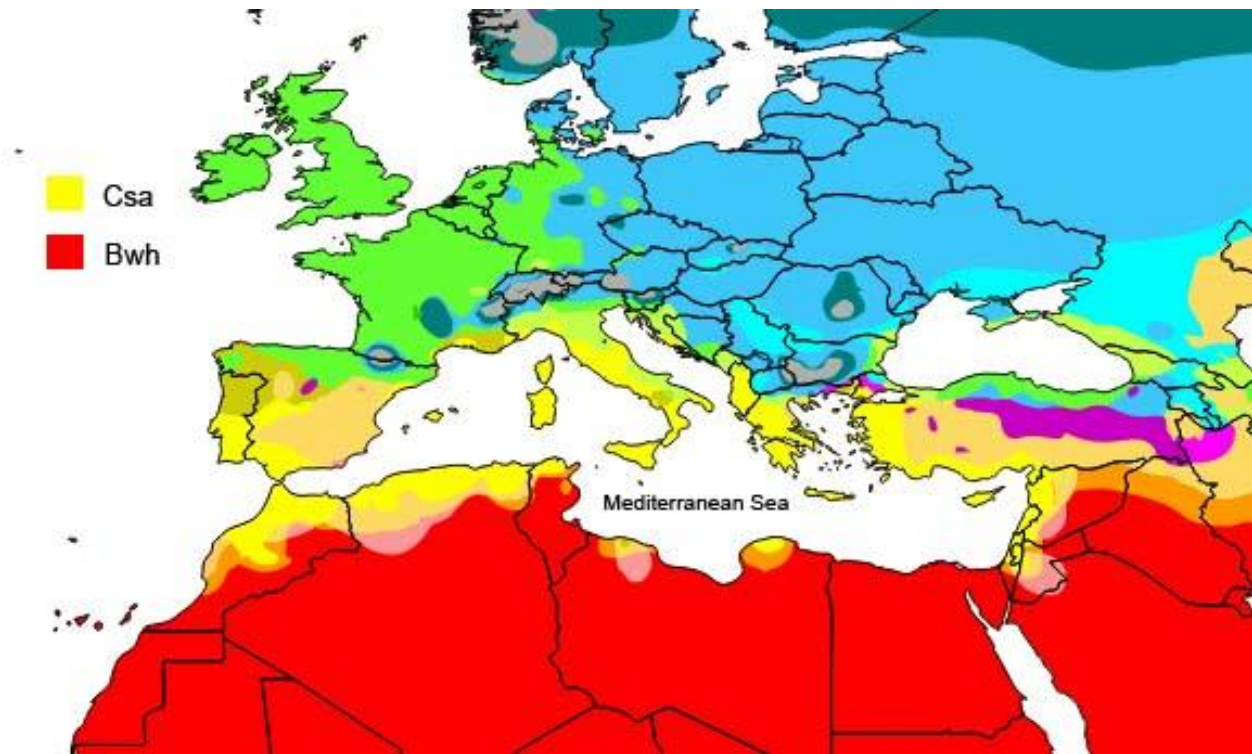


Figure (2.1) Map Showing Köppen Climate Classification subtypes  
Source: (Peel, Finlayson and McMahon 2007, p.1642)

When comparing between the two Mediterranean climates, we can see that there are subtle differences in climate affected by variations in the geographical peripheral extremities. In the north there are massive forests and great continental rivers – some of which contribute strongly to ensuring survival - and in the south we have the Sahara Desert belt. East and West slide slowly towards the South, below the 37th north parallel (Corpus 2003, ch.1, p.2). There is a difference between the local winds of the shores of Europe and that of Africa. The European shores are injected by cold northerly conditions whereas the African shores import the conditions of the Sahara. These winds are actuated by a series of depressions coming from the nearby waters. It causes disagreeably strong winds in the winter extending as far as the west of Spain. The same depressions also cause the inflow of the hot, dry winds of the Sahara creating over the North African coast oven-like conditions (Carrington 1971, p.26).

<sup>34</sup> Computer simulation demonstrated that the almond shape of the medina offers an aerodynamic shape pointing southwards, breaking the sirocco's blast (Cadoni and Masetto 2006, p.266).

#### 2.1.4. Typology

The Mediterranean area carries a diversity of urban and housing typologies. The climate resulted in the urban structure and architecture of the majority of the coastal cities.

##### Urban Typology

Grouped housing is the main form of living for the Mediterranean population. It takes up 80% of the housing typologies, while scattered housing takes up 20%<sup>35</sup> (Corpus 2002, ch.2, p.4). Grouped housing comes in the form of compact dense villages which are organised around public spaces, integrating religious and political buildings, symbols, markets, celebrations, feasts and public events and their morphology and location are conditioned by orography, the need for farming land and safety considerations (Corpus 2002, ch.1, p.3). This type of urban structure protects the city from increased solar exposure due to the significant amount of shading and sharing of walls in almost all dwellings.

##### Housing Typology

In the Mediterranean region, three types of dwellings are found each depending on the site conditions while considering the local climate: the patio house with an internal courtyard, the terraced house stepped down the hillside, and the simple row house that defines the street corridors in relatively flat land. The courtyard house is found in variations from North Africa to southern Spain to the Greek islands. These courtyards regulate the indoor temperature; provide protection from wind and thieves, privacy, recreation and an outdoor space for celebration, meditation, and work. The terraced house takes advantage of the natural site conditions and topography for light, view, and ventilation. The basic row house on flat land creates outdoor spaces from front or rear yards, projecting balconies and roof terraces (Goldfinger 1969, p.16). Combinations of these types of houses sometimes occur depending on the terrain conditions.

##### Courtyard Housing

*“Shelter is of supreme importance to man. It is the prime factor in his constant struggle for survival. In his efforts to shelter himself against the extremes of weather and climate he has, over the ages, evolved many types of dwellings, one of which is the court house.”* (Rapoport 1969, p.19).

##### a. History and Development

The idea of the courtyard as a plan configuration dates back to Neolithic settlements. In the beginning, the logic of this plan was to provide a protective area from outside forces: humans and wild animals. Many civilizations have used it since prehistoric times like the Assyrians, Persians, Greeks, Romans and Byzantines (Wadah 2005, p.220). In Syria, excavations were found for a settlement containing courtyard houses dating back to 3500 B.C. called Habuba Kabira<sup>36</sup>. Courtyard houses were also found in another ancient civilization excavated at Kahun Egypt and is believed to be 5000 years old (Oliver 2003, p.119).

Later, in Greek architecture, the courtyard houses were simple courts surrounded by rooms and stores. Some of these houses date back to 2000 B.C. Another form was the Greek pre-style house

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<sup>35</sup> Scattered housing is present in all Mediterranean countries and is associated with the rural environment, depending on the size and type of agrarian farms or herds which greatly influence the definition and morphology of the areas. Both modest peasants and wealthy families live in houses of a similar construction (Corpus 2003, ch.2, p.5)

<sup>36</sup> This settlement is around 18 hectares in area and was built on a regular plain with strong defensive walls. Excavations were done from 1969 to 1975 by a Deutsche Orient-Gesellschaft team led by Ernst Heinrich and Eva Strommenger as part of the Tabqa Dam rescue excavation effort (Strommenger 1980).

which was a court surrounded by a row of columns and was usually found in public buildings (Islam and Al-Sanafi 2006, p.112).

Later on, around 700 B.C. in Italy, a new courtyard design which was referred to as the atrium house and its design had a small courtyard surrounded by rooms, with a container in the center of the courtyard to gather the rainwater to drink. The main purpose of this design, which is an open to the sky is to provide a private outdoor space (Abass and others 2016, p.2558).

Around 275 B.C., Roman architecture became mix features inherited from the Etruscans and the Greek, after Southern Italy was occupied by the Romans. The atrium house met up with Greek pre-style (court enclosed by columns), and this resulted in big houses containing two styles (atrium pre-style), the atrium near the street and pre-style at the back of the house (Abass and others 2016, p.2558).

With the expansion of Islam around 670 AD, the Arabs controlled the north coast of Africa including Tunisia, Algeria, Morocco and Andalusia, calling this conquered territory Maghreb, meaning the West. The main component of the urban fabric of these Islamic cities was the clusters of the courtyard houses forming small neighborhoods (Sibley 2005, p.67). Under the influence of the Islamic religion, the importance of the courtyard increased to the point that it became the most essential architectural aspects of Arabic dwellings and gave rise to a range of associated developments such as loggias, galleries, high level openings and elaborate sun-shade ornamentation (Wadah 2006, p.220). The courtyard type also responded effectively to the essential Muslim requirements of secluding and protecting women. This explains the easy transition of the Umayyads from earlier Yemenite models to the courtyard type when they reached the shores of the Mediterranean. (Petruccioli 2006, p.15).

## **b. Sustainability**

In the countries of the Mediterranean coasts and islands where the sun is desirable in the winter, but cooling and ventilating is necessary in the summer, the courtyard is one of the most unique elements of the local architecture. Whether the house is on a hill or plain, in the city or in the village, they form the heart of the Mediterranean dwelling, spatially, socially, and environmentally. Their form evolved naturally based on the local climatic conditions, the needs of the family, and the social structure of the community (Serghides 2010, p31).

There are many sustainable advantages of the courtyard. First, it provides a controlled space which protects against nature's unwanted forces like storms and harsh winds. Second, it is described as an "energy garden"<sup>37</sup> (Pfeifer and Brauneck, 2008, p.18) which is comprised of glazed surfaces combined with storage walls oriented towards the sun, making it realise more energy gains. Another energy advantage is that since the dwellings are connected from at least three sides, it requires less surface area. This connection also results in adding or subtracting to these modules with minimal constructional efforts (Pfeifer and Brauneck, 2008, p.18).

In addition, after an extensive study of the environmental performance of courtyards, this type of housing was found the most efficient in site coverage<sup>38</sup>. In the study, the term "best use" was defined by measuring parameters such as 'built potential' which is "the ratio of the floor area of the built form to the site area" (Martin and March 1972) and 'daylight availability'. After

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<sup>37</sup> The description of the courtyard, "energy garden", was used by authors of the book entitled *Courtyard Houses: A Housing Typology* (2008) by Gunter Pfeifer and Per Brauneck.

<sup>38</sup> This study was done at Cambridge University in the late 1960s by Leslie Martin and Lionel March. The study led to a radical speculation to replace the centre of Manhattan with large courts, thus reducing the height of buildings from an average of 21 storeys to 7 (Raydan, Ratti and Steemers 2005, p.193).

mathematically analysing different archetypal built forms, such as pavilions, streets and courtyards, it was concluded that the courtyard was eventually the best performing urban type in terms of efficiency in site coverage (Raydan, Ratti and Steemers 2005, p.193). In one of the papers published after the study, was the result:

*“The court form is seen to place the same amount of floor space on the same site area with the same condition of building depth and in approximately one-third the height required by the pavilion form”* (Martin and March 1972, p. 38) (Raydan, Ratti and Steemers 2005, p.193).

Of course the question of “best use” cannot have an absolute answer. In order to achieve an optimum geometry, the climatic conditions must be taken into consideration.

Courtyard design varies from region to region and they create the appropriate environment through their varied design depending on climatic conditions of the winter and summer. The following drawings (figure 2.2) show different forms of courtyard houses which can be connected from all four sides. They are shown as single houses for clarification.

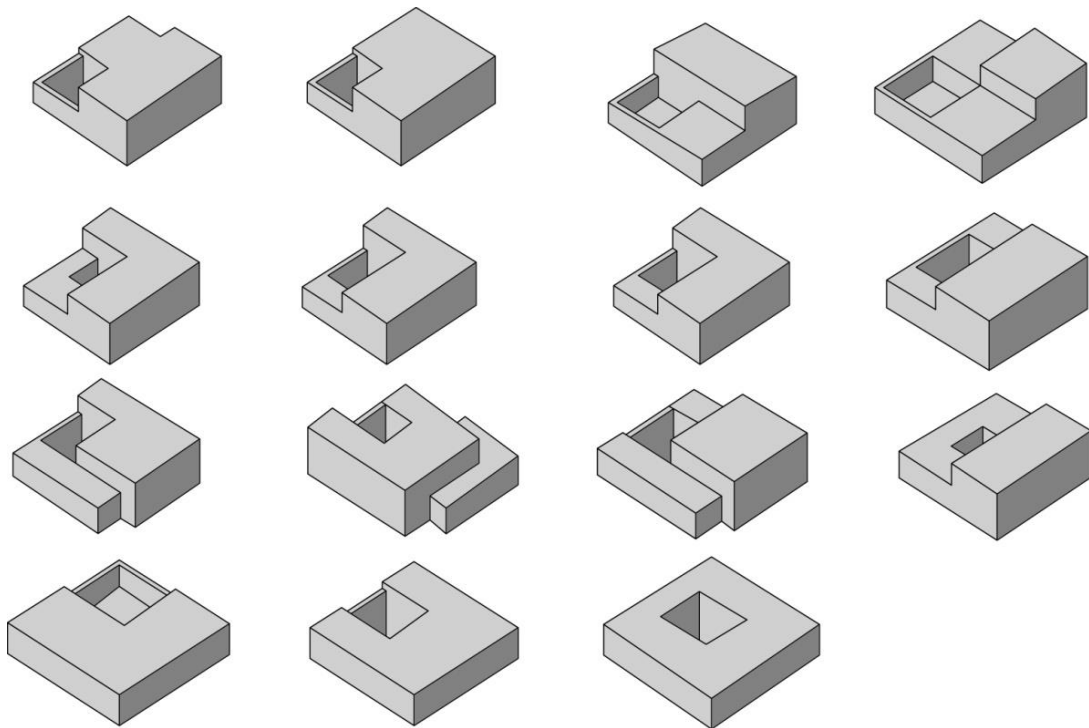


Figure (2.2) Different Forms of Courtyard Houses  
Source: (Hakmi 2005, p.263)

## **2.2. The Passive Design Strategies in a Dense Urban Structure and Courtyard Houses of the Mediterranean Region**

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When speaking about the characteristics of Mediterranean cities, it is important to highlight the factors that affect the climate of the city with regards to the sun and wind, starting from the site of the city as a whole, moving on to the characteristics of the dense urban fabric of the settlement, moving on to the passive design strategies of the courtyard house and finally the elements that can be found in the courtyard house and contribute to the thermal comfort of the house. All of these features are analyzed for their response to the sun and wind in Mediterranean conditions.

The most important literature used to gather the facts included in this chapter were, from an urban planning aspect, the book *Environmental site layout planning: solar access, microclimate and passive cooling in urban areas* by P.J. Littlefair; M. Santamouris; S. Alvarez; A. Dupagne; D. Hall; J. Teller; J. F. Coronel and N. Papanikolaou provided general information on site layout planning in order to improve solar access, passive cooling and microclimate. It does not speak about the design of the building itself. When speaking about architecture, the book *Passive solar architecture for Mediterranean area* by R. Colombo; A. Landabaso and A. Sevilla was a small source of information specializing in the solar factor only of passive architectural design in the Mediterranean area. In the field of vernacular sustainable architecture, Hasan Fathy's *Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates* was an essential book which presented the vernacular wisdom of indigenous architectural forms that have evolved in hot arid climates. It focused on different elements and spaces found in vernacular dwellings. In addition to the proceedings of the 23<sup>rd</sup> PLEA conference published in the book *Learning from Traditional Architecture: Achieving Climatic Buildings by Studying the Past*, edited by Willi Weber and Simos Yannas, where environmental aspects from vernacular buildings from around the world were presented without focusing on a specific area. Finally, the book *Courtyard Housing: Past, Present and Future* contributed to this chapter through its environmental analysis of courtyard housing in general.

All of these sources provided solid information for the basis of this chapter where pieces were collected from each one in order to create a complete guide covering the climatic design tools (sun and wind factors) of site, urban structure, architecture and elements found in the vernacular dense urban structure and courtyard houses of the Mediterranean Area.

### **2.2.1. SITE: The Climatic Characteristics of a Site**

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The sustainability of a site is affected by its physical nature. Vernacular village sites were chosen after considering climate, best soils for agriculture, for cattle and breeding, close to water bodies, large channels of communication and exchange, and also an effective protection against dangers coming from the sea. Most important, the site of many vernacular villages was chosen for reasons of climate. In Ibiza, Spain, for example, houses were built on a south facing slope so the north winds would be blocked by the hills protecting the fields and houses. Traditional dwellings were sometimes built under the overhangs of cliffs for protection from the rain, wind and sun like in Setenil, Spain (Steen 2003, p.238). The town of Skyros in Greece is situated on the hilly slopes of a great rocky mound and is protected from the strong winds along the seaward side of the hill (Goldfinger 1969, p.50). Different elements affect the climate of a site:

## a. SOLAR FACTOR

### • Topography

In the Mediterranean area, it is beneficial for a slope to have southern orientation in order to receive maximum solar energy in the winter. Buildings built on a southern facing slope benefit from the low altitude sun and still achieve the same solar access if they are closer together with the main window facing down the slope. The ground is also warmer because it faces the sun for most of the year (Littlefair, Santamouris, Alvarez, Dupagne, Hall, Teller, Coronel, Papanikolaou 2000, p.29)<sup>39</sup>.

An east or west-facing slope will result in zero solar access at particular times of day and have little benefit from the sun around noon making it a negative solution for passive solar heating in winter (Littlefair and others 2000, p.29-31).

In summer, the sun is higher so there is no significant effect of the slope, negative or positive. Whether on a slope or on a plain, the high sun needs to be controlled by different methods of shading.

The following figure (2.3) shows the spacing to height ratio for good solar access depending on the slope degrees in the Mediterranean region (Latitude 45°). For example, in figure (2.4) if the angle of the slope is 10°, then the optimum spacing to height ratio is 2 where building height is 3m and spacing between the buildings is 6m.

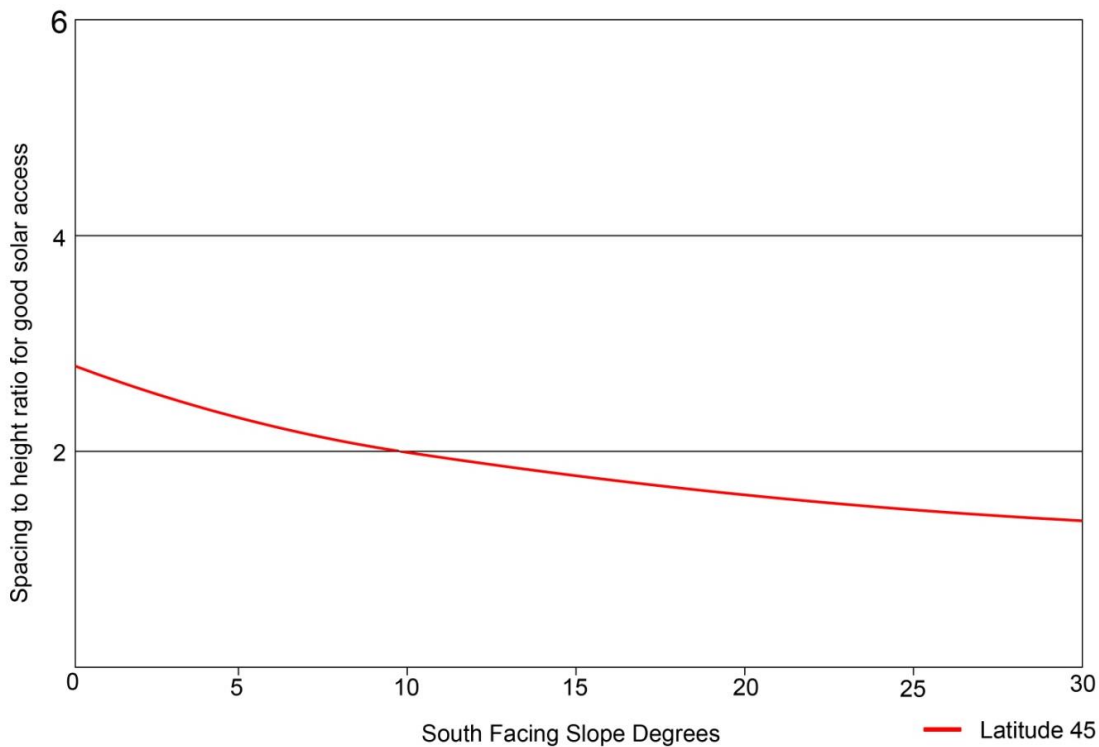


Figure (2.3) Spacing/Height ratio for Rows of Houses on a Slope  
Source: (Littlefair and others 2000, p.30).

<sup>39</sup>This book is the principal output of a project to develop guidance on site layout planning to improve solar access, passive cooling and microclimate. The project is jointly funded by the European Commission JOULE programme and the UK Department of the Environment, Transport and the Regions. The European project is coordinated by BRE and includes the University of Athens, LEMA (University of Liege) and AICIA (University of Seville).

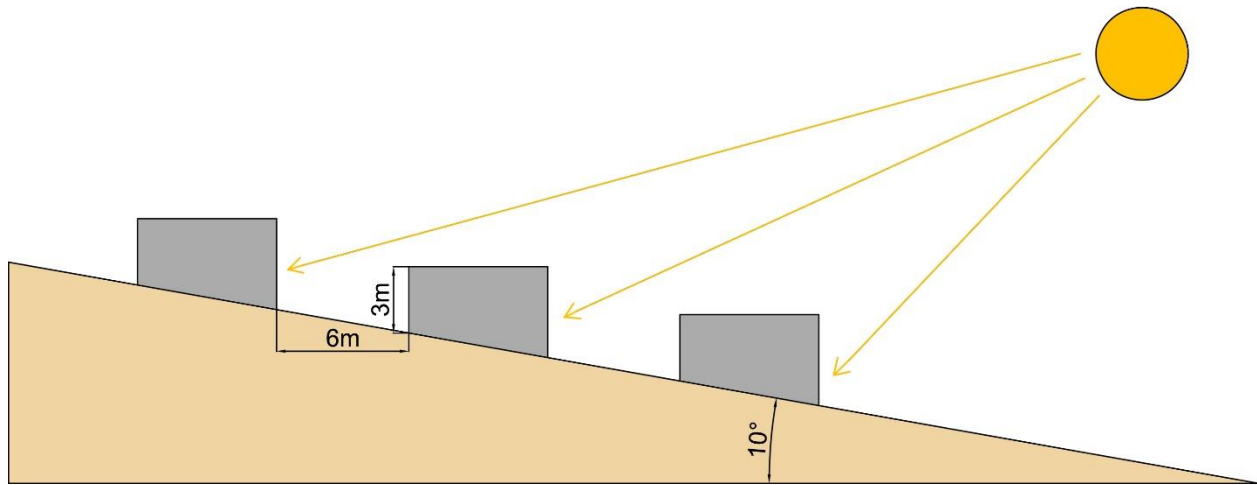


Figure (2.4) Spacing/Height ratio=2  
Source: (Littlefair and others 2000, p.30).

### • Vegetation

The climate of the village is affected by vegetation and this impact depends on the size and location of the vegetation. Examples of vegetation on a large-scale, is the surrounding land, or large areas within a city such as forests and urban parks. On a medium-scale (at the urban layout level) examples include planting strategies and the distribution of green, non-built and built up areas (Littlefair and others 2000, p.19).

On the large and medium scale, the major effect of vegetation is from the process of evapotranspiration. Vegetation absorbs up to 90% of solar radiation depending on the type of plant, meaning very low solar radiation reflected (low albedo). This absorption results in the evapotranspiration of plants which can reduce summer air temperatures. This process adds moisture to the air. However, the positive cooling effect of vegetation usually outweighs any undesirable gains in humidity.

A lot of research has been done on the effect of vegetation on the climate. Numerical simulations reported by W. Gao<sup>40</sup> show that vegetation can decrease maximum air temperatures in streets by 2 °C (Gao 1993, p.488). Another researcher, Baruch Givoni<sup>41</sup>, recommends spacing trees and public parks throughout the urban area rather than concentrating them in a few spots. This is preferable for effective cooling of surrounding areas (Givoni 1998) (Littlefair and others 2000, p.19).

When comparing the biophysical factors between grasslands and forests, we can see that since a grassland has higher reflectivity (albedo), it reflects more sunlight than a forest does, cooling surface air temperatures relatively more. In contrast, since the forest absorbs more solar radiation, it evaporates more water and transmits more heat to the atmosphere cooling it locally. This can lead to more cloud formation and increased rainfall (Jackson and others 2008) (figure 2.5).

<sup>40</sup> Weijun Gao is a researcher at with Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu, Japan. He is the author of many papers on Environmental Planning and Energy Saving.

<sup>41</sup> Baruch Givoni is the author of many books on climate and architecture like *Passive Low Energy Cooling of Buildings*, *Climate Considerations in Building and Urban Design* and *Man, Climate and Architecture*.



Light absorbed by the leaves is also used for photosynthesis which removes carbon dioxide from the atmosphere and releases oxygen, which slightly offsets the amount of greenhouse gas being released in the atmosphere through the burning of fossil fuels (Colombo, Landabaso and Sevilla 1994, p.37).

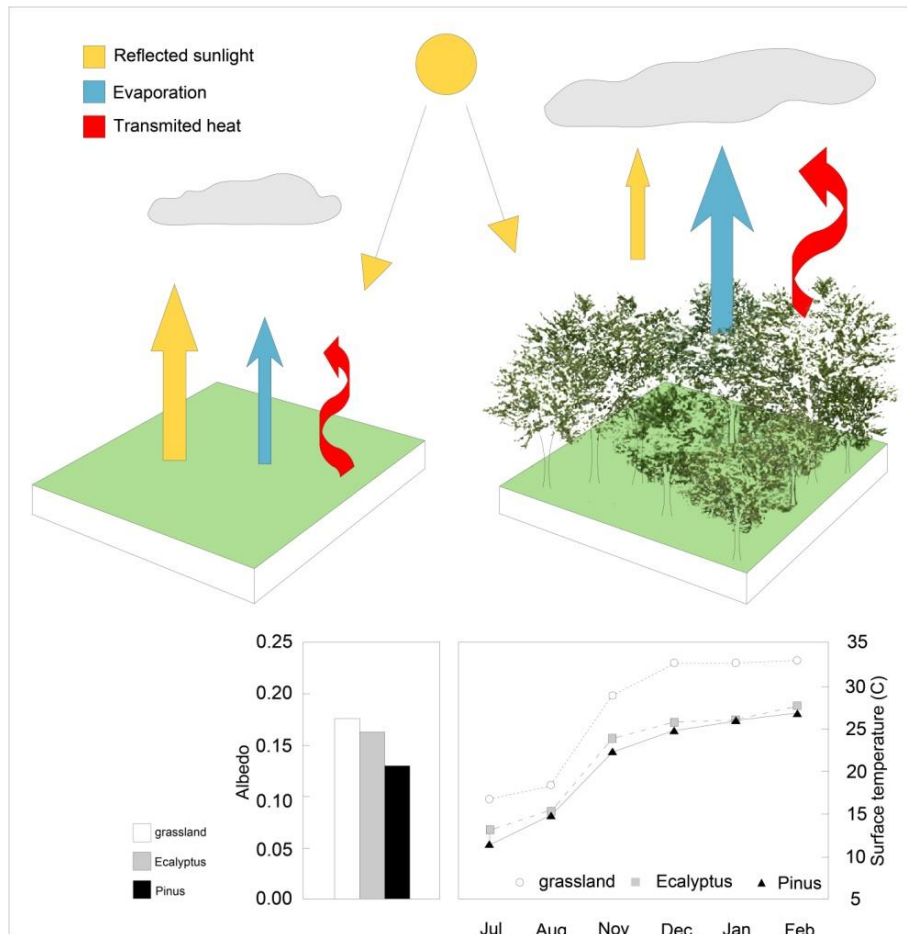


Figure (2.5) The Process of Evapo-transpiration  
Source: (Jackson and others 2008)

- **Water Bodies**

The existence of the Mediterranean Sea plays a very important role in the climate of the Mediterranean coastal cities. This is due to the physical qualities of water, which has a greater ability to store heat than many other substances. Consequently, large bodies of water heat up and cool down slower than adjacent land masses, so their temperature changes less dramatically with the seasons. Therefore, large water bodies, like seas, oceans and big lakes, release heat during the winter and soak it up during the summer, keeping temperatures within a more moderate range<sup>42</sup>. The average temperatures these water bodies vary only by 10°C throughout the year (Colombo and others 1994, p.37).

<sup>42</sup> <https://sciencing.com/large-bodies-water-affect-climate-coastal-areas-22337.html>

## b. WIND FACTOR

### • Topography

The movement of air up or down a slope occurs due to buoyancy. This means that the air warmed by the ground on a calm, sunny day will rise up a slope (anabatic flow<sup>43</sup>), while air cooled by the ground on a calm, clear night will drift down it (katabatic flow<sup>44</sup>) (figure 2.6). Typical speeds for such flows are from 1 to 2 m/s, depending on the extent and steepness of the slope. For example, in mountainous regions, much stronger flows can occur (Littlefair and others 2000, p.31).

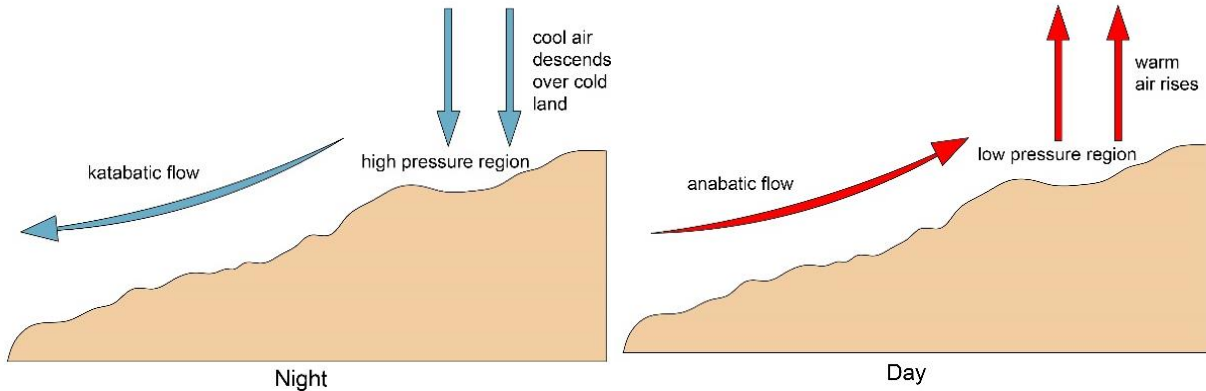


Figure (2.6) Effect of Topography on Wind Conditions

Source: (Colombo and others 1994, p.38).

The rising warm humid air meets the barrier and leads to condensation and formation of clouds. Then, rain may fall creating humid conditions on the windward side of the barrier and dry conditions on the landward side.

### • Vegetation

On a large urban scale, trees and bushes act as windbreaks which reduce the wind velocity about 50% at a distance about five times their height (figure 2.7). They allow some air to pass causing minor turbulence and a bigger calm zone (Colombo and others 1994, p.47), unlike buildings, solid fences or earth banks which generate downdraughts. Therefore, tall trees can offer substantial wind protection if they are placed in a suitable way.

<sup>43</sup> Anabatic is a Greek term meaning moving upward. An anabatic flow is also known as an upslope flow.

<sup>44</sup> Katabatic is the antonym of anabatic referring to a downslope flow.

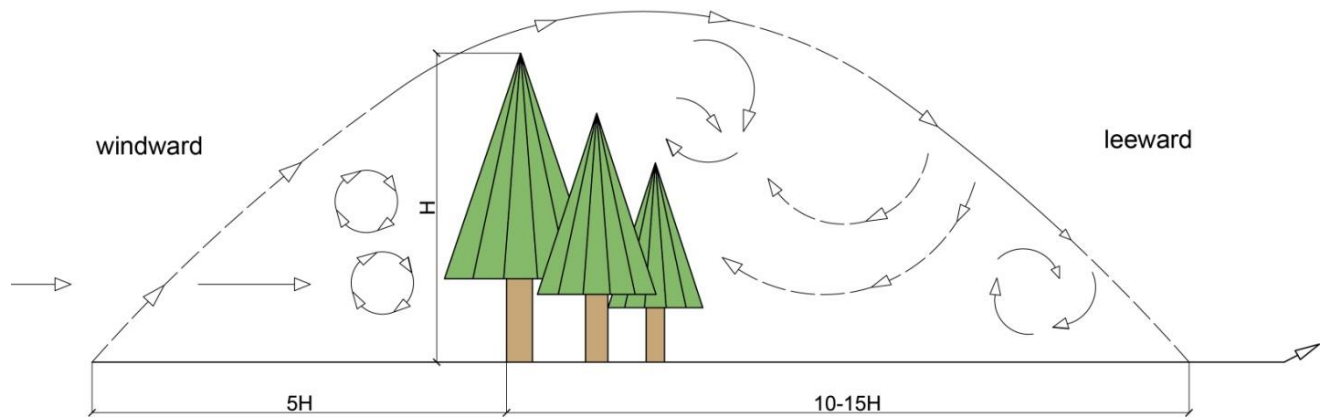


Figure (2.7) Trees as Windbreaks  
 Source: (Littlefair and others 2000, p.109).

- **Water Bodies**

As mentioned, water bodies change temperature very slowly. This constant temperature makes it act as an air conditioning system which heats up or cools down the air passing over it. This results in relatively warm air being sent to the land in winter and relatively cool air is sent in summer, making extreme temperatures less likely to occur. This action is more noticeable in summer because this air flow travels twice a day from the sea to the land and back again producing the sea-breeze effect (figure 2.8) (Colombo and others 1994, p.39).

In the case of a small water body, like a pond or river, the influence on the surrounding area is less and depends on the length of the mass of water in the direction of the prevailing winds and the air velocity. Researchers have found that when comparing a built up area surrounding a pond, to the same area when the pond is drained, the area surrounding the pond was 3 °C cooler when the pond was filled with water in the early afternoon (Littlefair and others 2000, p.39).

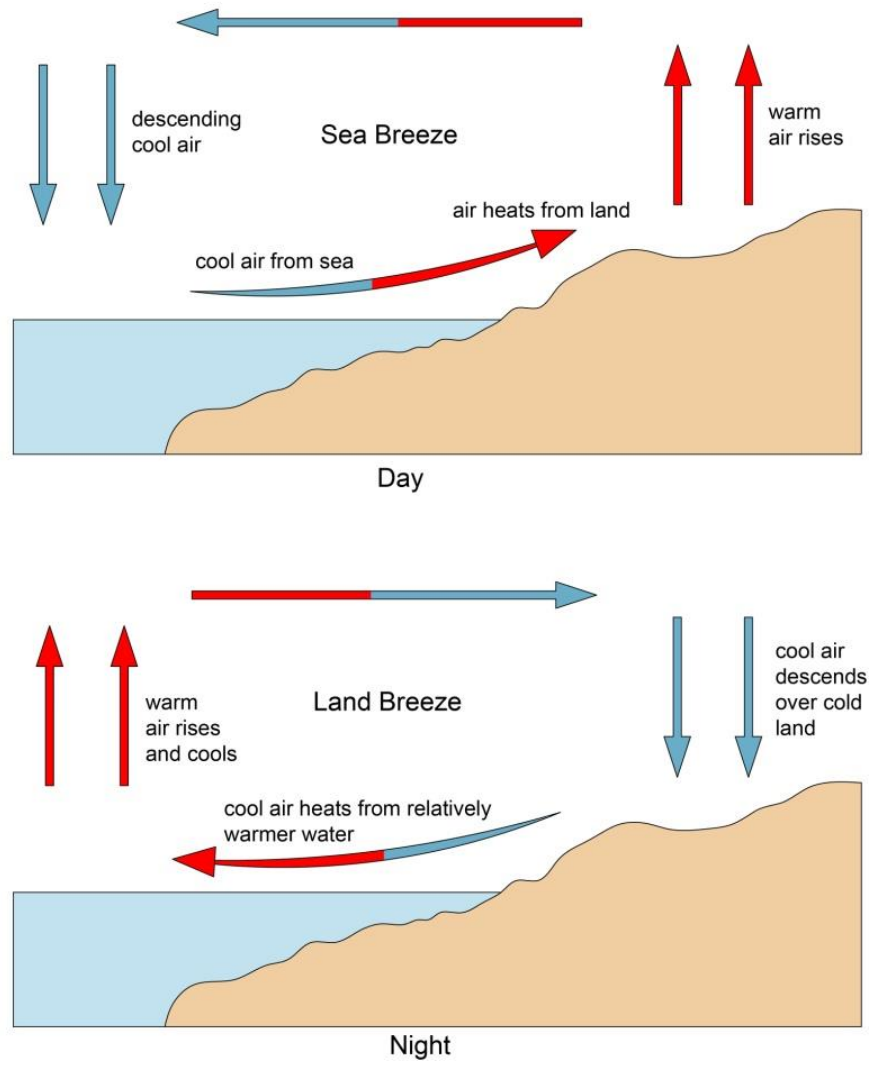


Figure (2.8) Sea Breeze Effect  
Source: (Gibson 2015)

### c. Comparative Analysis Matrix

The following matrix gives a general sample on a rating system for each characteristic or passive design strategy according to the sun and wind factors. Each tool in the SITE category is given a score according to its influence on energy savings and is based on the following matrix:

<b>CATEGORY (influence on building energy savings)</b>	<b>POINTS</b>
<b>Very high influence</b>	<b>16</b>
<b>High influence</b>	<b>12</b>
<b>Medium influence</b>	<b>8</b>
<b>Low influence</b>	<b>4</b>
<b>No influence</b>	<b>0</b>

Matrix (2.1) Evaluation according to Influence on Energy Savings

#### 1. Topography:

According to Sun Factor, when the buildings are properly spaced according to the figure (2.2), pg. 27, a south-facing slope with an optimal angle can reduce the heating load in winter of a Mediterranean climate. The spacing is based on achieving sun at midday on December 21 south of 46.5°N (Littlefair and others 2000, p.29).

According to the Wind Factor, topography affects the wind flow and speed up and down the slope depending on the steepness. It also carries humid air in the case of a slope facing a water body. This affects the wind flow and humidity of a site especially when the site is at the bottom of the slope (Littlefair and others 2000, p.31).

Topography was given the “high influence” due to its significant influence on energy savings and was not given “very high influence” due to the existence of factors which have more influence on energy savings.

2. **Vegetation:** Although the condition of vegetation may change, it has a significant positive effect on the climate of a site. According to the Sun Factor, the most important characteristic of vegetation is its ability to cool temperatures by evapo-transpiration affecting the site as a whole. According to the Wind Factor, the effect of trees on wind is significant because they protect the site from strong undesirable winds or direct desirable winds.

Vegetation was given the “very high influence” due to its significant influence on energy savings.

3. **Water Bodies:** The existence of large water bodies nearby cities affects the climate of the site significantly and was given “very high influence”. According to the Sun Factor, the heat storage capacity of a large water body results in a warmer climate. According to the Wind Factor, the sea breeze effect creates airflow between the land and sea.

<b>Site (SI)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>SI 1. Topography</b>	<b>12</b>	<b>6</b>	<b>6</b>
<b>SI 2. Vegetation</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SI 3. Water Bodies</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>Total for SI Category: 44</b>			

Matrix (2.2) Evaluation of Tools in SITE Category

## 2.2.2. SETTLEMENT: Urban Structure and Density: The Traditional Compact City in the Mediterranean Area

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*“This logic of climatic optimisation extends to the scale of the urban as well as the building plan..... when buildings come together they have the potential to take advantage of their juxtaposition to increase rather than diminish their ability to control and moderate the climate”* (Cofaigh, Olley and Lewis 1996, p.9).

Human settlement layouts vary from linear, nodal, compact and dispersed. Each layout deals with the climate in a different way. The typical layout in Mediterranean vernacular cities is the compact human settlement. A compact human settlement has many ecological advantages that result in the reduction of energy consumption due to the lack of high-tech systems. The design of the dense urban structure of vernacular cities has many passive design characteristics which contribute to regulating the climate. The thermal response of this type of urban structure is studied according to factors of sun and wind in Mediterranean conditions:

### a. SOLAR FACTOR

The sun has a huge effect on the climate of a settlement. A dense urban fabric reacts positively to solar radiation due to several characteristics.

#### • Compact Geometry

A compact geometry is typical to the courtyard house urban fabric where *“solid prevails over void, and in which the void is like an incision in the solid”* (Moccia and Neglia 2006, p.176).

The urban geometry of a city affects the way the surface materials receive the heat or cold and therefore affect the indoor and outdoor temperatures (Bougiatioti 2006, p.1). The surface to volume ratio is the key factor in determining the amount of heat or cold a building receives. For example, when one courtyard house is standing alone hollow square, it will maximize the surface to volume ratio which is suitable for a small building in a hot humid climate. However, when many courtyard houses are packed in a compact urban structure, that minimizes the surface to volume ratio which is appropriate for hot arid climates (Lepore 2006, p.170). This is because *“the higher the ratio the higher the potential for heat loss during the winter and heat gain during the summer”* (Martin and March 1972, p. 57) (Raydan, Ratti and Steemers 2005, p. 199).

Mediterranean vernacular villages when seen from above are monolithic structures with many houses under one continuous roof which is perforated by courtyards and light wells for air and light (Ibrahim 1998, p.6). The compact geometry provides maximum volume, minimum surface area, and mutual shade. The maximum mass of the whole building group increases the time lag of heat transfer, the minimum surface area reduces the exposure to the outside heat, and mutual crowding provides shading, and also reduces the areas exposed to the sun (Rapoport 1969, p.89). This is because the buildings share three and sometimes four exterior walls which reduce the amount of heat gain in the building. That makes the exposure to the sun limited to one or no wall and the roof (Naciri 2007, p.4).

In figure (2.9), the Surface to volume ratio in block 1 is 0.25 and S/V in block 2 is 0.42. Therefore, the heat loss and heat gain in block 1 is less than that in block 2, making compact multi unit blocks more sustainable than single houses. In addition, when buildings are compact, the roof areas are increased and radiative exchanges are increased. When using appropriate materials, the solar

radiation received by roofs can be reflected away to the sky<sup>45</sup>, and therefore decreasing the air temperature in external spaces (Abed 2012, p.42).

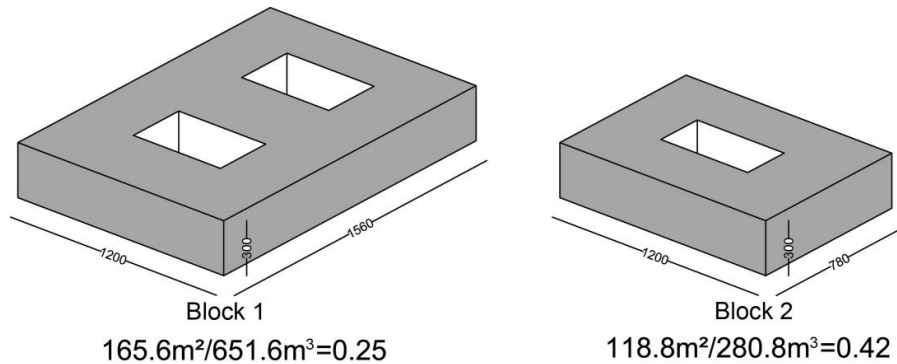


Figure (2.9) Surface to Volume Ratio

• **Block Orientation**

The Mediterranean Sea is located at latitude 35° N with a subtropical climate. In these areas, the optimum orientation of building blocks with regard to the sun factor is along east-west axis with an optimum proportion of 1:1.3 (figure 2.10). Rooms on the southern façade always have advantages. In the summer, the sun is high over the horizon and the building block can be shaded using a small overhang. In the winter, the sun is low allowing its rays to penetrate into the interior and making use of its heat. The eastern façade is exposed to the sun from sunrise to noon (Fathy 1986, p.44). The western façade is exposed to the sun from afternoon to sunset. Sometimes the orientation of a settlement as a whole affects the orientation of the majority of the building blocks.

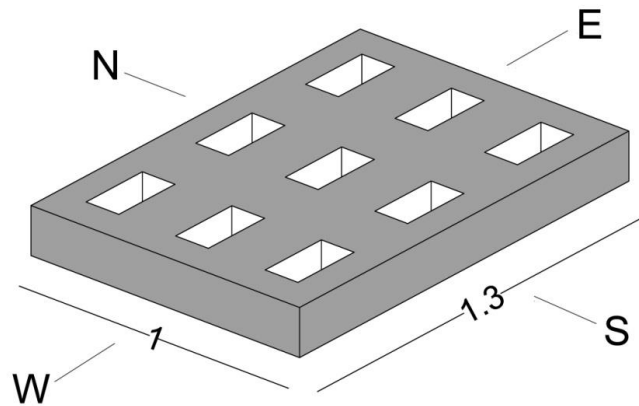


Figure (2.10) Optimum Orientation and Proportion of a Building Block

The northern façade is the least exposed to the sun. Exposure occurs only in the early and late hours of summer days when the angle of altitude is low and the angle of declination is such that the sun's rays is almost tangential to the surface of the wall. The rooms on the northern façade have evenly distributed illumination (Fathy 1986, p.44).

However, sometimes the optimal orientation of buildings in terms of the sun factor cannot always be achieved for different reasons like the necessity of facing a street or a square. This issue can be

<sup>45</sup> This means using materials with a high albedo (reflectance) and it is explained in the section about surface materials.



solved with appropriate means of shading. For example, a building's long side oriented east and west is the worst case due to the amount of heat gain during the summer day and the angle of altitude which allows the sun to penetrate to the interior. In this case, blocks of buildings can be aligned and therefore shade one another. This can be done by considering the height of buildings, width of the street, and the angle of altitude (Fathy 1986, p.43).

In Mediterranean vernacular cities, the building blocks with the longer side oriented to the east or west were shaded by the close aligned buildings due to the compact structure of vernacular cities. In some cases, overhangs on the eastern and western facades were applied or building the second floor over the street.

- **Street Orientation**

In hot climates in summer, thermal comfort in outdoor areas is improved if shade is provided. Solar penetration into urban streets depends first on street orientation and second on the street width and building height.

A northeast-southwest or northwest-southeast orientation is recommended for blocking solar radiation and consequently producing low temperatures on the surfaces surrounding the pedestrian, reducing the infrared radiation. This result was found after calculating sunlight penetration using the BRE sunlight availability indicators produced for the POLIS project<sup>46</sup>. The results showed that east-west streets are to be avoided in hot climates because they have significantly higher annual sunshine penetration than the other street orientations, and all of this occurs in the six summer months. North-south streets have the least sun penetration, and around a third of it occurs in the six winter months when it will be more welcome. The sunlight is concentrated around the middle of the day, and at other times of day the whole of the street will be in shade (Littlefair and others 2000, p.51). Therefore, a grid system of NE-SW and NW-SE orientation, coupled with narrow width of streets, has less sun penetration than a grid system with a NS-WE orientation (figure 2.11) (Littlefair and others 2000, p.52).

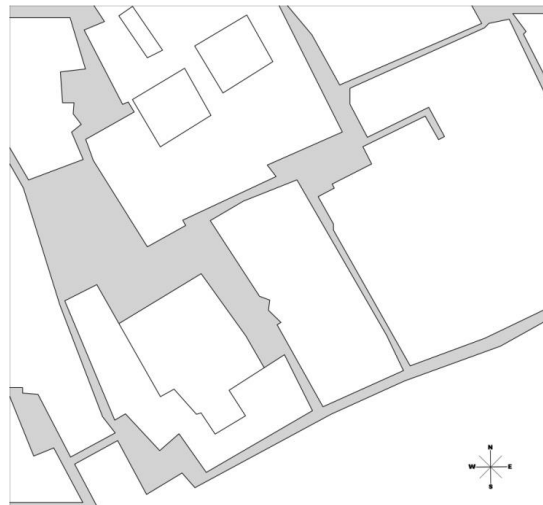


Figure (2.11) Santa Cruz area of Seville, Spain with a NE-SW and NW-SE grid  
Source: (Littlefair and others 2000, p.53).

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<sup>46</sup> The POLIS project is a 3-year research project, sponsored jointly by the European Commission's JOULE research programme and by national funding agencies including the UK Department of the Environment, Transport and the Regions (DETR). The guide *Environmental Site Layout Planning* is the result of this research (Littlefair and others 2000, p.iv).

- **Narrow Streets**

In hot climates, high freestanding buildings are totally unsuitable due to their increased exposure to solar radiation and they do not provide shaded outdoor spaces for the occupants. Whether built on a hill or terrain, buildings in vernacular Mediterranean villages reach maximum three storeys running along narrow pathways creating shaded spaces for the pedestrians and affect the overall temperature (Karasu 2009, p.45). The amount of shade depends on the height of the building and the width of the street. It also changes according to the direction and angle of the sun during the different months of the year (figure 2.12, 2.13) (Tsianaka 2006, p.3). The higher the wall in relation to the width of the streets, the greater amount of shade.

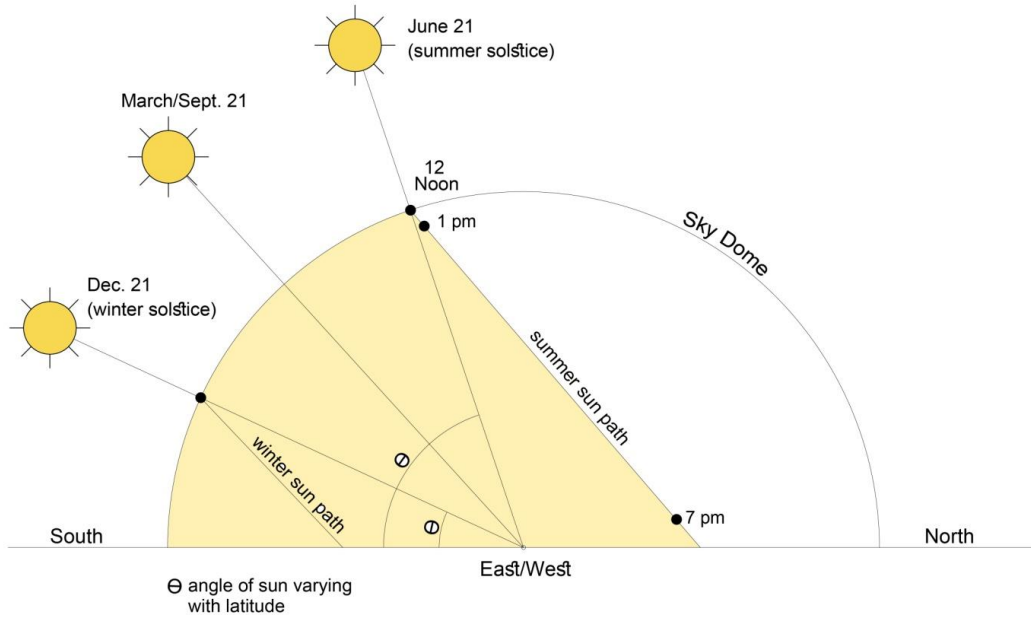


Figure (2.12) Solar Geometry  
Source: (Lechner 2014)

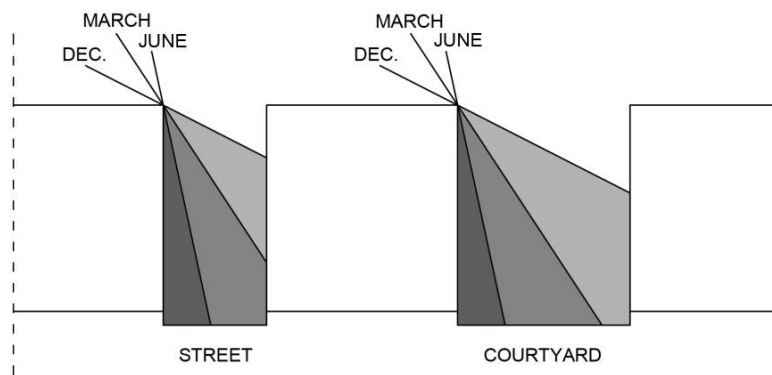


Figure (2.13) Shade and Solar Penetration  
Source: (Tsianaka 2006, p.3)

The lateral distance of shade created by the building walls on the summer and winter solstice can be calculated in the equation:  $L=H \times \text{COT}\theta$  (Hakim 2009, p.124) (figure 2.14). **L**: Lateral Distance of shade on streets, **H**: Height of building,  $\theta$ : Summer Solstice,  $\theta$ : Winter Solstice.

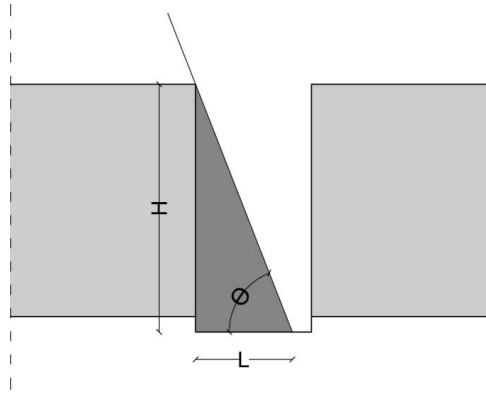


Figure (2.14) Lateral Distance of Shade on Street  
Source: (Hakim 2009, p.124)

- **Open Spaces**

In the hot-arid climate of Mediterranean cities, outdoor spaces are very important in the residential areas. The irregular form of the villages results in spaces with different forms and functions and they contribute to the climate comfort of the outdoor life of the Mediterranean. Similar to the streets, the amount of shade in these spaces is also calculated by the Lateral distance of shade equation depending on orientation and dimensions. Examples of these open spaces are:

**Irregular Open Space or Pathway Intersection** which can act as shaded meeting space or café for the residents of the neighbourhood.

**Public Courtyard** which act as a semi private enclosed and shaded meeting space or play area for children.

**Cul de Sac** which is a narrow street with closed ends giving access to the residential buildings and are a direct result of the gradual congestion of the neighborhood and the consequent subdivision of the lots into smaller dwellings (Moccia and Neglia 2006, p.175). It is also a shaded semi private space for the residents.

**Covered Passageway** which are created by roofs overhanging buildings by three meters or more (figure 2.15). Sometimes in multiple storey dwellings, the floors of the succeeding storeys extend outward each providing shade for the story below (Crouch 2001, p.103). In Tunisia, this element is called “sibat” which are elevated ways creating covered passages among the houses. In the summer, water is spread under the sibat to create a cool atmosphere in these shady areas which are used by the residents of the neighborhood for napping or chatting (Cadoni and Masetto 2006, p.266).

**Covered Markets** were also covered to protect the goods from the sun and rain by barrel arched roofs or a series of domes.

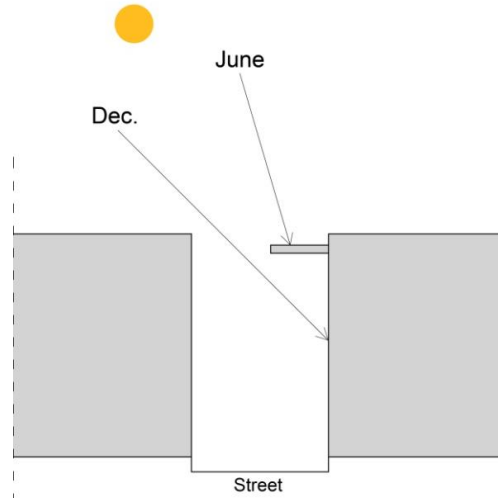


Figure (2.15) Benefit of Overhang in summer and winter

- **Vegetation**

The effects of vegetation on a large scale have been mentioned in the Site section<sup>47</sup>. On a small-scale, local features such as trees and green areas at street level and in open spaces have a significant effect on the climate of the streets and buildings. In the form of trees, they have shading effects and a consequent mitigation of the solar heat gain. When placed next to buildings, they cause a reduction of surface temperatures. In the form of ground cover plants, they cause a reduction of short-wave and long-wave radiation from soil to environment or to building (Littlefair and others 2000, p.19).

Computer simulations were done by Akbari et al (Akbari and others 1997) to study the combined effect of shading and evapotranspiration of vegetation on the energy use of typical one-story buildings. The results showed that by adding one tree per house, the cooling energy savings range from 12 to 24%, while adding three trees per house can reduce the cooling load by 17–57% (Littlefair and others 2000, p.20). Deciduous trees give the benefit of shading in the summer and allow solar penetration in the winter (figure 2.16).

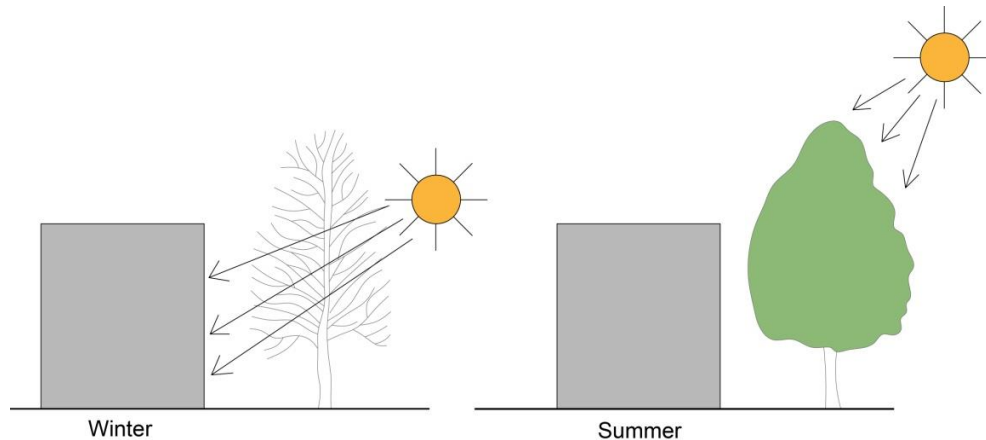


Figure (2.16) Benefit of Deciduous Trees next to Buildings

<sup>47</sup> See 2.2.1. Site, a. Solar Factor – Vegetation, p37.

- **Public Fountains and Wells**

Water fountains can be effective air-conditioning systems in open spaces because of their ability to keep water temperatures lower than air temperature. They also have a low reflectivity of approximately 3% at times of maximum solar radiation, and therefore reflect little solar radiation towards occupied zones. They absorb up to 80% of the solar radiation depending on the depth of the water feature. However, this does not increase water temperature because of the water's thermal inertia and evaporation at its surface which is directly proportional to its depth. With increasing water pond inertia, the water temperature decreases. The amount of evaporation of water is proportional to the air-water contact surface area and subsequent decrease in water temperature. In Fountains and sprayers, the smaller the drops are, the greater the air-water contact surface is resulting in increased evaporation and decreased water temperatures<sup>48</sup>. (Littlefair and others 2000, p.117).

- **Surface Materials**

The surface materials in an urban settlement affect the amount of solar radiation received and emitted and consequently affect the temperature.

### **Ground Surface Material**

Paving materials affect the climate of a city because they can improve or control solar gain which can increase or decrease the heat island effect. A material's contribution to a heat island decreases with increasing the Solar Reflectance Index (SRI)<sup>49</sup> and they are referred to as cool materials. The solar reflectance<sup>50</sup> and the thermal emittance<sup>51</sup> of a material are needed to calculate the SRI. The reflectance of a material increases as the material lightens. (The University of Tennessee Center for Clean Products 2009, p.1).

Vernacular Mediterranean cities were paved with light natural materials such as light coloured stone which aided in reflecting the excessive solar energy in summer. Studies have shown that light coloured natural stone has a potential for being cool paving materials and can decrease the heat island effect if the SRI is sufficient. The SRI of a small piece of natural stone was measured with a value in the area of 0.60<sup>52</sup>. On the other hand, the SRI of asphalt is 0. An asphalt surface can reach 51° C in air temperature which is 36°C. (The University of Tennessee Center for Clean Products 2009, p.2).

### **Building Surface Materials**

The energy balance of a building is highly affected by the surface materials and the materials albedo. Large-scale changes in urban albedo may have important indirect effects on the climate of the settlement. Surface temperature differences of up to 15 °C can occur between similar walls and roofs having different external finishes (Littlefair and others 2000, p.103).

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<sup>48</sup> With a constant flow rate, the contact surface produced by a nozzle (drops of the order of 1 mm or less) is 100 times greater than from a sprayer (drops with a diameter of the order of several mm) (Littlefair and others 2000, p.117).

<sup>49</sup> (SRI) is the materials ability to reject solar energy.

<sup>50</sup> Solar reflectance (albedo) is the ability of a material to reflect, rather than absorb solar energy.

<sup>51</sup> Thermal emittance is the ability of a body to release heat.

<sup>52</sup> A list of the SRI of common building materials was published by the University of California's Lawrence Berkeley National Laboratory (LBNL), which is the leading research group on cool roof materials.

Limestone is the most widely used building material in the Mediterranean region. Whitewashed stone, is a typical material in the Mediterranean vernacular villages. Limestone has an albedo of (0.30-0.45) and whitewashed stone has an even higher albedo of 0.80 (Taha, Douglas and Haney 1997). Many studies have been performed to evaluate direct effects of the albedo of a surface material. One study by Bretz et al reports that the increase in the roof albedo of a house in a city with a hot Mediterranean climate from 0.2 to 0.78 reduced the cooling energy consumption by 78% (Bretz, Akbari, Rosenfeld and Taha 1992) (Littlefair and others 2000, p.120).

## **b. WIND FACTOR**

The layouts of the traditional cities in the Mediterranean region are characterized by narrow winding streets which are caused by the density of the buildings, with open spaces forming at intersections. The air flow in these urban canyons and open spaces depends on factors of orientation and dimensions.

### **• Compact Geometry**

As mentioned in the Solar Factor, the surface to volume ratio is the key factor in determining the amount of heat or cold a building receives. In winter, when this ratio is higher, the building is exposed to the harsh winds by more surfaces compared to its mass and loses heat more, especially in the existence of windows (figure 2.9).

### **• Block Orientation**

The effect of block orientation on the wind factor is different in the summer and winter. Passive ventilation for cooling in the summer must be considered together with restricted incoming air in winter, so that minimum fresh air requirements can be maintained without causing draughts or excessive heat loss<sup>53</sup>.

In the winter, unwanted winds can be avoided by orientating a building's long axis parallel to dominant winds and avoid large walls which face them. It is also recommended to avoid funnel-like gaps between buildings and long parallel rows of smooth buildings. Instead, steps can be introduced into a façade in order to provide resistance to wind (Figure 2.17) (Littlefair and others 2000, p.84).

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<sup>53</sup> Source: (<http://www.level.org.nz/passive-design/ventilation/>)

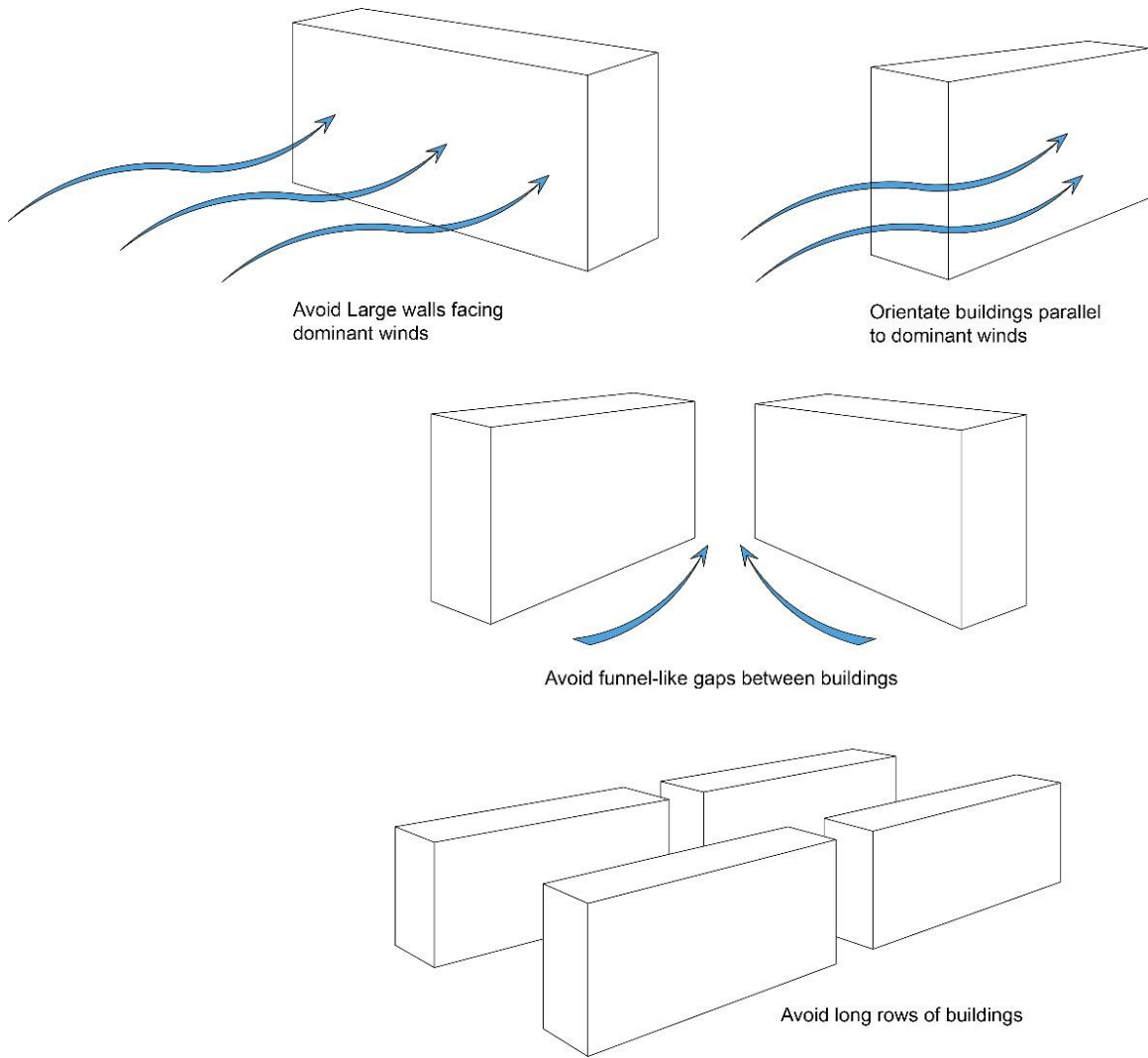


Figure (2.17) Orientation of Building blocks in Relation to Wind (winter)  
 Source: (Littlefair and others 2000, p.84).

The ideal situation is to orientate a building to receive desirable winds in summer and avoid undesirable winds in winter, however in cases where this is not possible, unlike the sun, wind can be diverted by installing fences, outbuildings, plants, trees and windows that open widely (figure 2.18).

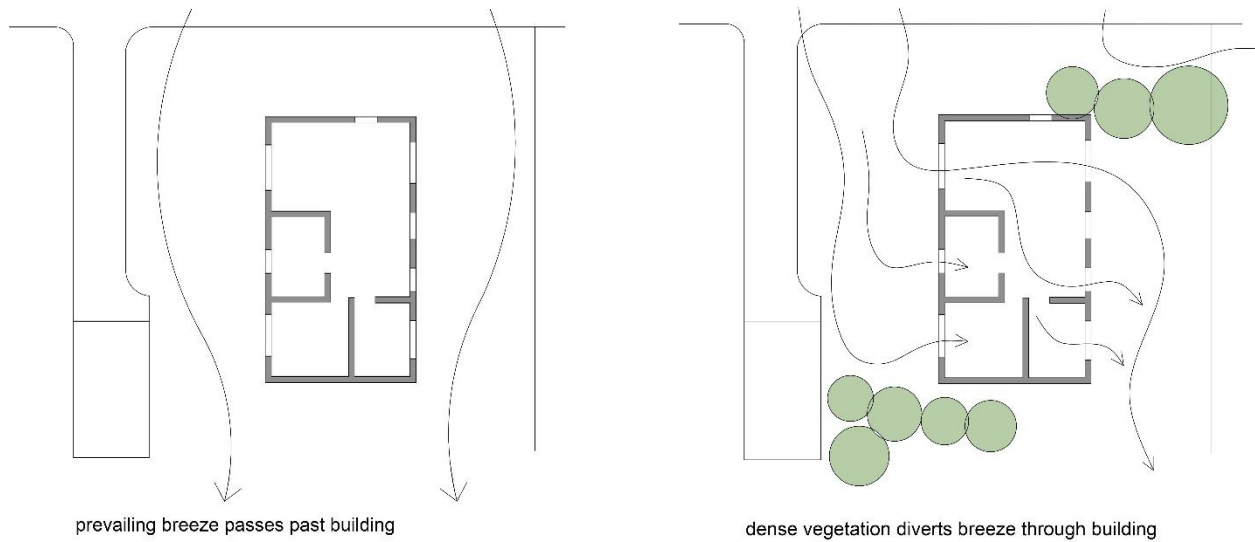


Figure (2.18) Diverting desirable winds through buildings  
 Source: <http://www.yourhome.gov.au/passive-design/orientation>

• **Street Orientation**

The air flow in the streets of an urban settlement is described as an urban canyon which depends on the street orientation in addition to the dimensions of the streets explained in the following section. When speaking of street orientation, vernacular settlements were aligned to ensure that the prevailing winds were efficiently channelled through the streets and alleys to flush the heat from them, and provide cooling by convection and evaporation (Meir and Roaf 2006, p.217). When possible, the streets were directed in a way to receive the desirable prevailing winds or to block the undesirable winds (figure 2.19).

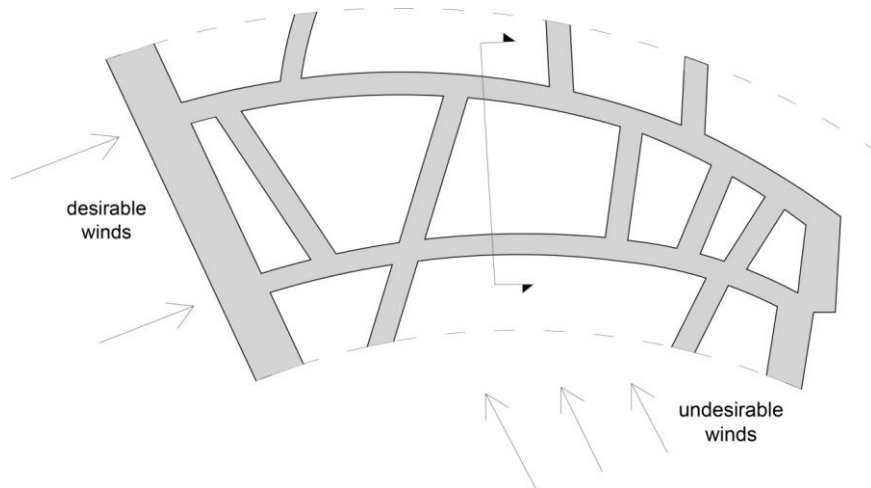


Figure (2.19) Example of Street Orientation to receive or block prevailing winds  
 Source: (Cadoni and Masetto 2006, p.266).



- **Narrow Streets**

The air flow in an urban canyon also depends on three main parameters: (Littlefair and others 2000, p.47).

$H$  = the height of the buildings,  $W$  = the width of the canyon (streets),  $L$  = the canyon length  
 In order to determine if the wind entering the canyon is desirable or not, the  $H/W$  ratio must be calculated. Studies have shown that when the buildings are well apart, their flow-fields do not interact (figure 2.20, a). When the buildings are closer, this causes the disturbance of air movement at the back of the first building and the front of the second (2.20, b). If the buildings are even closer with a greater  $H/W$  and building density, a skimming flow occurs where most of the air flow does not enter the canyon and a stable circulatory air is established between the buildings (2.20, c). In case of a variation in the heights of buildings, the skimming flow is easily disrupted (Littlefair and others 2000, p.48).

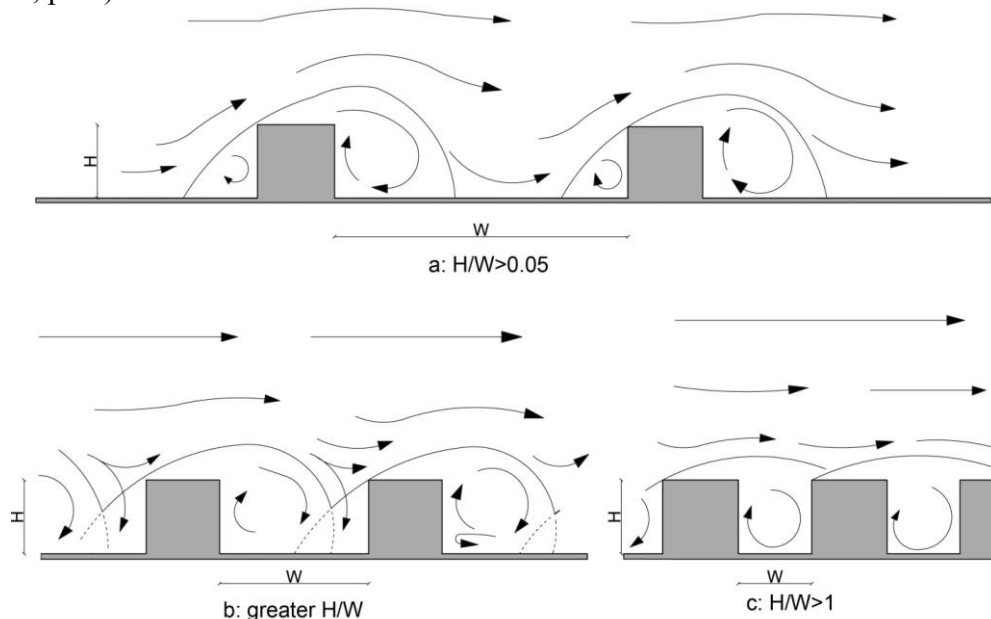


Figure (2.20) Air Flow according to  $H/W$   
 Source: (Littlefair and others 2000, p.48).

Therefore, in the narrow streets of vernacular cities, the desirable winds can be received and the undesirable winds can be blocked if the settlement is orientated in a suitable way (figure 2.19, 2.21).

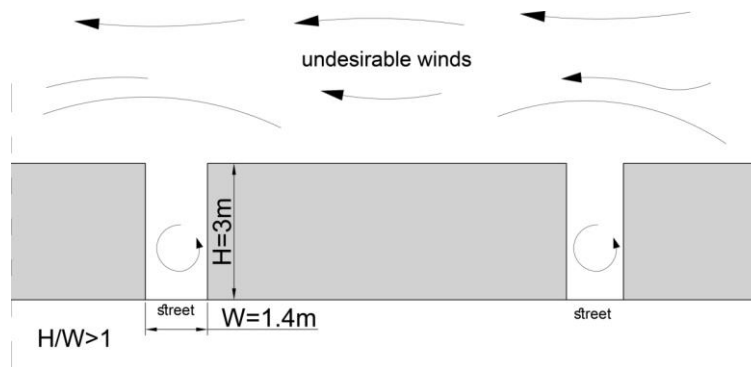


Figure (2.21) Section: Blocking Undesirable Winds  
 Source: (Cadoni and Masetto 2006, p.266).

- **Open Spaces**

Similar to the streets, the ventilation of open spaces depends on the height to width ratio, H/W. When the H/W is low ( $< 0.3$ ) ventilation is sufficient. When H/W increases, air flows become more unstable. When  $H/W = 1$  there is good ventilation with a vortex of air in the street which flows opposite to the wind direction. Finally, when H/W is large, ventilation is insufficient in addition to the creation of stagnant air which although can be cool in summer, can also trap pollutants. In vernacular cities, buildings do not exceed 3 storeys so the H/W ratio is never too large allowing some ventilation. In addition, traffic pollution does not exist in these cities (Littlefair and others 2000, p.60). Examples of these open spaces are:

**Irregular Open Space or Pathway Intersection** which are ventilated in the summer or protected in the winter depending on their direction and dimensions.

**Public Courtyard** which are enclosed from all sides acting as a reservoir of cool air like a regular private courtyard.

**Cul de Sac** which, climatically speaking, has the same function as a courtyard. The cool night air is retained from being swept away by the winds as would occur in the case of a grid plan with wide boulevards (Fathy 1986, p.64).

**Covered Passages** which aid in the circulation of cool air into the interiors of the dwellings.

**Covered Markets:** The roofs covering the market have the function of allowing the heat to rise to the highest point of the arches. That is why air vents in the form of caps or lanterns are placed in the roofs to allow the hot air to escape and provide natural light. Fresh air is naturally drawn from street level to replace it<sup>54</sup> (Johnson 1995, p.14).

- **Vegetation**

On a small urban scale, in the streets and public spaces of Mediterranean vernacular cities, vegetation can be found in a variety of forms affecting the wind speed and pattern in different ways. For example, grassy areas give maximum ventilation conditions. A single tree with a high trunk and wide canopy can concentrate the wind near the ground, thus increasing the wind speed while a group of trees with the same size significantly reduce wind speed in their area. A large tree placed beside a window on the windward side of a building can improve the indoor ventilation. (Littlefair and others 2000, p.113).

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<sup>54</sup> The Bernoulli effect: From the outside, the arches force the air to speed up as it flows over them creating suction and this draws air out more rapidly. To encourage this effect, barrel arches are built at right angles in the direction of the summer prevailing winds (Johnson 1995, p.15).

- **Public Fountains and Wells**

In the Solar Factor section about fountains, the process of the solar absorption and evaporation of the water is explained<sup>55</sup>. In this section, the process is continued to describe the effect in relation to air and wind:

Since the water temperature is cooler than the air temperature, heat flows from the air to the drop which causes the water to evaporate from the drop to the surrounding air. The hotter the drop is; the more water will be evaporated. This evaporation will cool it down. As a result of these two opposite occurrences, the wet bulb temperature of the air<sup>56</sup> is reached. Once the drop has reached the wet bulb temperature, the process is repeated and as a result, the surrounding air and passing wind is cooled (Littlefair and others 2000, p.117).

- **Surface Materials**

Wind aids in cooling surfaces. As mentioned in the Solar factor, it is recommended to use surface materials which are “cool materials” with an increased SRI (Solar Reflection Index). However, in the case where dark materials which absorb heat are used, the wind will aid in cooling it down.

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<sup>55</sup> See 2.2.2. Settlement, a. Solar Factor, Public Fountains and Wells, p.50.

<sup>56</sup> Wet-bulb temperature is the lowest level of temperature that can be obtained through evaporative cooling of a wet ventilated surface (<https://www.corrosionpedia.com/definition/1176/wet-bulb-temperature>)

### **c. Comparative Analysis Matrix**

Each design tool in the SETTLEMENT category is evaluated with a score according to its contribution to achieving thermal comfort and consequent energy savings. This score is then divided 50% for the sun and 50% for the wind and is based on the Matrix (2.1)<sup>57</sup>.

#### **1. Compact Geometry**

Compact geometry was given “very high influence” because it aids in decreasing the heat gain in summer and heat loss in winter due to the decreased surface to volume ratio.

#### **2. Block Orientation**

Block orientation is an important tool along with its dimensions due to the importance of benefiting from the southern orientation in winter and protecting the building from the eastern western exposure in summer. It was given “high influence” and not “very high influence” because in the case of courtyard houses, the house orientation is more important with the longer elevation facing south.

#### **3. Street Orientation**

Street orientation affects the street temperature and pedestrian thermal comfort. Since this tool slightly effects the building due to the effect on the surface temperature of the building, it was given a “low influence” rating.

#### **4. Narrow Streets**

According to the Sun Factor, narrow streets protect the buildings from the extreme sun in summer affecting the energy savings.

According to the Wind Factor, narrow streets protect from the undesirable wind (carrying sand in desert climates). Although it reduces ventilation in the streets, the open spaces offer areas with better ventilation. This tool was given “very high influence” due to the significant importance of shading in this climate.

#### **5. Open Spaces**

Like streets, open spaces offer thermally comfortable places for pedestrians. However, they do not effect the building energy savings significantly, only by slightly effecting surface temperatures. Therefore, they were given a “low influence” rating.

#### **6. Vegetation**

Vegetation affects the overall climate of a settlement in a significant way, by shading the buildings and cooling the overall atmosphere. Vegetation also positively affects the winds passing through the settlement. This tool was given a “very high influence” rating.

#### **7. Public Fountains**

Water elements throughout the settlement effect the thermal comfort of the pedestrians and like the streets and open spaces, don't have a significant effect on the buildings, therefore they were given a “low influence” rating.

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<sup>57</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, Matrix (2.1) Evaluation according to Influence on Energy Savings, p.42.

## 8. Surface Materials

The Surface Materials tool was given a “very high influence” rating due to its significant influence. Using light materials with high albedo affect the climate positively and aid in reducing the energy consumption of the buildings.

<b>Settlement (SE)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>SE 1. Compact Geometry</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 2. Block Orientation</b>	<b>12</b>	<b>6</b>	<b>6</b>
<b>SE 3. Street Orientation</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 4. Narrow Streets</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 5. Open Spaces</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 6. Vegetation</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>SE 7. Public Fountains and Wells</b>	<b>4</b>	<b>2</b>	<b>2</b>
<b>SE 8. Surface Materials</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>Total for SE Category: 88</b>			

Matrix (2.3) Evaluation of Tools for the SETTLEMENT Category

### **2.2.3. DWELLING: Passive Design Strategies of Courtyard Houses in the Mediterranean Area**

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As we move from the general characteristics of an urban fabric into the details of the courtyard house in the Mediterranean area, we can highlight the factors that create a guide for passive design. Thermal comfort is achieved through simple methods which take into consideration orientation, configuration and dimension. These simple methods create a comfortable living space with minimum energy consumption. First we can highlight how a building works when dealing with heat gain and loss.

#### **2.2.3.1. Thermal Gain and Loss in Buildings**

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Dwellings can gain or lose heat in natural simple ways depending on the design and orientation of the building (figure 2.22).

**Heat gain** (Fathy 1986, p.24).

Solar radiation is the source of heat in hot arid zones and this heat can be transmitted to the interior of the building in many ways.

- The most important method is by conduction of the solar radiation which is absorbed by the walls or the roof of the building at a rate depending on the thermal conductance (or thermal resistivity) of the material used, the surface area, and the properties of the surface (colour and texture).
- Openings permit solar radiation to penetrate into the interior of the building and the direct heating of the internal air, surfaces, and objects. This heat gain can be avoided by preventing the passage of light.
- Ventilation occurs when warm outside air flows into the building replacing the cool inside air that escapes to the outside. The rate of heat gain depends on the ventilation rate. This kind of heat gain can be avoided by restricting the size of opening during the heat of day.
- Shading for the walls, roofs and openings can be used to control the amount of heat gained by the building.
- Other sources of heat gain are the inhabitants themselves and household equipment such as electric lights and appliances which can contribute to heat gain during the day and night.

**Heat Loss** (Fathy 1986, p.24-25).

As in the process of heat gain, heat is lost by conduction through the walls, or through the roof by a combination of convection and conduction.

- Ventilation also causes heat loss when hot air escapes from an opening to be replaced by cool air entering from the outside.
- Evaporation can produce a cooling affect on the building either from the surface or from objects within the building. This is an effective cooling mechanism in hot arid climates where evaporation from the dry air is high.

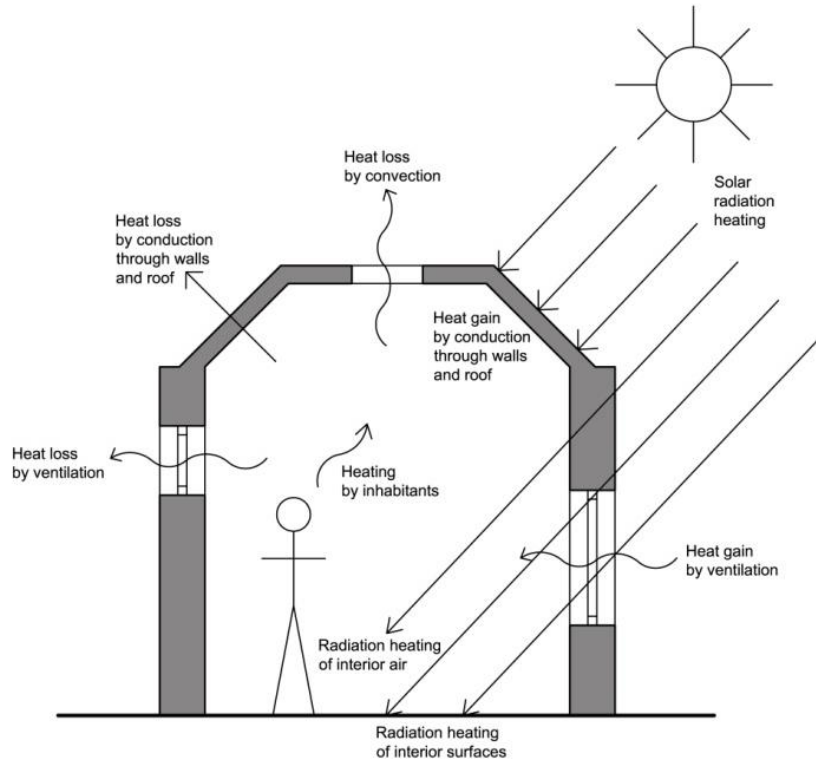


Figure (2.22) Diagram of Heat Gain and Loss in a Building  
 Source: (Fathy 1986, p.75)

### 2.2.3.2. The Courtyard as a Response to Mediterranean Conditions

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#### a. SOLAR FACTOR

- **Shape and Form**

The shape of a building affects thermal comfort from the aspect of self shading. Even with the same surface to volume ratio, buildings with an L-shape, U-shape, and even more the courtyard, benefit from self shading more than regular rectangle or square (figure 2.23) (Abed 2012, p.59).

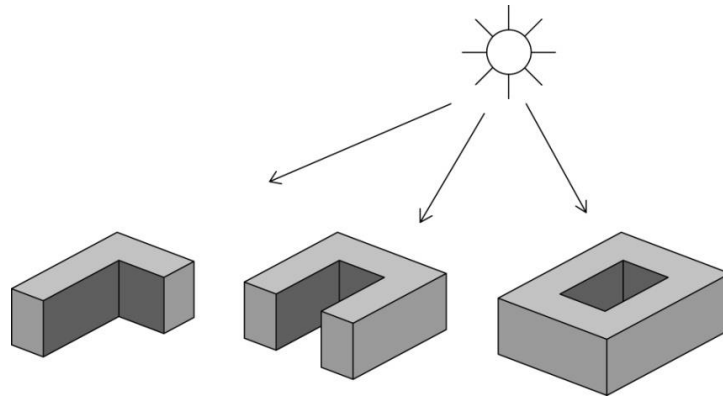


Figure (2.23) Effect of Shape on Self Shading  
Source: (Abed 2012, p.59).

- **Orientation**

As mentioned previously, the optimal orientation in the Mediterranean basin is the east-west axis giving it a south-southwestern exposure (Petruccioli 2006, p.5). In the winter, access to the sun is the most important factor. Therefore, when the longer side of the courtyard is directed to the south, it allows extreme access to the sun and allows the sunlight to penetrate into the rooms which are positioned alongside each other directly next to the courtyard (Serghides 2010, p.32). It is also easy to shade during the excessive summer months. When the dwelling is located on the perimeter of the block, it benefits from double exposure to its southern elevation (figure 2.24).

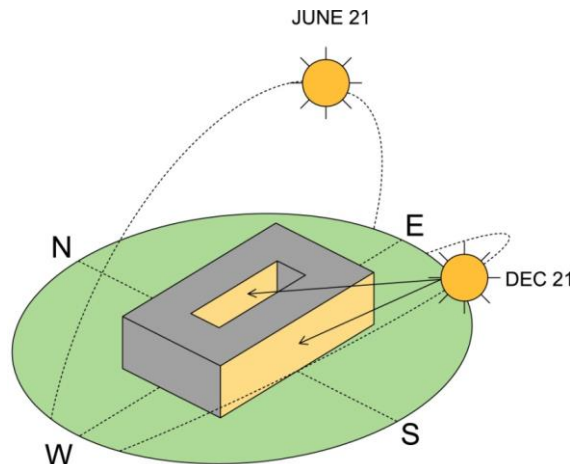


Figure (2.24) Double Exposure of Southern Elevation  
Source: (Serghides 2010, p.32).



- **Dimensions and Shade**

As mentioned on the previous section, one of the main characteristics of courtyard houses is self shading. The amount of shade depends on the courtyard dimensions.

**Lateral Distance of Shade**

When the walls are higher in relation to the width of the courtyard, this results in a greater amount of shade (Hakim 2009, p.124). The lateral distance of shade created by courtyard walls on the summer and winter solstice can be calculated in the equation:  $L=H \times \text{COT}\Theta^{58}$  (figure 2.25).

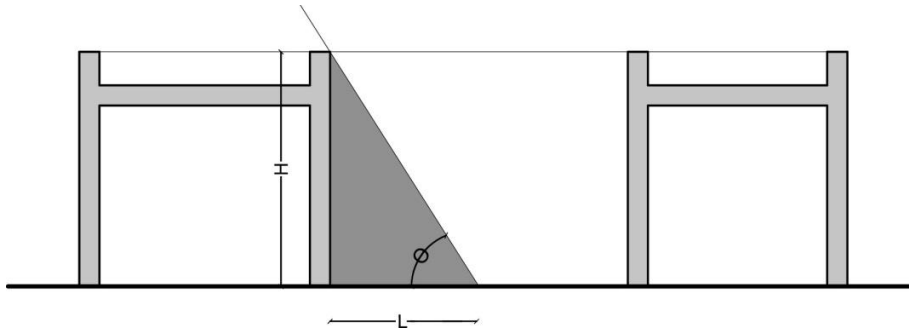


Figure (2.25) Lateral Distance of Shade in Courtyard  
Source: (Hakim 2009, p.124).

**L:** Lateral Distance of shade on courtyard surface  
**H:** Height of courtyard

**Θ:** Summer Solstice  
**Θ:** Winter Solstice

**b. WIND FACTOR**

Wind affects the convective heat exchanges of a building envelope and air infiltration, making it a great influence on the design of buildings. On a larger level, wind is effected by many factors such as topography, vegetation and building configuration while on a local level, building height and distances between them affect the formation of pressure zones (Abed 2012, p.20). Each climate requires different design strategies to benefit or protect from wind and its positive or negative effects. In summer, the wind should be utilized to improve ventilation, while in winter, it is necessary to avoid the negative effect of wind which increases the infiltration heat loss (Abed 2012, p.20).

In the Mediterranean area, there are a few pleasant months of the year when natural or fan-forced ventilation is enough for cooling the building (Colombo 1994, p.115). This ventilation depends on different factors.

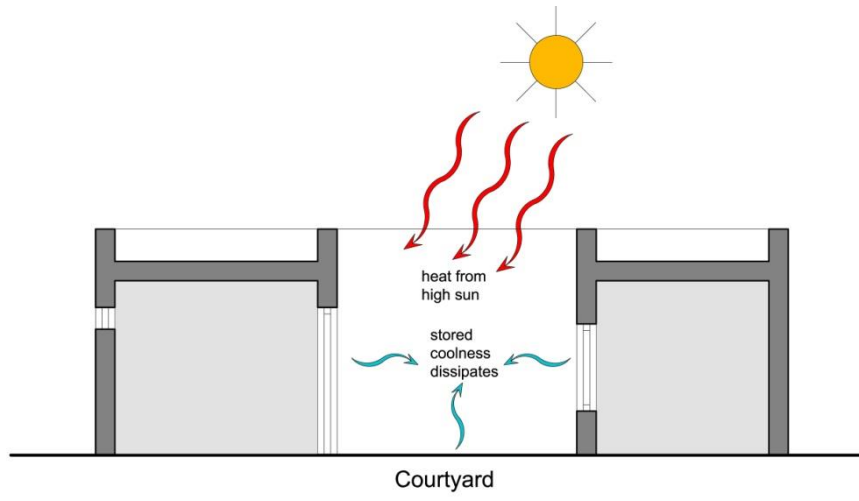
<sup>58</sup> See 2.2.2. Settlement, a. Solar Factor – Narrow Streets, pg.47.

- **Shape and Form**

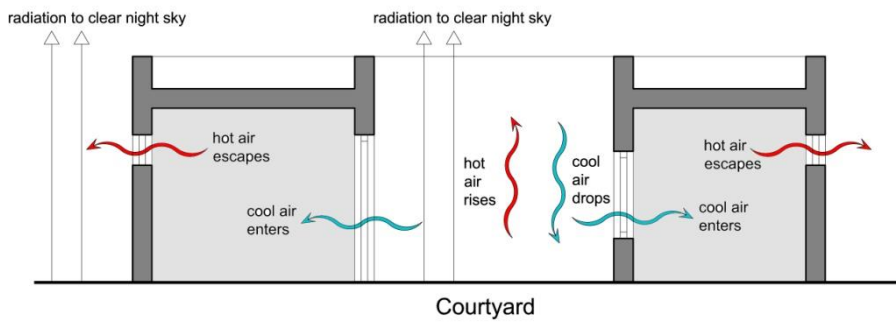
The shape of a building determines the effect of the wind in the summer and winter. The courtyard shape has many advantages, the most significant is the process of ventilation by convection which occurs in summer inside the courtyard:

Air circulation is caused by differences in air density. Therefore, when there are solid elements which are shaded and void elements which are open to the sun, a difference in temperature occurs and this causes the difference in air density. In the courtyard house, there exists a play of solid and void and that causes good cross ventilation during warm weather due to the process of convection and the connection of the rooms directly to the courtyard. The process occurs as follows: (figure 2.26).

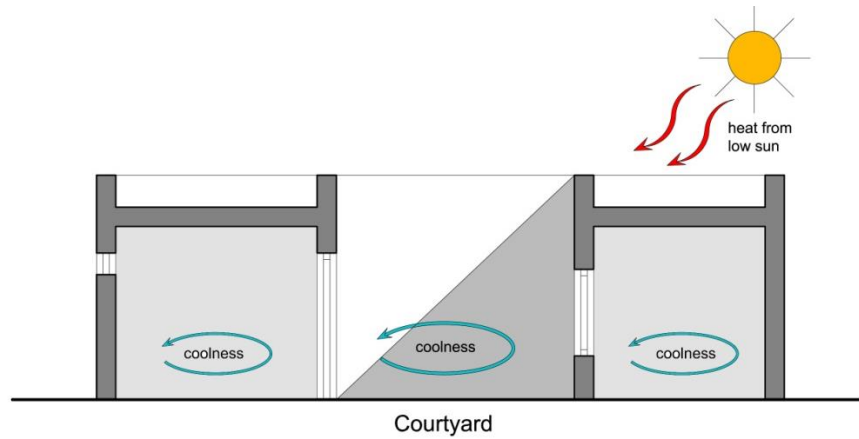
1. During the day time, the courtyard is heated directly by the sun and indirectly by the surrounding buildings. Air temperatures drop after sunset in hot dry regions, from re-radiation to the night sky. Unlike warm humid regions, this air is free of water vapor which would normally reflect the heat back to the ground (Fathy 1973, p.62).
2. During the evening, the warm air of the courtyard rises and is gradually replaced by the already cooled night air from above. This cool air gathers in the courtyard and finds its way into the surrounding rooms (Fathy 1973, p.63). The high windows in an Arab house which is mainly for privacy allows hot air to escape and be replaced by the cooler air from the courtyard which enters the room by the large lower windows (Hakim 2009, p.124).
3. Shaded by the walls of the courtyard, the coolness is stored in the floor, walls and furniture until the next day around afternoon when the sun is high in the sky and begins to penetrate the courtyard at noon. At that time, a process of convection is created as the cool air dissipates from the floor and adjacent rooms, and therefore adds to the comfort within the house (Naciri 2007, p.8). Thick walls do not permit the heat to enter the inside of the house. The warm wind passing above the house during the day does not enter the courtyard making it a reservoir of coolness (Fathy 1973, p.63). As the house gets warmer by late afternoon, more convection currents occur until sunset when most of the cool air spills out of the rooms (Lepore 2006, p.169).



Afternoon



Sunset to Sunrise



Sunrise to Noon

Figure (2.26) Thermal System of the Courtyard  
Source: (Lepore 2006, p.169).

In winter, an enclosed courtyard house would be protected from the undesirable winter winds when compared with an L-shaped or rectangular building. Courtyard houses were sometimes protected from extreme exposure to wind by raised courtyard walls or lowered courtyard floors to provide shelter from the strong winds (figure 2.27) (Stasinopoulos 2006, p.5).

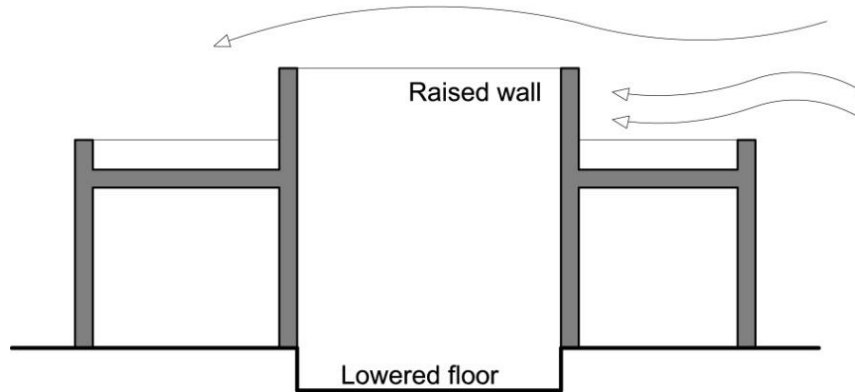


Figure (2.27) Protection of the Courtyard with raised wall or lowered floor  
Source: (Stasinopoulos 2006, p.5)

- **Orientation**

As mentioned in the section about the orientation of building blocks in the Settlement category, it is recommended to orientate the buildings long axis parallel to the dominant winter winds in the case of a free standing courtyard house or a series of attached courtyard houses. This influence increases in the case of exterior windows.

In the summer, the orientation is determined by the prevailing winds linked with the dimensions explained in the following section. For maximum benefit from the prevailing winds in summer, a malqaf (wind tower) was usually directed to face the desirable winds. It is described in the Element category.

- **Dimensions and Air Flow**

In courtyard dwellings, outdoor air access and indoor air recirculation will vary according to aspect ratios. For low aspect ratios, like wide courtyards with  $H/W < 0.3$ , a great deal of outdoor air enters and the air does not recirculate very much (figure 2.28-a). When courtyards get narrower, and  $0.3 < H/W < 1$ , outdoor air access becomes less efficient. However, recirculation occurs with the appearance of a swirl or vortex which efficiently mixes the air in the internal courtyard (figure 2.28- b). For high aspect ratio courtyards, when  $H/W > 1$ , both the recirculation and the outdoor air entrance drop dramatically (figure 2.28-c)<sup>59</sup> (Littlefair and others 2000, p.91).

Therefore, heat dissipation is better for medium aspect ratios,  $0.3 < H/W < 1$ , since efficient mixing is very important in spite of the reduced incoming outdoor air.

In the courtyard houses of the Mediterranean vernacular cities, most of the dwellings are one or two storeys high and this results in the ideal medium aspect ratio (in the case of a wide courtyard in a two storey dwelling). However, when the dwelling is three storeys high, this results in decreased recirculation and air entrance. The advantage of the courtyard with all aspect ratios is the natural convection described in the previous section. This process is similar for all aspect ratios

<sup>59</sup> The representation of the courtyard was done with CFD tools at the University of Seville.

with an advantage for the larger  $H/W$ , which aids in keeping the cool air near the ground and prevents it from dissipation. (Littlefair and others 2000, p.92). It also protects the courtyard from occasional uncomfortable windy conditions.

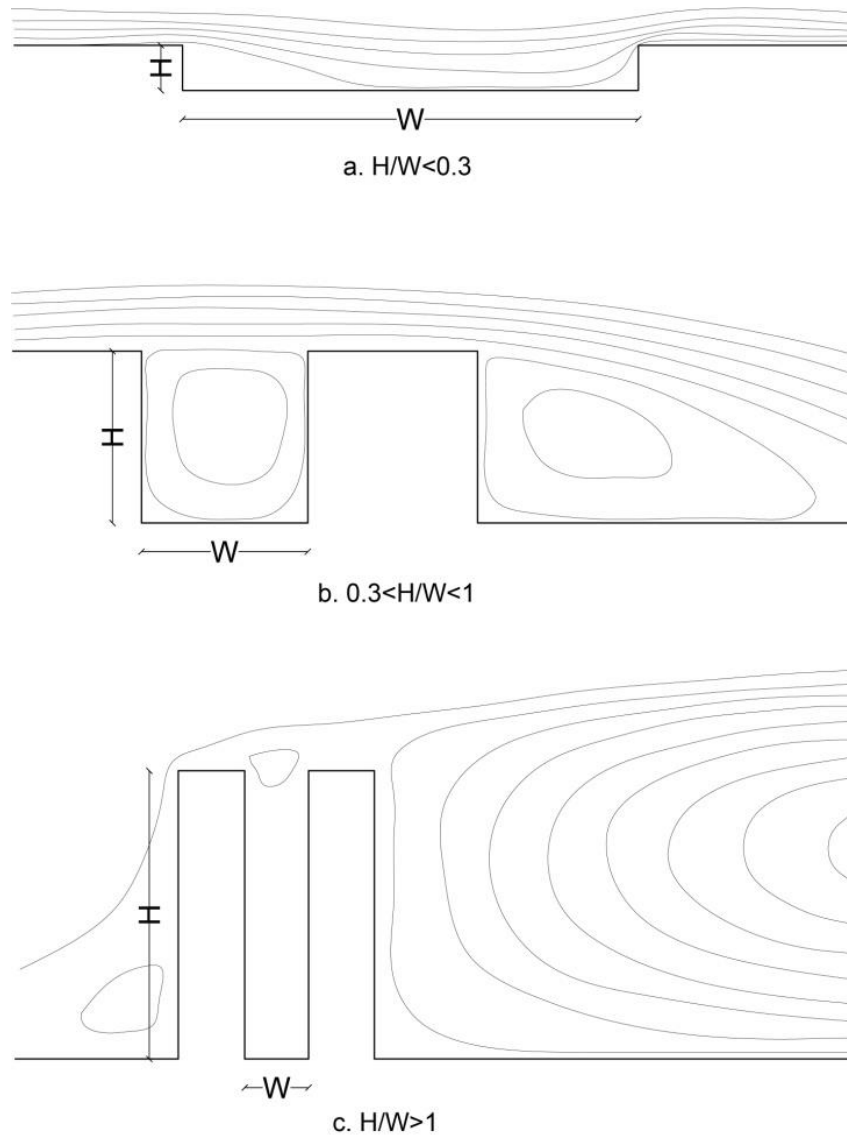


Figure (2.28) Air Flow in Courtyards with different Aspect Ratios  
Source: (Littlefair and others 2000, p.92).

### 2.2.3.3. Additional Thermal Regulating Spaces in Courtyard Houses

In addition to the courtyard itself as a thermal regulating space in Mediterranean courtyard houses, other spaces aid in the thermal comfort of the dwelling:

#### a. SOLAR FACTOR

- **The Liwan**

The Liwan is found in the courtyard houses of many countries of the Middle East including Lebanon, Syria and Turkey. The liwan itself is a roofed area centrally positioned between two enclosed rooms but open on one side to make use of an attractive view to the outdoors. The liwan serves as a general living space and an area to receive visitors with benches around the walls and in later versions have a small, central fountain, similar to a courtyard (Noble 2007, p.62). In the traditional courtyard houses of Mediterranean vernacular cities, the liwan is of the same importance as the courtyard itself. Since this space is meant for spending the afternoon, it is directed in a way which is against the morning sun towards the south or against the mid afternoon sun towards the east (Güleç, Canan and Korumaz 2006, p.3) (Figure 2.29, 2.30).

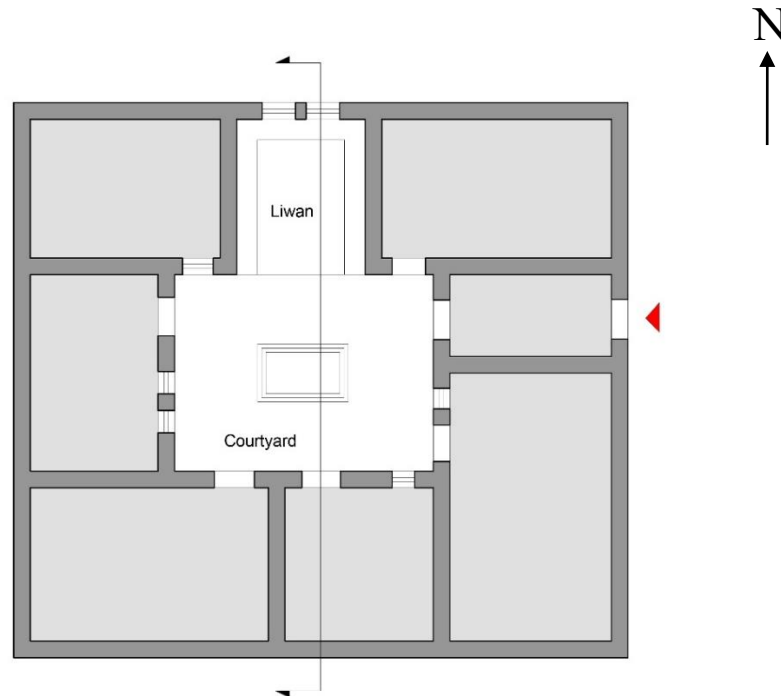


Figure (2.29) The Liwan Plan  
Source: (Güleç, Canan and Korumaz 2006, p.3)



Figure (2.30) The Liwan Section

- **The Arcade (Riwak)**

When there is sufficient space in the courtyard, a *riwak*, which is a semi open space, is located on any of the four sides of the courtyard and covered with a roof supported by columns. When compared with the liwan, it provides a shady space for sitting and resting while being open from three sides rather than one (Güleç, Canan and Korumaz 2006, p.4-5). It also creates a buffer zone against the heat from entering the interior of the building (Crouch 2001, p.101). In the courtyard houses of Tunis, this colonnaded gallery is called “burtal” and it has the function of giving importance to one of the rooms, sun protection, and/or giving access to service or stairs (Hakim 2009, p.121) (figure 2.31).

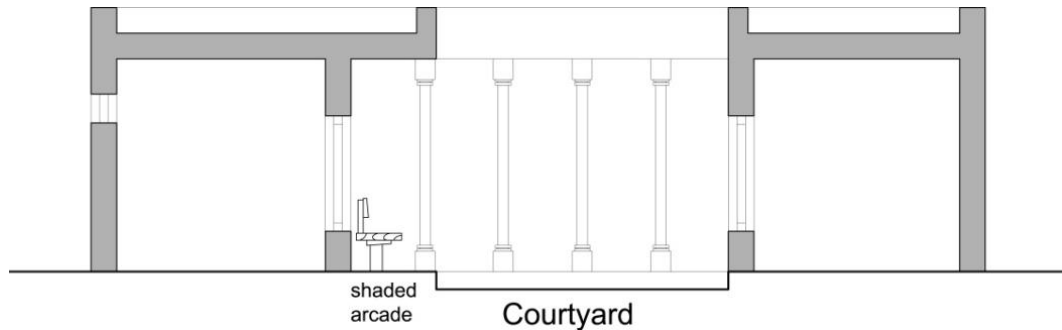


Figure (2.31) Shaded Arcade

- **The Terrace**

The terrace is a typical Mediterranean place, with a great richness in terms of activities. The Mediterranean terrace is much more than just an open room in the house: it is a place for drying fruits and linen. It is altogether a summer room, a private outdoor space and a social place. It is sometimes a passageway, a rainwater collector and a watch-post onto the horizon (Corpus 2002, ch.2, p.13).

The terrace of a Mediterranean dwelling is like a semi-enclosed outdoor room, open to the sky and provides a shaded meeting place for the members of the household. Like the arcade, it also creates a buffer zone against the heat. It can be covered and shaded with the roof, an upper floor or a wooden pergola (figure 2.32).

- **The Roof**

In courtyard houses, where terraces do not exist, the flat roof has the same functions and richness of a terrace. It is also used for drying fruits and laundry, sleeping, and relaxing. (Corpus 2002, ch.2, p.13-14). These roof terraces provide spectacular views of the city and its surrounding environment especially when the city is built on a sloping site as is the case in the Casbah of Algiers (Sibley 2005, p.80).

Vegetation and horizontal trellises can also be placed on the roof to provide shade and a pleasant environment. They also protect the roofs from excessive heat (figure 2.32).

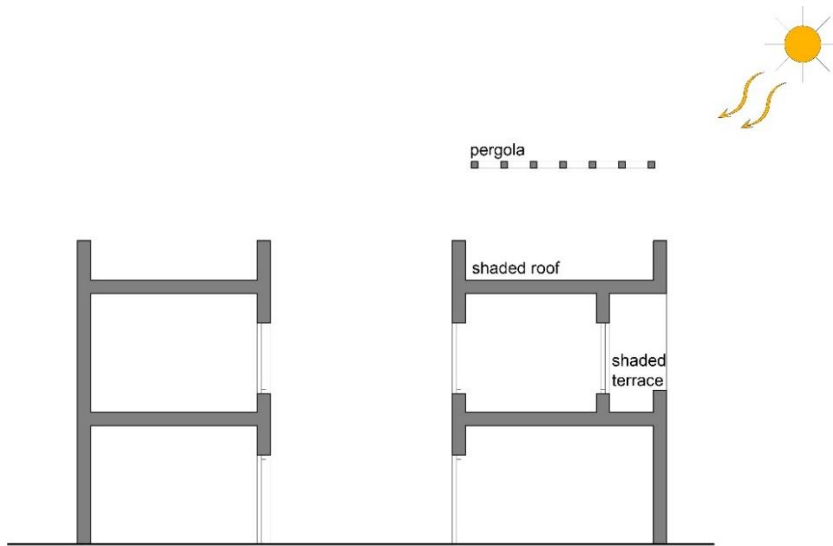


Figure (2.32) Shaded Terrace and Roof

## b. WIND FACTOR

### • The Loggia (Takhtabush)

The traditional courtyard house contains another element which produces a nice airflow through convection. This space is the “takhtabush” which is found in many North African courtyard houses. The takhtabush is a kind of loggia. It is a covered sitting area at ground level which separates the courtyard from the back garden. It is completely open to the courtyard and open to the back garden through a mashrabiya. Since the back garden is less shaded than the courtyard, the hot air rises from the floor through convection and draws cool air from the courtyard through the takhtabush, causing a pleasant cool draft for the people sitting there (Naciri 2007, p.8) (figure 2.33).

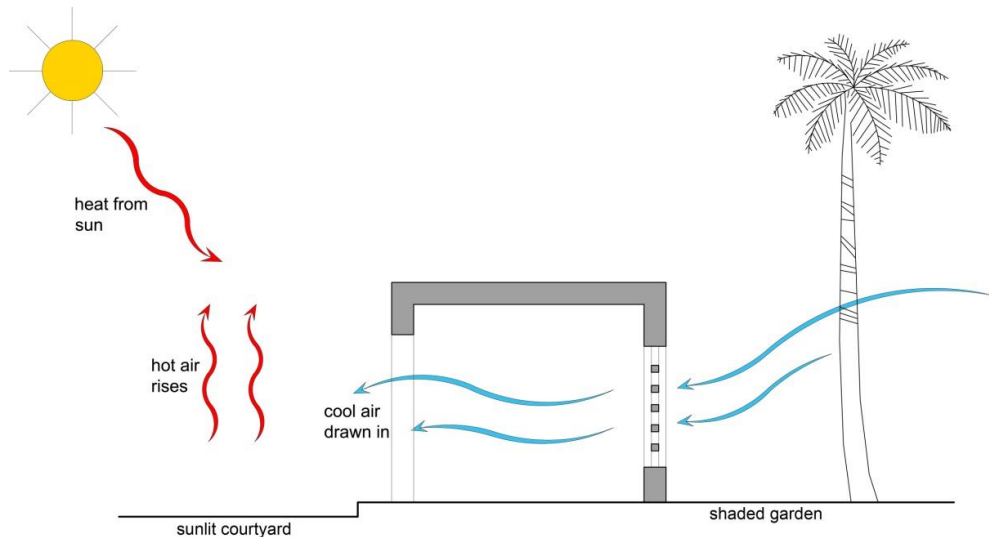


Figure (2.33) Wind Motion by Convection

Source: (Naciri 2007, p.8)



The same case can be seen when the loggia is completely open from the leeward side and open to the windward side by only a row of small openings high up on the wall. This is due to pressure differential where the airflow over and round the loggia creates low pressure within it. The low pressure results in a steady stream of air being pulled into the loggia through the small openings (figure 2.34). On the other hand, a loggia with a large opening to the windward side, and no openings or only small openings to the leeward side, will fill up with stale air leaving the fresh air to pass over the loggia instead of through it (Fathy 1973, p.47).

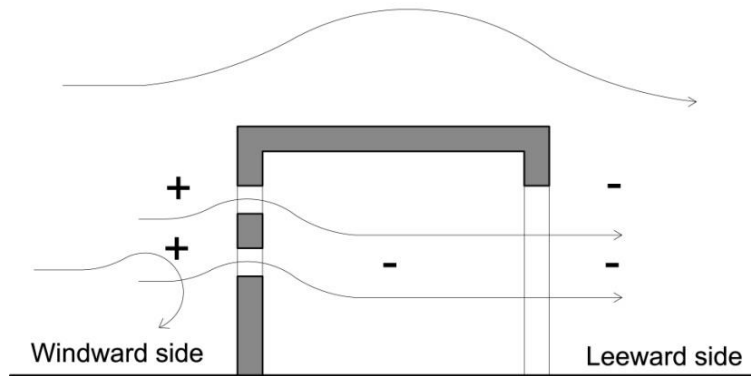


Figure (2.34) Wind Motion by Pressure Differential  
Source: (Fathy 1986, p.105)

- **The Liwan**

The liwan generally has a window directed towards the north which provides natural ventilation and cools the space (Güleç, Canan and Korumaz 2006, p.3). When directed towards the prevailing wind, the liwan can also act as a loggia between two open spaces, the courtyard (completely open) and the exterior (small windows) (figure 2.35) either by convection (figure 2.33) or by pressure differential (figure 2.34).

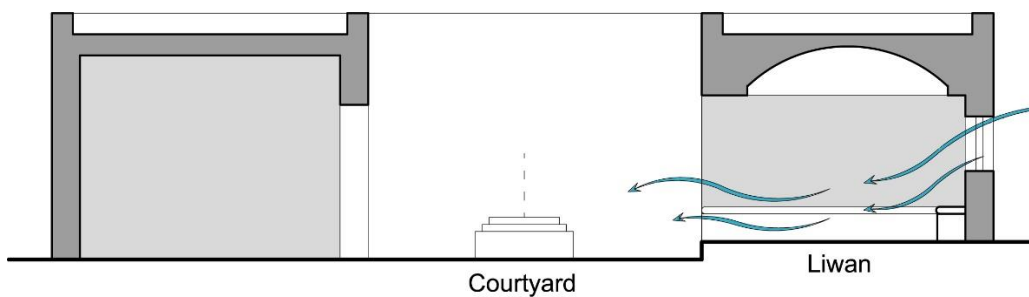


Figure (2.35) Liwan Cross Ventilation

- **The Terrace/Roof**

Terraces in the Mediterranean were directed in a way to receive the prevailing wind in the summer. It also aids in providing a breeze through the dwelling by convection in the case of another opening facing the terrace opening.

Roofs in the Mediterranean were used for sleeping during the hot summer months due to cool nights. Since it is open from all sides, it welcomes the prevailing winds and makes a cool sitting area (figure 2.36).

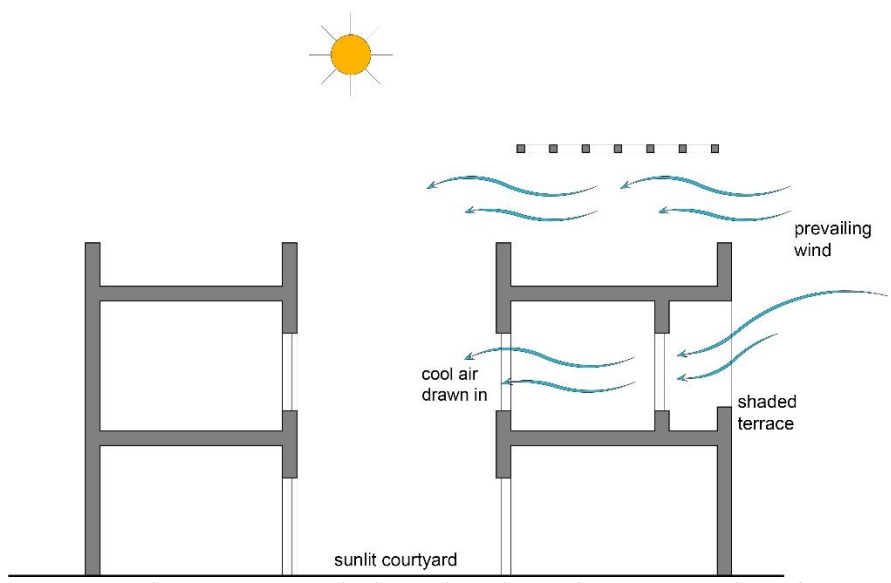


Figure (2.36) Wind passing through terrace and roof

### **c. Comparative Analysis Matrix**

Each design tool in the DWELLING chapter is evaluated with a number of points depending on its importance in its contribution to achieving thermal comfort and consequent energy savings. This score is divided into 50% for the sun and 50% for the wind, where relevant, based on Matrix (2.1)<sup>60</sup>.

#### **1. Shape and Form**

The courtyard house form significantly contributes to the energy savings of a house and therefore given a “very high influence” rating. From the solar factor, the courtyard house has the benefit of self shading from all four sides. From the wind factor, the shape allows it to achieve ventilation by convection in its courtyard.

#### **2. Orientation**

The orientation of the courtyard house is very important in the summer and winter. From the solar factor, if the dwelling is orientated on an east-west axis, it receives the southern sun in winter and reduces the eastern and western sun in summer., heating and cooling loads are greatly reduced. From the wind factor, whether the dwelling faces the desirable or undesirable winds, has a significant effect on the building. Therefore, this tool was given a “very high influence” rating.

#### **3. Dimensions**

The dimensions of the courtyard (height and width) are an important tool contributing to energy savings. According to the solar factor, the dimensions of the courtyard (height and width) determine the amount of shade created. According to the wind factor, dimensions of the courtyard determine whether the wind enters the courtyard or not in addition to its speed. This tool was given a “high influence” rating and not “very high influence” because they determine the level of influence already caused by the Shape tool.

#### **4. Additional Spaces (The Liwan, The Arcade, The Loggia)**

These spaces create comfortable living areas for the residents and they contribute to the energy savings in the dwelling, therefore they were given a “medium influence” because they contribute to part of the dwelling. The arcade is an element utilized to create a shaded space so it is not applicable for the wind factor. Vice versa, the loggia is a space designed to create cross ventilation and is not applicable for the sun factor.

#### **5. The Roof/Terrace/Garden**

These outdoor spaces aid in the shading and ventilating of indoor spaces, and they create comfortable sitting areas for the residents. When they are shaded, they create a buffer area protecting the walls and roof of the dwelling. They were given a “medium influence” rating.

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<sup>60</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, Matrix (2.1) Evaluation according to Influence on Energy Savings, p.42.

<b>Dwelling (DW)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>DW 1. Shape and Form</b>	16	8	8
<b>DW 2. Orientation</b>	16	8	8
<b>DW 3. Dimensions</b>	12	6	6
<b>DW 4. Liwan</b>	8	4	4
<b>DW 5. Arcade</b>	8	4	N/A
<b>DW 6. Loggia</b>	8	N/A	4
<b>DW 7. Terrace/Roof</b>	8	4	4
<b>Total for DW Category: 68 (total - N/A elements)</b>			

Matrix (2.4) Evaluation of Tools for the DWELLING Category

#### **2.2.4. ELEMENT: Thermal Regulating Elements in Courtyard Houses**

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As we go into more detail within the courtyard house, we can find elements which aid in the thermal comfort of the dwelling. In the absence of a significant factor in the design of a site, settlement or dwelling, these elements can either replace or enhance the performance of any passive design factor.

##### **a. SOLAR FACTOR**

- **Windows**

In Mediterranean climate, windows are small and few to create cool and dark cave-like interiors to relieve the inhabitants from the heat. On the east and west elevations, the openings are small to avoid the summer sun in the morning and the afternoon. On the north elevation, the openings are small to avoid the cold winter winds and to achieve cross-ventilation in the summer. On the south elevation, the openings are large to gain maximum benefit from the winter sun. Windows facing the interior courtyard are large to provide light for the surrounding rooms.

The performance of a window is affected by many factors including the window's material, orientation and the window to wall area ratio which is the most influential factor. The greater the window area, the more solar gain during winter (Abed 2012, p.39).

In Mediterranean climate, windows must be shaded. Window shutters are closed during the hottest hours of the day and should be completely open at night to benefit from the cooling effect of nocturnal ventilation (Crouch 1998, p.78). They are also fully opened during early morning for ventilation and to admit daylight (Karasu 2009, p.49).

- **Mashrabiya**

The mashrabiya is an element used to improve the comfort level of a built environment and is found in hot arid climates across the Middle East and North Africa.

The word “mashrabiya” is derived from the Arabic word “drink” and originally meant “a drinking place”. It was a cantilevered space with lattice openings where small water jars were placed (Fathy 1986, p.46). The evaporation effect would cool the water as air passed through the opening. These spaces are located on the upper storeys of large houses and always protrude from the façade to permit a view of the street and produce shade. A wooden lattice is on the outside and can be opened for ventilation or an unobstructed view (figure 2.37).

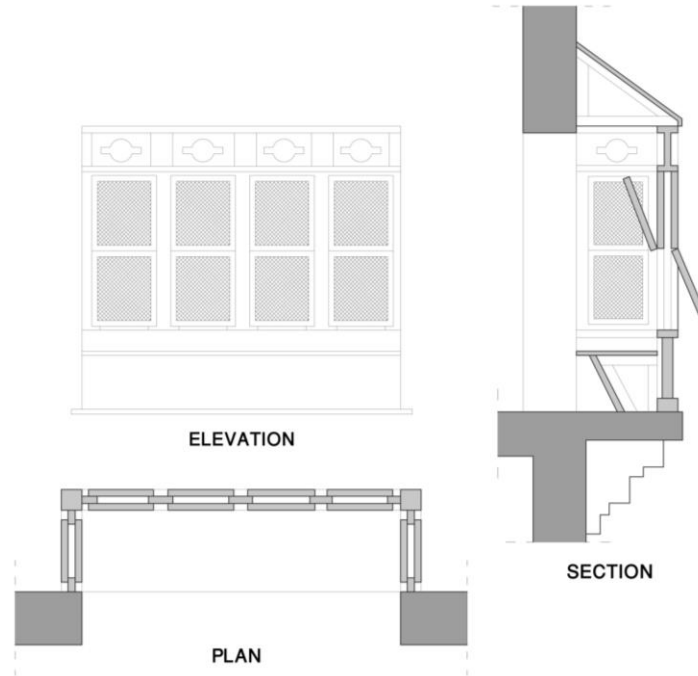


Figure (2.37) Mashrabiya  
Source: (Hakim 2009, p.75)

The word “Mashrabiya” is now used for an opening with a lattice screen made of wood and composed of circular section balusters placed at equal dimensions creating different decorative geometric patterns (Fathy 1986, p.47). The mashrabiya has five functions, which are: controlling light passage, controlling air flow, reducing the temperature of the passing air, increasing the humidity of the passing air and providing privacy.

In different conditions, the need for each of these function varies, therefore, the patterns are distinguished from one another by the specific conditions each function satisfies. Design adjustments include the interstices (spaces between the balusters) and the baluster diameter (Fathy 1986, p.47). Figure (2.38) shows a mashrabiya with large interstices.

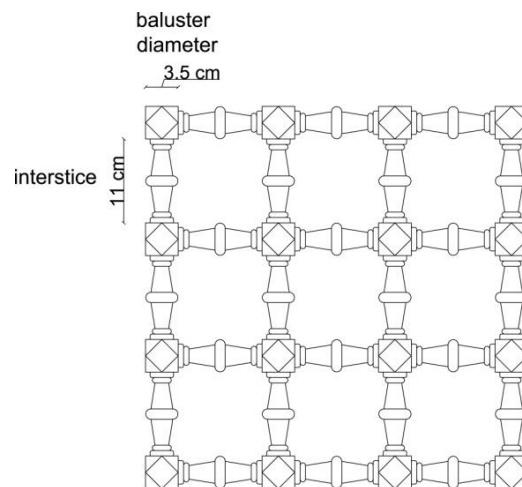


Figure (2.38) Mashrabiya Interstices  
Source: (Fathy 1986, p.91).

When speaking about the effect of the Solar Factor, the Mashrabiya has three functions: Controlling Sunlight, Cooling and Humidifying:

### Controlling Sunlight

A south facing opening allows two components to enter: the direct high-intensity sunlight at angles normal to the plane of the opening, and the lower-intensity reflected glare which enters nearly normal to the opening. Direct sunlight should be blocked to prevent heating of the inside surfaces and glare should be blocked to prevent visual discomfort (Fathy 1986, p.47). In order to intercept the direct sunlight, the sizes of the interstices and balusters are adjusted. This requires a lattice with smaller interstices. The advantage of the round section of the balusters is that the light gradually reaches its surfaces, and thus the contrast between the darkness of the opaque balusters and the brightness of the glare entering through the interstices is softened (figure 2.39) (Fathy 1986, p.47).

At eye level, the spaces between the balusters are small in order to intercept direct sunlight and reduce the glare caused by the contrasting elements in the pattern. However, obstructing the sunlight causes a dimming affect which can be compensated by increasing the size of the interstices in the upper part of the *mashrabiya* above eye level. This creates a striking effect in rooms with high ceilings and brightens the upper part of the room. An overhang at the top of the opening prevents direct sunlight from entering. However, the *mashrabiya* on a north facing opening is designed with large interstices to lighten the room regarding that direct sunlight is not a problem (Fathy 1986, p.48).

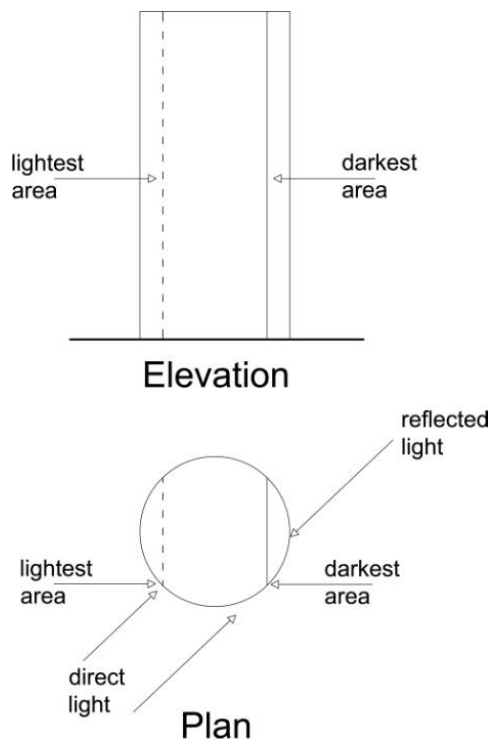


Figure (2.39) Round Section of Balusters  
Source: (Fathy 1986, p.91).

### **Cooling and Humidifying**

The function of cooling and humidifying is provided by the material of the *mashrabiya* which is wood. Wood fibers have the ability to absorb, retain, and release water. This quality is found in plants which can provide regulation of their skin temperatures through a process called evapotranspiration (Fathy 1986, p.48). Even after the wood fibers are cut from a tree and used in buildings, they retain this ability as long as the pores are not covered by an impervious paint (Fathy 1986, p.49).

The process of cooling and humidifying occurs as follows:

During the night time, when the wood of the *mashrabiya* is cool, the passing wind gives up some of its humidity to the porous wooden balusters. During the day, when the *mashrabiya* is heated by the sun, the humidity is released to the air passing through the interstices. This process humidifies and cools the dry air during the day. The amount of humidification and cooling is dependent on the area of the surfaces exposed to air and the rate of air passing through. Thus, when the size of the balusters is increased, the area exposed is increased. In addition, the baluster will then have more volume, which means it has more capacity and will release the water over a longer period of time (Fathy 1986, p.49).

### **• Courtyard Vegetation and Shade**

In the hot dry regions of the Mediterranean, the courtyard is where the inhabitants spend most of their time. Vegetation is an important element because it provides shade and a cool atmosphere<sup>61</sup>. During the POLIS project, experimental results revealed a significant decrease of the air temperature (3–5 °C) in courtyards with tall and dense trees compared with those without vegetation (Littlefair and others 2000, p.20).

In Mediterranean courtyard houses, the courtyard is filled with vegetation according to the occupation and orientation. In the areas most occupied, trees and dense vegetation provide shade in the summer and in the less occupied spaces of the garden, fruit bushes and vines are used forming half open spaces. When placed on the east and west sides, dense vegetation protects the building from the low summer sun in the morning and afternoon, reducing the temperature by as much as 22 °C (Littlefair and others 2000, p.113). On the southern side, climbing deciduous plants like traditional grape-vines, horizontal pergolas offer shade in the summer but allow the sun to penetrate in the winter. (Serghides 2010, p.33).

Tall trees with a wide canopy, rising above the roof of the courtyard house, can also provide shade. This can aid in cooling the air during late evening and at night when the upper part of the tree's leaf canopy loses heat to the sky by transpiration. The leaves then cool the air around them, which becomes heavier and sinks into the courtyard (Littlefair and others 2000, p.92).

Gardens are sometimes divided by high walls with climbing plants but are visually connected with wall openings. By dividing the courtyard garden in this way, well defined areas with varying degrees of shade create aesthetic properties as well as providing thermal comfort for the occupants. A study was done by Dr. Maher Laffah to calculate the different proportions of shade in different courtyard houses in the Mediterranean area. Conclusions showed that in small courtyard gardens, the shaded space is 25% and it increases to 40% in the larger courtyard gardens. The explanation for these results is the difficulty of planting trees with thick foliage in small gardens in addition to the shade provided by the dividing walls in large courtyards (Laffah 2005, p.216).

Shading by a canvas awning is also possible, but it should be closed during daytime and open at night to help night radiative cooling of the space and make the courtyard more comfortable.

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<sup>61</sup> See 2.2.1. Site, a. Solar Factor - Vegetation, pg.37.



(Littlefair and others 2000, p.92). A movable type of shading might not have been found in a Mediterranean vernacular courtyard house, but can be incorporated into modern dwellings.

- **Water Features**

Water is an essential element in the traditional courtyard garden due to its important role as a cooling device in hot climatic conditions. The process of evaporation of the water needs the aid of the sun therefore water bodies are usually placed in the centre of the courtyard to benefit from the vertical midday sun in summer (Wadah 2005, p.224). During daytime, water features have a reduced temperature due to the high thermal capacity of the water. However, little heat is transferred from the air into plain horizontal water. Therefore, if water runs down a slope or, if the ponds include fountains or sprays with fine droplets, better conditions are achieved<sup>62</sup> (Littlefair and others 2000, p.92-93). Examples of these water features are:

**Fountain:** The most widespread water elements are fountains, springs and canals of geometric shapes and are always placed on the main axis of the garden framed by plants and low walls. Water can be used in two forms, moving and still, both giving beautiful visual properties. To provide movement in the water, elements like fountains and springs were integrated to achieve audible and visual pleasure while using the least possible amount of water by means of recycling (Laffah 2005, p.216).

**Salsabil:** The salsabil is another architectural element which is found in places where the pressure of the water is insufficient to allow the water to spout from the fountain. The salsabil is a metal plate decorated with patterns in the form of water and wind, and is placed against a wall in a courtyard at an angle to allow the water to flow down its surface. Then the water flows through a marble channel until it reaches the fountain in the centre of the courtyard (Fathy 1986, p.67).

**Maziara:** The maziara is a porous water jar system and is found in many locations of the Middle East. This device consists of a large porous water jar which is placed in a windward opening. In an experiment to test the functionality of the maziara, the results showed that the temperature of the maziara water remained constant at 20 °C, although the outside temperature ranged from 19° to 36 °C. This constancy is due to the fact that as outside air temperature rises, relative humidity decreases, and as the air becomes drier more water evaporates and the cooling rate increases. This cooling efficiency improves when the maziara is combined with a wind catcher (Noble 2007, p.229).

Spraying or washing the courtyard ground with water also increases the humidity and cools the atmosphere (Serghides 2010, p.33).

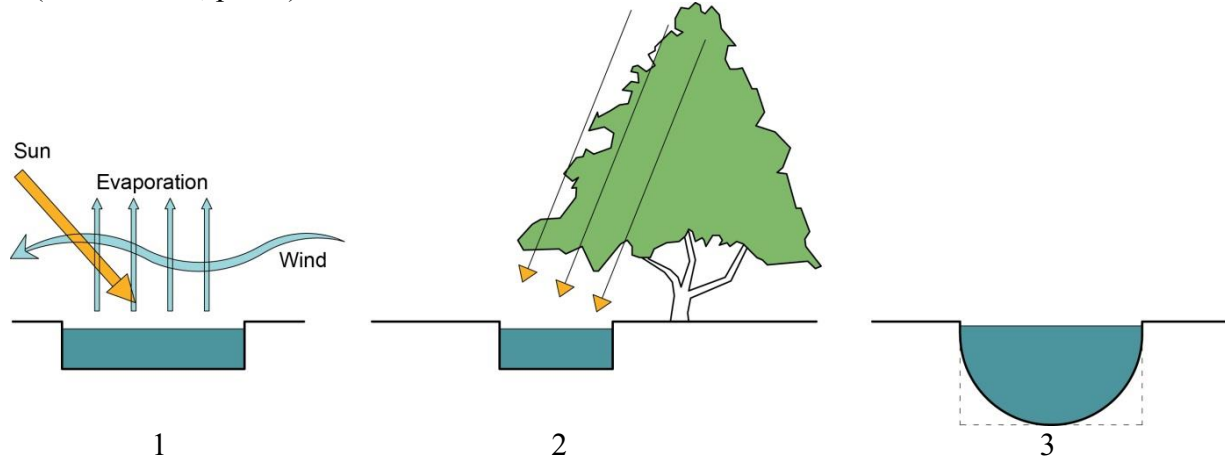
The environmental and climatic benefits of water elements in a courtyard garden are: (figure 2.40)

- a. Their location inside garden courtyards behind high walls, protects the water from strong sandy winds that often blow in desert regions.
- b. When water elements are surrounded by plants, this helps to decrease the level of evaporation, in addition to the aesthetic effect given by the reflection of plants on the water's surface.
- c. When these water elements are built in the shape of narrow canals (approximately 50 cm in depth), this helps to lower the level of evaporation. Building them with a half-oval shape also

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<sup>62</sup> See 2.2.2. Settlement, a. Solar Factor, Public Fountains, p.50.

discourages stagnant areas and gives the impression of more water than there is in reality (Laffah 2005, p.218).



- 1: interaction of sun and water to produce evaporative cooling
- 2: use of trees to prevent evaporation of scarce water
- 3: use of deep canals to reduce surface evaporation and rounded shape to discourage stagnant areas

Figure (2.40) How Water Elements Regulate the Climate  
Source: (Laffah 2005, p.21)

- **Thermal Mass**

Hot, dry areas of the Mediterranean region are characterized by high daytime temperatures and low night time temperatures. This fluctuation in temperatures demands delaying the transfer of heat as long as possible so that it will reach the interior later on in the evening, when it is most needed. To achieve this, it is best to use materials with thermal mass<sup>63</sup>. These materials provide a “heat sink,” absorbing heat during the day, slowly spreading it (thermal conductivity<sup>64</sup>) through the mass and then releasing the heat energy throughout the evening and night (Rapoport 1969, p.89).

Vise versa, in order for the material to store coolness at night and release it during the day, thermal mass is also needed. Thick walls serve as extensive thermal masses, which creates cave-like temperatures inside the house. Since the temperatures in a cave are constant, there could be diurnal temperature differences of 41°F to 59°F between the exterior and the interior of the house. This can be explained when considering an outside wall exposed to a high outside temperature and a lower inside temperature, the rate of heat flow transmitted through the wall from the outside to the inside depends on the air temperature difference between inside and outside, the area of the wall, and the thermal conductivity of the material. Thermal transmittance<sup>65</sup> can be reduced by increasing the wall thickness (Fathy 1986, p.39).

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<sup>63</sup> Objects with thermal mass are typically dense, they have the ability to conduct heat slowly and release it at a later time.

<sup>64</sup> Thermal conductivity is a measure of the ability of a material to allow the flow of heat from its warmer surface through the material to its cooler surface.

<sup>65</sup> Thermal Transmittance is the rate of transfer of heat (in watts) through one square metre of a structure, divided by the difference in temperature across the structure.

Thermal mass is also beneficial in the winter time. It works like a heater by absorbing radiant heat from the sun through the southern facades, and also stores heat from other sources. The thermal mass will slowly release the heat into the building<sup>66</sup>.

The main building material in the Mediterranean region is stone<sup>67</sup> which is an excellent source of thermal mass for maintaining a stable indoor temperature (Steen 2003, p.58). The walls of the traditional dwelling in the Mediterranean region can be as thick as 45 to 100, sometimes even 120 cm (Corpus 2003, ch.3, p.4). The thermal conductivity of limestone is 1.53 W/m °C (Norton 1986, p.4).

Another building material used in the Mediterranean region is earth. Earth has an even lower thermal conductivity in addition to the thickness of most earth constructions. It is valued at .50 W/m °C for mud-brick, compared with 1.21 W/m °C for fired brick (Norton 1986, p.4).

## **b. WIND FACTOR**

### **• Windows**

In general, exterior windows in vernacular Mediterranean dwellings, if found, are placed high up on the walls for ventilation and prevention of heat and dust from entering the building (Hakim 2009, p.88). Openings are also located above the windows and doors for ventilation and light (Hakim 2009, p.78). Small openings are sometimes located in the roofs also for ventilation and lighting (Hakim 2009, p.98).

### **• Mashrabiya**

To provide airflow into the room, the *mashrabiya* is designed with large interstices to provide as much open area as possible in the lattice. However, in cases where small interstices are required to obstruct sunlight and the airflow is insufficient, the upper part of the *mashrabiya* can be designed with a large interstice pattern. That is why a typical mashrabiya is composed of two parts: the lower part with small interstices to control the direct sunlight, and the upper part with large interstices to lighten the room and provide airflow. Sometimes when the airflow is still insufficient due to the small size of the lower interstices, the *mashrabiya* can be increased to fit any opening, even to the size of the entire wall. This can also solve the problem of dimming in a room. Sometimes a *mashrabiya* is used indoors between two rooms for cross-ventilation (Fathy 1986, p.48).

### **• Courtyard Vegetation**

In the courtyard, vegetation affects the wind when it is in the form of trees. High trees can act as a barrier which can affect winds coming into the courtyard. When a tree is high with a large canopy, it creates a semi-barrier between the courtyard air space and the ambient air above reducing air exchange on windy days (Littlefair and others 2000, p.92).

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<sup>66</sup> <http://gruenecodesign.com.au/how-can-thermal-mass-help-in-winter-or-summer-to-regulate-room-temperature/>

<sup>67</sup> A study of Traditional Mediterranean Architecture by the CORPUS project, which is a part of the Euromed Heritage programme in 2002 showed that 60% of their chosen typologies were constructed with stone. Unprocessed earth in the form of mud or terracotta brick is used in about 30% of the studied typologies (Corpus 2003 ch.2, p.14). Mixed solutions like stone/earth or stone/brick were present in 8% of the studied typologies. Plant material as main construction material such as thatch or straw (not including wooden structures), was found in only 5% of all typologies (Corpus 2003 ch.2, p.15).

- **Water Features**

Aided by the sun, water elements in the courtyard aid in cooling the passing winds and providing thermal comfort for the residents. This is explained in detail in the Settlement category<sup>68</sup>.

- **Thermal Mass**

Since thermal mass also stores coolness, it is also relevant in the wind factor when cool winds result in lower temperatures<sup>69</sup>.

- **Malqaf (Wind Catcher)**

This element is found in hot arid regions and across the Mediterranean. It is a feature of vernacular architecture and was invented owing to the great demand for air movement in these climates<sup>70</sup>. In hot arid zones, there is a difficulty in achieving appropriate ventilation by using only windows. Small windows create air movement but reduce room lighting, large windows for lighting and view allow hot air to enter, as well as glare. This difficulty in hot arid regions, lead to the invention of the malqaf or wind catcher. The malqaf is a shaft rising high above the building with an opening facing the prevailing wind<sup>71</sup>. It traps the cool and strong wind and channels it down to the building interior. In addition, the wind captured above the building carries less sand and dust than the winds at lower levels, thus reducing the sand carried into the building. Any sand which does enter is dumped at the bottom of the shaft (Fathy 1986, p.56).

The system of the malqaf depends primarily on air movement by pressure differential, and secondarily on air movement by convection. When a considerable amount of air flows into the malqaf, a wind-escape must be provided which can be in the form of high clerestory windows in the ceiling when there is a difference in the ceiling heights of two adjacent spaces. (Fathy 1986, p.57). An example of a space containing a malqaf and an air escape, is a traditional dwelling in Egypt with a central hall and adjacent northern liwan (figure 2.41). The ceiling of the hall is higher than that of the liwan forming clerestory windows covered with a mashrabiya. The malqaf rises over the roof of the liwan and is placed on the northern side of the building (direction of the prevailing wind). It channels the cool breeze from the north down into the room due to the increased air pressure at the entrance of the malqaf caused by the wind. Once inside the space, the air slows down, flows through the room, rises into the upper part by convection, and escapes through the mashrabiya. Depending on the shape of the roof, dome or sloped, the outside wind blowing over the roof accelerates according to the Bernoulli principle, causing low pressure in the outside wind. Therefore, air from the inside escapes through the mashrabiya, and is continuously replaced by outside air (Fathy 1986, p.57-58). In addition, air movement by convection is also important because warm air in the central hall rises naturally to the upper part of the room. Since the upper part of the central hall is exposed to the sun, the upper air heats even more, and rises even faster into the upper part of the central hall, and thus escapes through its mashrabiya openings (Fathy 1986, p.58). This arrangement of openings provides circulation of air indoors even when the air outside is still. The location of the hall in the centre of the building protects it from the outside heat, and can ensure a considerable temperature difference between the lower and upper

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<sup>68</sup> See 2.2.2. Settlement, b. Wind Factor - Public Fountains, p.56.

<sup>69</sup> See 2.2.4. Element, a. Solar Factor - Thermal Mass, p.79.

<sup>70</sup> The idea of the malqaf dates back to the times of the ancient Egyptians and was used in the houses of Tal Al-Amarna. It was also represented in the wall paintings of the tombs of Thebes, like the tomb of Neb Amun which dates back to 1300 B.C. It has two openings, one on the windward side and the other on the leeward side, in order to evacuate the air by suction (Fathy 1986, p.58).

<sup>71</sup> Another form of a wind tower is called the badgir which is found in the areas of the Arabian Gulf. In such areas, the winds are variable, therefore the badgir is open from several directions (Johnson 1995, p.14).

parts of the central hall resulting in air circulation (Fathy 1986, p.58). The same process can be achieved when the central hall is replaced by an open courtyard and the air rises by convection.

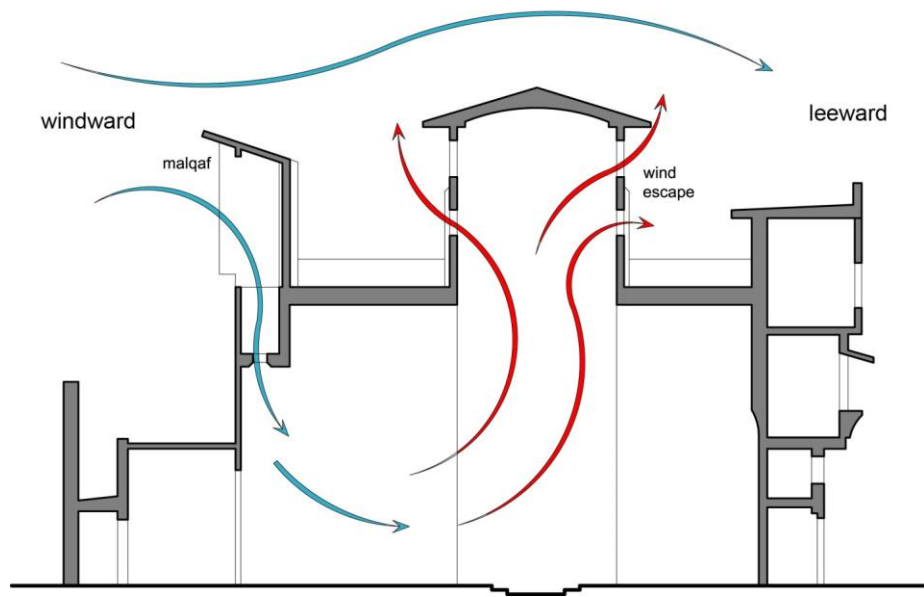


Figure (2.41) Air Circulation in a Space with a Malqaf and Wind Escape  
Source: (Fathy 1986, p.117).

The size of a malqaf is determined by the external air temperature. When the temperature at the intake is low, a larger size is required, and vice versa, when the air temperature at the intake is higher than the limit for thermal comfort, a smaller size is required for the malqaf. In the latter situation, the air flowing through the malqaf is cooled before it enters the interior by the process of evaporation (Fathy 1986, p.59). This can be done by hanging wet mats to cool the wind flowing into the interior.

### **c. Comparative Analysis Matrix**

Each design tool in the ELEMENT chapter is evaluated with a number of points depending on its importance in its contribution to achieving thermal comfort and consequent energy savings. This score is divided into 50% for the sun factor and 50% for the wind factor. This rating was based on Matrix (2.1)<sup>72</sup>

#### **1. Windows**

Windows are an important tool contributing to the energy savings in the dwelling. According to the sun factor, the location and size of windows have a significant effect on the amount of heat gain and loss. As for the wind factor, the size and location also have a significant effect on the ventilation of the dwelling. Therefore, this tool was given a “very high influence” rating.

#### **2. Mashrabiya**

Due to the many functions of the Mashrabiya, its existence in many rooms of the dwelling results in a significant effect on the thermal comfort of the rooms both in terms of the sun and wind. Therefore, it was given a “high influence” and not “very high influence” because it can only be found on the exterior of the dwelling where possible (not many in dense urban fabrics).

#### **3. Vegetation**

Vegetation as an element in a courtyard which contributes significantly to the energy savings as a shading and cooling element and as a wind barrier in the courtyard. Therefore, it was given a “very high influence” rating.

#### **4. Water Features**

Water features throughout the house in the form of fountains and maziaras have an effect on the humidity levels and cool the air passing over it. Since it is an element which aids other main elements in thermal comfort, it is considered a tool with a “medium influence” on energy savings.

#### **5. Thermal Mass**

Thermal mass has a significant effect on energy savings. Thick walls made of high storage capacity materials delay the transfer of heat into the buildings and create cave-like interiors in summer. Vice versa, thermal mass also stores heat and releases it to create warm interiors in winter. It was given a “very high influence” rating.

#### **6. Malqaf**

The malqaf has a significant effect on the ventilation of a dwelling, making it an important tool in energy savings. Therefore, it was given a “very high influence” rating. It is applicable only for the wind factor.

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<sup>72</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, Matrix (2.1) Evaluation according to Influence on Energy Savings, p.42.

<b>Element (EL)</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>
<b>EL 1. Windows</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>EL 2. Mashrabiya</b>	<b>12</b>	<b>6</b>	<b>6</b>
<b>EL 3. Courtyard Vegetation</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>EL 4. Water Features</b>	<b>8</b>	<b>4</b>	<b>4</b>
<b>EL 5. Thermal Mass</b>	<b>16</b>	<b>8</b>	<b>8</b>
<b>EL 6. Malqaf</b>	<b>12</b>	<b>N/A</b>	<b>6</b>
<b>Total for DW Category: 74 (total - N/A elements)</b>			

Matrix (2.5) Evaluation of Tools in the ELEMENT Category

After categorizing the tools according to their positive effect on the climate and energy savings in the general analysis of SITE, SETTLEMENT, DWELLING, ELEMENT, Chapter 3 and 4 display four case studies where each tool is given an evaluation for its existing performance. This score is a percentage out of the original evaluation given in chapter 2.

# 3

## **Mediterranean Vernacular: Site...Settlement...Dwelling...Element**

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*“whitewash exists wherever peoples have preserved intact the balanced structure of a harmonious culture... In the course of my travels I found whitewash wherever the twentieth century had not yet arrived” (Le Corbusier 1925, p.189).*



## Introduction: Case Studies

This chapter analyses two case studies:

**1.** Sidi Bou Said, Tunisia is a village in the northern suburbs of Tunis, situated on a promontory at an altitude of 129 meters on the sea coast (figure 3.1). It is a well preserved vernacular city and a very popular destination for tourism. This typical structure is characterized by density, narrow winding streets and courtyard houses dominating the urban fabric. These characteristics contribute to the thermal comfort of the village and the dwellings due to the passive design methods which result from the urban and architectural design of the village.

**2.** The Casbah of Algiers is the traditional quarter of Algiers in the north-central portion of Algeria. It is built on a hill with the slope facing the Mediterranean Sea (figure 3.1). It has a dense urban fabric and still retains its original aspect. It had a great influence on the architecture and town planning of North Africa. It shares similar urban and architectural design aspects as Sidi Bou Said which result in passive design strategies and elements.



Figure (3.1) Location of 1. Sidi Bou Said and 2. Algiers

Source: Google Maps

### 3.1. Sidi Bou Said, Tunisia

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Figure (3.2) Areal Photo of Sidi Bou Said, Tunisia  
Source: Google maps



Figure (3.3) View of the Village of Sidi Bou Said  
Source: Agha Khan Development Network<sup>73</sup>

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<sup>73</sup> <https://www.akdn.org/architecture/project/conservation-sidi-bou-sa%C3%AFd>

## Urban Development

Presence of people on the site of Sidi Bou Said can be proved by archeological evidence from the 5<sup>th</sup> century B.C. As a capital during the Roman times, Carthage was a prosperous trading nation with influence throughout the Mediterranean. After the Islamic conquest in 703, Tunisia took the name of Ifriqiya and the capital was moved from Carthage to Kairouan. Under the ruling of the Aghlabids, in 800 and the following hundred years, it became culturally active in the fields of scholarship, religion and the arts and the two great mosques of Tunis and Kairouan were built (Hakim 2009, p.11). To protect this prosperous trade against a sea attack, the Aghlabids built a series of fortifications (ribat) along the African shore, with a part on the promontory of Cape Carthage (which is now Sidi Bou Said) and a lighthouse. During the time of the Fatimids, many internal conflicts resulted in the destruction of the waterworks, olive groves, vineyards and urban settlements dating back to the Roman times. During the Hafsid Era, the ribat of Sidi Bou Said were transformed from a military function to a religious one. Although there was no urban agglomeration at this time, there was a cemetery and simple shelters used as hotels. Sufism developed in Morocco by the Almohad and rapidly spread into Algeria and Ifriqiya (Hakim 2009, p.12). One of the Sufic leaders was Abou Said who chose the promontory overlooking the sea as his retreat for teaching, praying and meditating<sup>74</sup>. The country fell into the Spanish anarchy in the 15<sup>th</sup> century until the Turkish conquest in the 16<sup>th</sup> century. In the early 17<sup>th</sup> century, Sidi Bou Said started to take its present form due to the increasing frequency of pilgrimages to the tomb of the saint, allowing hawkers to build stalls at the site of the present souq. Other residents were the families of the readers of the Quran, the conductor of prayers and the teachers who gathered around the mausoleum. In the 18<sup>th</sup> century, during the Husaynid Dynasty, the mosque of Abou Said and the mausoleum were restored and additions were built. In the 19<sup>th</sup> century, around the time of the French protectorate in 1881, the village became more and more a retreat for the rich and high officials of the court. New construction crowded around the mosque for protection of the saint. Large blocks were built for the princes and smaller summer residences were built by the wealthy upper class of Tunis making Sidi Bou Said a summer resort until the end of the Second World War (figure 3.4) (Hakim 2009, p.14).

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<sup>74</sup> It is from Abou Said that Sidi Bou Said gets its present name. He died there in 1231 and was buried near the lighthouse which then became a retreat for his followers who consider him a great saint.



Figure (3.4)  
Source: (Hakim 2009, p.15)

In 1915, a decree was designed to preserve the village's beauty and provide guidelines for alterations of existing buildings and the erection of new ones<sup>75</sup>. Since 1960, the village experienced a dramatic rise in tourism and a large increase in the number of foreign residents (Hakim 2009, p.16).

<sup>75</sup> This was done by influence from a retired British banker and resident of Sidi Bou Said who appreciated the built form and character of the village.



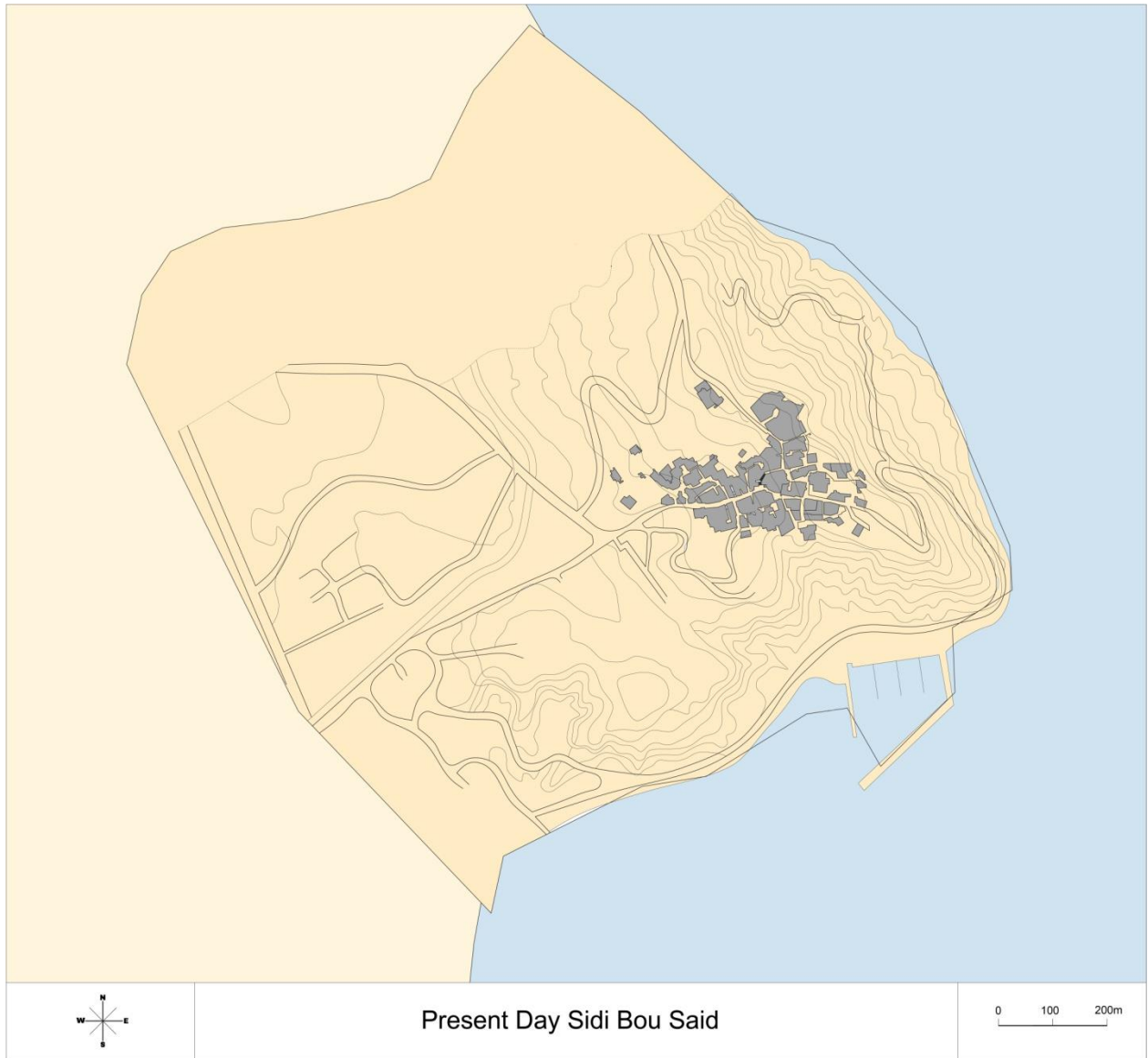


Figure (3.5)  
Source: (Hakim 2009, p.8)

### 3.1.1. SITE: The Climatic Characteristics of the Site of Sidi Bou Said

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#### A. General Climate

Latitude: 36 52N

Longitude: 010 21E

Sidi Bou Said is classified under the Köppen Climate Classification as a "dry-summer subtropical" climate which is often referred to as "Mediterranean" (C). The subtype is Csa which is "hot, dry summer"<sup>76</sup>.

This climate zone has relatively mild winters and hot summers. The precipitation in the driest month of summer is less than 30 mm and less than 90 mm wettest month of the winter. The temperature of warmest month is 22 °C or above<sup>77</sup>.

In Sidi Bou Said, the warmest month, on average, is August with an average temperature of 26.6°C and the coolest month on average is February, with an average temperature 11°C<sup>78</sup>.

The maximum sun angle at noon is 28° in winter and 75° in summer. The highest exposure to the sun is from the South, Southwest and West and the lowest exposure to the sun is from the Northeast. The prevailing winds in winter from October to March are moderate to strong winds from the West to the Northwest. In the summer from April to September, the prevailing winds are moderate from the Northeast (Hakim 2009, p.4).

#### B. The Effect of Different Elements on the Climate of Sidi Bou Said

##### a. SOLAR FACTOR

- **Topography**

The village of Sidi Bou Said is perched on a promontory facing the Mediterranean Sea from the East and South. Since prehistory, this promontory has been modified as a result of the erosive forces of the wind, rain and sea. Erosions have cut its cliffs, which caused landslides into the sea. The promontory is inaccessible to the east and south where the cliffs drop steeply towards the sea-coast (figure 3.6). (Hakim 2009, p.3).

The village of Sidi Bou Said benefits from the low altitude sun in winter on its south facing slope affecting the buildings which are located on this slope and the vegetation (figure 3.7). However, the amount of solar exposure for the buildings can be determined when considering the angle of the slope, the height of the buildings and the width of the street. According to figure (2.2)<sup>79</sup>, when the angle of the slope is approximately 8° as in the case of Sidi Bou Said, the Spacing to Height ratio should be 2.2 for good solar access. This is not achieved in most of the streets due to the narrow street structure of this vernacular city (figure 3.8).

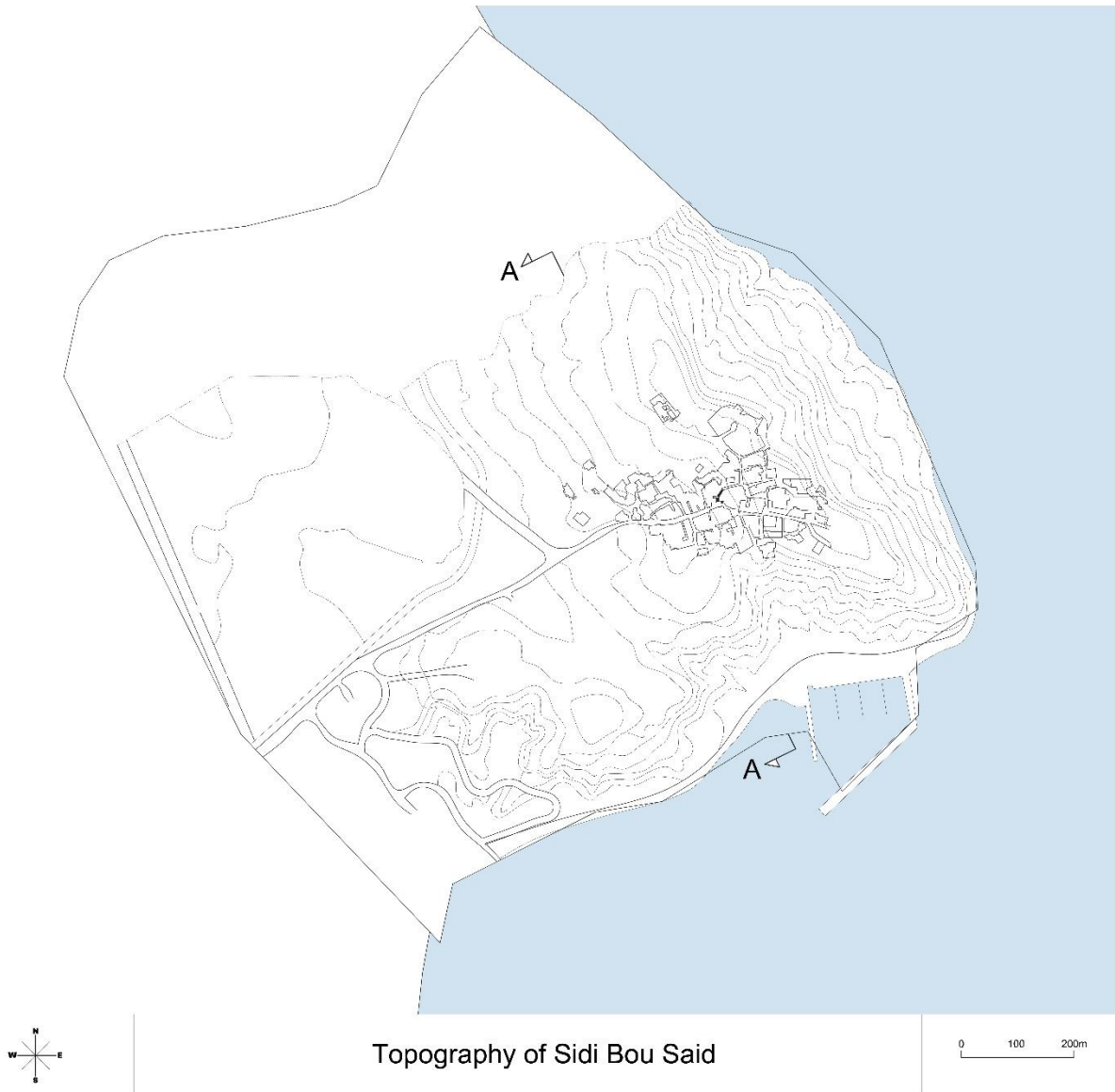
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<sup>76</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=605805&cityname=Sidi+Bou+Said%2C+Tunis%2C+Tunisia&units=>

<sup>77</sup> <https://www.britannica.com/science/Mediterranean-climate#ref1092481>

<sup>78</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=605805&cityname=Sidi+Bou+Said%2C+Tunis%2C+Tunisia&units=>

<sup>79</sup> See 2.2.1. Site, a. Solar Factor – Topography, p.36.



Topography of Sidi Bou Said

Figure (3.6)  
Source: (Hakim 2009, p.8)

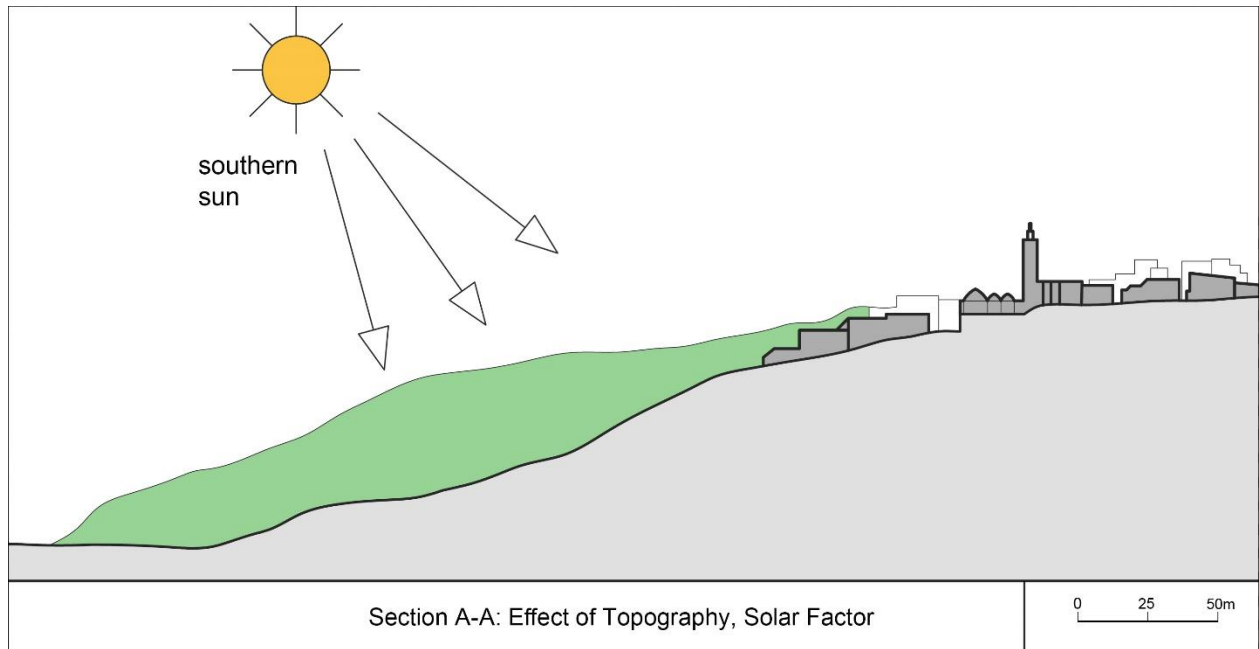


Figure (3.7)  
Source: (Hakim 2009, p.4)

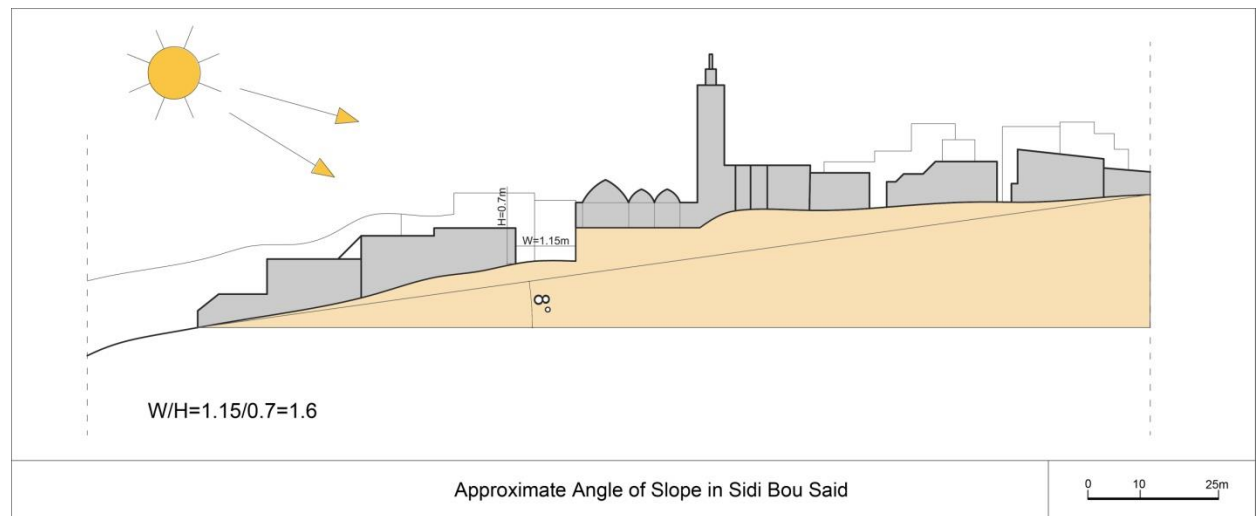


Figure (3.8)  
Source: (Hakim 2009, p.4)



- **Vegetation**

The hills surrounding the village of Sidi Bou Said are covered with rich vegetation including pine and oak trees surrounding the village from three sides (figure 3.9). The climate of Sidi Bou Said is affected by this vegetation due to its characteristics. The albedo of the pinus species is about 9%, which is less than that of other species resulting in more absorption of sunlight which consequently increases humidity and reduces air temperature. When comparing this type of vegetation to grassland, it absorbs more sunlight resulting in more evaporation<sup>80</sup> (figure 3.10).

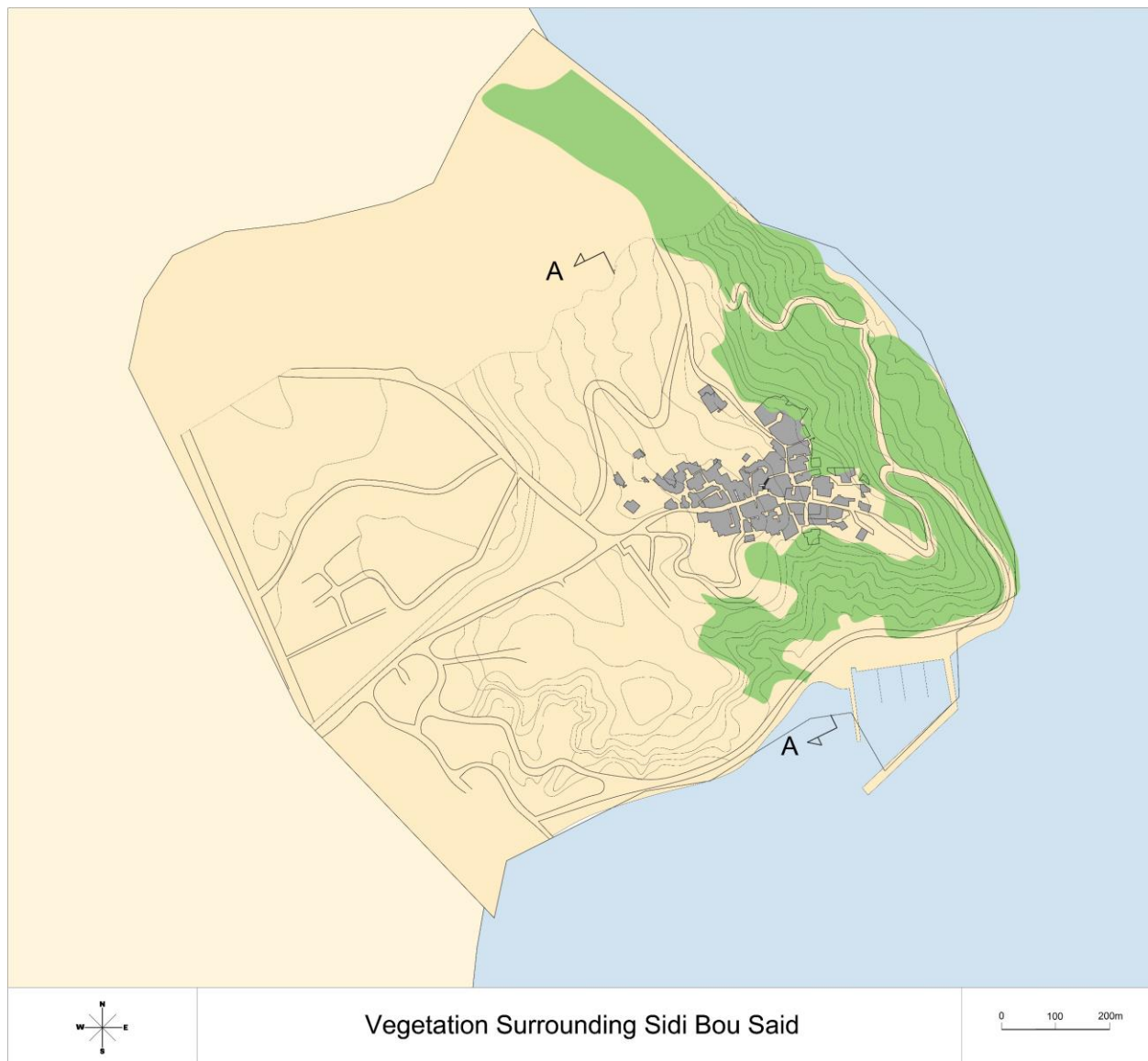
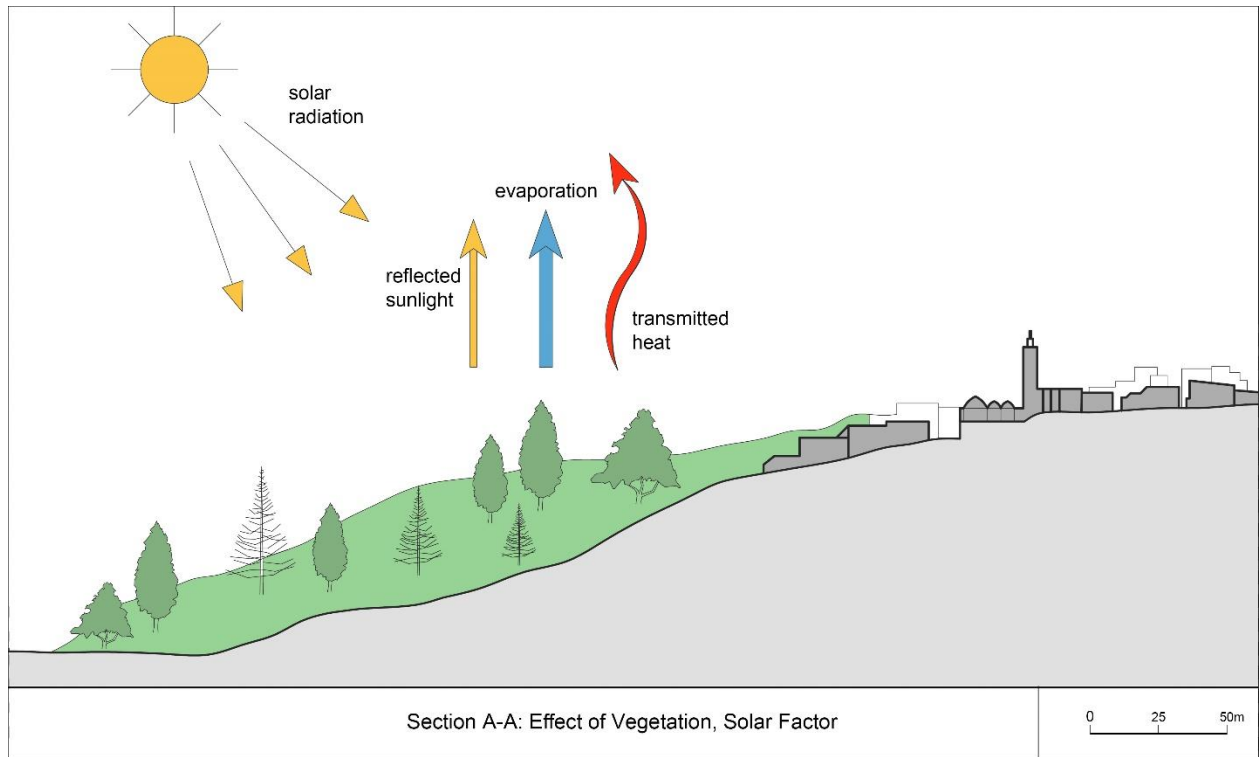


Figure (3.9)  
Source: (Hakim 2009, p.8) and (Google Maps)

<sup>80</sup> See 2.2.1. Site, a. Solar Factor -Vegetation, pg.37.



Section A-A: Effect of Vegetation, Solar Factor

0 25 50m

Figure (3.10)  
Source: (Hakim 2009, p.4)

- **Water Bodies**

Sidi Bou Said is surrounded by water from the northeast and southeast. The existence of the Mediterranean Sea plays a very important role in the climate of Sidi Bou Said. Sidi Bou Said has a warm climate due to the large heat capacity of large water bodies<sup>81</sup> (figure 3.11).



Water Surrounding Sidi Bou Said

Figure (3.11)

Source: (Hakim 2009, p.8)

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<sup>81</sup> See 2.2.1. Site, a. Solar Factor –Water Bodies, pg.38.

## b. WIND FACTOR

### • Topography

As a result of the topography of Sidi Bou Said, the warm humid air coming from the sea creates a humid atmosphere on the seaward side and dry conditions on the leeward side<sup>82</sup>. This effect modifies the climate of Sidi Bou Said and consequently the type of vegetation. This explains the dense vegetation on the seaward side of the village (figure 3.13).

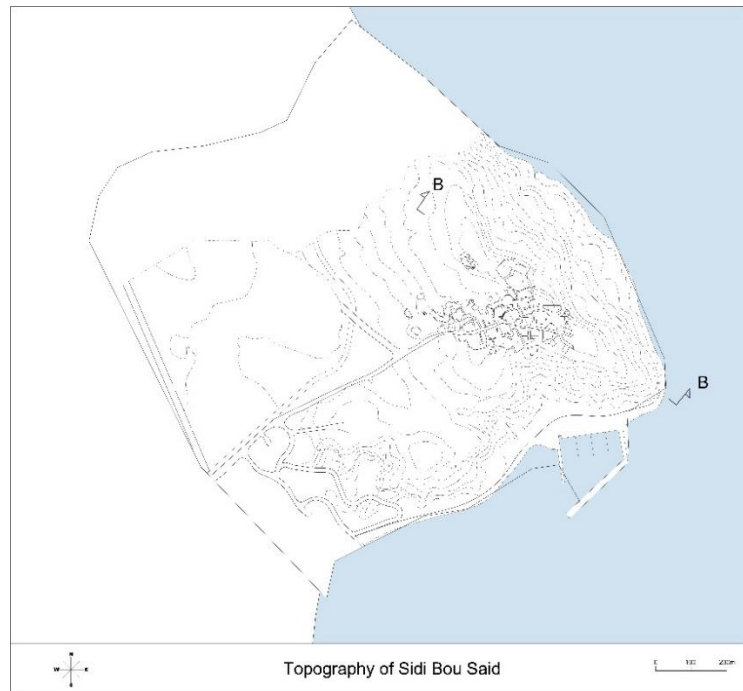


Figure (3.12)

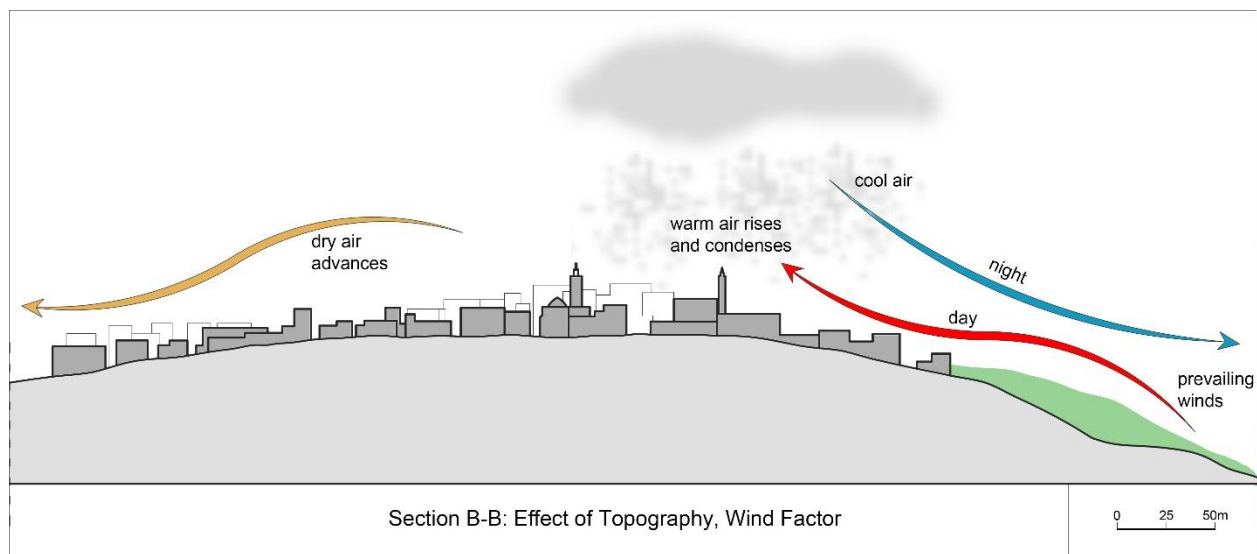


Figure (3.13)

Source: (Hakim 2009, p.4)

<sup>82</sup> See 2.2.1. Site, b. Wind Factor - Topography, pg.39.

- **Vegetation**

The trees surrounding Sidi Bou Said act as barrier which reduces the wind velocity coming from the sea. They create minor turbulence and calm zones close to the buildings<sup>83</sup> (figure 3.15). However, the lack of trees on the northwest side of the village, gives it no protection from the strong winter winds.

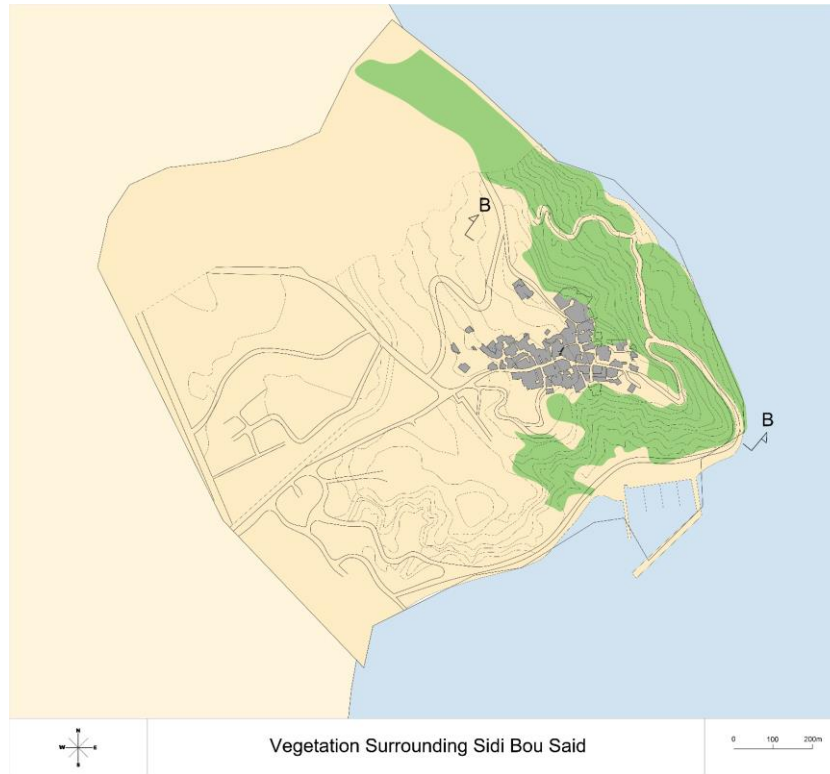


Figure (3.14)  
Source: (Hakim 2009, p.8)

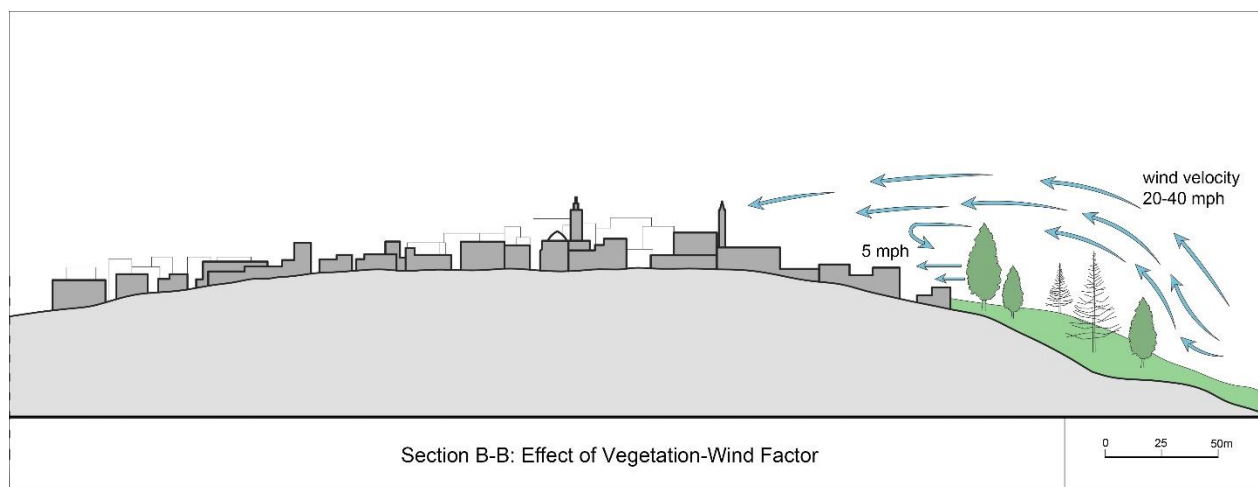


Figure (3.15)  
Source: (Hakim 2009, p.4)

<sup>83</sup> See 2.2.1. Site, a. Wind Factor -Vegetation, pg.39.

- **Water Bodies**

In the hot summer of Sidi Bou Said, the Mediterranean sea creates the sea breeze effect when the air flows twice a day from the sea to the land and back again, causing a more comfortable microclimate<sup>84</sup> (figure 3.17).



Figure (3.16)

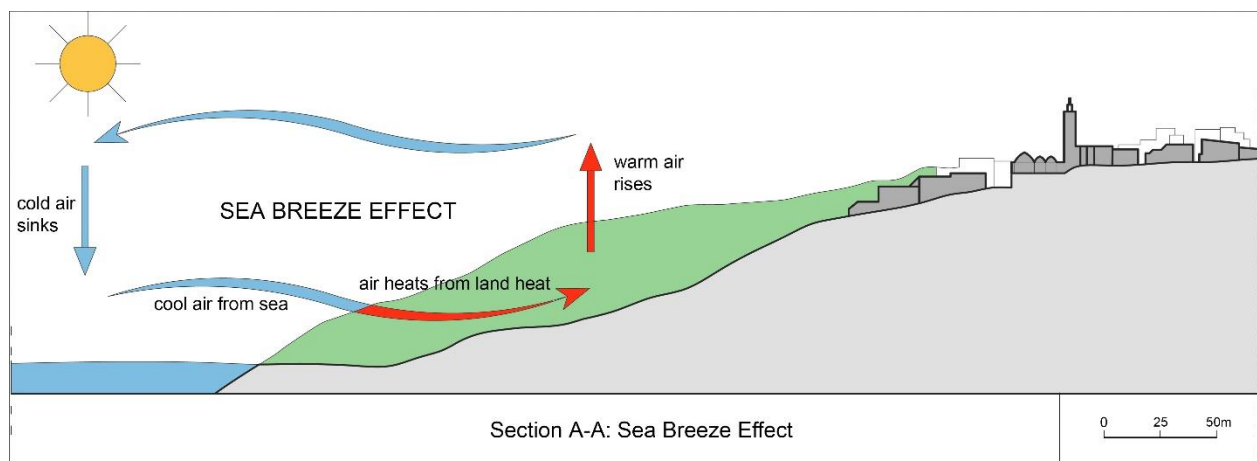


Figure (3.17)

Source: (Hakim 2009, p.4)

<sup>84</sup> See 2.2.1. Site, a. Wind Factor –Water Bodies, pg.40.

### c. Comparative Analysis Matrix

The following evaluation is the result of analysing the SITE of Sidi Bou Said. Each tool was evaluated for its performance in this case study and given a score out of the amount given for each tool in the chapter 2 general analysis<sup>85</sup>. The score was based on the following:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (3.1) Evaluation for Existing Situation of Tools (EE)

#### 1. Topography

The southern facing slope in Sidi Bou Said does give it benefit to the winter sun, however, the angle along with the spacing between the buildings is not the ideal situation for maximum benefit. Therefore, the sun factor was given a “good” rating.

The wind flow due to the slope has a positive effect, however since the settlement is at the top of the slope, it does not benefit from the cool air which flows to the bottom at night. The wind factor was given an “average” rating.

#### 2. Vegetation

According to the Sun Factor, the large amount of vegetation surrounding the city of Sidi Bou Said affects the climate positively giving it a “very good” rating.

According to the Wind Factor, the trees provide a barrier to the undesirable winds only from one side. That is why it was given a “good” rating.

#### 3. Water Bodies

The Mediterranean Sea has a significant effect on the climate of Sidi Bou Said from both the sun and wind factor giving it a “very good” rating.

\*EE =Existing Evaluation

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<sup>85</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, p.42.

<b>Site (SI) – SIDI BOU SAID</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SI 1. Topography</b>	12	6	6	75%	50%	7.5
<b>SI 2. Vegetation</b>	16	8	8	100%	75%	14
<b>SI 3. Water Bodies</b>	16	8	8	100%	100%	16
<b>Total for SI Category: 44      Final Points for SI – Sidi Bou Said: 37.5</b>						

Matrix (3.2) Sidi Bou Said SITE Evaluation



### 3.1.2.SETTLEMENT: Urban Structure and Density: The Traditional Compact City of Sidi Bou Said

---

#### a. SOLAR FACTOR

- **Compact Geometry**

Sidi Bou Said is characterized by a dense urban structure where most blocks consist of multiple houses (figure 3.18). In the plan of the village, very few of the houses are single and are located in the outside part of the village. They are also the ones added at a later date (after 1928). (figure 3.19).



Figure (3.18)  
Source: (Ben-Achour 1973, p.188)

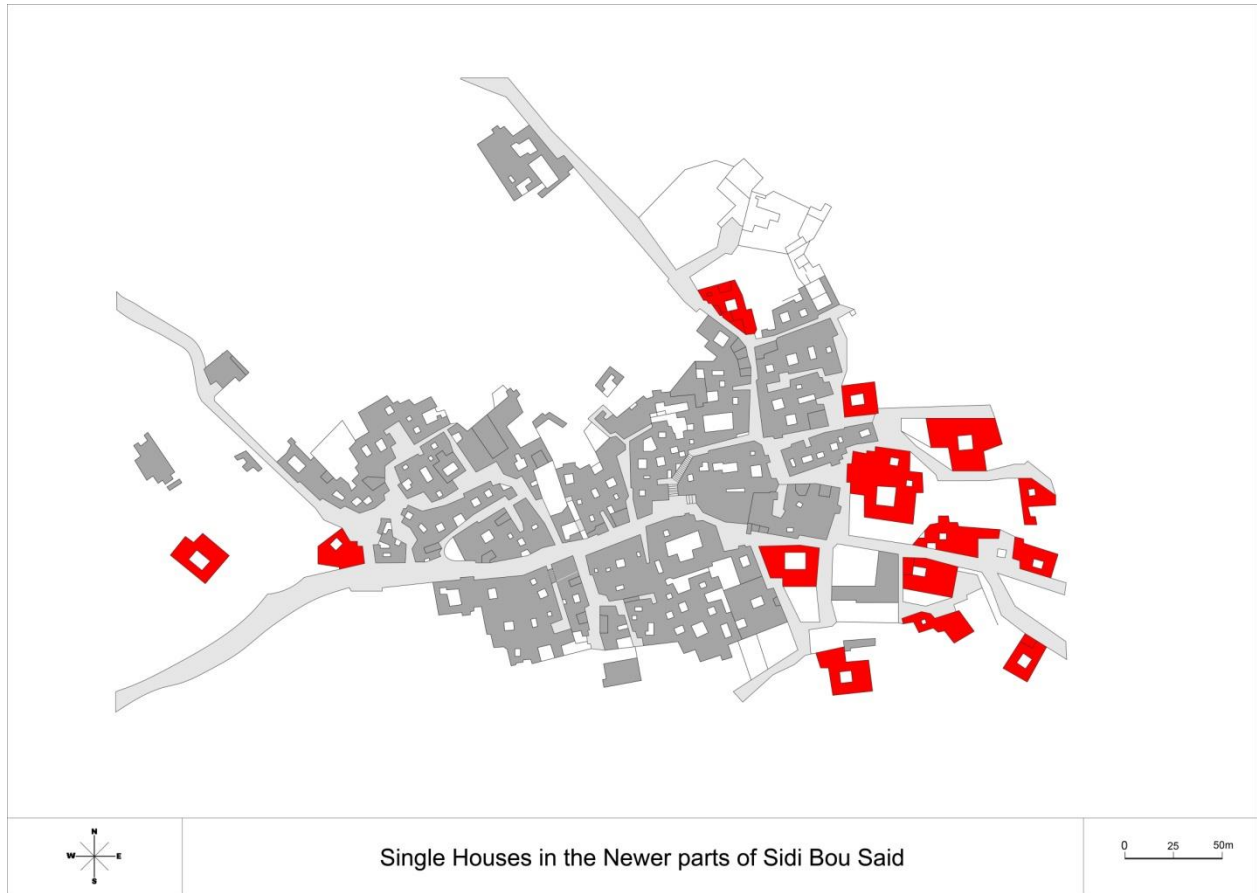


Figure (3.19)  
Source: (Hakim 2009, p.15)

Since this compact geometry reduces the surface to volume ratio, the exchange of heat and cold is reduced. When comparing the surface to volume ratio of a single house in Sidi Bou Said to a block of multiple houses, the one with the lesser amount is the one with the reduced heat gain and loss<sup>86</sup> (figure 3.21).

<sup>86</sup> See 2.2.2. Settlement, a. Solar Factor - Compact Geometry, pg.44.



Figure (3.20)

Source: (Ben-Achour 1973, p.188)

In Block 1, the surface to volume ratio is  $1141\text{m}^2/3226\text{m}^3=0.35$

In Block 2, the surface to volume ratio is  $1583\text{m}^2/4917\text{m}^3=0.32$

In Block 3, the surface to volume ratio is  $4169\text{m}^2/17208\text{m}^3=0.24$  (figure 3.21)

We can see that the larger the block, the smaller value of the S/V ratio, and the less heat loss and heat gain, making compact multi unit blocks more sustainable than single houses. This is because the multiple houses in these blocks share up to four walls, which limits the exposure to the sun to one roof in the internal houses and one wall and one roof in the external houses (figure 3.22).

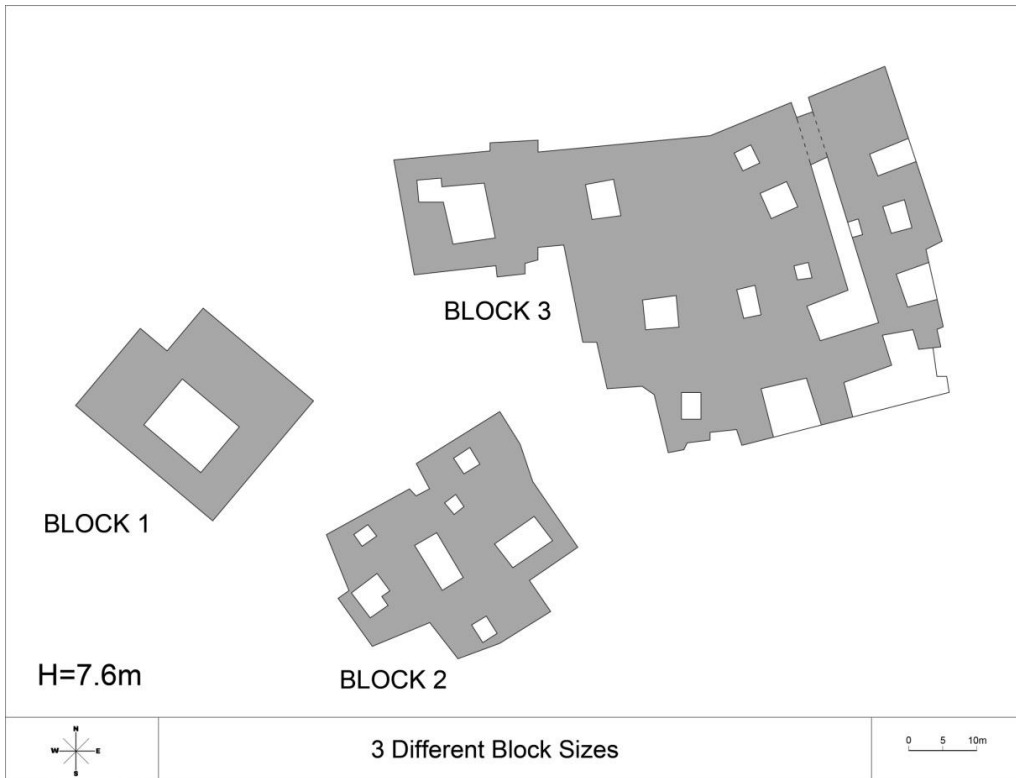


Figure (3.21)



Figure (3.22)

Source: (Ben-Achour 1973, p.189)

- **Block Orientation**

The blocks of the settlement of Sidi Bou Said are irregular and have no real orientation or W/L proportion. However, it can be noticed that the village of Sidi Bou Said is orientated on an east-west axis (figure 3.23), which resulted in many of the blocks have the longer side facing south, making more houses benefit from the southern sun<sup>87</sup>.

- **Street Orientation**

The east-west orientation of the settlement is a result of the east-west orientation of the main street (figure 3.23). According to the POLIS studies, this orientation results in the solar penetration of the main street for most of the day<sup>88</sup>. The streets orientated north-south results in solar exposure from the east and west. This is a disadvantage in summer but can be shaded due to the narrow streets as mentioned in the following section.

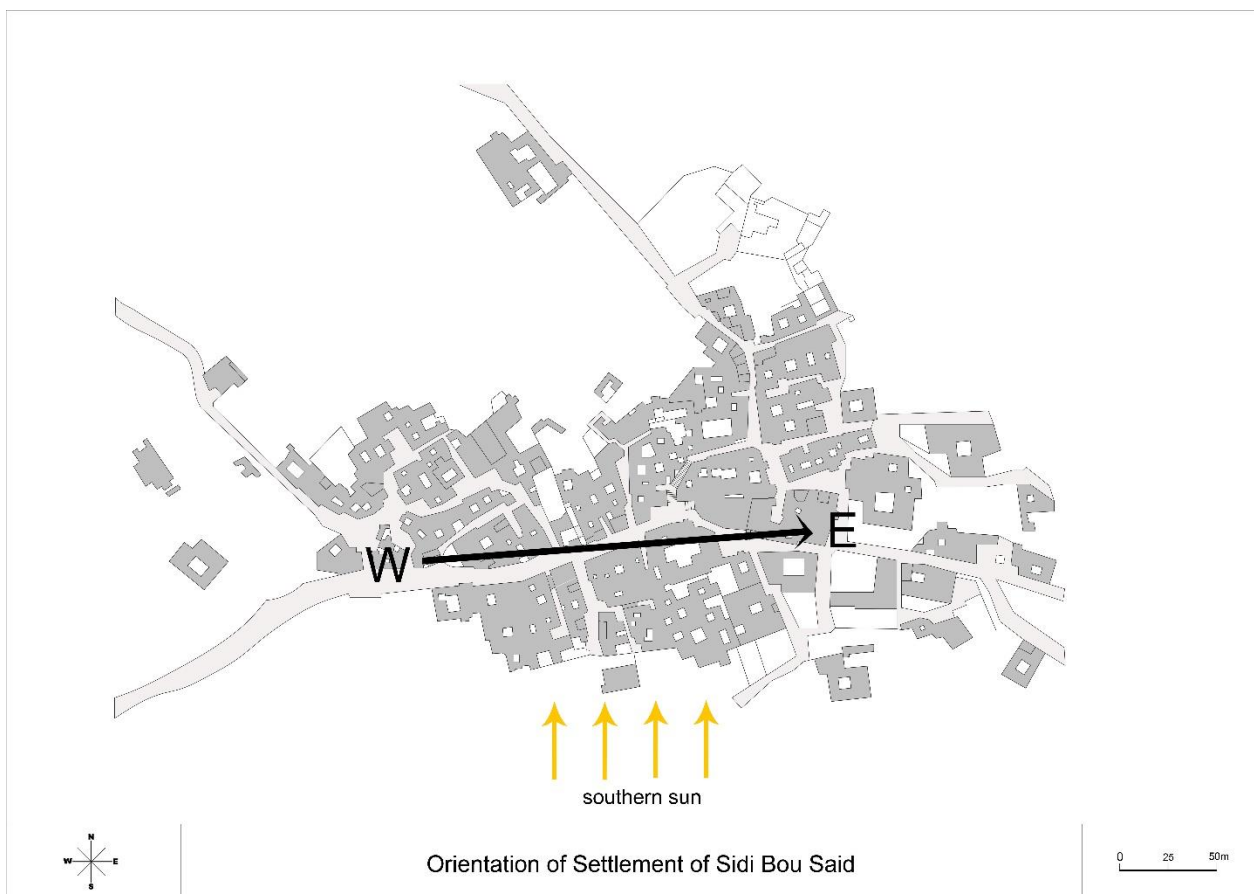


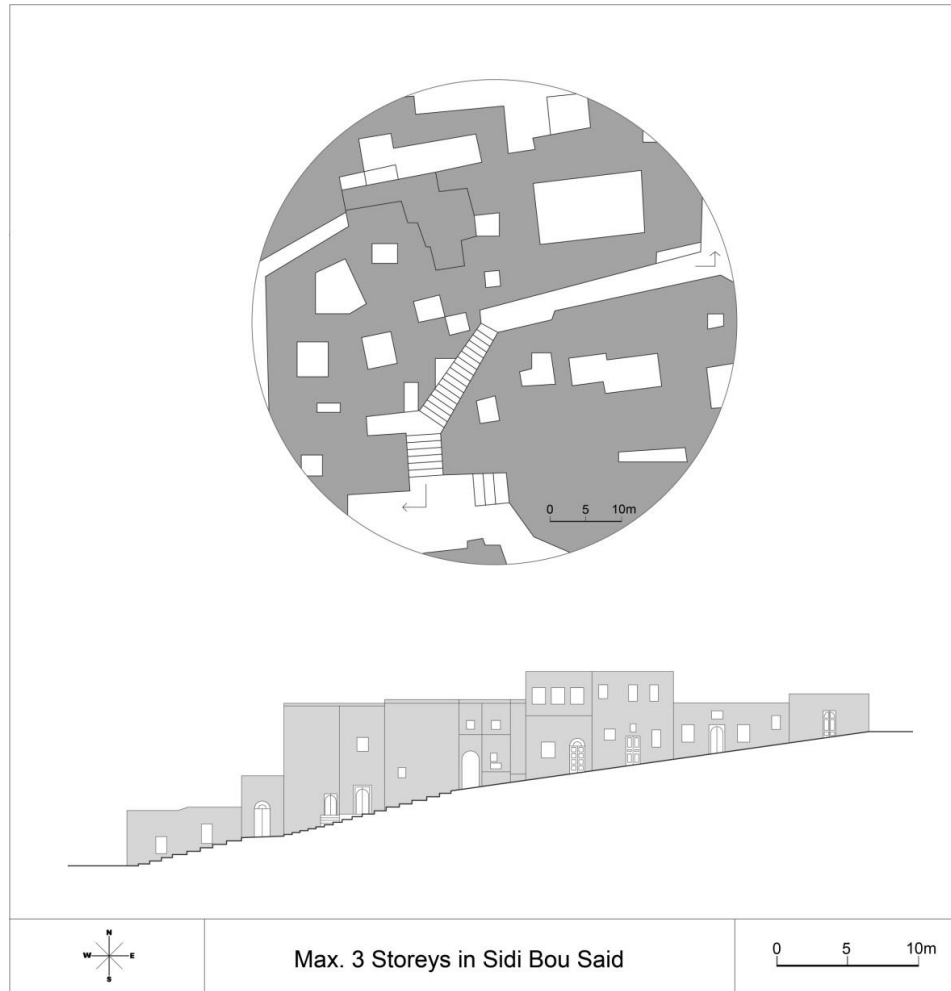
Figure (3.23)  
Source: (Ben-Achour 1973, p.188)

<sup>87</sup> See 2.2.2. Settlement, a. Solar Factor – Block Orientation, p.45.

<sup>88</sup> See 2.2.2. Settlement, a. Solar Factor – Street Orientation, p.46.

- **Narrow Streets**

When the streets are irregular in a vernacular village like Sidi Bou Said, some may have the optimum orientation and some may not, therefore, shading is the best way to protect the buildings and streets from extreme solar gain. The narrow streets and two storey houses (max. three storeys) makes them benefit from shade significantly (figure 3.24).



Max. 3 Storeys in Sidi Bou Said

Figure (3.24)

Source: (Hakim 2009, p.28)

The amount of shade can be determined when the dimensions and angle of the sun are known. The **Lateral Distance of Shade** can be calculated from the equation<sup>89</sup>: (figure 3.25)

$$L = H \times \text{COT} \Theta$$

**Summer:**

$$L = 6.6 \times .27 = 1.78\text{m}$$

**Winter:**

$$L = 6.6 \times 1.88 = 12.4\text{m}$$

**L:** Lateral Distance of shade on street surface

**H:** Height of building

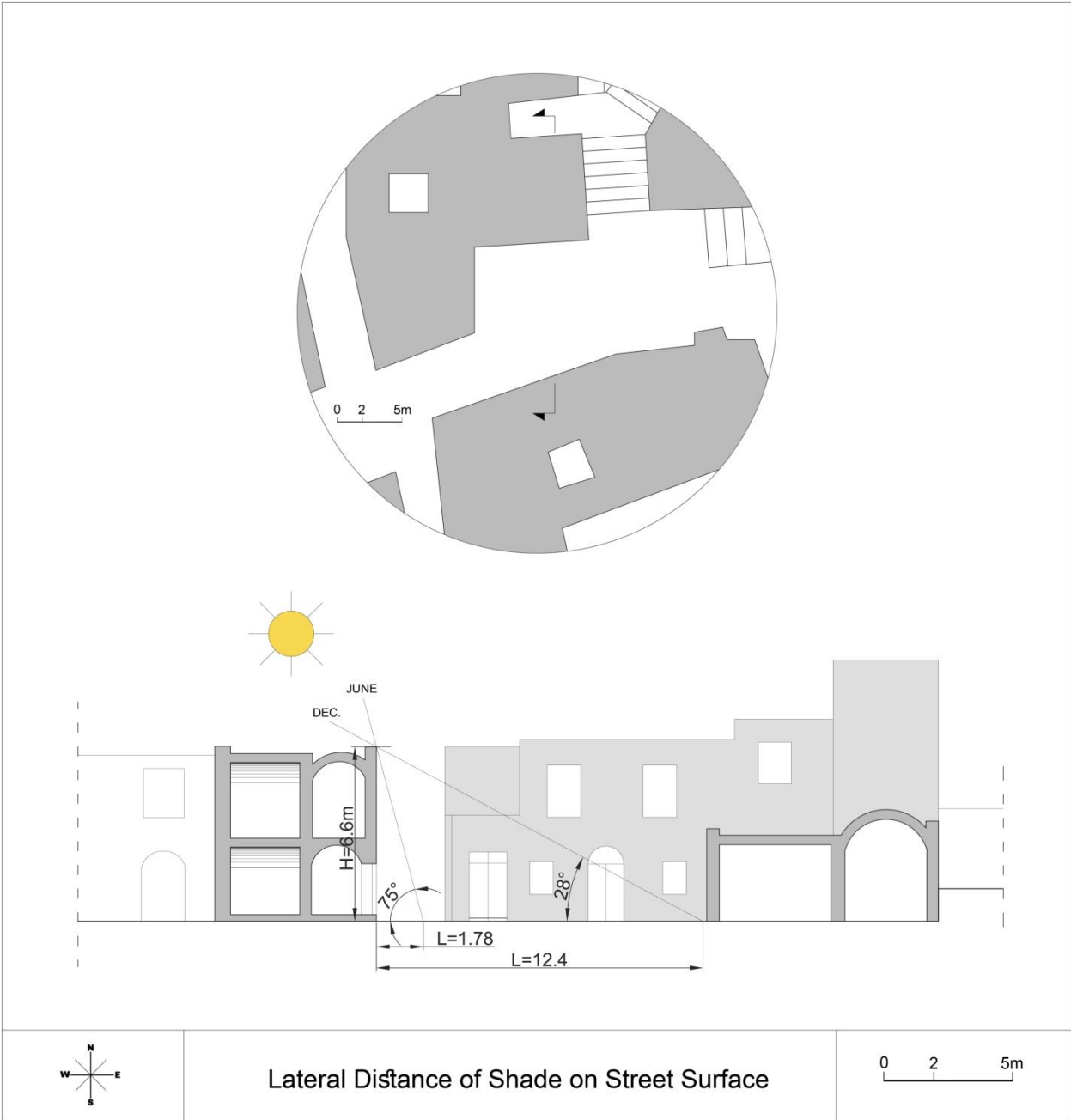
$\Theta = 75^\circ$  (Summer Solstice in Sidi Bou Said)

$\Theta = 28^\circ$  (Winter Solstice in Sidi Bou Said)

$\text{Cot } 75^\circ = .27$

$\text{Cot } 28^\circ = 1.88$

<sup>89</sup> See 2.2.2. Settlement, a. Solar Factor – Narrow Streets, pg.47.



Lateral Distance of Shade on Street Surface

Figure (3.25)

Source: (Hakim 2009, p.111)

- **Open Spaces**

The irregular form and direction of the streets of Sidi Bou Said resulted in the formation of open spaces. In addition to the need for an entrance to a house or shop which lead to the formation of a space along the street (figure 3.26).

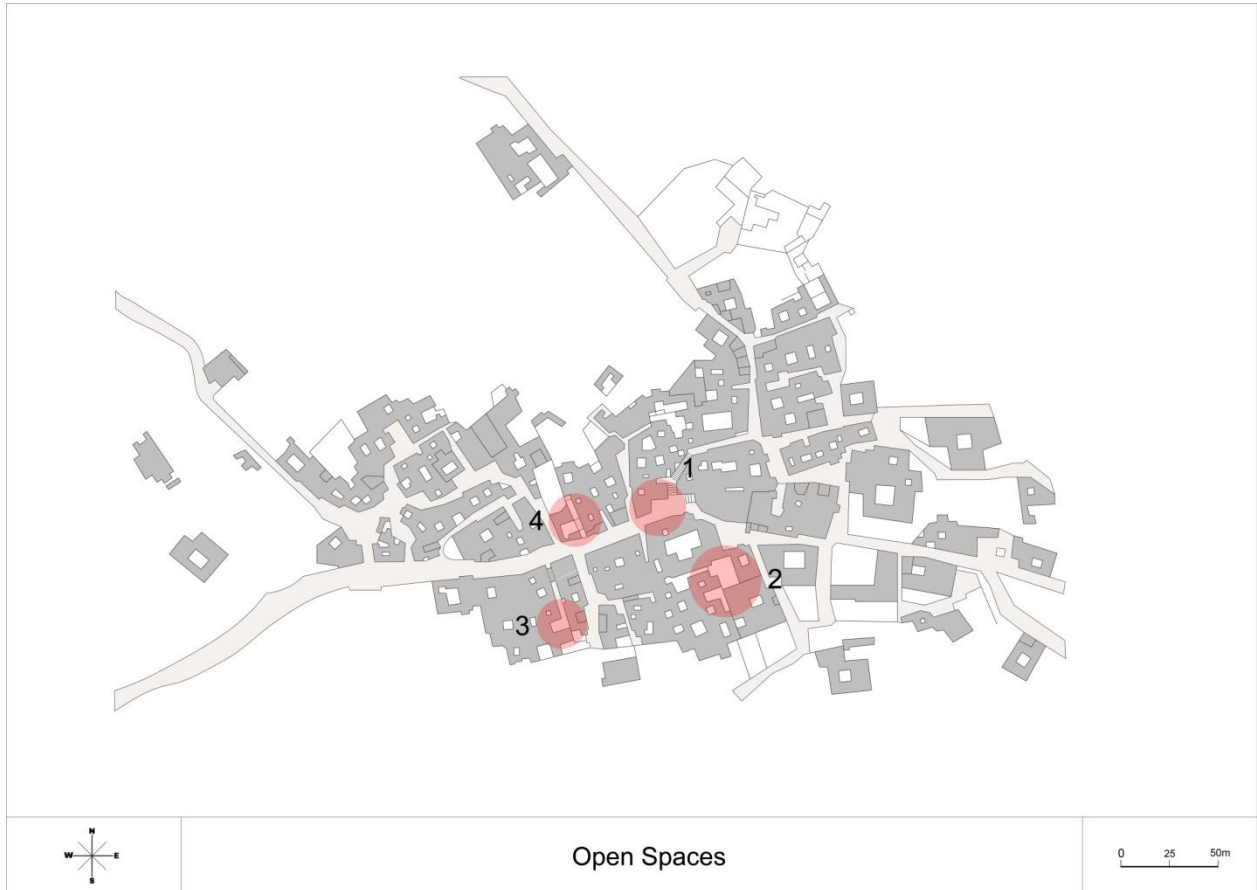


Figure (3.26)

Source: (Ben-Achour 1973, p.188)



### Open Space 1: Irregular Open Space

In Sidi Bou Said, one of the irregular open spaces was transformed into an outdoor café. It is orientated towards the south making it benefit from the winter sun and shaded from the summer sun during sunset by the two storey building from the west (figure 3.27).

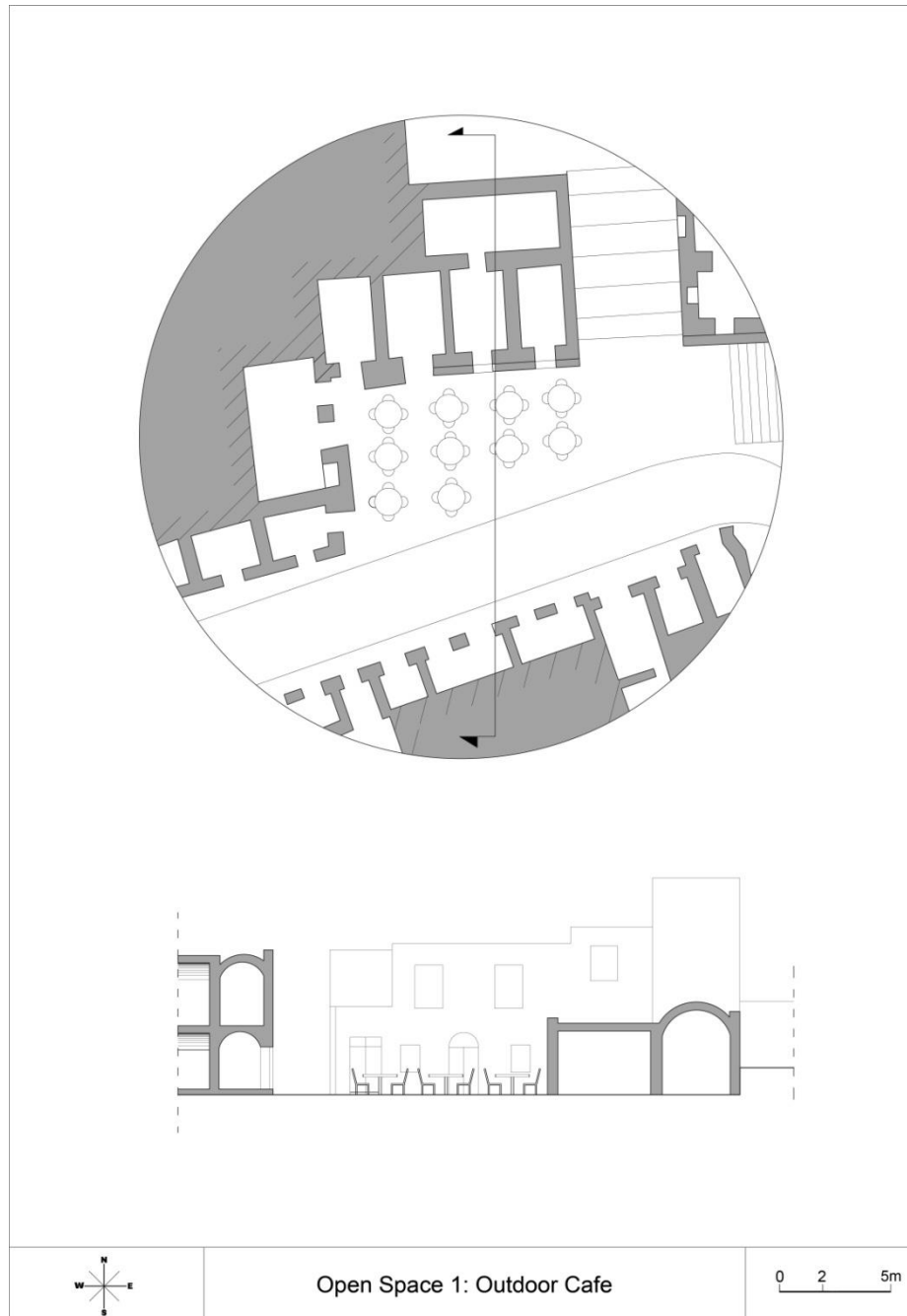


Figure (3.27)

Source: (Hakim 2009, p.110-111)

### Open Space 2: Semi-Private Courtyard

In Sidi Bou Said, Impasse Thameur is a plaza outside one of the oldest houses in Sidi Bou Said. It is entered through a portal which leads off the main street and is considered a semi-public space used today as a shaded outdoor playground. The second smaller plaza has a more intimate semi-private atmosphere and leads to two other house entrances (figure 3.28).

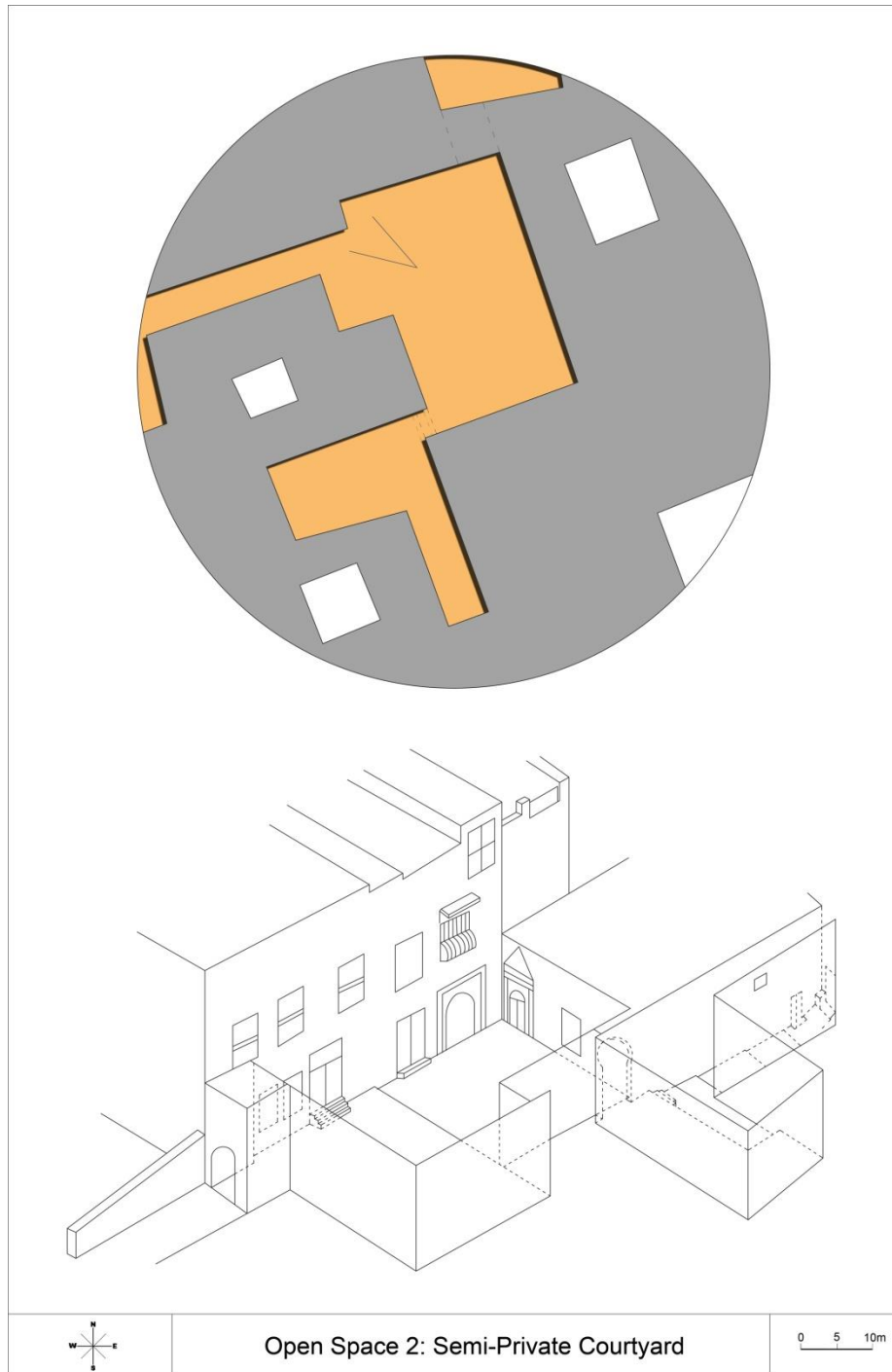


Figure (3.28)  
Source (Hakim 2009, p.40)

### Open Space 3: Cul de Sac

The dense urban structure of Sidi Bou Said results in many cul de sacs which act as shaded semi-private spaces for the neighbours (figure 3.29).

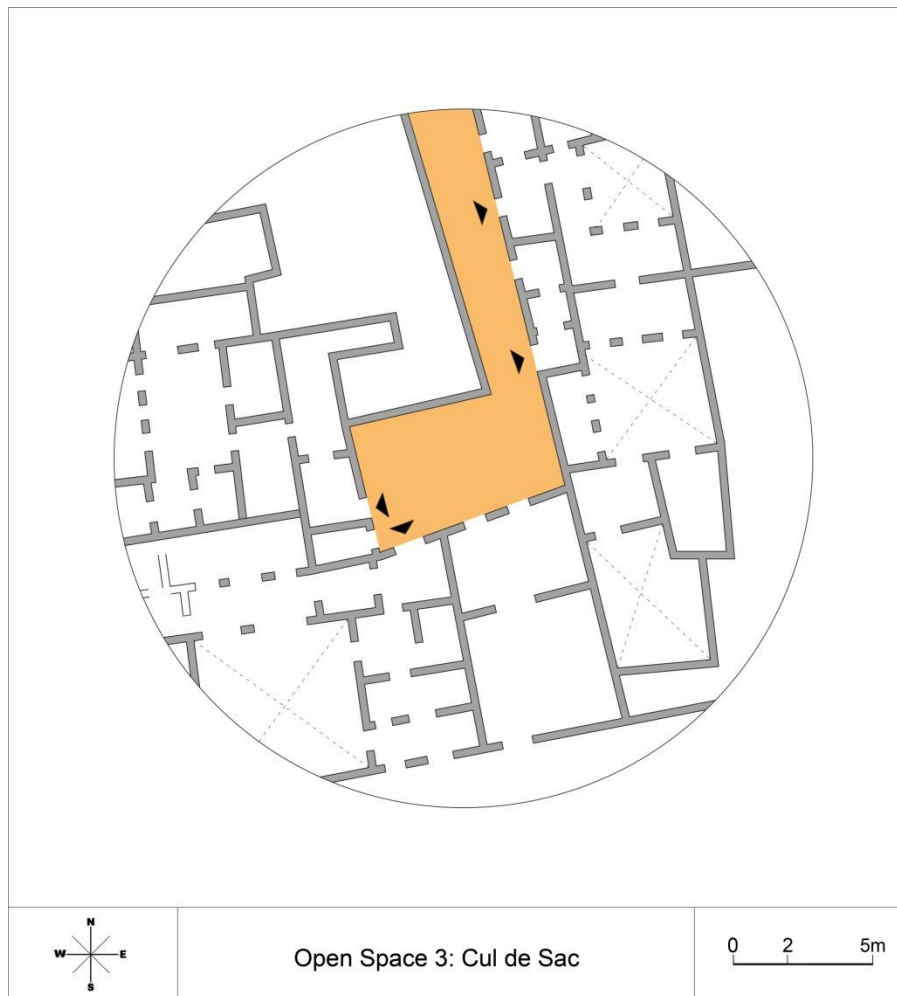


Figure (3.29)

Source: (Ben-Achour 1973, p.189)

### Open Space 4: Covered Passages

The covered passage is very common in Sidi Bou Said. This shaded passageway protects the east and west facades from the excessive heat of the summer sun. It contains benches for seating and covers some of the entrances of the dwellings (figure 3.30).

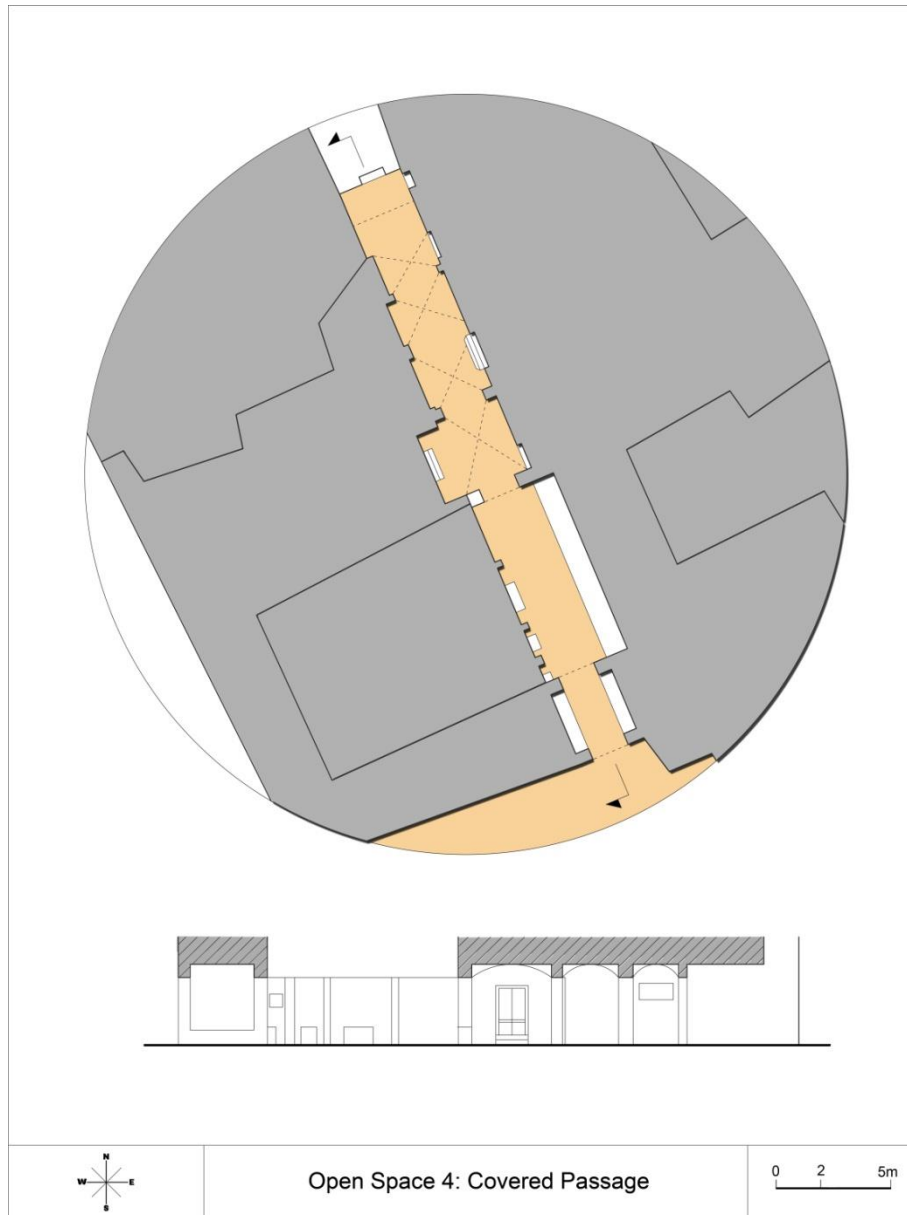


Figure (3.30)  
Source: (Hakim 2009, p.34)

- **Vegetation**

The streets of Sidi Bou Said have little vegetation, only courtyard plants which occasionally grow over the walls, therefore their influence over the streets is very insignificant.

- **Public Fountains and Wells**

In Sidi Bou Said, wells provided the residents with water<sup>90</sup>. They consisted of a simple stone structure enclosing a small reservoir which was filled from the well. Water fountains on the side of the structure were used for animals (Hakim 2009, p.61).

The rainwater collector was built in 1848 for the people living in the high part of the village. It consisted of a large sloping area which drained into two large reservoirs, one was for public use and the other supplied a public fountain (Hakim 2009, p.61). (figure 3.31).

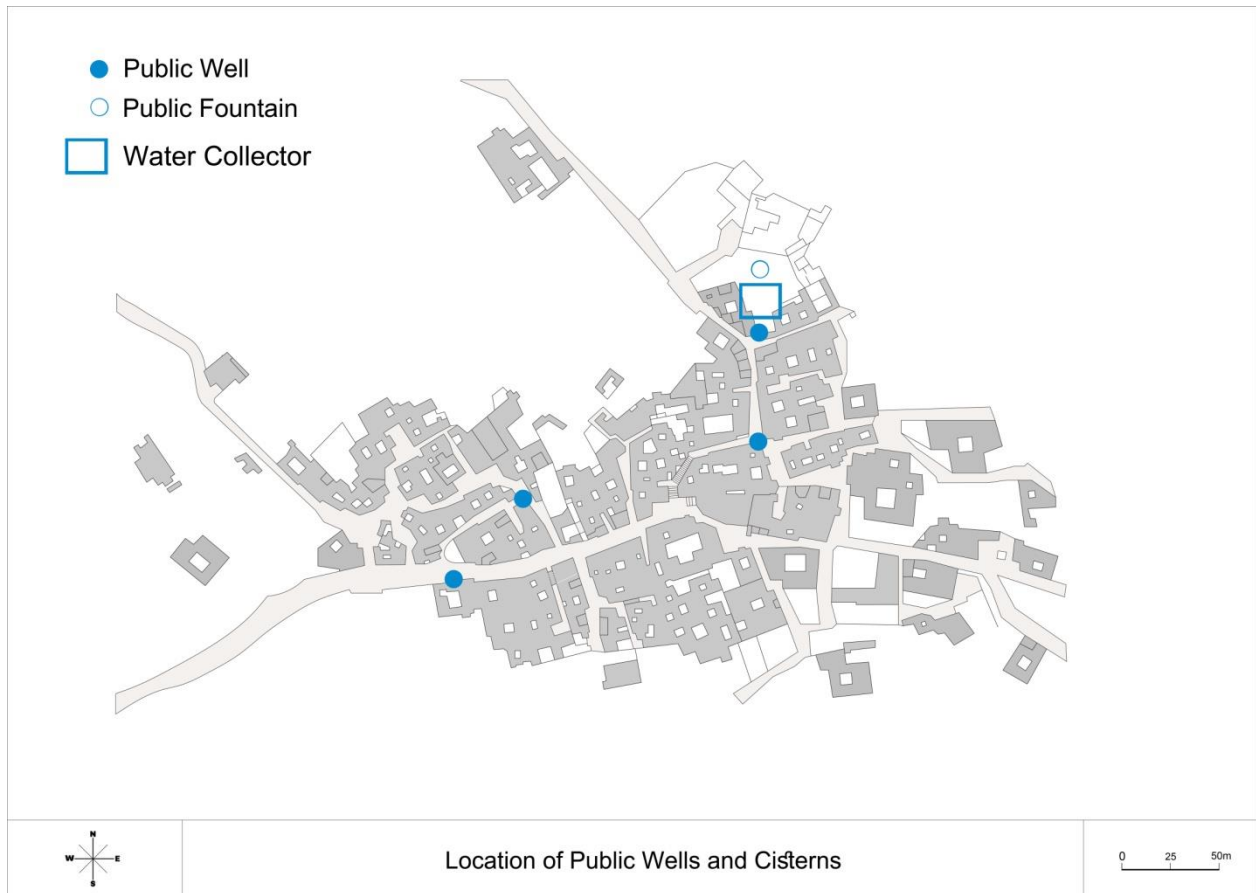


Figure (3.31)  
(Hakim 2009, p.58)

With the aid of the sun, the amount of evaporation from these fountains depends on their surface, depth and the air-water contact<sup>91</sup>.

<sup>90</sup> In Sidi Bou Said, the problem of obtaining water is due to the elevation which places it high above the water level. Cisterns were used to collect rainwater in ancient times until the 18<sup>th</sup> and 19<sup>th</sup> century when the town began to grow and the town was provided with public wells (Hakim 2009, p.61).

<sup>91</sup> See 2.2.2. Settlement, a. Solar Factor - Public Fountains and Wells, pg.50.

- **Surface Materials**<sup>92</sup>

**Ground Surface Materials**

In Sidi Bou Said, streets between the dwellings were made of white cobblestone. Cobblestone has a solar reflectance of 0.21 and the SRI is 18. This reduces the heat island effect and therefore reduces the overall temperature in the streets of Sidi Bou Said.

**Building Surface Materials**

The compact structure of Sidi Bou Said results in the increased surface of roofs and since the buildings are covered with whitewash, the solar radiation received by the roofs is reflected away to the sky. The solar reflectance (albedo) of whitewashed limestone is 0.8.

**b. WIND FACTOR**

- **Compact Geometry**

The compact geometry and decreased S/V ratio of Sidi Bou Said building blocks aids in protecting the dwellings from the harsh winter winds and from heat loss during the winter<sup>93</sup>.

- **Block Orientation**

The blocks in Sidi Bou Said have different orientations. Blocks along the main street have the advantage of being parallel to the winter winds. Other blocks are facing the winter winds coming from the northwest. Regarding the summer winds, most of the building blocks seem to have the advantage of an elevation facing these desirable winds<sup>94</sup> (figure 3.32).

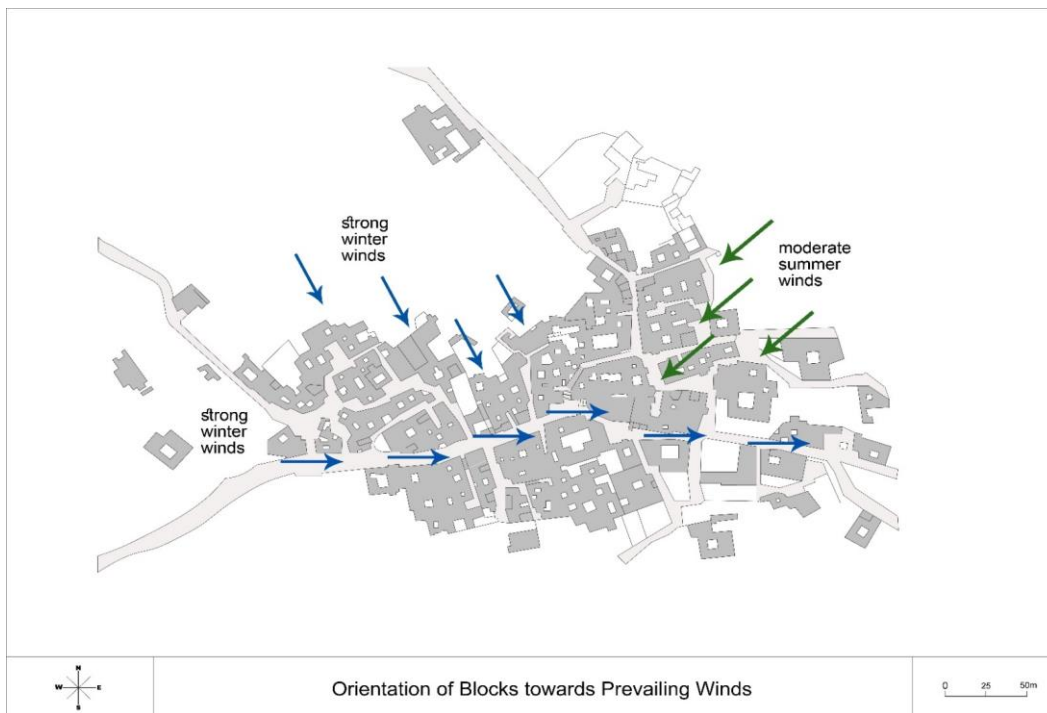


Figure (3.32)

Source: (Ben-Achour 1973, p.188) and (Hakim 2009, p.4)

<sup>92</sup> See 2.2.2. Settlement, a. Solar Factor - Surface Materials, pg.50.

<sup>93</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.

<sup>94</sup> See 2.2.2. Settlement, b. Wind Factor – Block Orientation, pg.51.

- **Street Orientation**

In Sidi Bou Said, some of the narrow winding streets benefit from the desirable winds in the summer coming from the sea. In the winter, the strong winds coming from the west are received then blocked when the main street changes direction. The streets directed northwest seem to welcome the strong winds but are blocked after reaching the core of the village<sup>95</sup> (figure 3.33).

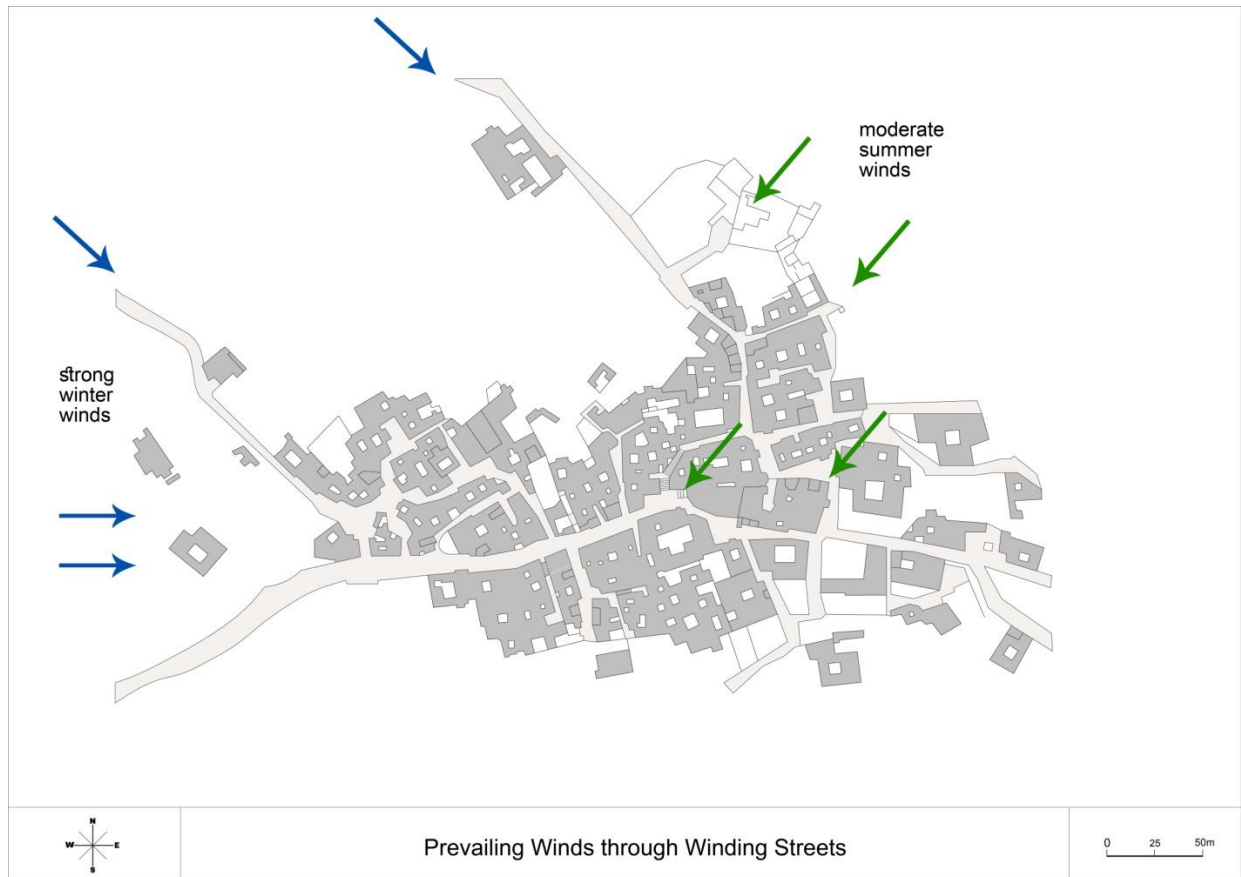


Figure (3.33)

Source: (Ben-Achour 1973, p.188) and (Hakim 2009, p.4)

- **Narrow Streets**

The airflow in the streets also depends on dimensions. To determine whether the winds are entering the streets, the H/W ratio should be calculated. The results are that the narrow streets of Sidi Bou Said make it under the category c.  $H/W > 1$ <sup>96</sup> (figure 3.34). This means that there is a skimming flow over the buildings with only a small amount entering the street. The narrow streets are therefore protected from the strong winter winds coming from the west. However, this also means that the moderate summer winds are also blocked in some streets but welcome in others depending on orientation.

<sup>95</sup> See 2.2.2. Settlement, b. Wind Factor – Street Orientation, pg.53.

<sup>96</sup> See 2.2.2. Settlement, b. Wind Factor – Narrow Streets, pg.54.

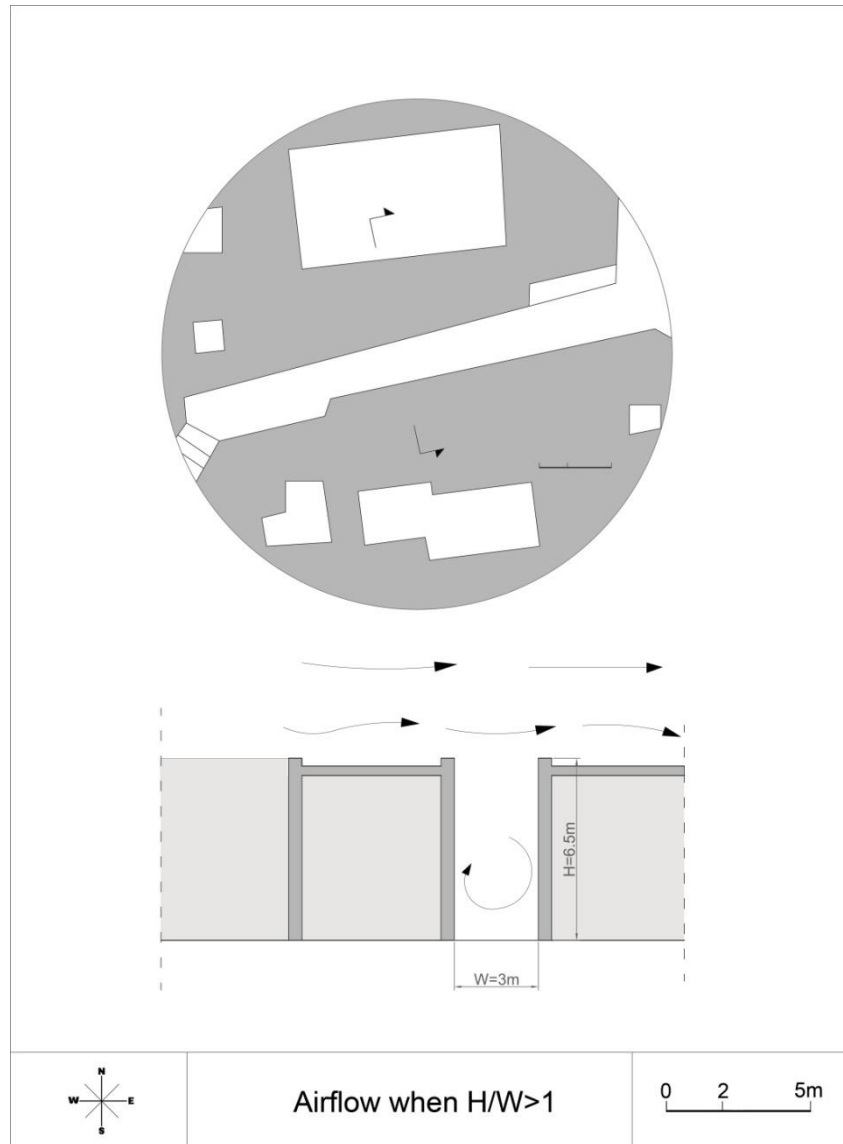


Figure (3.34)

- **Open Spaces**

The open spaces mentioned in the section about the effect of the solar factor, can also be analyzed for the effect of the wind factor.

**Open Space 1: Outdoor Café:** The  $H/W$  ratio is 0.5 which means that there is good ventilation in the open space<sup>97</sup> (figure 3.35).

<sup>97</sup> See 2.2.2. Settlement, b. Wind Factor – Open Spaces, pg.55.



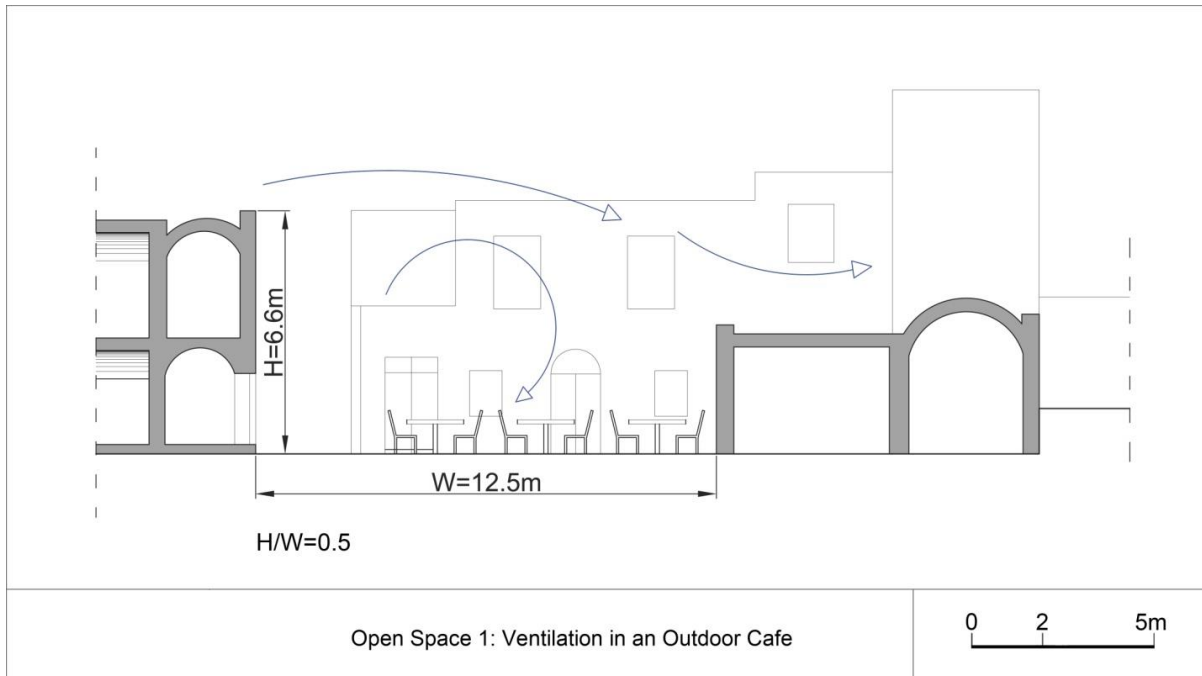


Figure (3.35)  
Source: (Hakim 2009, p.111)

**Open Space 2: Semi-Private Courtyard:** These courtyards act as reservoirs of cool air like a regular courtyard (see figure 3.28). The amount of ventilation also depends on the dimensions of height and width.

**Open Space 3: Cul de Sac**

The enclosed position of the cul de sac also makes it act as a cooling reservoir similar to a courtyard (see figure 3.29).

**Open Space 4: Covered Passage**

Due to the significant amount of shade in a covered passage, a temperature difference between the passage and uncovered streets result in air flow between these spaces (see figure 3.30).

- **Vegetation**

The streets of Sidi Bou Said have little vegetation, only courtyard plants which occasionally grow over the walls, therefore their influence over the streets is very insignificant<sup>98</sup>.

- **Surface Materials**

Surface temperatures can be decreased in the event of cool winds, however, in Sidi Bou Said, these winds are effective if they are channeled through the narrow streets and can reach these surfaces.

<sup>98</sup> See 2.2.2. Settlement, b. Wind Factor – Vegetation, pg.55.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the SETTLEMENT of Sidi Bou Said based on the general analysis found in chapter 2<sup>99</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (3.1)<sup>100</sup>.

#### **1. Compact Geometry**

The geometry of Sidi Bou Said is mainly compact with a few single houses built at a later date. This gave it a “very good” rating for both the sun and wind factors.

#### **2. Block Orientation**

According to the sun factor, most of the blocks have no real orientation, but the orientation of the settlement gives southern exposure to some of the blocks. According to the wind factor, the irregular form of the settlement resulted in some of the blocks facing winter undesirable winds and other parallel to them. The same case applies to the desirable summer winds. Therefore, this tool was given “average”.

#### **3. Street Orientation**

According to the sun factor, the east-west orientation of the main street results in its exposure to the sun most of the day, therefore, it was given “below average”. According to the wind factor, the main street is orientated towards the undesirable winds but the winding streets occasionally change its direction. The desirable winds are welcomed through some of the streets facing north-east but are also blocked later giving this tool a “average” rating.

#### **4. Narrow Streets**

The narrow streets of Sidi Bou Said have a large impact on the street climate and the buildings due to the shading of facades. Considering the H/W ratio, these narrow streets protect from the undesirable winds giving both the sun and wind factors a “very good” rating.

#### **5. Open Spaces**

The variety of open spaces in Sidi Bou Said create comfortable meeting places for the residents. Some which are shaded and others act as outdoor courtyard with good ventilation. This tool was given “very good”.

#### **6. Vegetation**

The streets of Sidi Bou Said lack vegetation, only some hanging plants from the courtyards, therefore it was given “below average”.

#### **7. Public Fountains and Wells**

The streets of Sidi Bou Said are scattered with wells which are too deep to affect the outdoor climate significantly. Only one public fountain is known to exist. Therefore, this tool was given “below average”.

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<sup>99</sup> See 2.2.2. Settlement, c. Comparative Analysis Matrix, p.57.

<sup>100</sup> See 3.1.1. Site, c. Comparative Analysis Matrix, Matrix (3.1) Evaluation for Existing Situation of Tools (EE), pg.100.

## 8. Surface Materials

The light colours of the buildings of Sidi Bou Said have a significant effect on protecting the building from the heat due to the high reflectance of the material. Therefore, it was given “very good”. According to the wind factor, the exposure of these surfaces to cool winds also greatly reduces its temperature. This effect however, occurs only where buildings are exposed to cool winds, therefore it was given “average”.

Settlement (SE) - SIDI BOU SAID	Total Points	Sun 50%	Wind 50%	Sun EE*	Wind EE*	Final Points
<b>SE 1. Compact Geometry</b>	16	8	8	100%	100%	16
<b>SE 2. Block Orientation</b>	12	6	6	50%	50%	6
<b>SE 3. Street Orientation</b>	4	2	2	25%	50%	1.5
<b>SE 4. Narrow Streets</b>	16	8	8	100%	100%	16
<b>SE 5. Open Spaces</b>	4	2	2	100%	100%	4
<b>SE 6. Vegetation</b>	16	8	8	25%	25%	4
<b>SE 7. Public Fountains</b>	4	2	2	25%	25%	1
<b>SE 8. Surface Materials</b>	16	8	8	100%	50%	12
<b>Total for SE Category: 88      Final Points for SE – Sidi Bou Said: 60.5</b>						

\*EE =Existing Evaluation

Matrix (3.3) Sidi Bou Said SETTLEMENT Evaluation

### 3.1.3. DWELLING: Passive Design Strategies of Courtyard Houses in Sidi Bou Said

#### Case Study: Dar Toumi

On the site of a former palace, Dar Toumi was built in the mid nineteenth century as a summer residence and marked the village extensions towards the east<sup>101</sup> (figure 3.36). In 1931, it was renovated and transformed into a hotel. Although it had been handed over many times until its renovation, great care was taken in adding new elements to protect the originality and it was never enlarged (Hakim 2009, p.130).



Figure (3.36)  
Source: (Ben-Achour 1973, p.188)

<sup>101</sup> Dar Toumi was built for Cheikh Mohamed ech-Cherif el-Gorchi who chose this location for its vicinity to the Zawiya Mosque where he liked to frequent. The former palace belonged to Mahmud Bey along with residences for his secretary general and body guards (Hakim 2009, p.130).

Although Dar Toumi is freestanding, it is analyzed for its interior features as if it was connected to other dwelling from all sides (figure 3.37).



Figure (3.37)  
Source: (Hakim 2009, p.132)

### 3.1.3.1. The Thermal Response of the Courtyard of Dar Toumi

---

#### a. SOLAR FACTOR

##### • Shape and Form

Due to the shape of Dar Toumi and the existence of the main courtyard and the two smaller ones, the dwelling benefits from self shading<sup>102</sup> (figure 3.38).

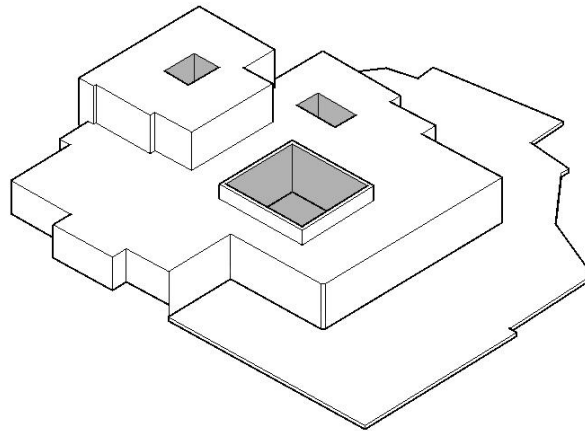


Figure (3.38) Effect of Shape on Self Shading in Dar Toumi

##### • Orientation<sup>103</sup>

Since Dar Toumi is a single courtyard house, it is exposed to the sun from all directions. In addition, its north-south axis is almost equal to its east-west axis. However, the existence of the courtyard gives it the benefit of double exposure to the southern sun in winter, the living area on the exterior southern façade and the living area on the interior southern façade. These internal rooms also benefit from direct sunlight from the courtyard. The stable occupies the north elevation but benefits from the southern sun due to the height of its walls and its own courtyard (figure 3.39). In summer, however, the eastern and western facades are exposed to excessive sun. This is compensated by the decreased number and size of exterior windows. The courtyard eastern and western walls are exposed to the summer sun.

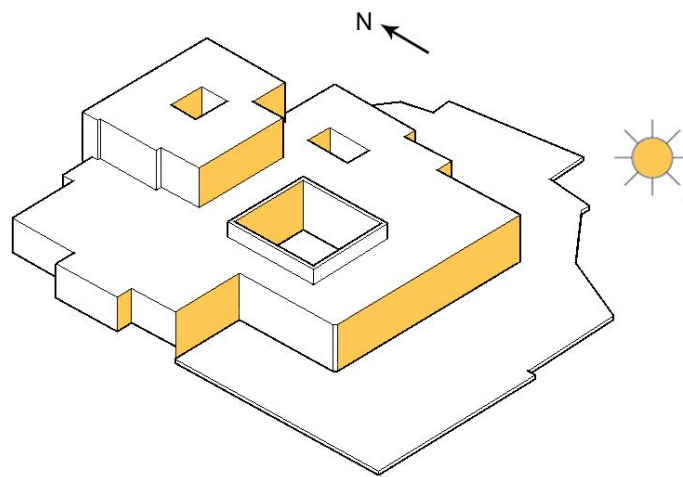


Figure (3.39) Exposure of Southern Elevation in Dar Toumi

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<sup>102</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Shape and Form, pg.61.

<sup>103</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Orientation, pg.61.

- **Dimensions and Shade**

As mentioned before, the shape of Dar Toumi gives it the benefit of self shading. However, the dimensions of the courtyard determine the amount of shade created during winter and summer. In addition, the courtyard walls of Dar Toumi were raised above the roof in order to compensate for the single storey height of the dwelling. This created more shade.

**Lateral Distance of Shade:**  $L=H \times \text{COT}\Theta^{104}$  (figure 3.40)

**Summer:**

$$L=5.5 \times .27 = 1.5\text{m}$$

**Winter:**

$$L=5.5 \times 1.88 = 10.3\text{m}$$

**L:** Lateral Distance of shade on courtyard surface

**H:** Height of courtyard

$\Theta = 75^\circ$  (Summer Solstice in Sidi Bou Said)  $\text{Cot } 75^\circ = .27$

$\Theta = 28^\circ$  (Winter Solstice in Sidi Bou Said)  $\text{Cot } 28^\circ = 1.88$

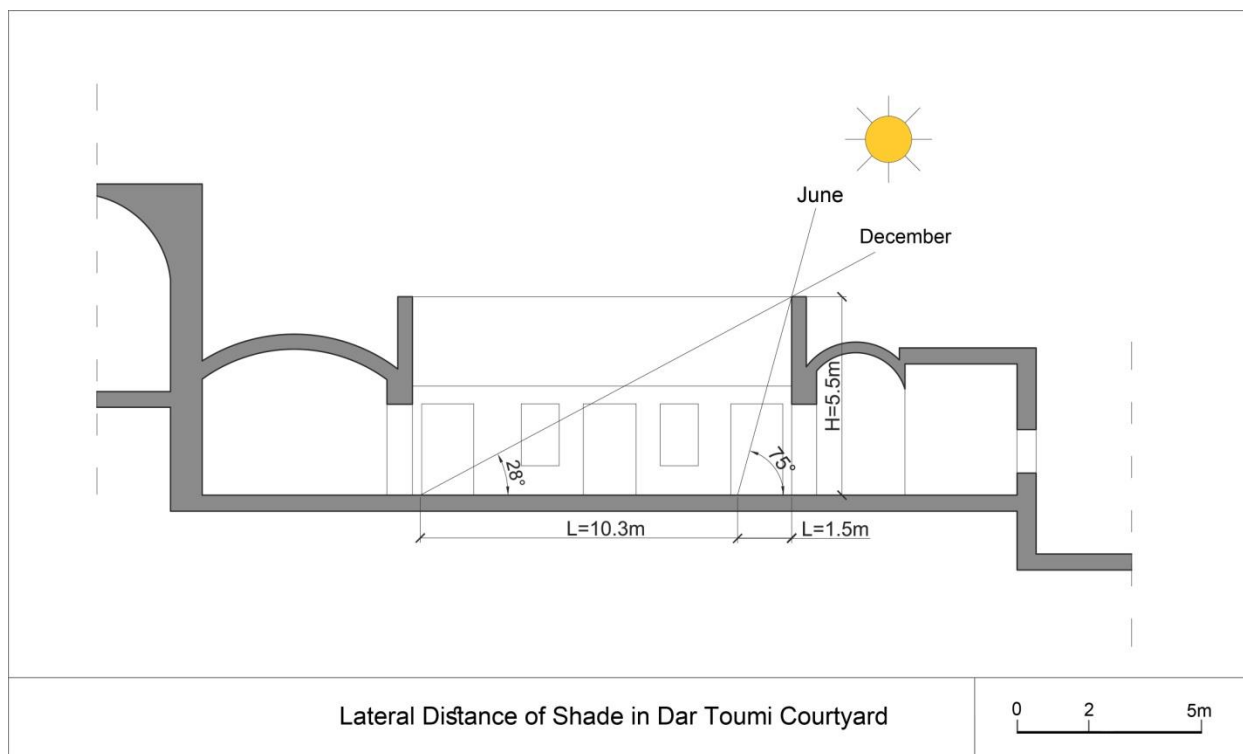


Figure (3.40)  
Source: (Hakim 2009, p.131)

<sup>104</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Dimensions and Shade, pg. 62.

## b. WIND FACTOR

### • Shape and Form

The courtyard in Dar Toumi regulates the climate by the process of ventilation by convection like any courtyard<sup>105</sup> (figure 3.41).

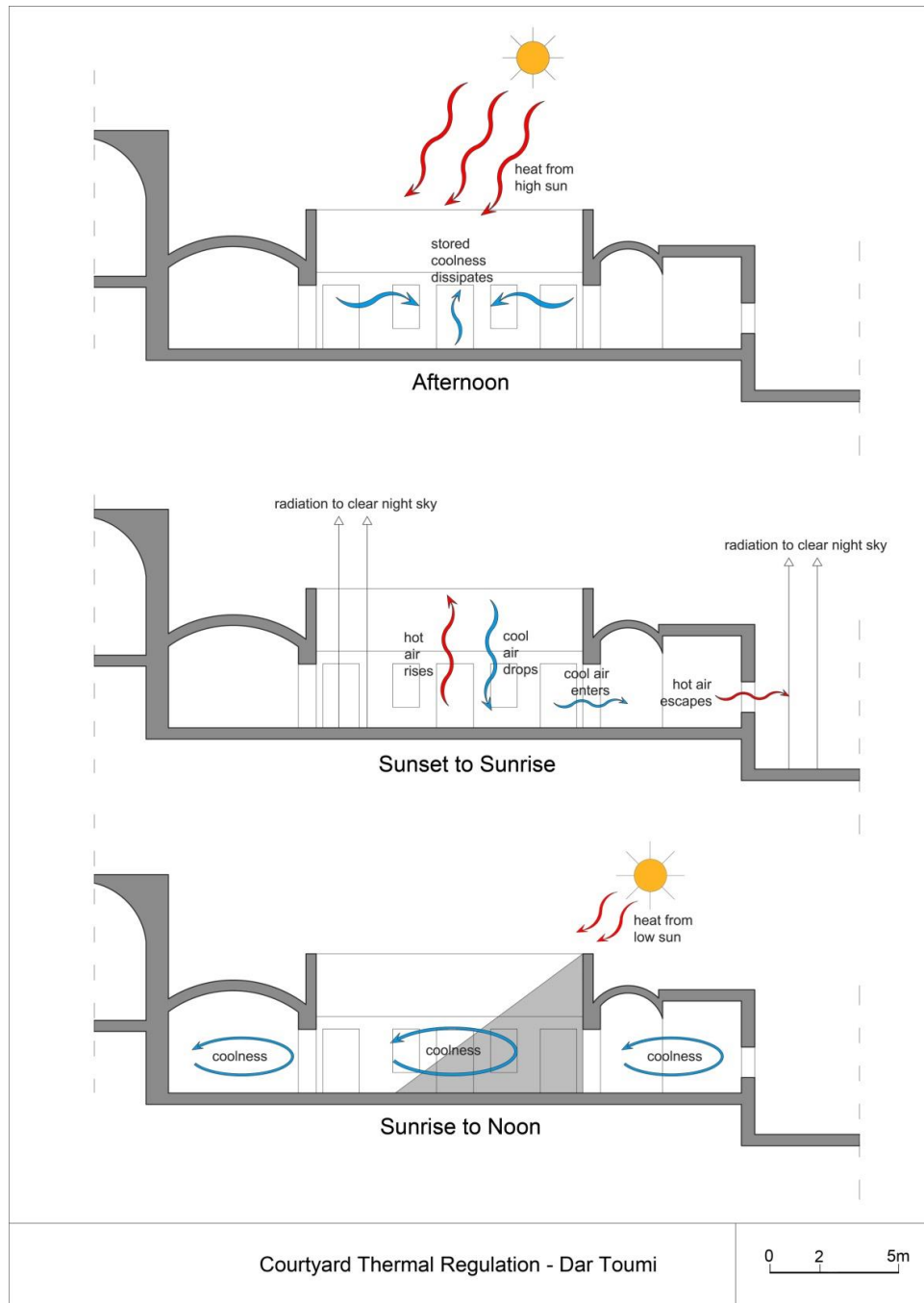


Figure (3.41)  
Source: (Hakim 2009, p.131)

<sup>105</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Shape and Form, pg.63.



- **Orientation**

Dar Toumi is orientated parallel to the strong winter winds and facing the summer winds coming from the sea<sup>106</sup> (figure 3.42).

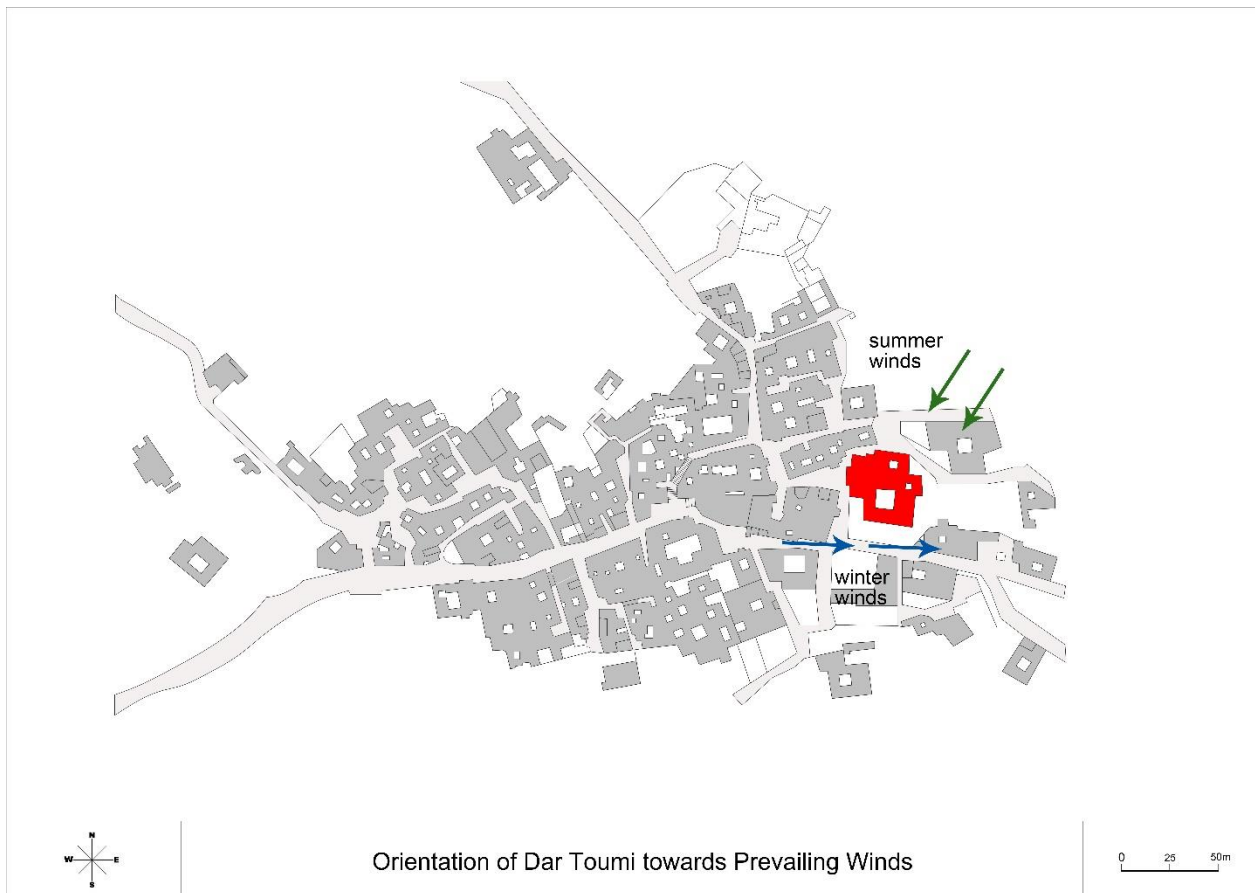


Figure (3.42)

Source: (Ben-Achour 1973, p.188)

- **Dimensions and Airflow**

The airflow in the courtyard of Dar Toumi depends on the height/width ratio.  $H/W=0.5$ , meaning it has a medium aspect ratio and recirculation occurs when a swirl of air enters the courtyard and mixes the air<sup>107</sup> (figure 3.43).

<sup>106</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Orientation, pg.65.

<sup>107</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Dimensions and Airflow, pg.65.

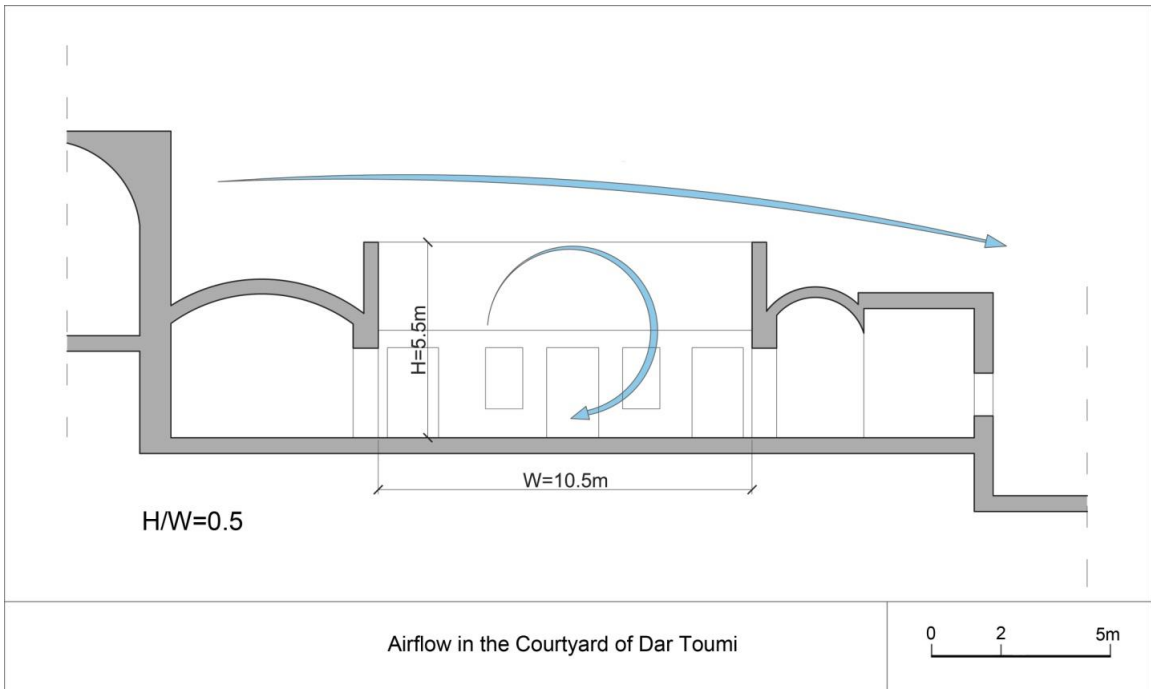


Figure (3.43)  
 Source: (Hakim 2009, p.131)

The increased height of the courtyard walls also aids in the wind factor. It keeps the cool air near the ground and protects the courtyard from strong uncomfortable winds (figure 3.44).

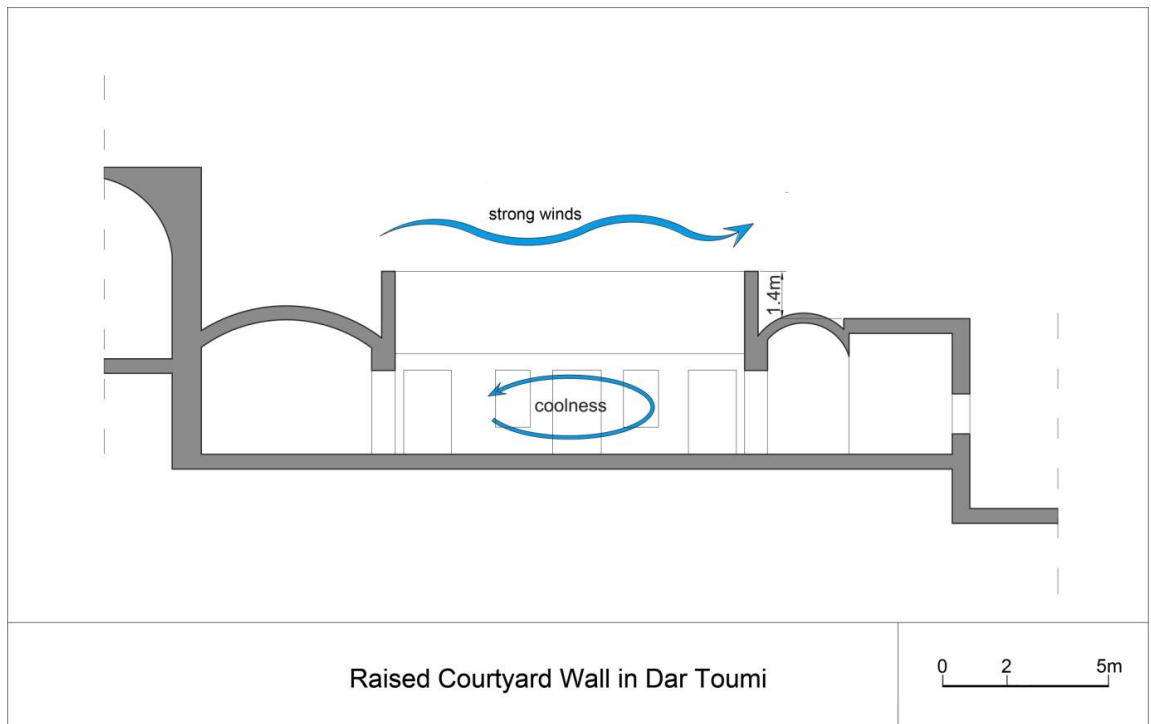


Figure (3.44)  
 Source: (Hakim 2009, p.131)

### 3.1.3.2. Additional Thermal Regulating Spaces in Dar Toumi

#### a. SOLAR FACTOR

- **The Garden**

The garden in Dar Toumi surrounds the house from the south and east. The southern side benefits from the winter sun and makes a warm pleasurable sitting place in winter. In the summer, the eastern side could be a desirable space in the afternoon and evening when the sun is on the other side (figure 3.45).



Figure (3.45)  
Source: (Hakim 2009, p.132)

## b. WIND FACTOR

- **The Loggia**

In Dar Toumi, there is a loggia which is similar to the traditional *takhtabush*. It is a space located between the courtyard and the garden. The courtyard openings are larger than the windows facing the garden. The warm air in the courtyard rises and draws cool air from the shaded garden through this loggia creating a pleasant breeze<sup>108</sup> (figure 3.46).

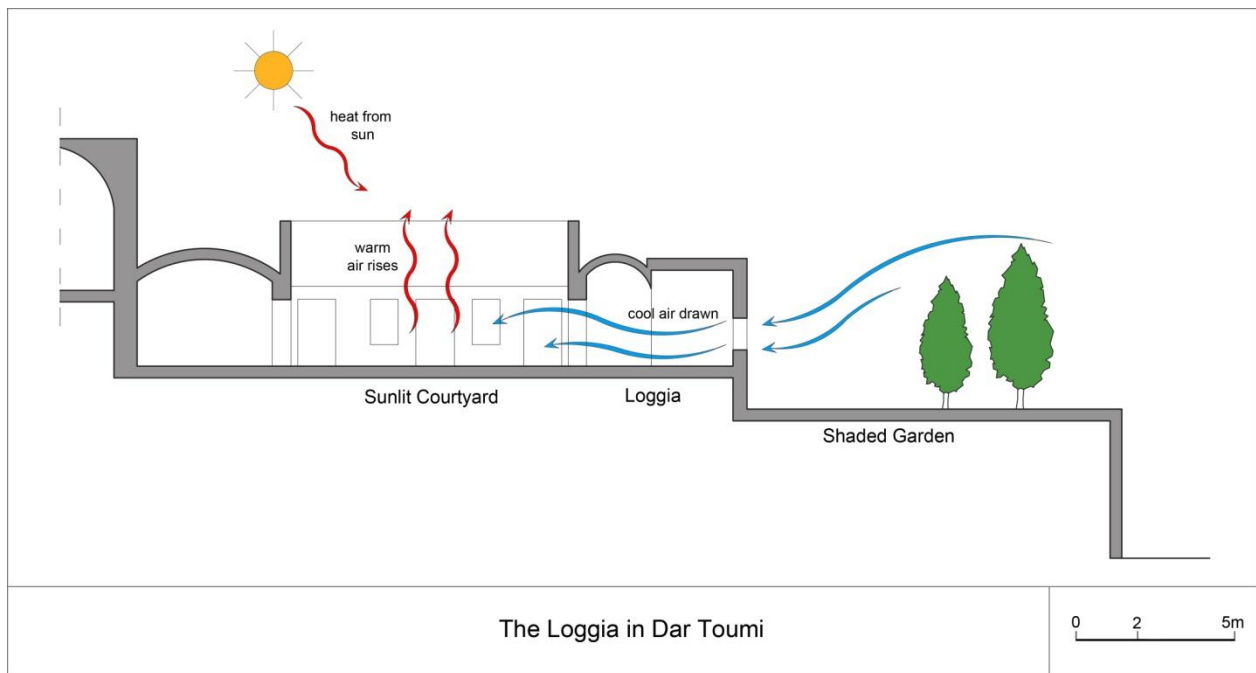


Figure (3.46)

Source: (Hakim 2009, p.131)

- **The Garden**

Other than the eastern side which is slightly facing the prevailing winds, most of the garden does not benefit from the desirable winds in summer. Although it is protected by the neighbouring buildings, strong winter winds could enter the garden.

<sup>108</sup> 2.2.3. Dwelling, 2.2.3.3. Additional Thermal Regulating Spaces, b. Wind Factor – The Loggia, pg.69.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the DWELLING of Sidi Bou Said based on the matrix found in chapter 2<sup>109</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (3.1)<sup>110</sup>.

#### **1. Shape and Form**

The courtyard form of Dar Toumi contributes to the energy savings of a house due to the benefit of self shading from all four sides. Dar Toumi has additional two courtyards giving the service areas benefit from self shading. Therefore, the sun factor was given “very good”. According to the wind factor, the courtyard shape regulates the climate by the process of convection giving it also a “very good” rating.

#### **2. Orientation**

The orientation of Dar Toumi gives the living spaces benefit from the southern sun in addition to the spaces facing the other two courtyards. Only service and other secondary spaces face the eastern and western façade. The square shape, however, gives an equal dimension to the east and west courtyard facades exposing them to the summer heat. Therefore, this tool was given “good” for the sun factor. According to the wind factor, Dar Toumi is orientated parallel to the winter winds and facing the desirable winds giving it a “very good” rating.

#### **3. Dimensions**

Although compensated by raising the courtyard walls, the dimensions of the courtyard of Dar Toumi (height and width) still do not give the courtyard the ideal amount of shade due to the one storey height of the dwelling. Therefore, it was given “good” from the sun factor. According to the wind factor, the H/W ratio resulted in more ventilation in the courtyard when compared with a deep courtyard, therefore, it was given “very good”.

#### **4. The Loggia**

The existence of the courtyard, the garden and the living space between them results in a loggia where an air flow passing through it is created. This tool was given “very good” from the wind factor and it is N/A regarding the sun factor.

#### **5. The Garden**

The garden is a comfortable area to spend time in the winter due to its southern exposure and makes a pleasant area in the afternoon and evening in summer. It was given “good” for the sun factor. According to the wind factor, it aids in the thermal comfort of the loggia, however, it may not receive desirable winds in summer and is slightly exposed to winter strong winds. Therefore, it was given “below average”.

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<sup>109</sup> See 2.2.3. Dwelling, c. Comparative Analysis Matrix, p.72.

<sup>110</sup> See 3.1.1.1. Site, c. Comparative Analysis Matrix, Matrix (3.1) Evaluation for Existing Situation of Tools (EE), p.100.

<b>Dwelling (DW) - SIDI BOU SAID</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>DW 1. Shape and Form</b>	16	8	8	100%	100%	16
<b>DW 2. Orientation</b>	16	8	8	75%	100%	14
<b>DW 3. Dimensions</b>	12	6	6	75%	100%	10.5
<b>DW 4. Liwan</b>	8	4	4	0	0	0
<b>DW 5. Arcade</b>	8	4	N/A	0	N/A	0
<b>DW 6. Loggia</b>	8	N/A	4	N/A	100%	4
<b>DW 7. Terrace/Roof/Garden</b>	8	4	4	75%	25%	4
<b>Total for DW Category (-N/A): 68      Final Points for DW – Sidi Bou Said: 48.5</b>						

\*EE =Existing Evaluation

Matrix (3.4) Sidi Bou Said DWELLING Evaluation

### 3.1.4. ELEMENT: Thermal Regulating Elements in Dar Toumi

#### a. SOLAR FACTOR

- **Windows**

In Sidi Bou Said, the original form of the houses was built without windows on the ground floor for reasons of privacy. Later, when windows were added, they were placed high above the streets as possible which maintains privacy. The windows facing the interior courtyard were larger and lower to the floor (Hakim 2009, p.73).

When studying the windows according to orientation and solar penetration in Dar Toumi, the windows located on the southern façade are the largest and the most in number. The eastern, western and northern windows are kept to a minimum in number and size<sup>111</sup> (figure 3.47).



Figure (3.47)  
Source: (Hakim 2009, p.132)

<sup>111</sup> See 2.2.4. Element, a. Solar Factor – Windows, pg.74.

The height of the courtyard windows allows the penetration of the southern sun in winter resulting in the maximum benefit for the rooms (figure 3.48).

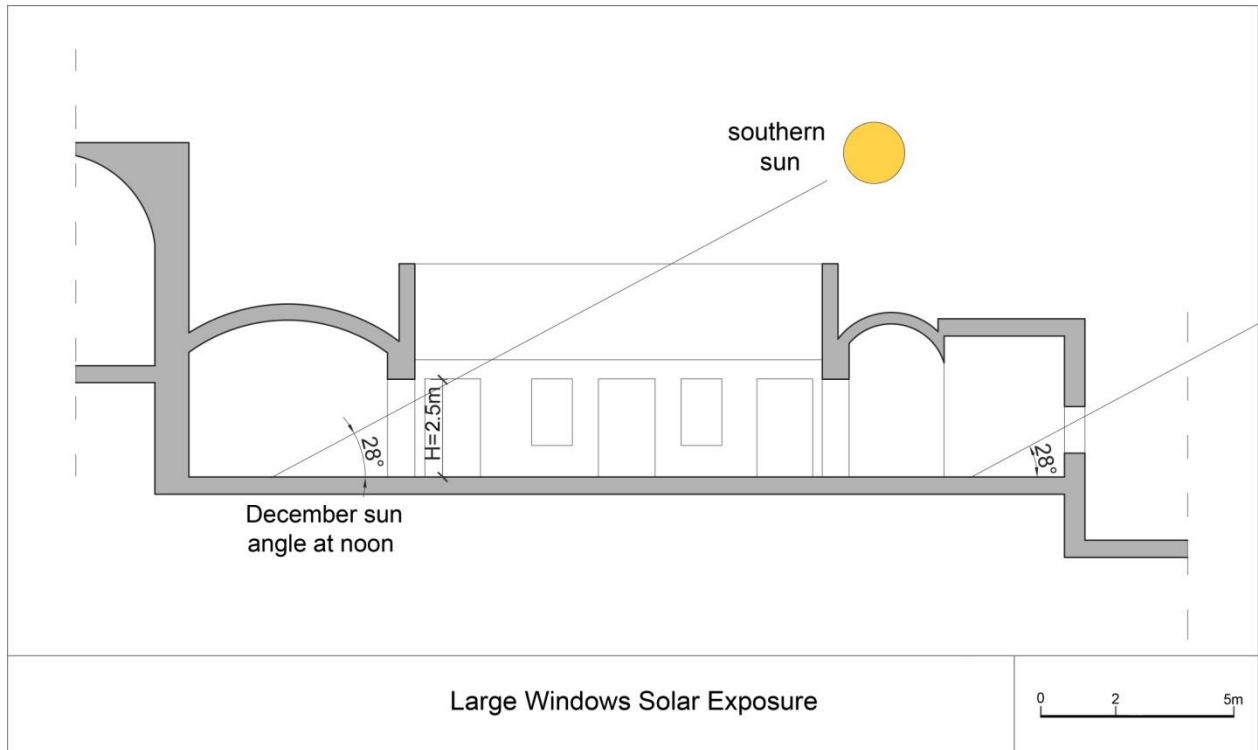


Figure (3.48)  
Source: (Hakim 2009, p.131)



- **The Mashrabiya**

The Mashrabiya is found in many houses in Sidi Bou Said. It has many thermal characteristics, one of them controlling solar exposure of the house either against heat or glare<sup>112</sup> (figure 3.49, 3.50).



Figure (3.49)

Source: (Ben-Achour 1973, p.191)

In Sidi Bou Said, in order to control direct sunlight, an example of a mashrabiya with smaller interstices are wooden strips 1.5cm by 0.7cm rounded along one side and crisscross at about 45°-60°: (Hakim 2009, p.75) (figure 3.50).

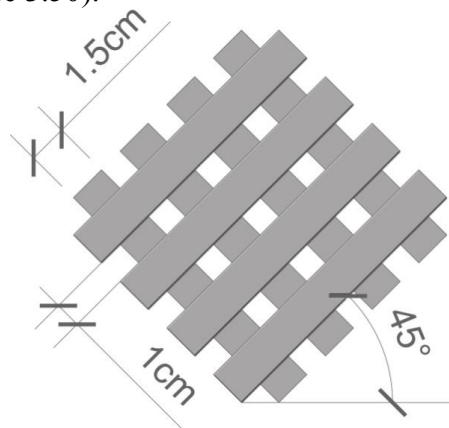


Figure (3.50) Mashrabiya with Small Interstices

Source: (Hakim 2009, p.75)

There is no evidence that a mashrabiya exists in Dar Toumi, however, due to the popularity of this element in Sidi Bou Said, the free standing position and the importance of this dwelling, it is predicted that a mashrabiya is most likely to be an existing element.

<sup>112</sup> See 2.2.4. Element, a. Solar Factor - The Mashrabiya, pg.74.

- **Courtyard and Garden Vegetation**

In the courtyard of Dar Toumi, grape vines wrap around a trellis (Hakim 2009, p.130) which provide shade during the day and slightly improve the overall thermal comfort of the courtyard<sup>113</sup>. The garden in Dar Toumi has vegetation in the form of large trees which create shade during the hot summer months.

- **Thermal Mass**

In Sidi Bou Said, walls were 50-80cm thick and were decreased in thickness towards the top<sup>114</sup>. They were made of flat stones bonded with an earth and lime mortar (Hakim 2009, p.92). Even the roofs were covered with a heavy layer of earth to increase the time lag of the sun penetration through the roof. This was also done to the second level floor due to the earth's function of shock absorber as well as thermal insulator (Hakim 2009, p.87) (figure 3.51).



Figure (3.51)

Source: (Hakim 2009, p.93)

<sup>113</sup> See 2.2.4. Element, a. Solar Factor, - Courtyard Vegetation and Shade, pg.77.

<sup>114</sup> See 2.2.4. Element, a. Solar Factor - Thermal Mass, pg.79.

## **b. WIND FACTOR**

- **Windows**

In some houses of Sidi Bou Said, square openings about 15cm wide were located in the roofs for ventilation and could have been present in Dar Toumi. Originally they were left open but then were glazed at a later date (Hakim 2009, p.98).

In general, semi-circular openings were located above the windows and doors for ventilation and light (Hakim 2009, p.78). The large courtyard windows allow the ventilation and coolness to enter the rooms.

- **Courtyard and Garden Vegetation**

The vegetation in the courtyard of Dar Toumi does not affect the wind in a significant way, however the large amount of trees in the garden protect from the winter winds when they are large canopy trees and close to the windows<sup>115</sup>.

- **Thermal Mass**

Since thermal mass also stores coolness, it is also relevant for the wind factor. This is achieved in Dar Toumi due to the thickness and material of the walls<sup>116</sup>.

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<sup>115</sup> See 2.2.4. Element, b. Wind Factor – Courtyard Vegetation, pg.80.

<sup>116</sup> See 3.1.4. Element, a. Solar Factor – Thermal Mass, pg.135.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the ELEMENTS found in the dwellings of Sidi Bou Said based on the matrix found in chapter 2<sup>117</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the total amount given for each tool in chapter 2. This was based on Matrix (3.1)<sup>118</sup>.

#### **1. Windows**

The windows on the southern façade are the largest in Dar Toumi giving maximum benefit from the southern sun. In addition to the large windows on the courtyard southern façade. According to the wind factor, high and roof windows were used for ventilation, in addition to the courtyard windows which significantly aid in the courtyard thermal regulation. This tool was given “very good” for both the sun and wind factors.

#### **2. Mashrabiya**

The Mashrabiya is found in most Sidi Bou Said houses aid in the thermal comfort of the dwelling due to its functions relating to the sun and wind. Although there is no evidence supporting its existence, it is very likely that the mashrabiya is found in Dar Toumi. Therefore, it was given “very good”.

#### **3. Vegetation**

The small amount of vegetation in the courtyard of Dar Toumi creates some shade but does not affect the wind. The large amount of trees in the garden compensated for the lack of this element in Dar Toumi and gave it a “good” rating.

#### **4. Thermal Mass**

The thick stone walls of Dar Toumi area an excellent source of thermal mass and it was given “very good” for both factors.

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<sup>117</sup> See 2.2.4. Element, c. Comparative Analysis Matrix, p.83.

<sup>118</sup> See 3.1.1. Site, c. Comparative Analysis Matrix, Matrix (3.1) Evaluation for Existing Situation of Tools (EE), p.100.

<b>Element (EL) - SIDI BOU SAID</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>EL 1. Windows</b>	16	8	8	100%	100%	16
<b>EL 2. Mashrabiya</b>	12	6	6	100%	100%	12
<b>EL 3. Courtyard/Garden Veg.</b>	16	8	8	75%	75%	12
<b>EL 4. Water Features</b>	12	6	6	0	0	0
<b>EL 5. Thermal Mass</b>	16	8	8	100%	100%	16
<b>EL 6. Malqaf</b>	12	N/A	6	N/A	0	0
<b>Total for EL Category (-N/A): 78      Final Points for EL – Sidi Bou Said: 56</b>						

\*EE =Existing Evaluation

Matrix (3.5) Sidi Bou Said ELEMENT Evaluation

After analysing the settlement of Sidi Bou Said in four categories, the points collected for each category were added to obtain a final score to define the level of Sustainability in the conclusion.

<b>CATEGORY</b>	<b>POINTS</b>
<b>Site (SI)</b>	37.5
<b>Settlement (SE)</b>	60.5
<b>Dwelling (DW)</b>	48.5
<b>Element (EL)</b>	56
<b>FINAL SCORE</b>	<b>202.5</b>

Matrix (3.6) Sidi Bou Said FINAL SCORE

### 3.2. The Casbah of Algiers, Algeria

*“The Casbah of Algiers [in contrast] made the site: it gave the name of White Algiers to this glittering entity, that welcomes, at dawn, the boats that arrive at the harbor. Inscribed in the site, it is irrefutable. It is in consonance with nature, because from every house, from the terrace—and these terraces add on to each other like a magic and gigantic staircase descending to the sea—one sees the space, the sea.” (Le Corbusier) (Çelik 1997, p.4).*



Figure (3.52) Areal Photo of the Casbah of Algiers  
Source: Google maps

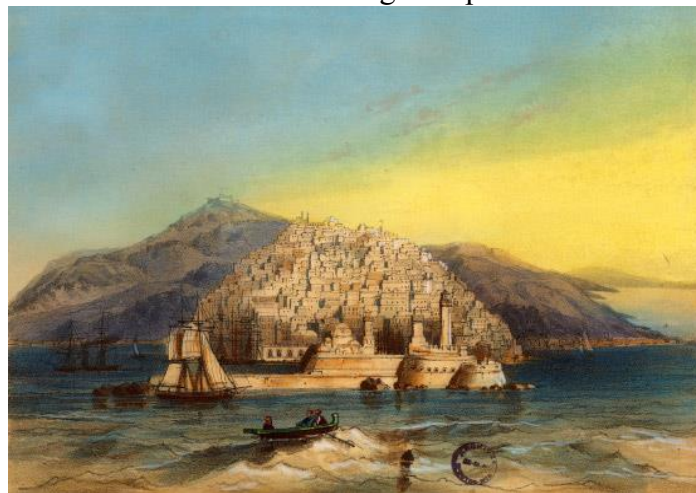


Figure (3.53) Casbah of Algiers 1830<sup>119</sup>

<sup>119</sup> Source: <http://cetaitlabaslalgerie.eklablog.fr/platanes-avant-propos-p550702>

The Casbah of Algiers is the ancient core of Algiers. It is the triangular-shaped town climbing the steep hill facing the Mediterranean Sea which forms the base of the triangle and the citadel is at the triangle's summit 122 metres (400 ft) above the sea. The modern part of the city is built on the level ground by the seashore (Çelik 1997, p.12).

### Urban Development

The settlement was founded by the Arab Zirid dynasty in the tenth century and like the rest of North Africa, it was ruled by successive Arab dynasties as a minor port until the sixteenth century. It was then made the capital of Algeria by the Ottomans (Çelik 1997, p.12).

The Ottoman walls ran continuously for 3,100 meters and enclosed the town from all sides, including the sea (figure 3.54). They were dotted with towers and had five gates: Bab Azzun to the south, Bab al-Jadid to the southwest, Bab al-Bahr on the sea front, Bab Jazira on entry of the harbor, and Bab el-Wad to the north. The citadel at the highest point on the fortifications was built in 1556 (Çelik 1997, p.13).

The road connecting Bab el-Wad to Bab Azzun divided Algiers into two zones, the upper (private) city, called al-Gabal or "the mountain," and the lower (public) city, called al-Wata or "the plains."<sup>120</sup> (figure 3.54). Typical of an Ottoman urban system, the upper city was comprised of approximately fifty small neighborhoods, each one was under the administrative responsibility of religious chiefs and judges (Çelik 1997, p.14). While the streets of the lower town were wide and prominent, the neighborhood streets were narrow, irregular, often with dead ends and they accommodated the lifestyle that was based on privacy of the home and the family, in addition to the use of gates to close off the neighborhoods in the evenings for safety (Çelik 1997, p.15) (figure 3.55).



Figure (3.54) Casbah of Algiers 1816.  
Private Upper City (yellow), Public Lower City (Orange)<sup>121</sup>

<sup>120</sup> The lower part developed as an administrative, military, and commercial quarter. Upper-class families with luxurious houses inhabited this area, like Dar al-Sultan, or the Janina Palace which was built in the 1550s as the residence of the dey. In addition to the major mosques and the military barracks. The souks were concentrated along the main streets, with the al-Souk al-Kabir located on the mentioned road dividing the city (road connecting Bab el-Wad to Bab Azzun). It is the widest street in Algiers, only 3 meters wide (Çelik 1997, p.13).

<sup>121</sup> Source: [https://commons.wikimedia.org/wiki/File:Plan\\_of\\_the\\_city\\_and\\_fortifications\\_of\\_algiers\\_-\\_1816.jpg](https://commons.wikimedia.org/wiki/File:Plan_of_the_city_and_fortifications_of_algiers_-_1816.jpg)



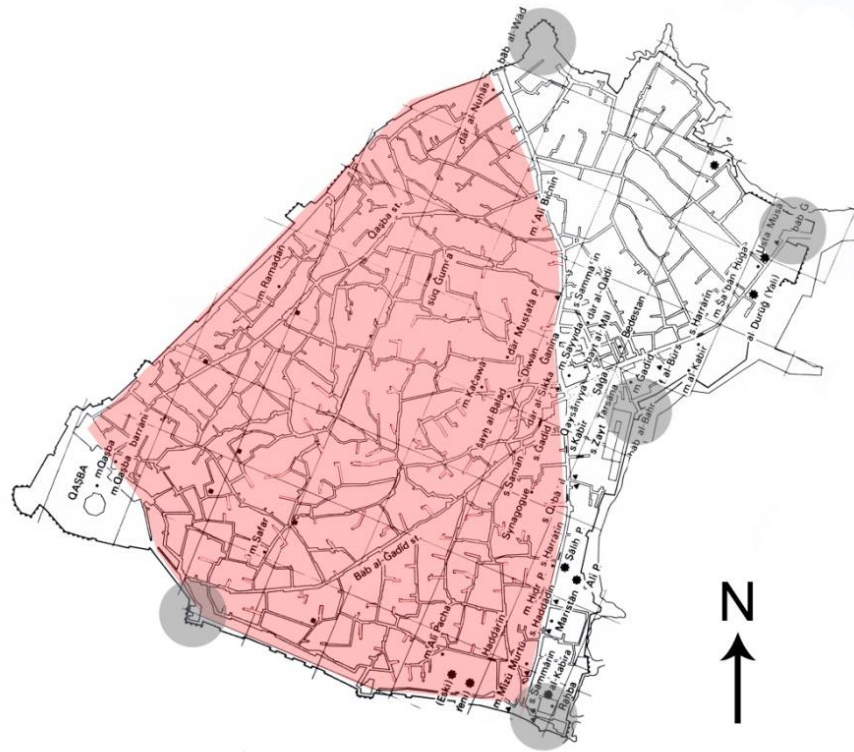


Figure (3.55) Plan Showing Street Structure and 5 Gates  
Source: (Kanoun 1995, p.12)

During the initial phase of colonization between 1830 and 1846, Algiers underwent certain transformations. While the upper part of the town was left practically untouched, the lower part underwent great changes due to the need for large streets and commercial movement<sup>122</sup>. (Çelik 1997, p.26). In 1834, an important intervention which affected the upper part was Boulevard de la Victoire which defined the highest boundary of the town. A new gate on the south walls was proposed with a street connecting this gate to the citadel. This new route facilitated military movements and vehicular circulation in the upper Casbah where the narrow streets were totally inaccessible to vehicles (Çelik 1997, p.31) (figure 3.56).

<sup>122</sup> The 1830 transformations consisted of widening the main streets and the appropriation and modification of houses, shops and religious buildings to accommodate military troops (Çelik 1997, p.27). In addition to the carving of a Place du Gouvernement which became a beautiful and commercial piazza with trees and fountains surrounded by two-storey residential buildings (Çelik 1997, p.28). This part became known as the Marine Quarter or the Quarter of the Ancient Prefecture.



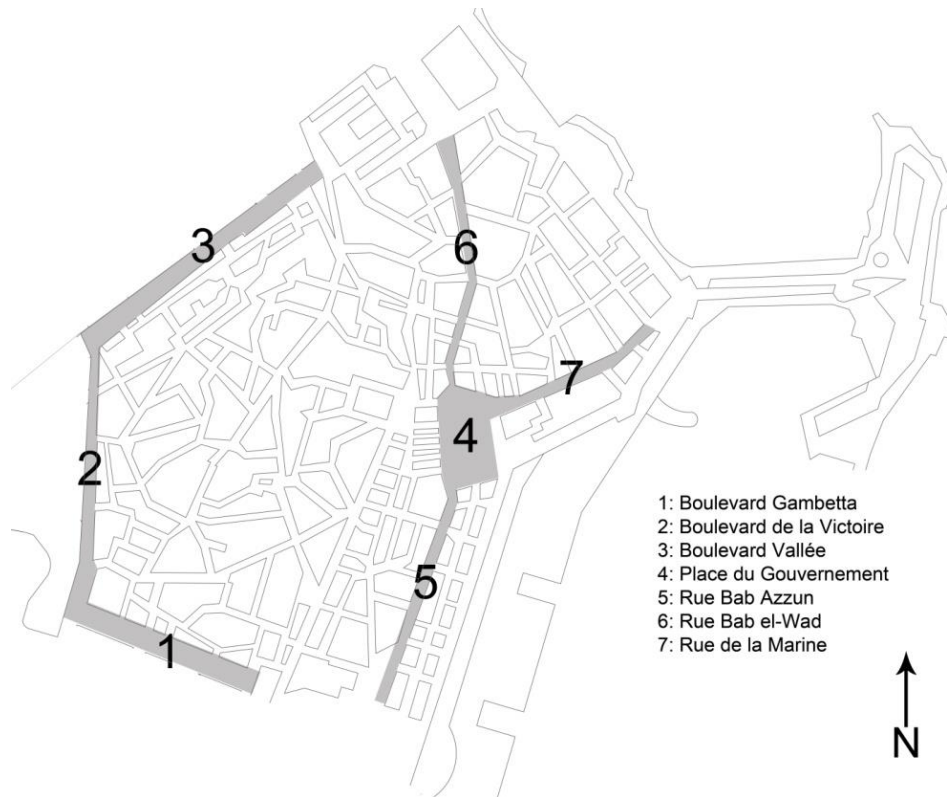


Figure (3.56) French Transformations  
 Source: (Çelik 1997, p.33)

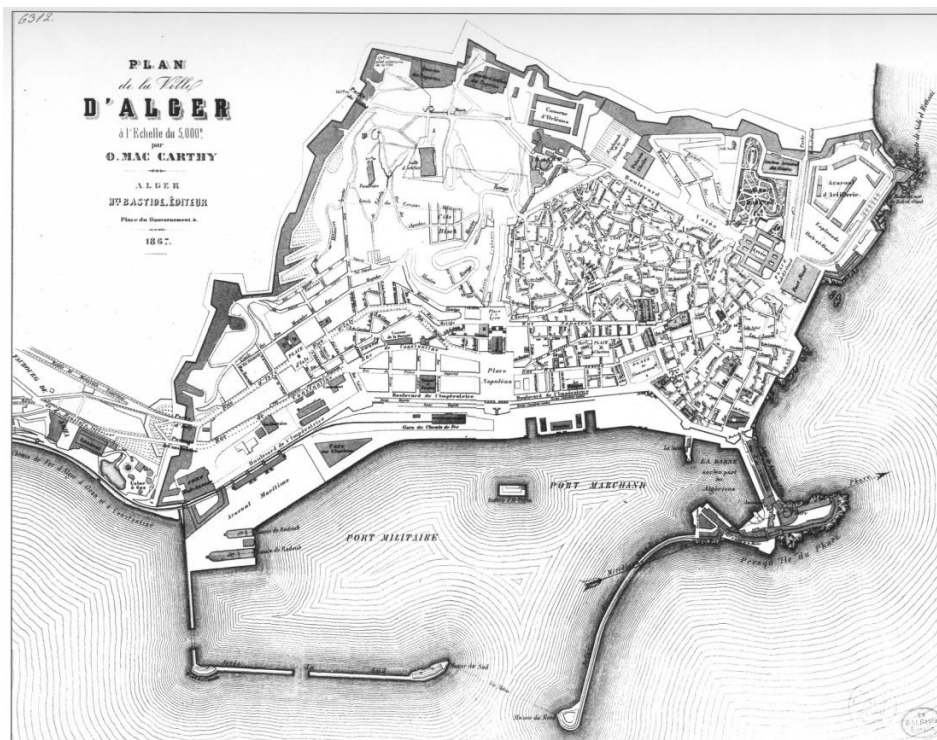


Figure (3.57) Plan of Algiers 1867  
 Source: (Tempus Rehabilitation of Islamic Cities Program)

After these initial interventions, the main issue of the Casbah was the destruction caused by neglect and lack of maintenance. The residents of the Casbah consolidated their unity and established their own system which operated on two levels: the maintenance of public open spaces by organized labor of renters and owners. With this move, the Casbah was transformed into a "counter space" that represented the oppositional voice of Algerians to colonial power (Çelik 1997, p.38).

During the two decades from the 1930s to the 1950s, the new directions agreed on the preservation of the precolonial heritage of the Casbah<sup>123</sup> (Çelik 1997, p.39). A special regulation, dated 13 June 1931, intended to conserve the "character and aesthetics" of the Casbah by "imposing on the inhabitants the obligation to restore their houses and to build new ones only in ways that serve to that effect, following the proportions and characteristics of the indigenous architecture of Algiers" (Çelik 1997, p.41).

Le Corbusier's projects for Algiers (1931 to 1942) pursued the same policy of preservation. The Casbah in his eyes was also "beautiful," "charming," and "adorable," and it "never, no, never must be destroyed". However, in order to solve its problem of overpopulation, Le Corbusier proposed to preserve the upper Casbah in its integrity while restricting the densities and intervening in the building use. A number of buildings were to be converted into arts and crafts centers to initiate an indigenous "renaissance." Some buildings were kept as residences however, the slums of the lower Casbah would be removed and the area would be replaced by parks and gardens. The mansions would be converted into specialized museums for the indigenous arts and the existing street network would be maintained to link the high Casbah to the Marine Quarter and to the harbor (Çelik 1997, p.42).

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<sup>123</sup> Hubert Lyautey, governor general of Morocco from 1912 to 1925, had two main principles, preservation of medinas out of respect for the local culture and building of new, modern cities for European populations. For Lyautey, the preservation of the Arab town had several meanings, some emotional, some practical. Above all, he savored the aesthetic qualities of the Arab town (Çelik 1997, p.39).

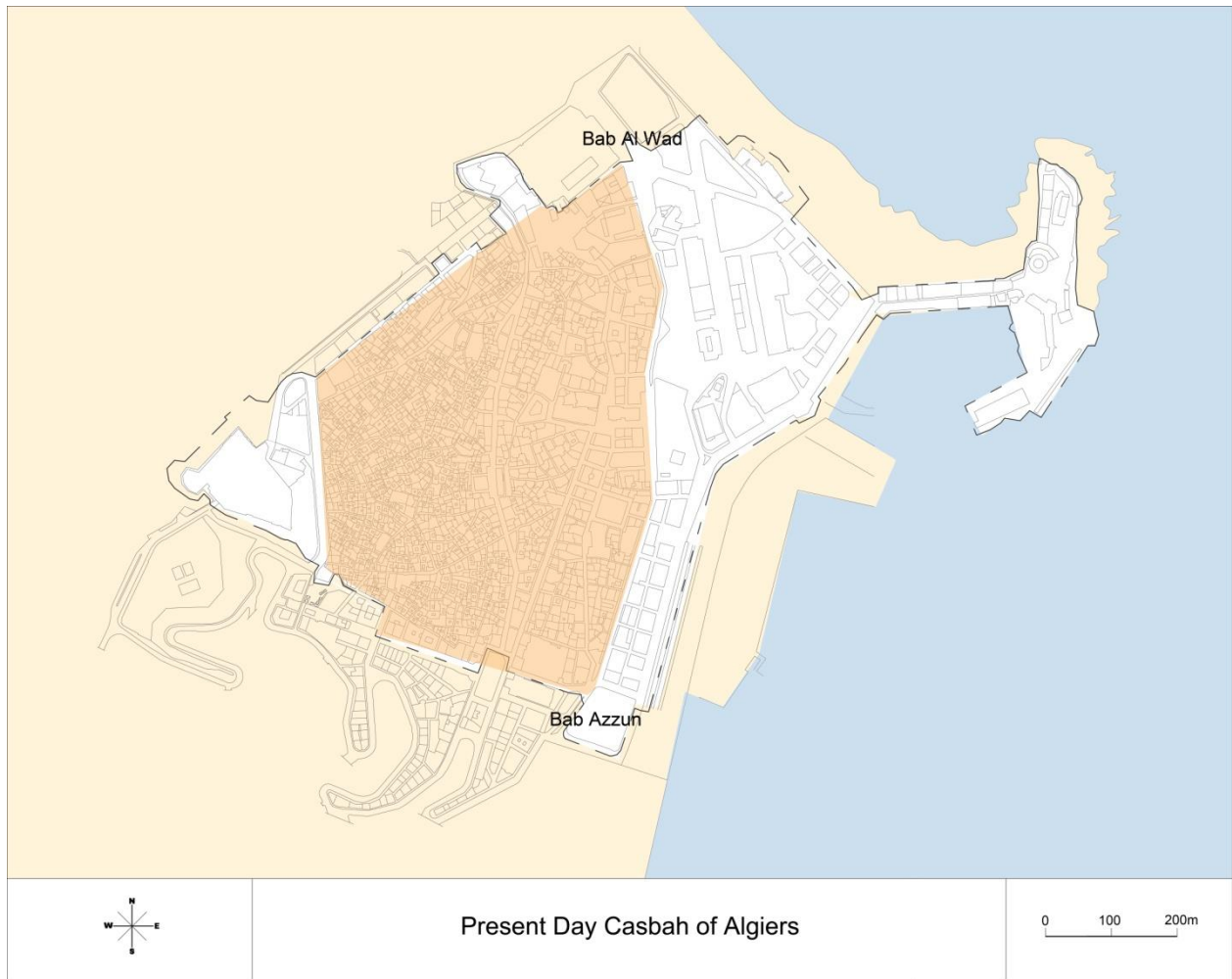


Figure (3.58)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

### 3.2.1. SITE: The Climatic Characteristics of the Site of the Casbah of Algiers

#### A. General Climate

Latitude: 36 43N

Longitude: 003 15E

Algiers is classified under the Köppen Climate Classification as a "dry-summer subtropical" climate which is often referred to as "Mediterranean" (C). The subtype is Csa which is "hot, dry summer"<sup>124</sup>. This climate zone has relatively mild winters and hot summers. The precipitation in the driest month of summer is less than 30 mm and less than 90 mm in the wettest month of the winter. The temperature of warmest month is 22 °C or above<sup>125</sup>.

In Algiers, the highest recorded temperature was 47.2°C in August and the lowest recorded temperature -2.8°C in January<sup>126</sup>. The maximum sun angle at noon is 30° in winter and 75° in summer<sup>127</sup>. The prevailing winds in winter are from the west and south. In the summer, the prevailing winds are moderate from the east and northeast<sup>128</sup>.

#### B. Effect of Different Elements on the Climate of the Casbah of Algiers

##### a. SOLAR FACTOR

###### • Topography

The Casbah of Algiers is situated on a 118m high hill. There are three levels forming this hill: The lower city is rather flat, followed by the mid-city which is a more or less regular slope, and finally the upper Casbah which has a very steep slope (Khalil 2006, p.419) (figure 3.59, 3.60).

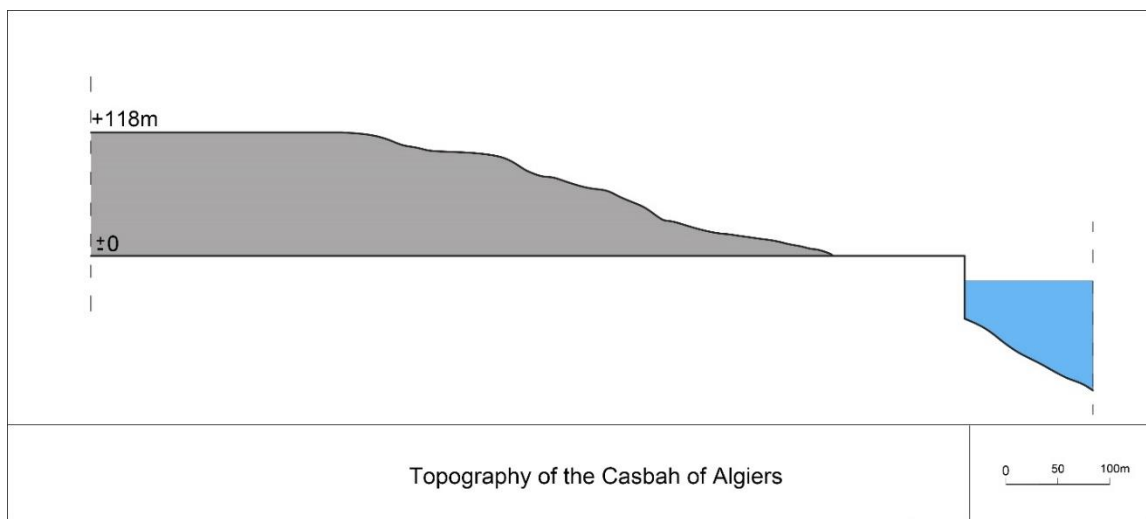


Figure (3.59)

Source: (Khalil 2006, p.419)

<sup>124</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=9306&cityname=Algiers%2C+Alger%2C+Algeria&units=>

<sup>125</sup> <https://www.britannica.com/science/Mediterranean-climate#ref1092481>

<sup>126</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=9306&cityname=Algiers%2C+Alger%2C+Algeria&units=>

<sup>127</sup> These sun angles were calculated from the online application (<http://susdesign.com/sunangle/>).

<sup>128</sup> These average wind directions were estimated from the historical weather records from (<https://www.worldweatheronline.com/algiers-weather-history/alger/dz.aspx>).

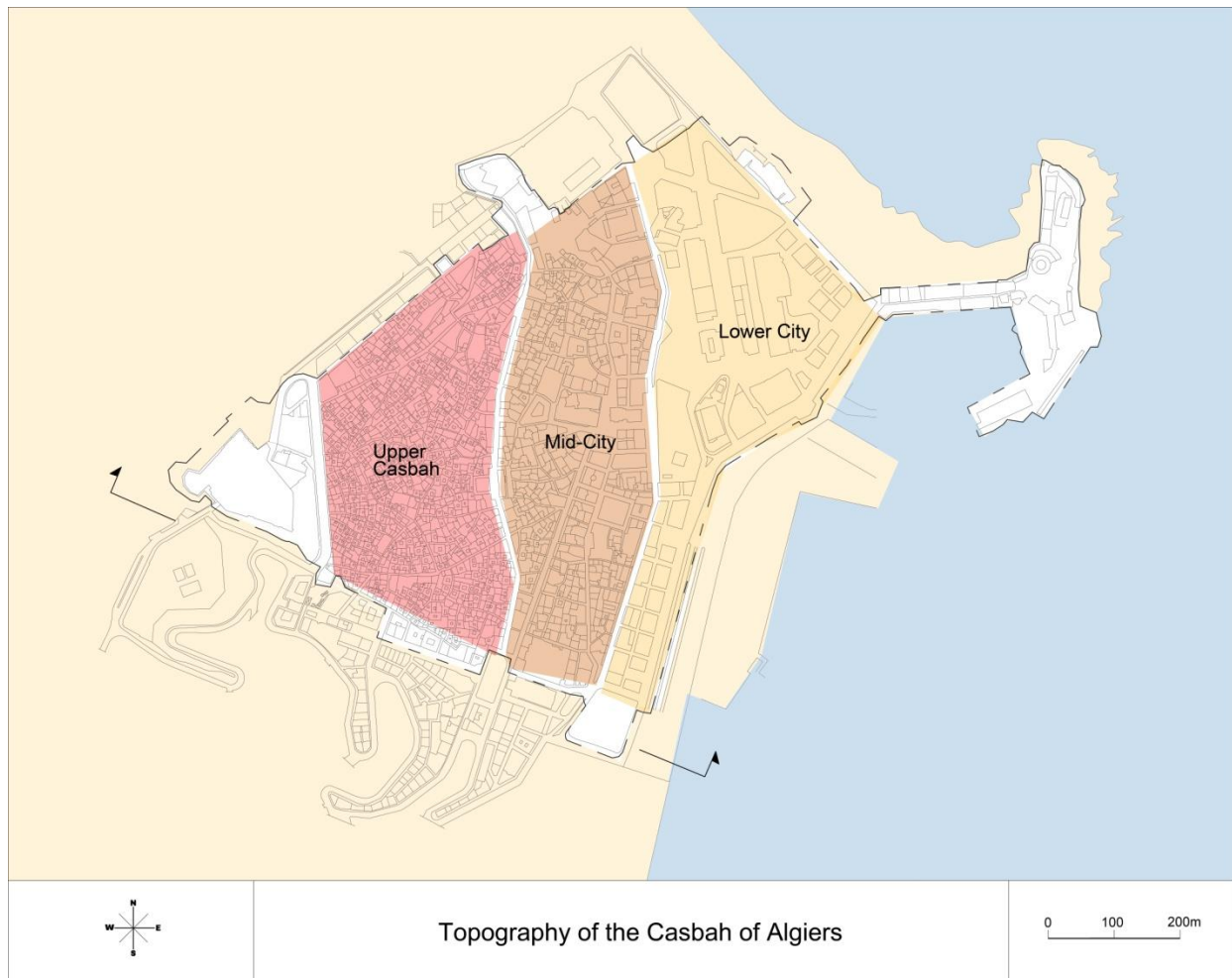


Figure (3.60)  
Source: (Khalil 2006, p.419)

Since the slope of the Casbah does not face south, the whole city does get maximum benefit from the winter southern sun. The terraced houses on east-facing slope receive sunlight from morning till noon (figure 3.61, 3.62). The spacing to height ratio is not calculated because it is not a southern facing slope.



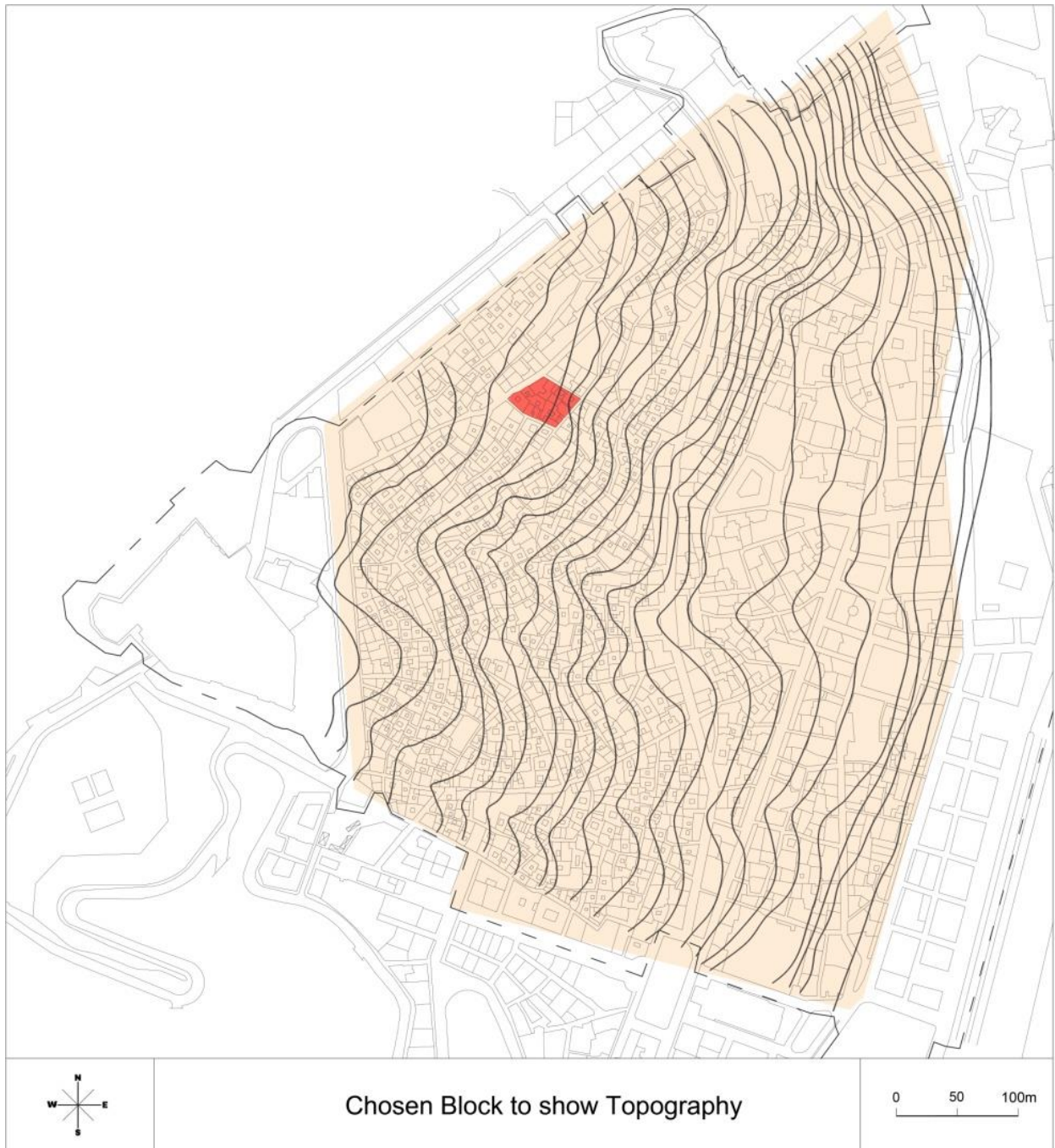


Figure (3.61)  
Source: (Tahari 2006, p.530)



Figure (3.62)  
Source: (Giovanetti 1992, p.72-73)

- **Vegetation**

There is no significant vegetation surrounding the Casbah of Algiers which can affect the climate of the site.

- **Water Bodies**

The Casbah of Algiers faces the Mediterranean Sea from its east side and is located in the Bay of Algiers (figure 3.63). The climate of the Casbah is affected by the large water body due to its large heat capacity<sup>129</sup>.



Figure (3.63)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

## **b. WIND FACTOR**

- **Topography**

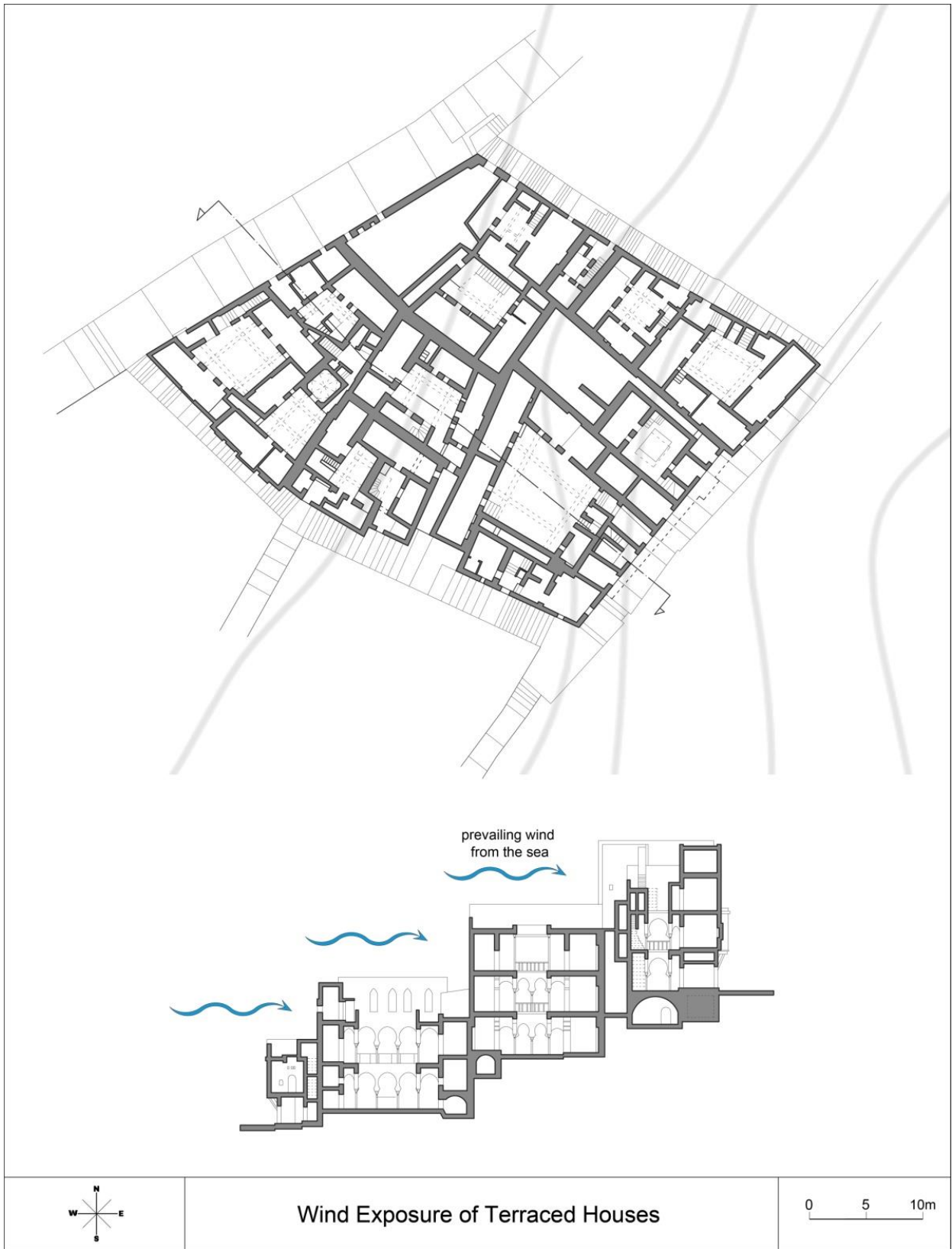
In the Casbah, prevailing winds that are easterly and north-easterly in summer change to west and south in winter. Therefore, the topography of the site with the slope facing east protects the site from the western winter winds and faces the sea breezes from the east in summer (Corpus). The terraced houses all benefit from the summer breeze (figure 3.64).

In addition, the slope causes movement of air up and down the slope during the day and night causing a breeze<sup>130</sup>.

<sup>129</sup> See 2.2.1. Site, a. Solar Factor – Water Bodies, pg.38.

<sup>130</sup> See 2.2.1. Site, b. Wind Factor – Topography, pg.39.





Wind Exposure of Terraced Houses

Figure (3.64)  
Source: (Giovanetti 1992, p.72-73)

- **Water Bodies**

The sea's air conditioning feature causes the sea breeze effect which sends air from the east in summer<sup>131</sup> (figure 3.65).

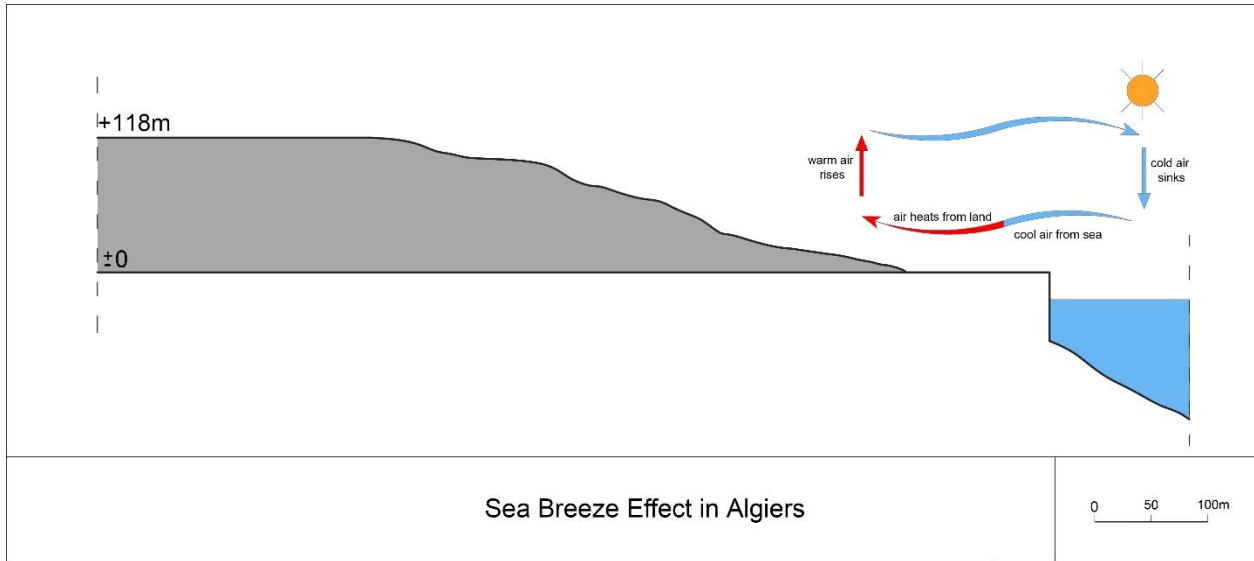


Figure (3.65)  
Source: (Khalil 2006, p.419)

<sup>131</sup> See 2.2.1. Site, b. Wind Factor - Water Bodies, pg. 40.

### c. Comparative Analysis Matrix

The following matrix is the result of analysing the SITE of the Casbah of Algiers based on the matrix found in chapter 2<sup>132</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The number of points was determined as a percentage based on the following:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (3.7) Evaluation for Existing Situation of Tools (EE)

#### 1. Topography

According to the sun factor, the slope of the Casbah of Algiers does not face south making the benefit from the winter sun less. Therefore, it was given “average”. For the wind factor, the slope causes air to travel up and down the slope creating a breeze. The slope also protects the whole Casbah from the winter western winds and receives the winds coming from the sea. Therefore, it was given “very good”.

#### 2. Vegetation

There is no significant vegetation surrounding the site of the Casbah of Algiers, therefore this tool was given “below average” for both factors.

#### 3. Water Bodies

The Mediterranean Sea has a significant effect on the climate of the Casbah of Algiers, therefore it was given “very good” for both factors.

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<sup>132</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, p.42.

<b>Site (SI) – CASBAH OF ALGIERS</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SI 1. Topography</b>	12	6	6	50%	100%	9
<b>SI 2. Vegetation</b>	16	8	8	25%	25%	4
<b>SI 3. Water Bodies</b>	16	8	8	100%	100%	16
<b>Total for SI Category: 44</b>		<b>Final Points for SI – Algiers: 29</b>				

\*EE =Existing Evaluation

Matrix (3.8) Casbah of Algiers SITE Evaluation

### 3.2.2. SETTLEMENT: Urban Structure and Density: The Traditional Compact City of Casbah of Algiers

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In the Casbah of Algiers, the upper city is the part of the city which went through the least interventions. This resulted in the preservation of the dense urban structure which carries the sustainable features of a vernacular village (figure 3.66).

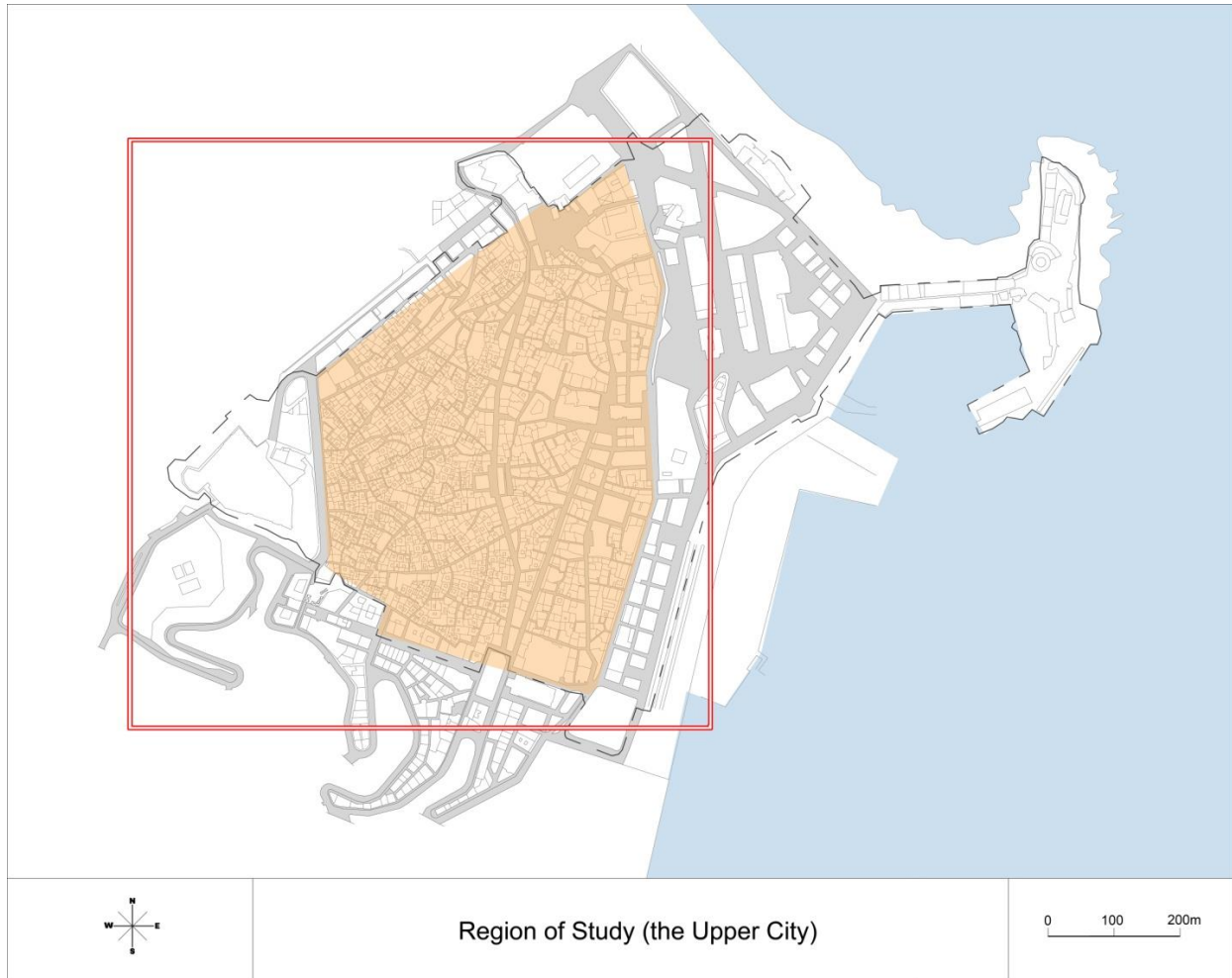


Figure (3.66)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

**a. SOLAR FACTOR**

- **Compact Geometry**

The urban structure of the Casbah of Algiers is characterized by density which has a positive effect on the thermal response of the city (figure 3.67, 3.68).

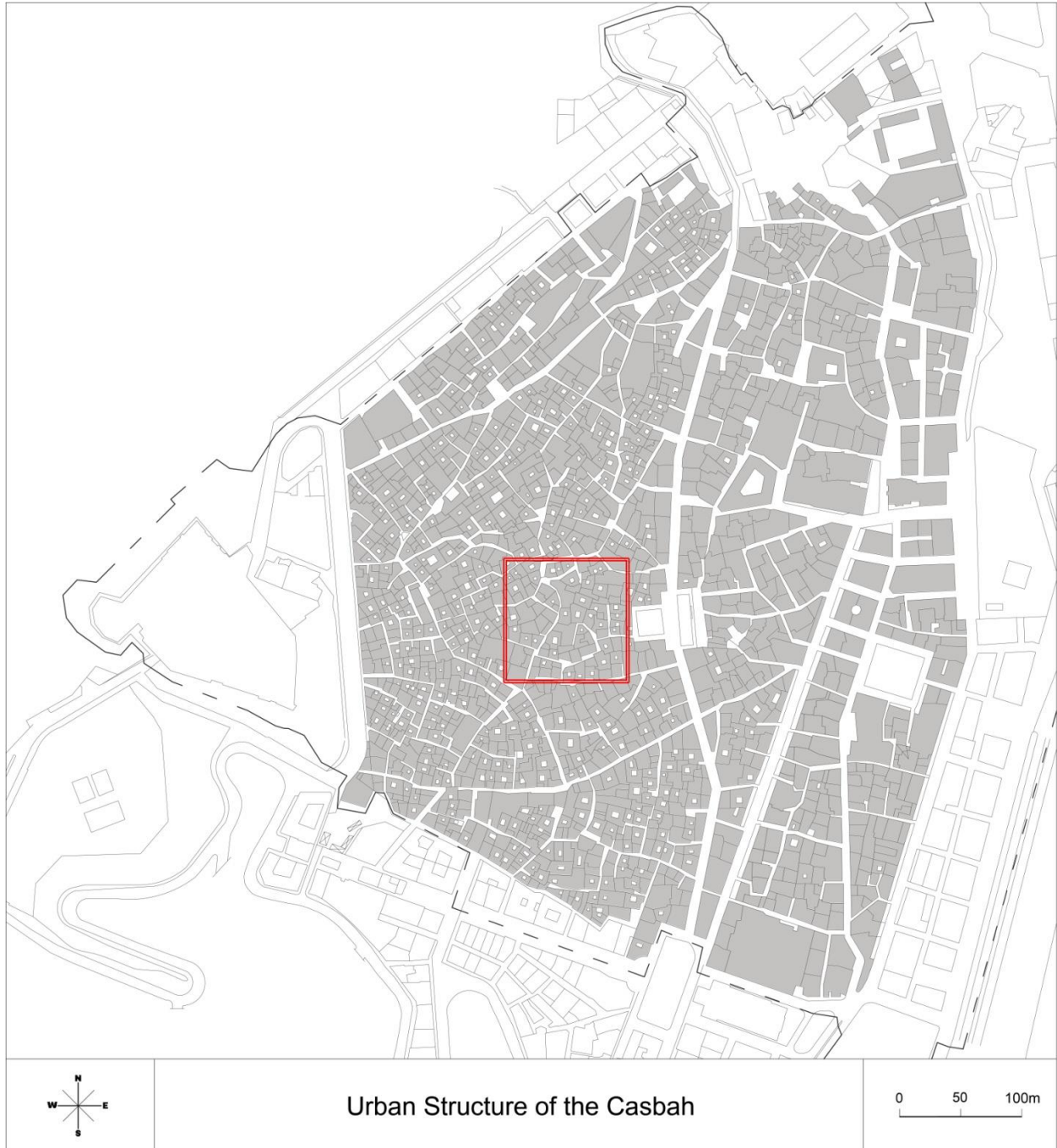


Figure (3.67)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

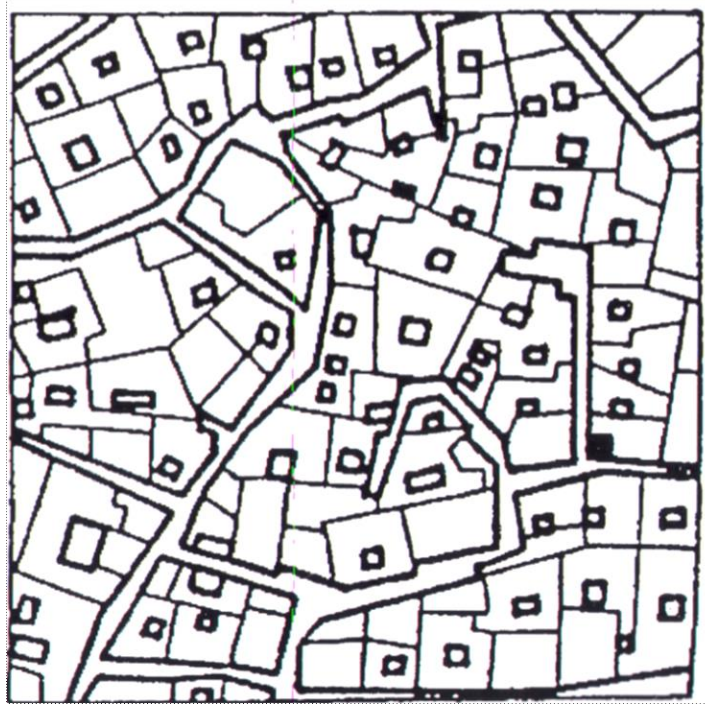


Figure (3.68) Detail of Urban Structure  
Source: (Tempus Rehabilitation of Islamic Cities Program)

This dense fabric results in compact building blocks which contain more than one dwelling<sup>133</sup> (figure 3.69). When comparing a block with only 3 houses and that with 10 or more houses, the results are:

**Surface to volume ratio** (figure 3.70)

In BLOCK 1, the surface to volume ratio is:  $2978\text{m}^2/14712\text{m}^3= 0.2$

In BLOCK 2, the surface to volume ratio is:  $963\text{m}^2/2341\text{m}^3= 0.4$

In BLOCK 3, the surface to volume ratio is:  $5689\text{m}^2/26508\text{m}^3= 0.22$

We can see that the smaller block has the greater value of S/V ratio and the more heat gain and loss. The two larger blocks have a similar S/V value. Although the larger size of Block 3 should result in a smaller S/V value than Block 1, it has a large surface area exposed to weather conditions, therefore it has more heat gain and loss than Block 1.

<sup>133</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.



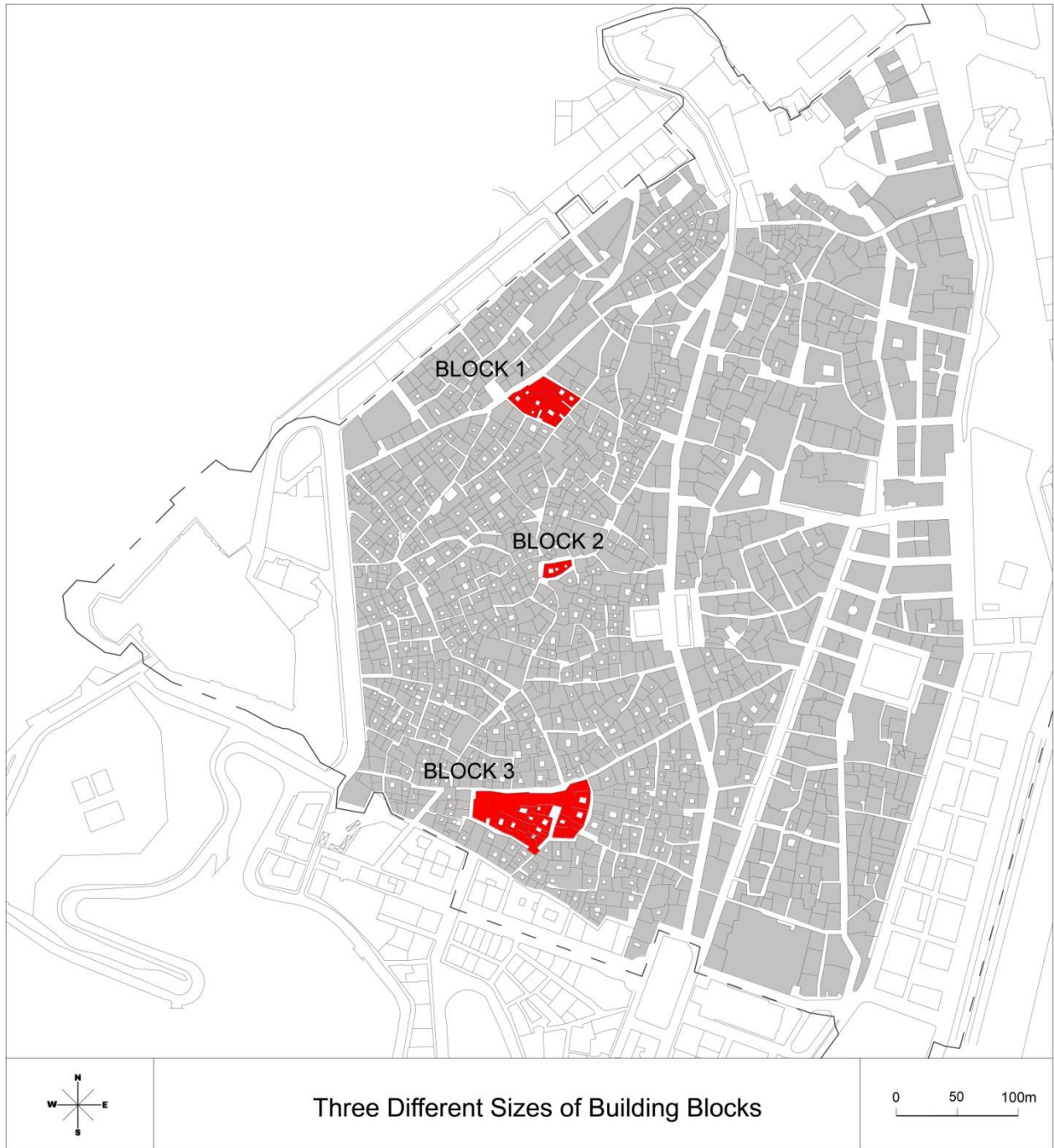


Figure (3.69)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))



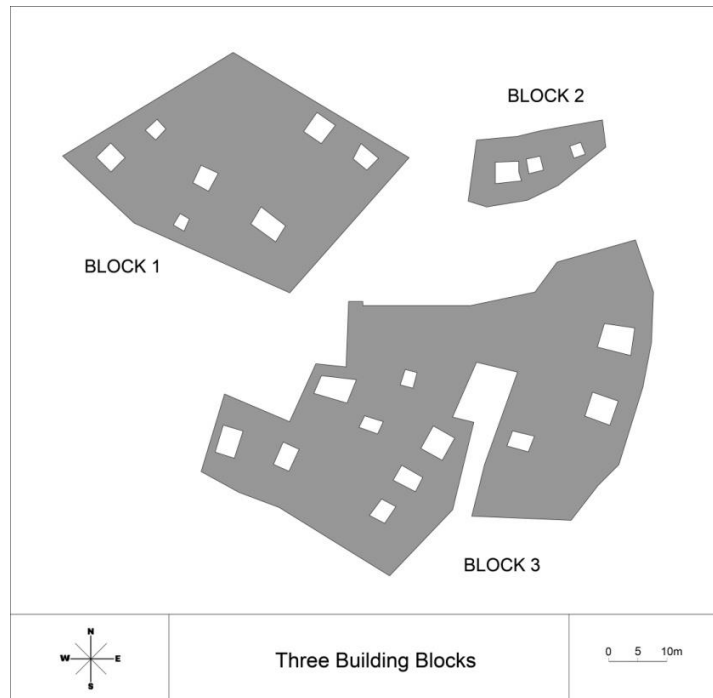


Figure (3.70)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

Block 1 is divided into 13 houses which share walls with one another and gain ventilation and light from the courtyards. Shared walls decrease the exposure to the outdoors and therefore decrease the heat gain and loss (figure 3.71).

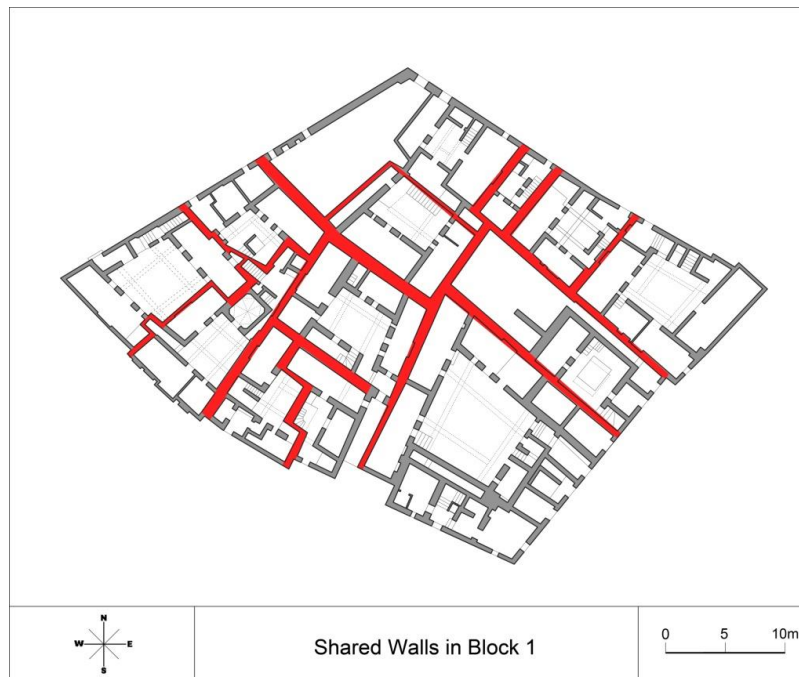


Figure (3.71)

Source: (Giovanetti 1992, p.72-73)

- **Block Orientation**

Due to the irregular form of the Casbah of Algiers, the building blocks have no real orientation or proportion. Some of these blocks could be slightly oriented on an east-west axis making them benefit from this advantage.

- **Street Orientation**

In the Casbah of Algiers, the orientation of the main streets is on a north south axis which exposes them and the buildings running along them to excessive heat in summer. However, there are only three main streets running in this direction and the rest of the Casbah is structured with narrow irregular streets. In spite of their irregularity, some of these streets seem to be running on NE-SW and NW-SE grid system (figure 3.72) which is the optimal system for solar exposure, coupled with the advantage of shade<sup>134</sup>.



Figure (3.72)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

<sup>134</sup> See 2.2.2. Settlement, a. Solar Factor – Street Orientation, pg.46.

- **Narrow Streets**

The narrow streets of the Casbah result in shade which protects the buildings from the excessive solar radiation from the east and west. Dimensions play an important role in the amount of shade created between the building blocks (figure 3.73).



Section line to show Distance of Shade

0 5 10m

Figure (3.73)

Source: (Giovanetti 1992, p.72)

The distance of shade on the street surfaces can be calculated from the equation<sup>135</sup>: (figure 3.74)

$$L = H \times \cot \theta$$

$\theta = 75^\circ$  (Summer Solstice in Algiers)

$\theta = 30^\circ$  (Winter Solstice in Algiers)

$\cot 75^\circ = .27$

$\cot 30^\circ = 1.73$

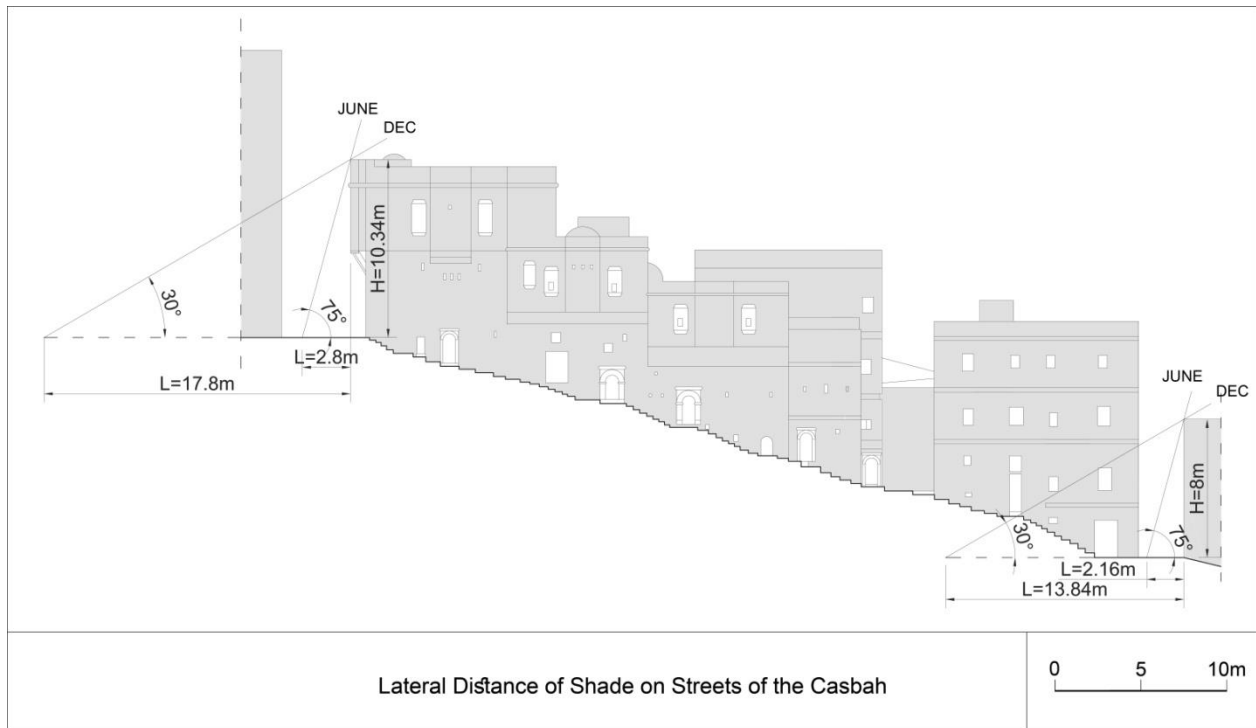


Figure (3.74)

Source: (Giovanetti 1992, p.73)

<sup>135</sup> See 2.2.2. Settlement, a. Solar Factor, Narrow Streets, pg.47.

- **Open Spaces**

The irregular form of the Casbah of Algiers results in the formation of thermally comfortable spaces available for the residents to sit, take walks and meet with neighbours. The density of the urban fabric protects these spaces from any harsh weather like the heat or strong winds (figure 3.75).



Figure (3.75)

Source: (Giovanetti 1992, p.72)



### Open Space 1: Pathway Intersection

The four intersecting pathways in a dense urban fabric create a small shaded square which can be a cool meeting place for the residents and children (figure 3.76).

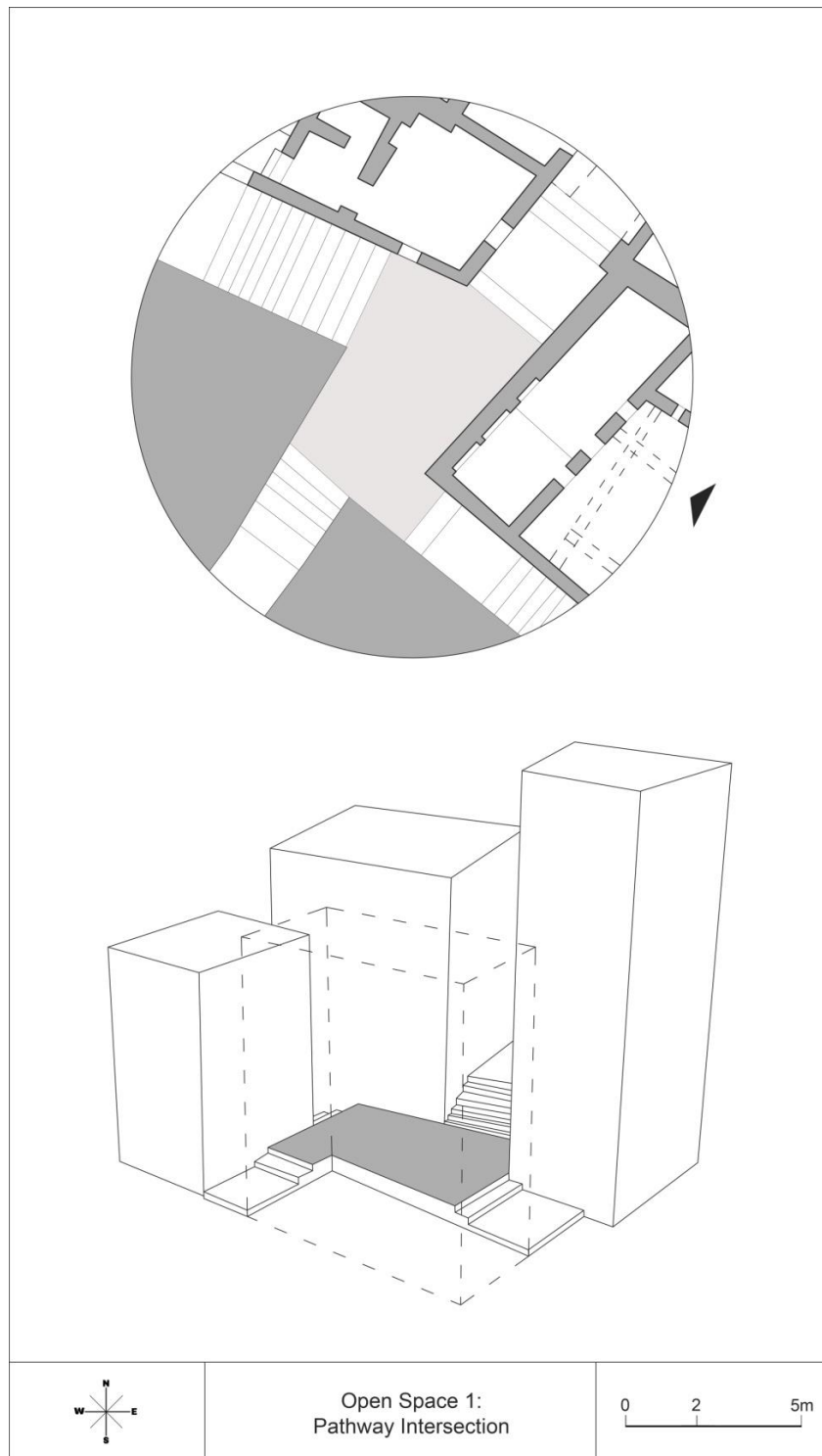


Figure (3.76)  
Source: (Giovanetti 1992, p.72)

### Open Space 2: Extended Upper Floor

In many dwellings of the Casbah of Algiers, the upper floor extends beyond the wall of the lower floor creating a shaded seating area for the residents in addition to shading and protecting the wall from the excessive summer heat. In some areas, the upper floor from two confronting houses extends until it reaches the other, creating an almost entirely covered and shaded passage (figure 3.77).

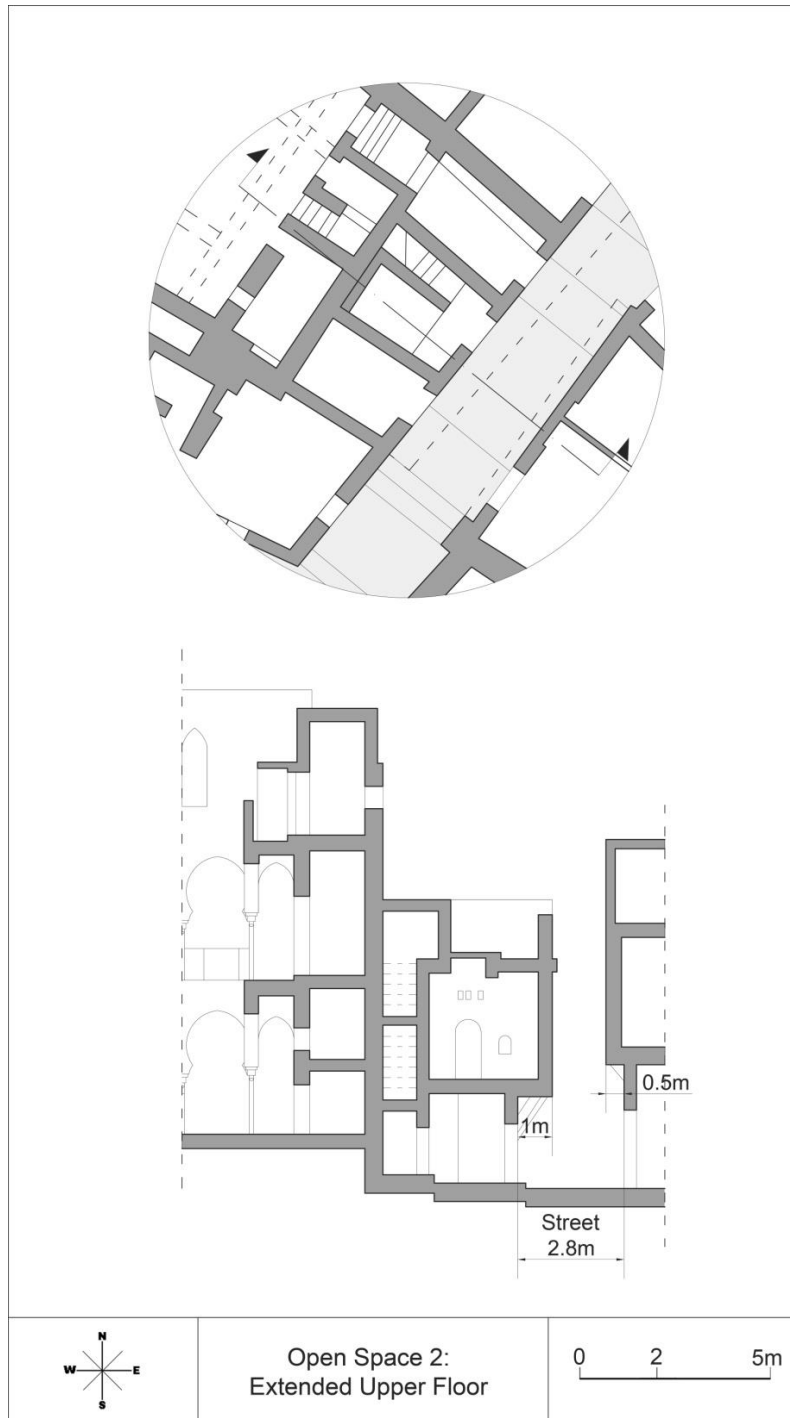


Figure (3.77)

Source: (Giovanetti 1992, p.72-73)

### Open Space 3: Cul de Sac

The cul de sac acts as a shaded semi-private space for the residents of the surrounding dwellings. Figure (3.78).



Figure (3.78)

Source: (Giovanetti 1992, p.72)

- **Vegetation**

There is a very small amount of trees and vegetation in the streets and open spaces of the Casbah which can effect the climate of the streets and shade the buildings.

- **Public Fountains and Wells**

There is no evidence showing that the streets of the Casbah have fountains. Wells for collecting water are more likely to be found.

- **Surface Materials**<sup>136</sup>

#### **Ground Surface Materials**

The streets of the Casbah are covered with a light natural stone which has a higher solar reflectance index of 0.6 making it reduce the overall temperature in the streets.

#### **Building Surface Material**

The vernacular dwellings in the Casbah are covered with whitewash which has a SRI of 0.8 making it reflect most of the solar radiation away from the dwellings.

<sup>136</sup> See 2.2.2. Settlement, a. Solar Factor - Surface Materials, pg.50.



## b. WIND FACTOR

- **Compact Geometry**

The compact geometry and decreased S/V ratio of the building blocks in the Casbah aids in protecting the dwellings from the harsh winter winds and from heat loss during the winter<sup>137</sup>.

- **Block Orientation**

The blocks of the Casbah of Algiers have no real orientation, some of them face the desirable winds and some not. The western winter winds are blocked due to topography.

- **Street Orientation**<sup>138</sup>

Since the slope of the Casbah of Algiers faces the east, many of the streets and passageways have taken the same orientation perpendicular to the contour lines. This resulted in the reception of the desirable summer winds coming from the sea in some of the streets (figure 3.79). The winter winds from the west are blocked due to topography, but the southern winds are received by the main streets.

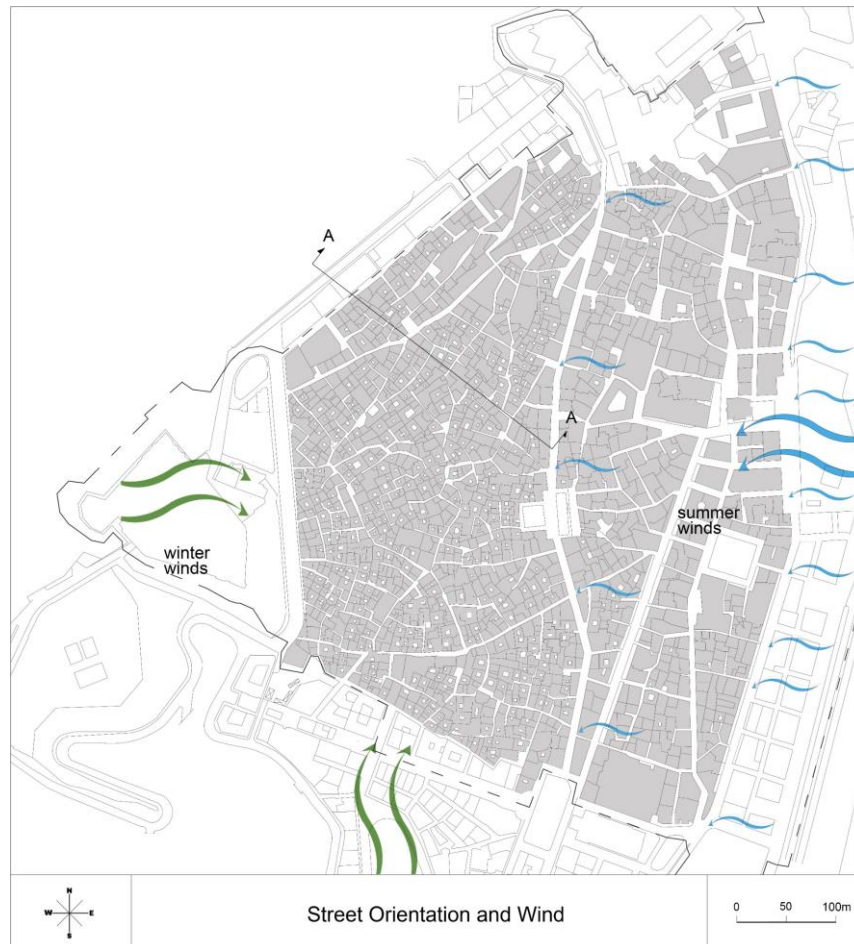


Figure (3.79)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

<sup>137</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.

<sup>138</sup> See 2.2.2. Settlement, a. Wind Factor – Street Orientation, pg.53.

- **Narrow Streets**

The airflow in the streets of the Casbah depends on the street dimensions which make it under the category c.  $H/W > 1$ <sup>139</sup> (figure 3.80). When compared with Sidi Bou Said, this ratio is larger due to the higher buildings and more narrow pathways. This means that there is a skimming flow over the buildings with a very small amount entering the street. This means that in the winter, the narrow streets of the Casbah are protected from the undesirable western winds and in the summer, however, the skimming flow slightly enters but is then disrupted due to the terraced buildings resulting in decreased ventilation of the streets.

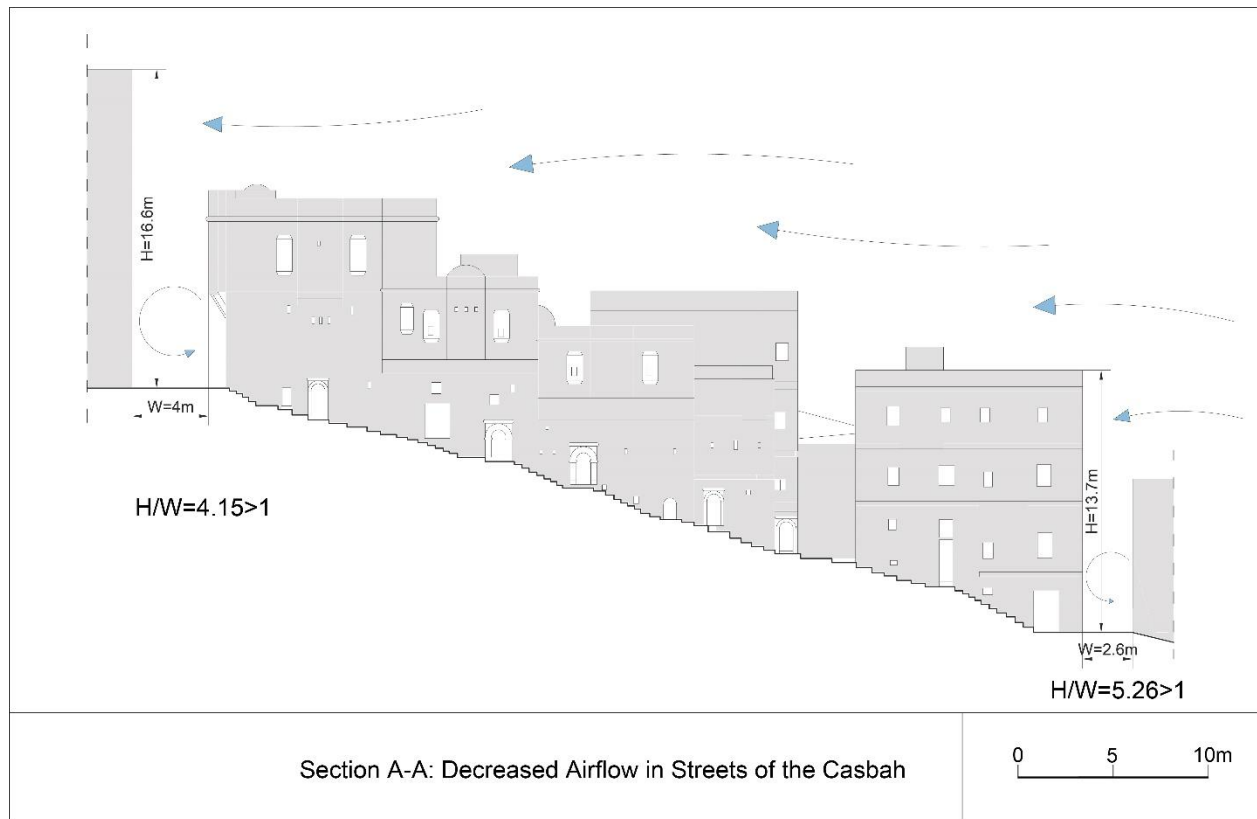


Figure (3.80)

Source: (Giovanetti 1992, p.73)

<sup>139</sup> See 2.2.2. Settlement, b. Wind Factor – Narrow Streets, pg.54.

- **Open Spaces**

The amount of ventilation in the open spaces of the Casbah depends on the H/W ratio of the open space<sup>140</sup>.

**Open Space 1: Pathway Intersection**

When taking the average height of the buildings  $H/W=8/6.8=1.17$ . This means that there is good ventilation with a vortex of air in the street which flows opposite to the wind direction.

**Open Space 2: Extended Upper Floor**

The difference in temperature in the covered passageway results in airflow through the passage.

**Open Space 3: Cul de Sac**

There is restricted ventilation when the cul de sac is a narrow street. Ventilation increases when it is a square depending on the H/W ratio.

- **Vegetation**

Although there is no significant amount of trees and vegetation in the streets and open spaces of the Casbah, the small amount still has some effect on the ventilation and air flow in the streets and buildings<sup>141</sup>.

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<sup>140</sup> See 2.2.2. Settlement, b. Wind Factor – Open Spaces, pg.55.

<sup>141</sup> See 2.2.2. Settlement, b. Wind Factor – Vegetation, pg.55.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the SETTLEMENT of the Casbah of Algiers based on the matrix found in chapter 2<sup>142</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (3.7)<sup>143</sup>.

#### **1. Compact Geometry**

The Casbah of Algiers has a compact geometry which decreases the heat gain and loss in the buildings giving it a “very good” rating for both factors.

#### **2. Block Orientation**

Most of the blocks have no real orientation, some benefit from the southern sun and others are exposed to the eastern and western sun. The same case is applicable for the wind factor where some blocks benefit from the prevailing winds and others don't. Therefore, this tool was given “average” for both factors.

#### **3. Street Orientation**

The main streets of the Casbah of Algiers have a north-south orientation giving it a disadvantage in the summer, however, many of the secondary streets seem to have an optimal orientation. According to the wind factor, many of the streets are perpendicular to the topography and therefore receive the prevailing winds. The southern winter winds are received by some of the main streets. This tool was given “average” for both factors.

#### **4. Narrow Streets**

The narrow streets of the Casbah of Algiers have a large impact on the street climate and the buildings due to the shading of the facades. It was given “very good” for the sun factor. However, the decreased H/W ratio protects from the undesirable winds in winter but decreases ventilation in the streets even more than the streets of Sidi Bou Said, therefore it was given “good” for the wind factor.

#### **5. Open Spaces**

The variety of open spaces in the Casbah of Algiers create comfortable meeting places for the residents. Some which are shaded and others act as outdoor courtyards with good ventilation. This tool was given “very good” for both factors.

#### **6. Vegetation**

There is no significant amount of vegetation in the streets of Algiers. It was given “below average” for both factors.

#### **7. Public Fountains and Wells**

Public wells are most likely to be found in the streets of Algiers but there is no evidence proving their existence. It was given “below average” for both factors.

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<sup>142</sup> See 2.2.2. Settlement, c. Comparative Analysis Matrix, p.57.

<sup>143</sup> See 3.2.1. Site, c. Comparative Analysis Matrix, Matrix (3.7) Evaluation for Existing Situation of Tools (EE), p.152.

## 8. Surface Materials

The light colours of the buildings of the Casbah of Algiers protect the buildings from the excessive summer heat giving it a “very good” for the sun factor. As for the wind factor, surfaces are cooled down from the wind only in the areas exposed to them. That is why, it this tool was given “average” for the wind factor.

<b>Settlement (SE) - CASBAH OF ALGIERS</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SE 1. Compact Geometry</b>	16	8	8	100%	100%	16
<b>SE 2. Block Orientation</b>	12	6	6	50%	50%	6
<b>SE 3. Street Orientation</b>	4	2	2	50%	50%	2
<b>SE 4. Narrow Streets</b>	16	8	8	100%	75%	14
<b>SE 5. Open Spaces</b>	4	2	2	100%	100%	4
<b>SE 6. Vegetation</b>	16	8	8	25%	25%	4
<b>SE 7. Public Fountains</b>	4	2	2	25%	25%	1
<b>SE 8. Surface Materials</b>	16	8	8	100%	50%	12
<b>Total for SE Category: 88</b>		<b>Final Points for SE – Algiers: 59</b>				

\*EE =Existing Evaluation

Matrix (3.9) Casbah of Algiers SETTLEMENT Evaluation

### 3.2.3. DWELLING: Passive Design Strategies of Courtyard Houses in the Casbah of Algiers

#### Case Study: Dar Aziza

Dar Aziza was built in the Ottoman period in the 16<sup>th</sup> century<sup>144</sup> (figure 3.81). The original plan consisted of two parts as shown in figure (3.82): the main body of the palace which still exists today and the smaller part which was demolished between 1831 and 1838 (Lafer 2018).

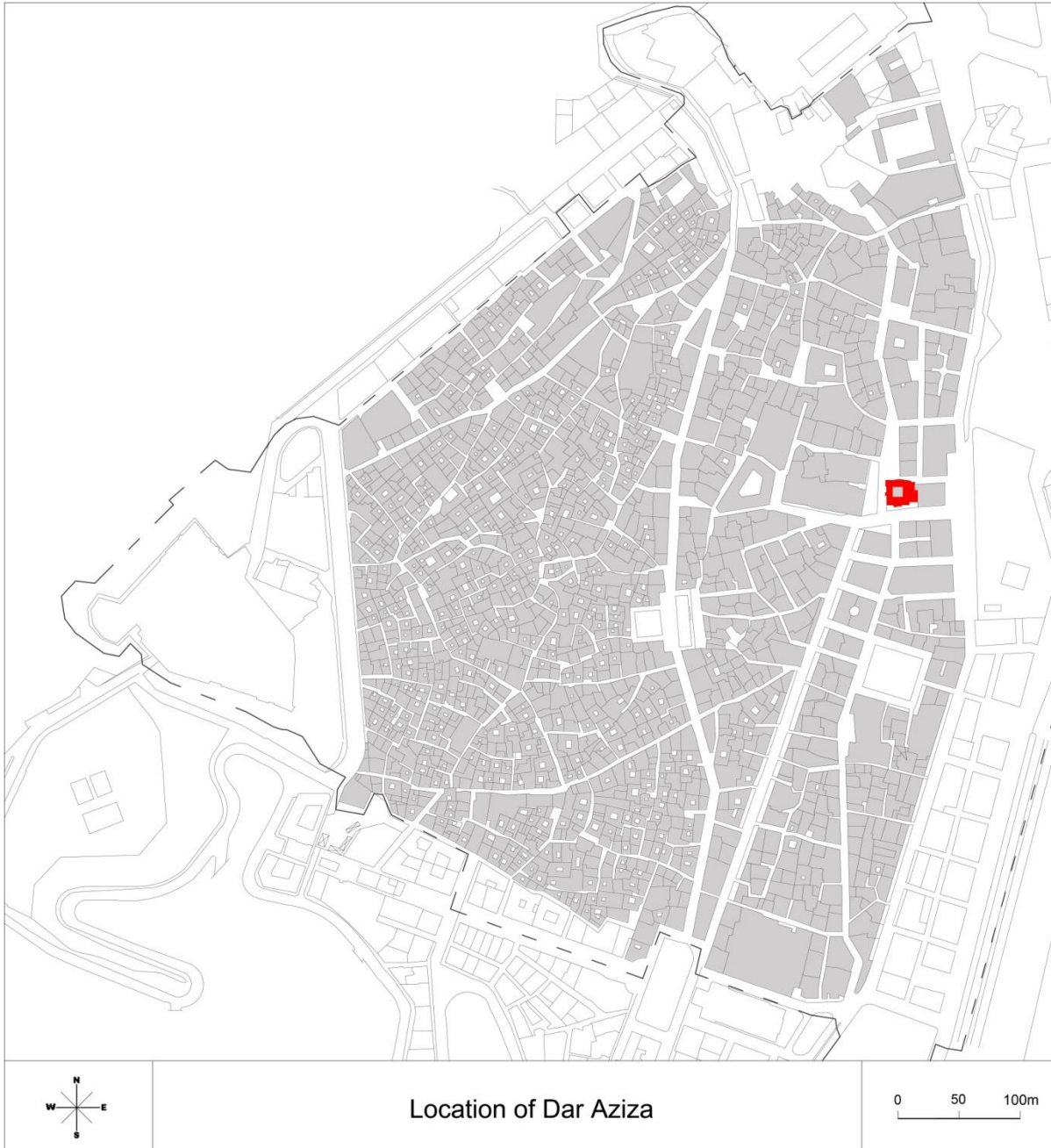


Figure (3.81)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

<sup>144</sup> It was named Aziza after the daughter of a dey who offered this palace to her as a gift.

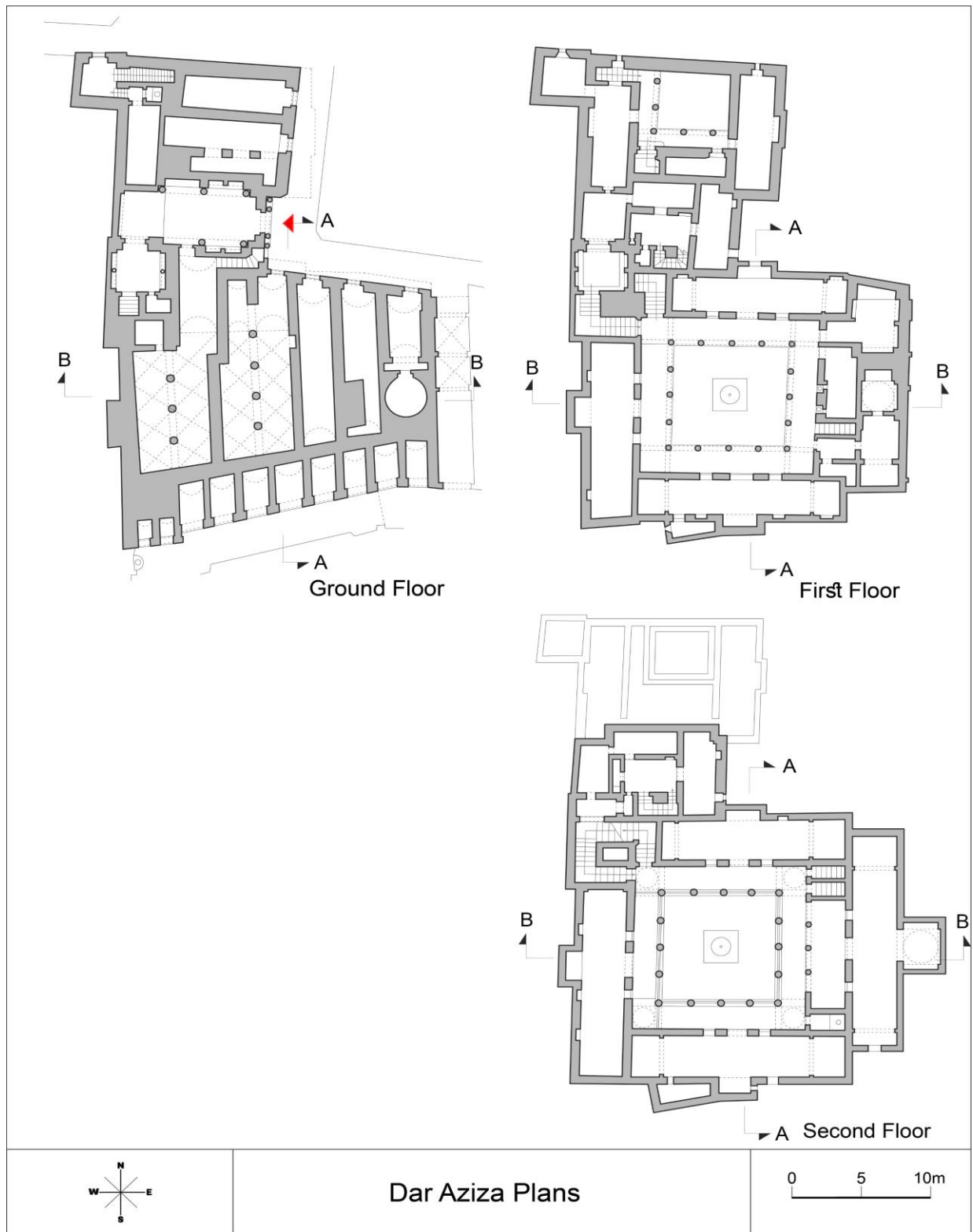


Figure (3.82)  
Source: (Lafer 2018)

### 3.2.3.1. The Thermal Response of the Courtyard of Dar Aziza

#### a. SOLAR FACTOR

- **Shape and Form**

Due to the shape of Dar Aziza and the existence of the main courtyard and the smaller one, the dwelling benefits from self shading<sup>145</sup> (figure 3.83).

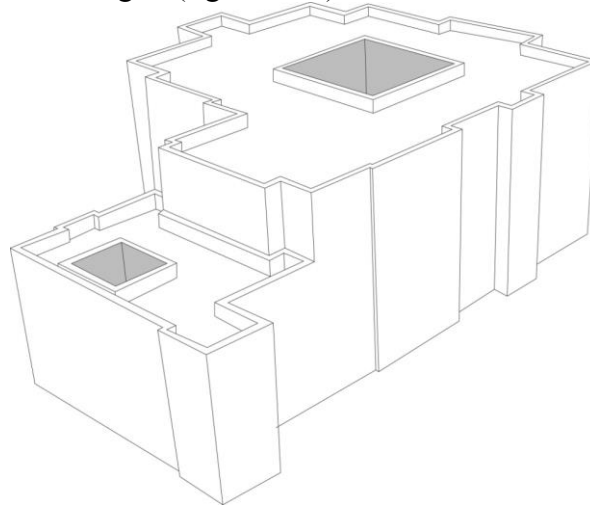


Figure (3.83)  
Effect of Shape on Self Shading

- **Orientation**

Dar Aziza is a detached courtyard house which is exposed from all directions. Although the original building is orientated on a north-south axis, the existing one is the main palace building which is an approximate square with the longer elevation orientated east-west, giving this elevation southern exposure and double exposure due to the existence of the courtyard<sup>146</sup> (figure 3.84). There are more than 10 metres between Dar Aziza and the building to the south of it, resulting in more solar exposure.

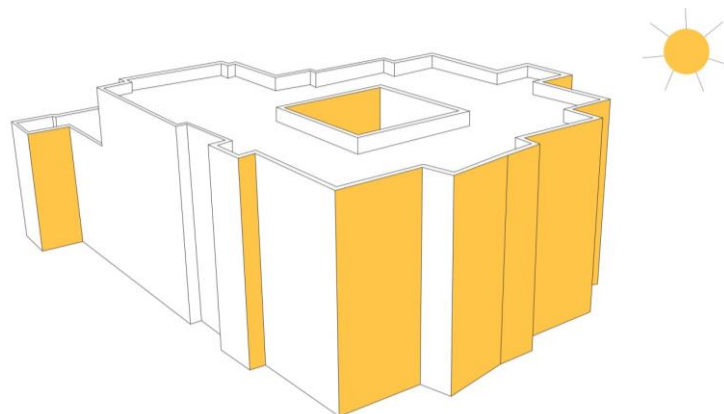


Figure (3.84)  
Exposure of Southern Elevation

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<sup>145</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Shape and Form, pg.61.

<sup>146</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Orientation, pg.61.



- **Dimensions and Shade**

As mentioned before, the shape of Dar Aziza gives it the benefit of self shading. However, the dimensions of the courtyard determine the amount of shade created which affects the way the courtyard works as a temperature regulator (figure 3.85).

**Lateral Distance of Shade<sup>147</sup>**

**$L=H \times \text{COT}\theta$**

Summer:

$L=10.5 \times .27=2.8\text{m}$

Winter:

$L=10.5 \times 1.73=18.2\text{m}$

**L:** Lateral Distance of shade on courtyard surface

**H:** Height of building

$\theta = 75^\circ$  (Summer Solstice in Algiers)

$\theta = 30^\circ$  (Winter Solstice in Algiers)

$\text{Cot } 75^\circ = .27$

$\text{Cot } 30^\circ = 1.73$

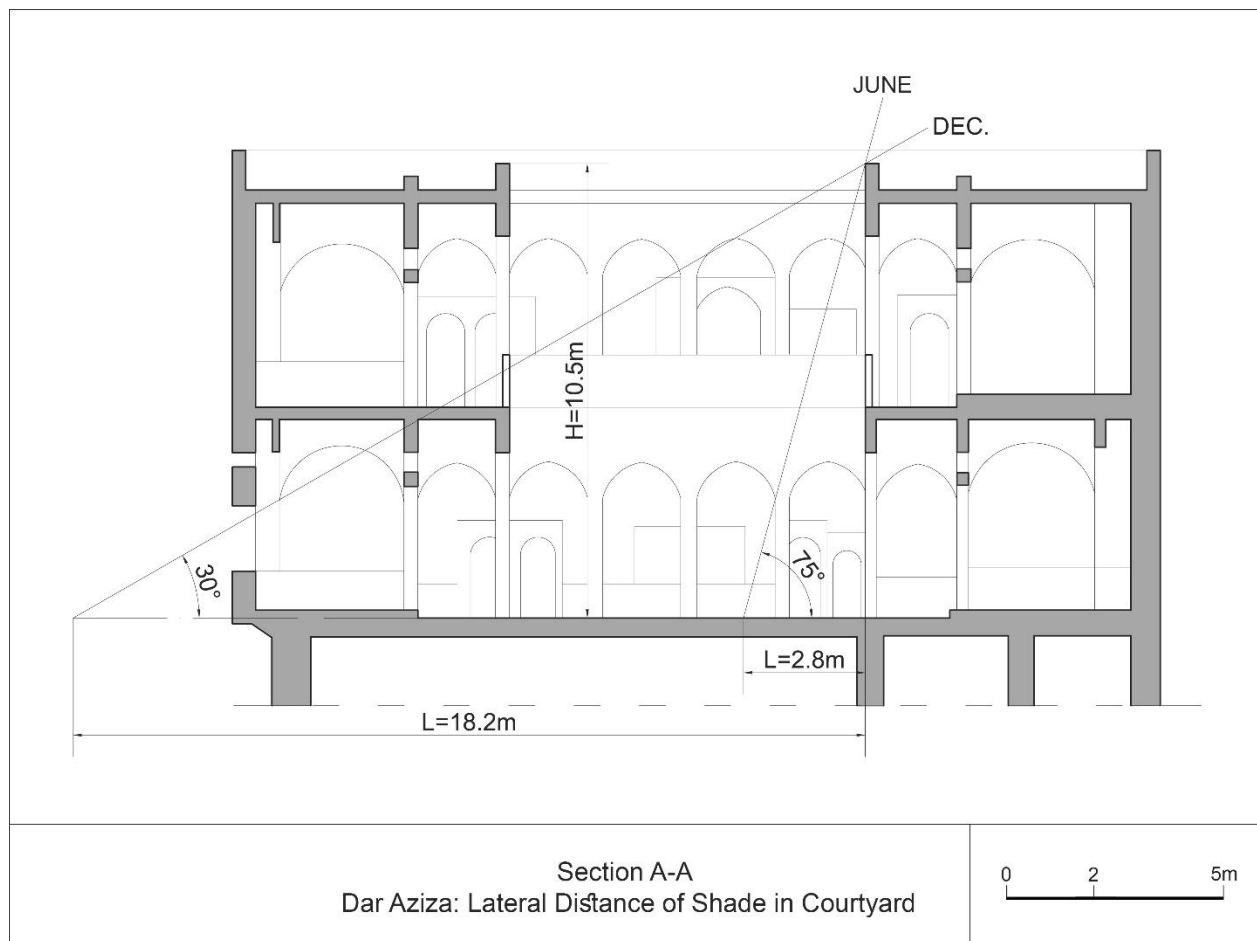


Figure (3.85)

Source: (Corpus 2001, p.8)

<sup>147</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Dimensions and Shade, pg.62.

## b. WIND FACTOR

### • Shape and Form

In addition to the thermal response of a courtyard house<sup>148</sup>, in Dar Aziza, the proportion of height to width of the courtyard results in a relatively deep courtyard and therefore keeps the cool air resulting from the convection process near the ground (figure 3.86).

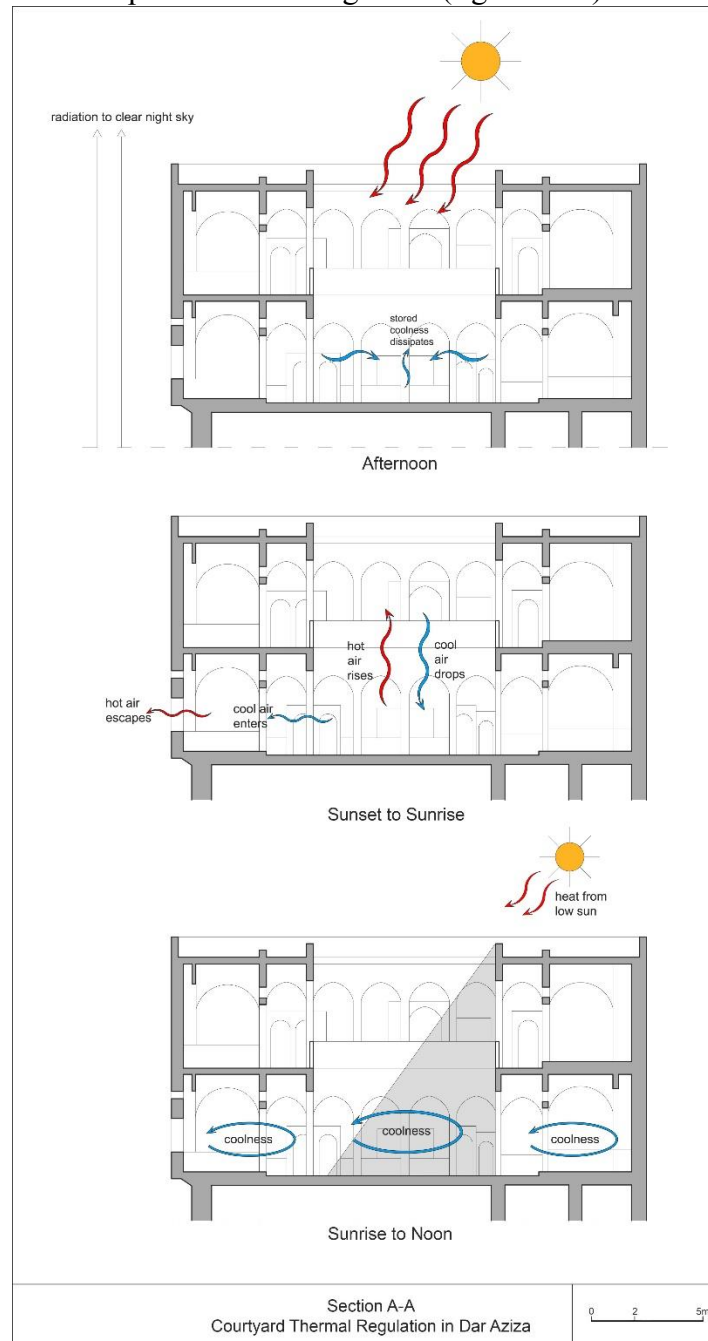


Figure (3.86)  
Source: (Corpus 2001, p.8)

<sup>148</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Shape and Form, pg.63.

- **Orientation**

Dar Aziza receives the desirable winds in summer and is protected from the eastern winter winds due to topography. The southern winter winds however can make its way to the house through the streets<sup>149</sup> (figure 3.87).

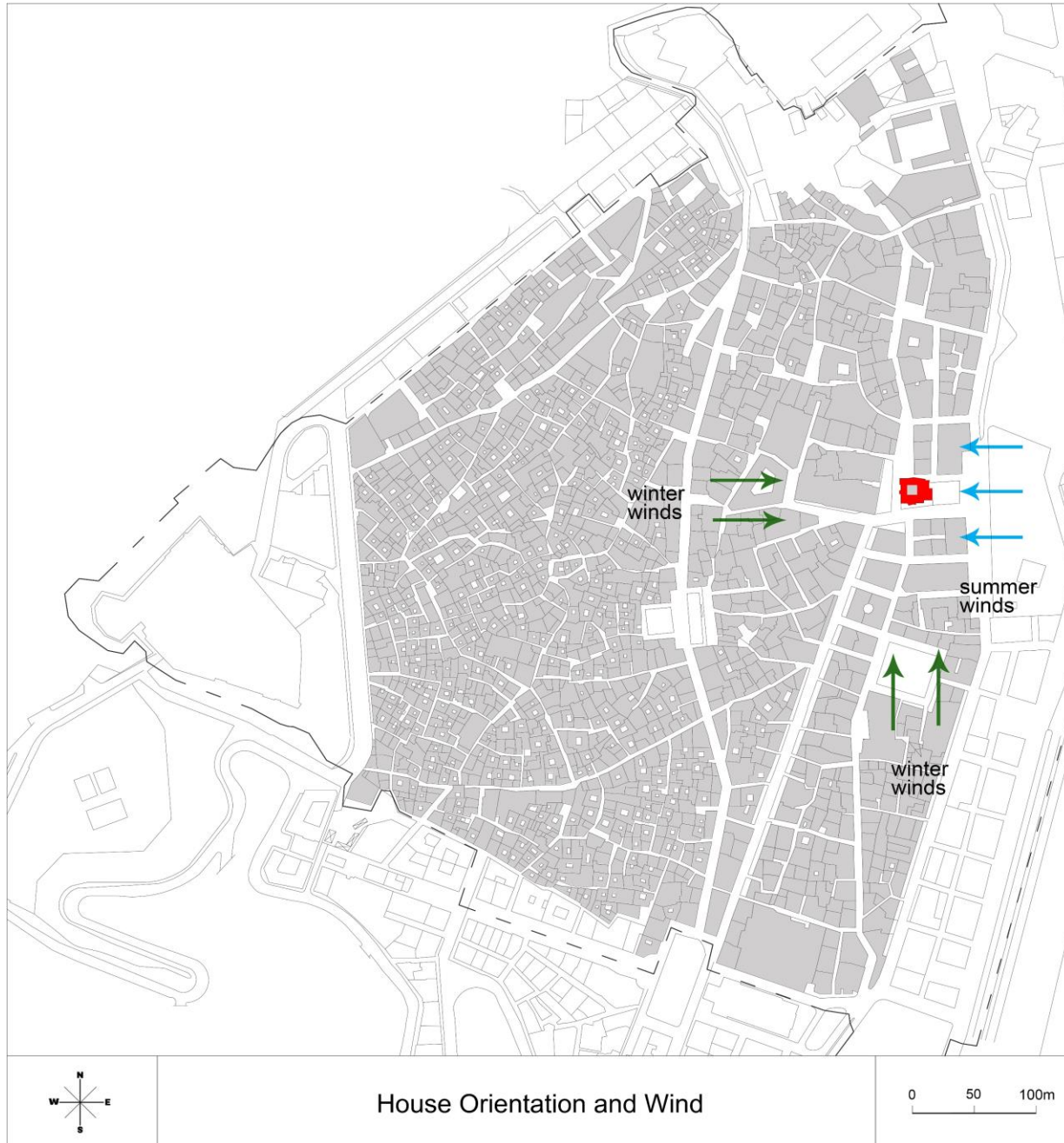


Figure (3.87)

Source: ([http://whc.unesco.org/en/list/565/multiple=1&unique\\_number=667](http://whc.unesco.org/en/list/565/multiple=1&unique_number=667))

<sup>149</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Orientation, pg.65.

- **Dimensions and Airflow**

The airflow in the courtyard depends on the H/W ratio. The airflow and ventilation in the courtyard decreases as this ratio increases. In the case of Dar Aziza, this ratio is a little over 1 so there is still some airflow but less when compared with Dar Toumi due to the 2 storey height of the courtyard walls<sup>150</sup> (figure 3.88).

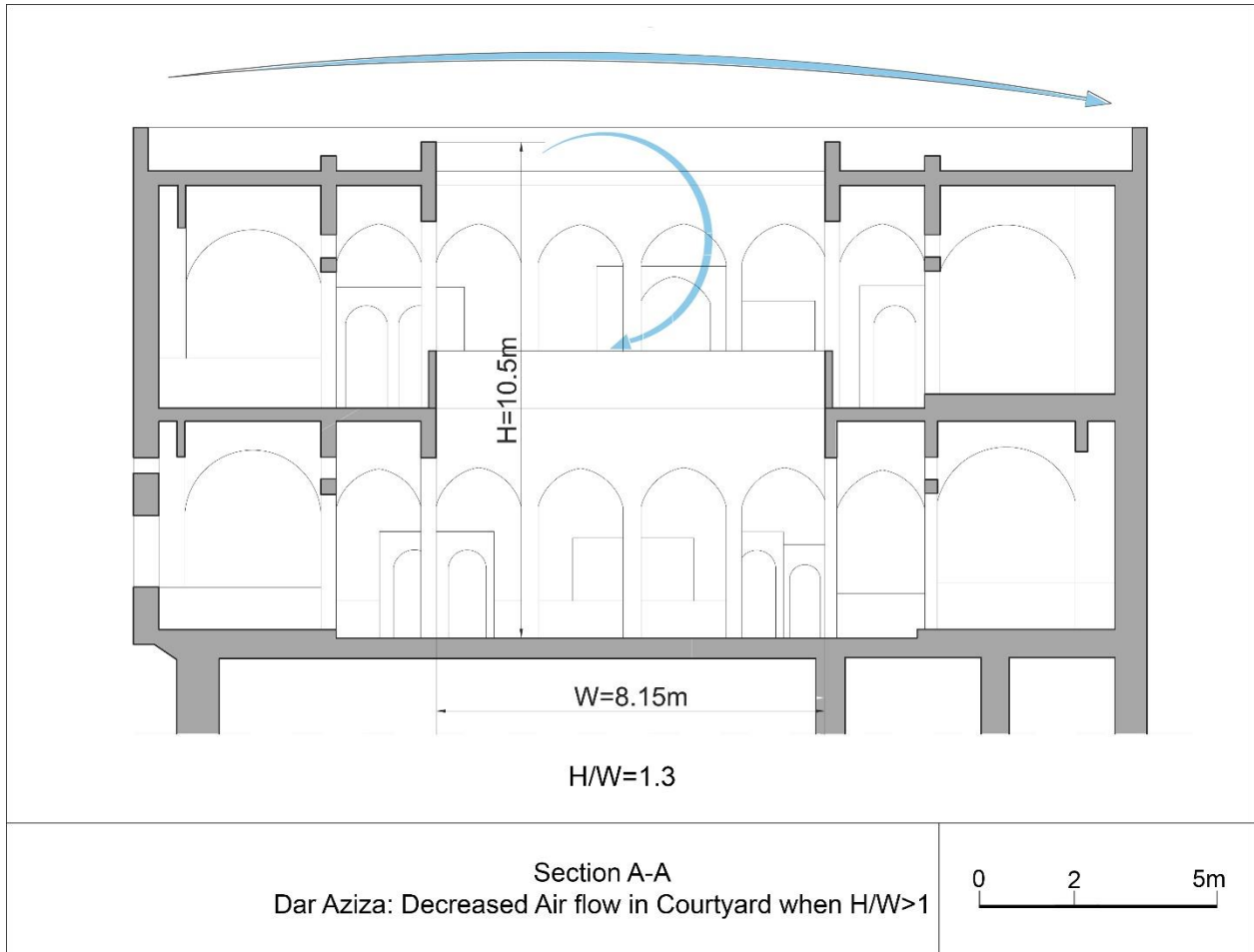


Figure (3.88)  
Source: (Corpus 2001, p.8)

<sup>150</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Dimensions and Airflow, pg.65.

### 3.2.3.2. Additional Thermal Regulating Spaces in Dar Aziza

#### a. SOLAR FACTOR

- **The Liwan**

In Dar Aziza, the liwan is located on the eastern elevation. It was considered a private space for relaxing<sup>151</sup> and is separated from the courtyard by two spaces which protect the liwan from the setting afternoon sun (figure 3.89).

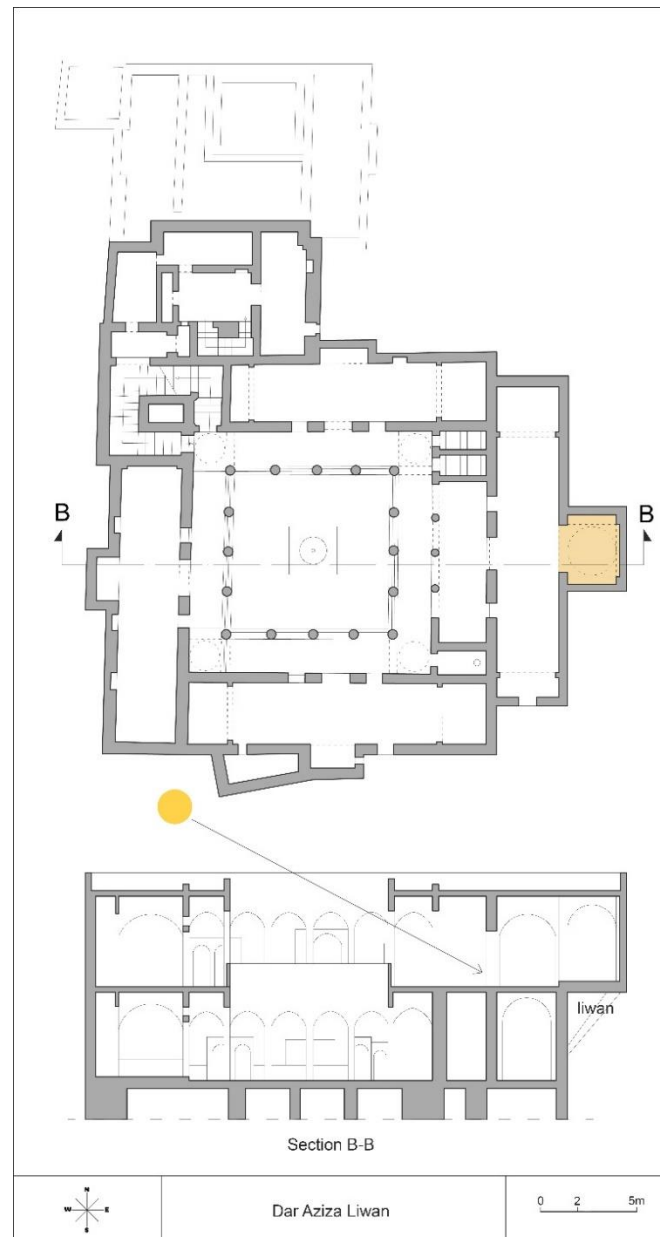


Figure (3.89)

Source: (Lafer 2018) and (Corpus 2001, p.8)

<sup>151</sup> See 2.2.3. Dwelling, 2.2.3.3. Additional Thermal Regulating Spaces, a. Solar Factor – The Liwan, pg.67.

- **The Arcade**

In the Casbah of Algiers, many of the large houses have an arcade (riwak) on all four sides of the courtyard. This provides a shady space for sitting and creates a buffer zone which protects the inside from the excessive heat<sup>152</sup>. In Dar Aziza, the small courtyard also has an arcade on two sides of the courtyard (figure 3.90).

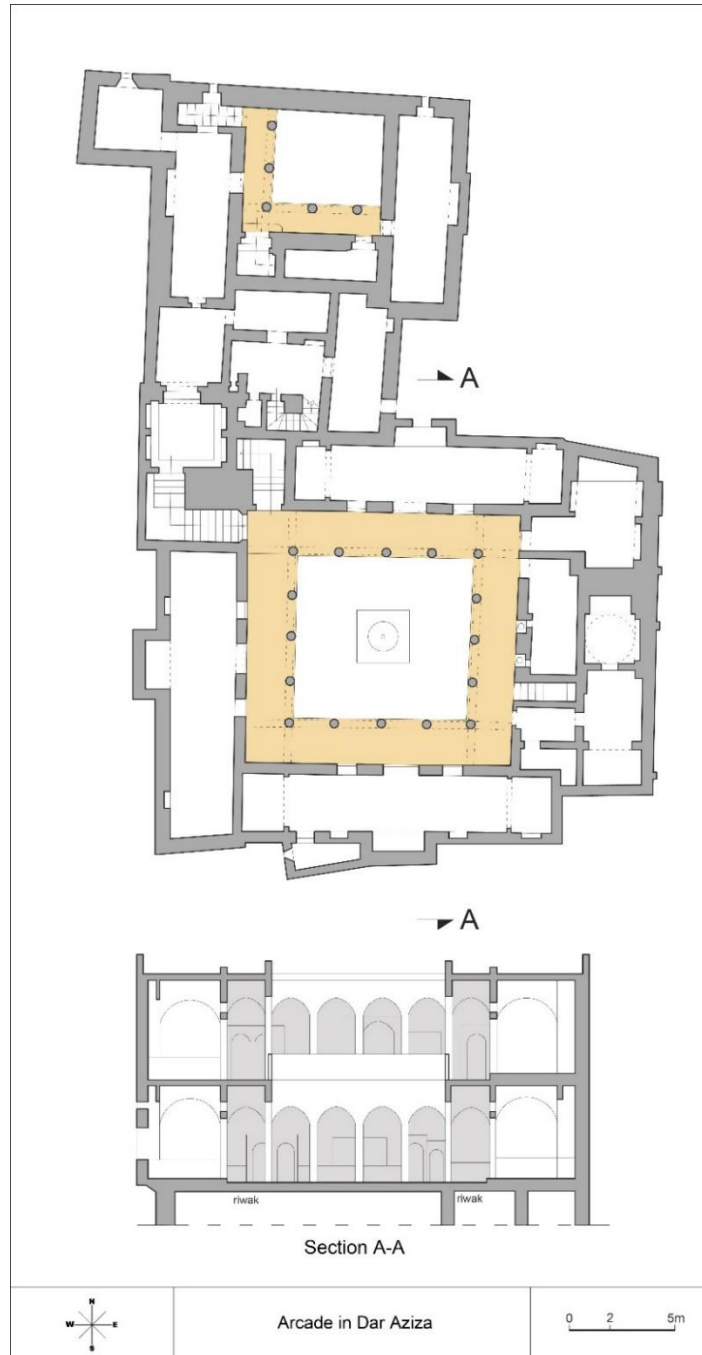


Figure (3.90)  
Source: (Lafer 2018) and (Corpus 2001, p.8)

<sup>152</sup> See 2.2.3. Dwelling, 2.2.3.3. Additional Thermal Regulating Spaces, a. Solar Factor – The Arcade, pg.68.

- **The Roof:**

Since Algiers is built on a slope, roof terraces are a very important element in the courtyard house where they provide a sitting area facing the city and the Mediterranean Sea. In the original building of Dar Aziza, the roof of the first and second floor can be used as terraces. However, the roof terrace does not benefit from the winter southern sun and in the summer, it is exposed to the eastern and western sun (figure 3.91). Pergolas could have been used to provide shade.

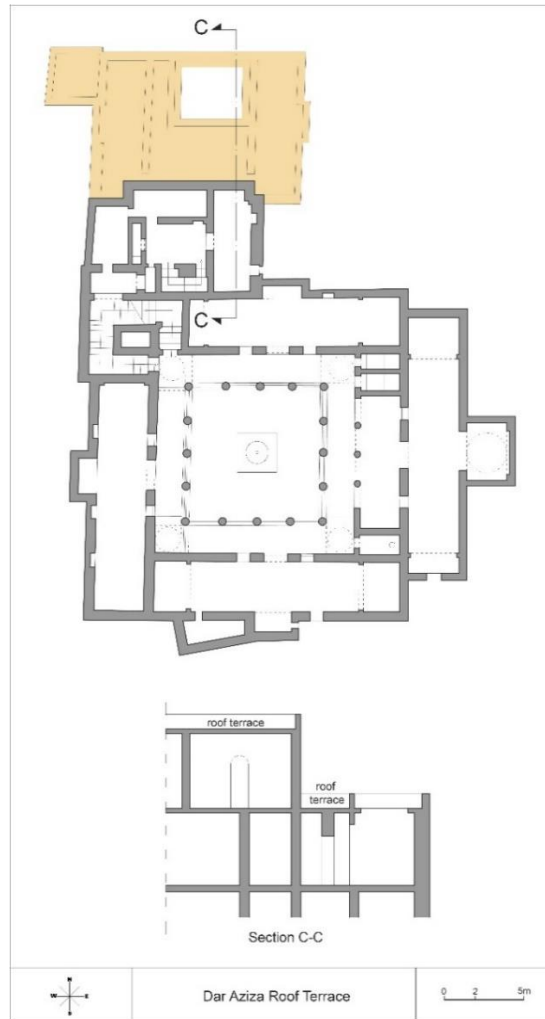


Figure (3.91)

Source: (Lafer 2018) and (Corpus 2001, p.8)

## b. WIND FACTOR

- **Liwan**

Since the liwan has no openings to the exterior and is far from the courtyard, it lacks ventilation.

- **The Roof**

The roof in Dar Aziza is exposed to the prevailing winds coming from the sea making it a desirable sitting area in the summer after sunset. In the winter however, it is also exposed to the western winds (figure 3.91).

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the DWELLING of the Casbah of Algiers based on the matrix found in chapter 2<sup>153</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (3.7)<sup>154</sup>.

#### **1. Shape and Form**

The courtyard form of Dar Aziza contributes to the energy savings of a house due to the benefit of self shading from all four sides. The original plan of Dar Aziza has an additional courtyard giving the service areas benefit from self shading. The courtyard shape also has the function of thermally regulating the dwelling by convection. This tool was given “very good” for both factors.

#### **2. Orientation**

The orientation of Dar Aziza gives the living spaces benefit from the southern sun in addition to the spaces facing the two courtyards. Therefore, it was given “very good” for the sun factor. As for the wind factor, Dar Aziza faces the desirable winds and is protected from the western winds due to topography, however the winter winds coming from the south could reach the dwelling. Therefore, it was given “good”.

#### **3. Dimensions**

The dimensions of the courtyard of Dar Aziza (height and width) give the courtyard a significant amount of shade due to the two storey height of the courtyard walls giving it “very good” for the sun factor. According to the wind factor, the dimensions result in less air flow entering the courtyard when compared with Dar Toumi, but the increased height of the courtyard walls keeps the cool air from escaping. This tool was given “good” for the wind factor.

#### **4. The Liwan**

The existence of the liwan creates a comfortable sitting area protected from the sun due to the spaces separating them. It was given “very good” for the sun factor. As for the wind factor, the liwan lacks ventilation, so it was given “below average”.

#### **5. The Arcade**

The arcade surrounding the four courtyard walls in the main courtyard protects the facades from the sun in addition to the two-sided arcade in the smaller courtyard. It was given “very good” for the sun factor and it is not applicable to the wind factor.

#### **6. Roof Terrace**

The roof terrace in Dar Aziza is a pleasant place for sitting in the event of pergolas to protect from the sun in the summer. The back terrace does not receive southern sun in winter. Therefore, it was given “average” for the sun factor. According to the wind factor, both roof terraces receive the desirable winds in summer but are exposed to the winter winds. This space was given “good” for the wind factor.

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<sup>153</sup> See 2.2.3. Dwelling, 2.2.3.2. c. Comparative Analysis Matrix, p.72.

<sup>154</sup> See 3.2.1. Site, c. Comparative Analysis Matrix, Matrix (3.7) Evaluation for Existing Situation of Tools (EE), p.152.



<b>Dwelling (DW) - CASBAH OF ALGIERS</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>DW 1. Shape and Form</b>	16	8	8	100%	100%	16
<b>DW 2. Orientation</b>	16	8	8	100%	75%	14
<b>DW 3. Dimensions</b>	12	6	6	100%	75%	10.5
<b>DW 4. Liwan</b>	8	4	4	100%	25%	5
<b>DW 5. Arcade</b>	8	4	N/A	100%	N/A	4
<b>DW 6. Loggia</b>	8	N/A	4	N/A	0	0
<b>DW 7. Terrace/Roof/Garden</b>	8	4	4	50%	75%	5
<b>Total for DW Category (-N/A): 68                      Final Points for DW – Algiers: 54.5</b>						

\*EE =Existing Evaluation

Matrix (3.10) Casbah of Algiers DWELLING Evaluation

### 3.2.4. ELEMENT: Thermal Regulating Elements in Dar Aziza

#### a. SOLAR FACTOR

- **Windows**

In Dar Aziza, there were originally very few windows with the exception of the ground floor. The windows found were small to reduce solar penetration and for privacy. However, to allow more light into the house from these small windows, they were tapered so that the inside dimensions were larger than the outside ones. As for the windows and doors facing the courtyard, they were plenty and large. The house depended on these openings for air and light (Corpus 2001, p.8) (figure 3.92).

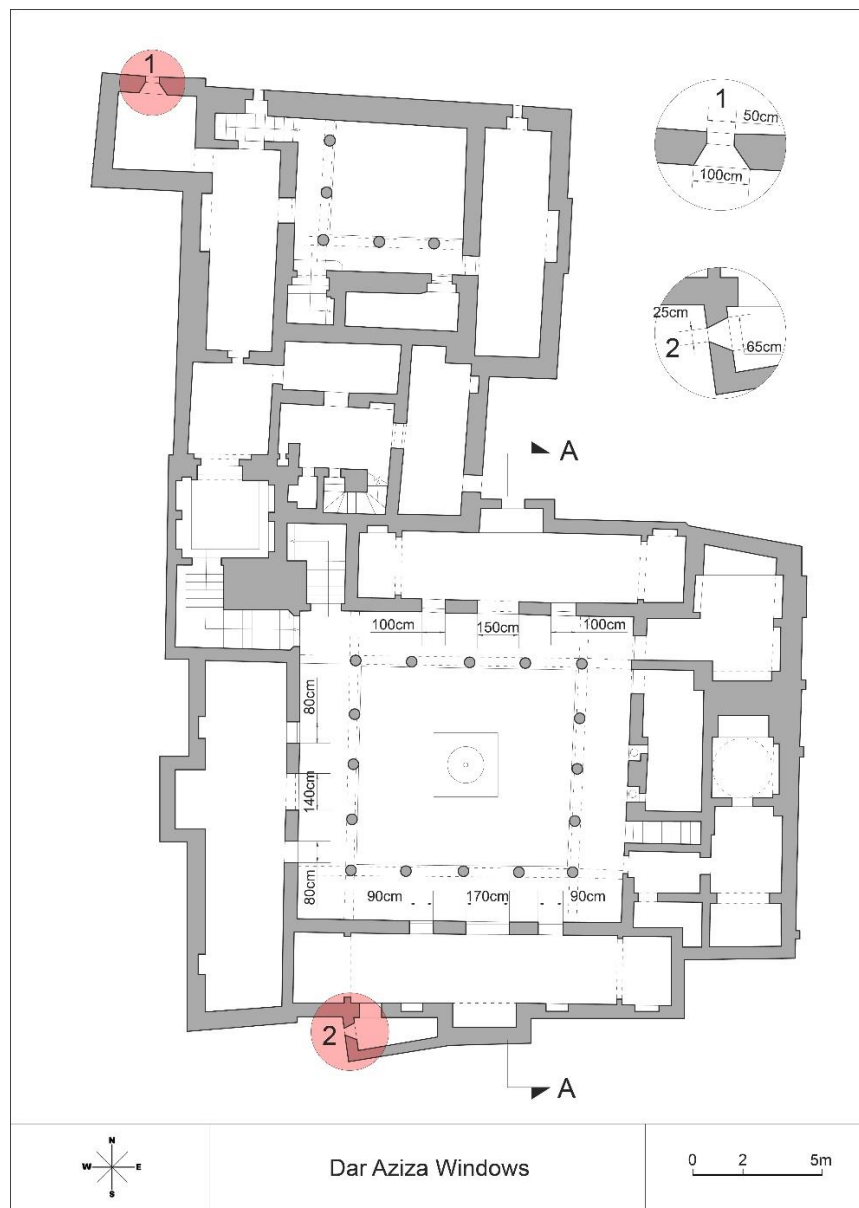


Figure (3.92)  
Source: (Lafer 2018)

The south facing windows allow solar penetration in winter due to their increased height. However, the dimensions of the courtyard allow the southern sun to penetrate only the upper floor windows (figure 3.93).

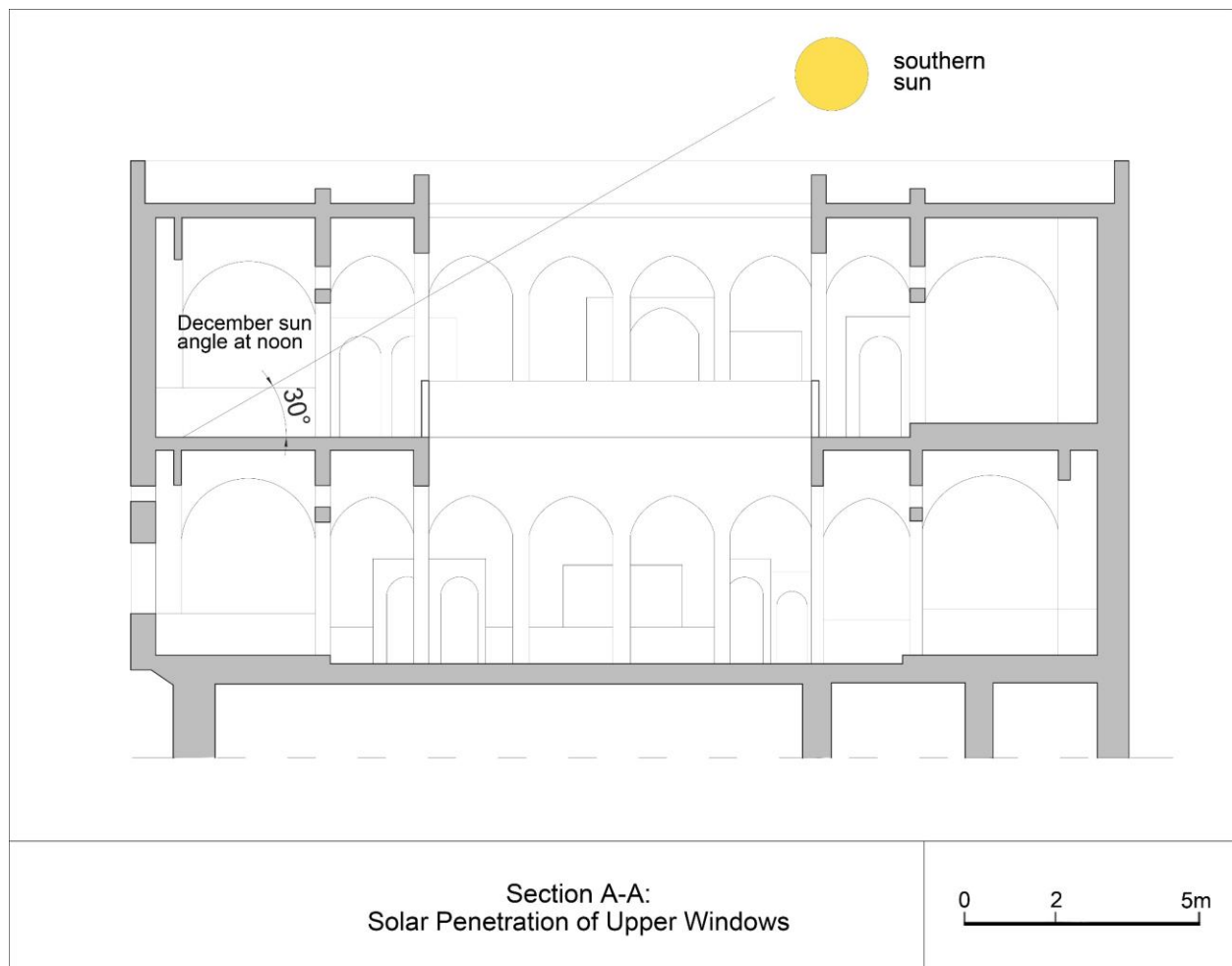


Figure (3.93)  
Source: (Corpus 2001, p.8)

- **Courtyard Vegetation and Shade**

There is no permanent vegetation in the courtyard of Dar Aziza, only small plants around the fountain.

- **The Fountain**

With the aid of the sun, the fountain in Dar Aziza is a main element which contributes to the humidity of the courtyard and cools the air above it<sup>155</sup> (figure 3.94, 3.95).

<sup>155</sup> See 2.2.4. Element, a. Solar factor- Water Features, pg.78.

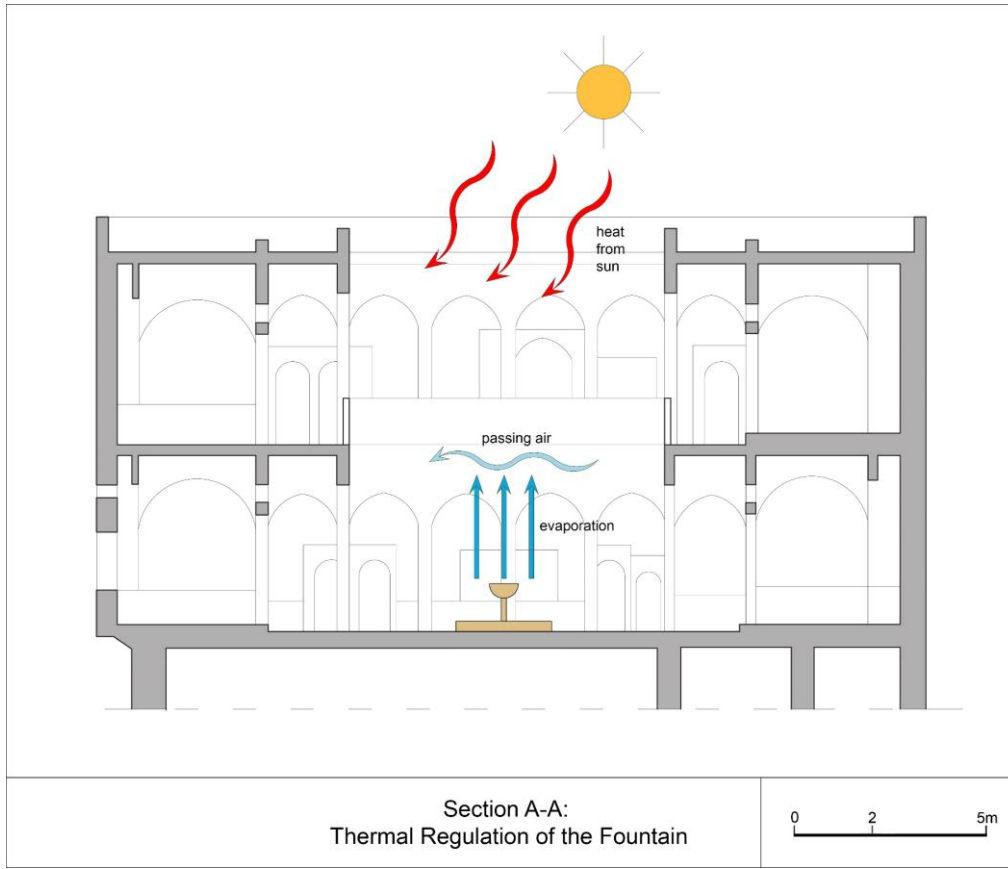


Figure (3.94)  
Source: (Corpus 2001, p.8)

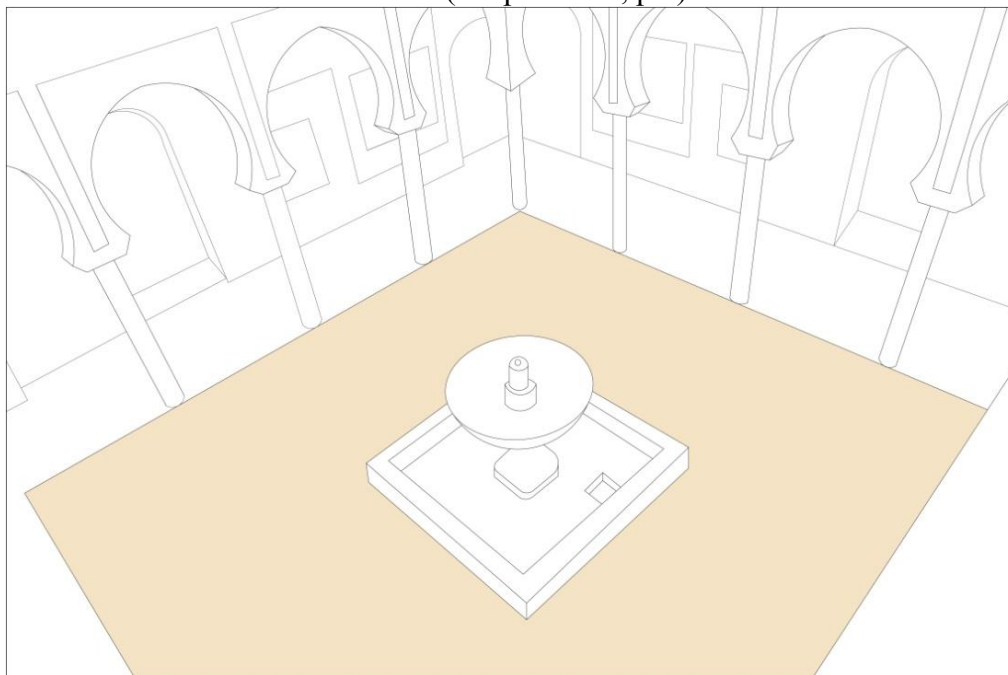


Figure (3.95)  
View of Courtyard Fountain in Dar Aziza

Source: ([http://www.qantara-med.org/qantara4/public/show\\_document.php?do\\_id=729](http://www.qantara-med.org/qantara4/public/show_document.php?do_id=729))

- **Thermal Mass**

In Dar Aziza, the bearing walls are built of lightly baked mud bricks with a bonding agent made of lime and thick mud<sup>156</sup>. The walls are the thickest at the lowest levels where they are sometimes reinforced at regular intervals with horizontal slabs of thuja logs. Even the roof was built with a thick layer of earth (40 to 70 cm), a surface of flat-laid bricks and rendered with lime (Corpus 2001, p.9) (figure 3.96).

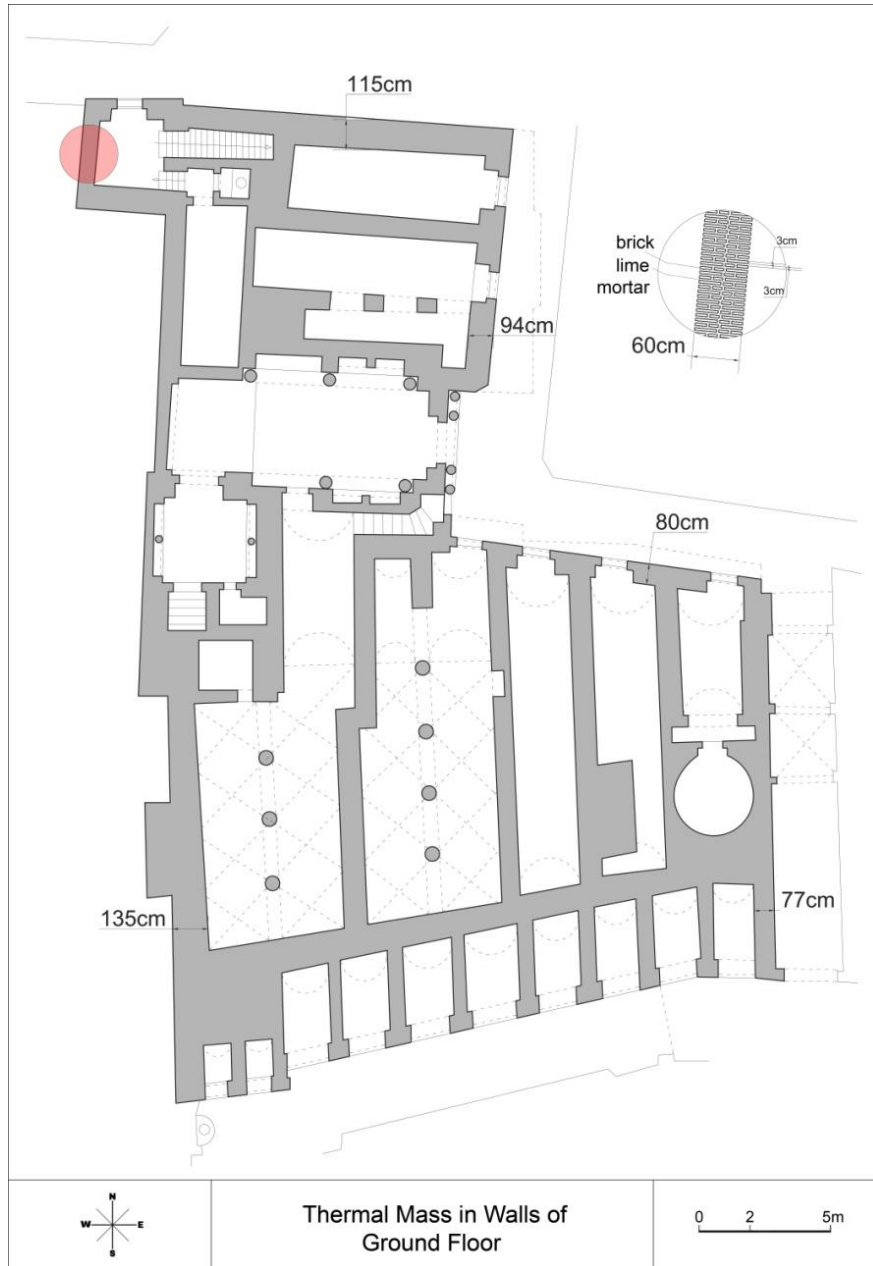


Figure (3.96)

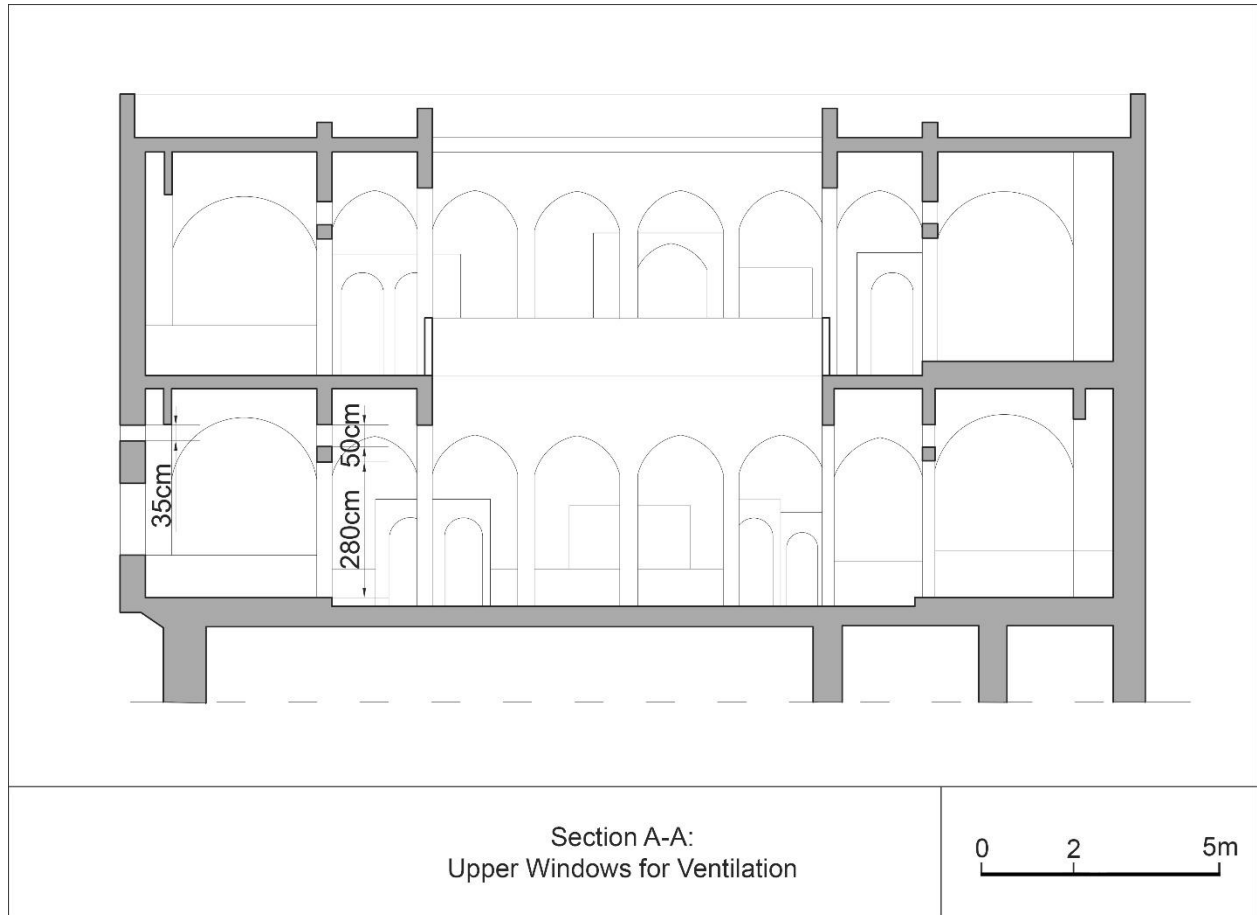
Source: (Abdessemed-Foufa and Benour 2010, p.278)

<sup>156</sup> See 2.2.4. Element, a. Solar Factor – Thermal Mass, pg.79.

## b. WIND FACTOR

- **Windows**

The large windows and doors facing the courtyard aid in achieving thermal comfort in the house. In addition to small openings located above the exterior and interior ones which provide ventilation for the house (figure 3.97).



Section A-A:  
Upper Windows for Ventilation

0 2 5m

Figure (3.97)

Source: (Corpus 2001, p.8)

- **Courtyard Vegetation**

The small amount of plants does not affect the ventilation in a significant way.

- **The Fountain**

With the aid of the sun, the fountain aids in cooling the air passing over it.

### c. Comparative Analysis Matrix

The following matrix is the result of analysing the ELEMENTS found in the dwellings of the Casbah of Algiers based on the matrix found in chapter 2<sup>157</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (3.7)<sup>158</sup>.

#### 1. Windows

The windows facing the courtyard are large making it benefit from the southern sun especially the upper level. Tapered windows controlled the sun and light. These large windows also provide ventilation in addition to small windows over the doors. This tool was given “very good” for both factors.

#### 2. Vegetation

The small amount of plants in the courtyard of Dar Aziza gave it a “below average” rating for both factors.

#### 3. Water Features

A fountain in the courtyard of Dar Aziza aids in the humidity and coolness of the courtyard giving it a “very good” for both factors.

#### 4. Thermal Mass

The thick stone walls of Dar Aziza are an excellent source of thermal mass which store heat and coolness, therefore it was given “very good” for both factors.

Element (EL) - CASBAH OF ALGIERS	Total Points	Sun 50%	Wind 50%	Sun EE*	Wind EE*	Final Points
EL 1. Windows	16	8	8	100%	100%	16
EL 2. Mashrabiya	12	6	6	0	0	0
EL 3. Courtyard/Garden Veg.	16	8	8	25%	25%	4
EL 4. Water Features	12	6	6	100%	100%	12
EL 5. Thermal Mass	16	8	8	100%	100%	16
EL 6. Malqaf	12	N/A	6	N/A	0	0
<b>Total for EL Category (-N/A): 78</b>		<b>Final Points for EL – Algiers: 48</b>				

\*EE =Existing Evaluation

Table (3.11) Casbah of Algiers ELEMENT Matrix

<sup>157</sup> See 2.2.4. Element, c. Comparative Analysis Matrix, p.83.

<sup>158</sup> See 3.2.1. Site, c. Comparative Analysis Matrix, Matrix (3.7) Evaluation for Existing Situation of Tools (EE), p.152.

After analysing the Casbah of Algiers from four categories, the scores from each category are added together for a final score which will be compared in the conclusion with other case studies and with the Sustainability Rating System.

<b>CATEGORY</b>	<b>POINTS</b>
<b>Site (SI)</b>	29
<b>Settlement (SE)</b>	59
<b>Dwelling (DW)</b>	54.5
<b>Element (EL)</b>	48
<b>FINAL SCORE</b>	<b>190.5</b>

Matrix (3.12) Casbah of Algiers Final Score



# 4

## **Modern Architecture of the Mediterranean Site...Settlement...Dwelling...Element**

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## 4.1. Influence of the Mediterranean Vernacular on Modern Architects

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Voyages to the Mediterranean for centuries have been part of any artistic education and included the grand tour to Italy. Gradually, from the end of 18<sup>th</sup> century onwards, the curiosity of the voyager changed from famous and well-known monuments to the “anonymous” architecture of small towns and villages (Guarneri 2010, p.231). Many architects travelled to the Mediterranean, were inspired by its vernacular architecture and translated their admiration into their designs. They had different visions towards vernacular architecture. In the 1997 article “The Vernacular, Modernism, and Le Corbusier”, Francesco Passanti argued that vernacular architecture had an essential role in the construction of modernist architecture. He differentiated the “vernacular modernism” of Hermann Muthesius, from the “modern vernacular” of Le Corbusier and the modern movement. He defined “vernacular modernism” as an approach to update local typologies to accommodate modern lifestyles with the formal model of the local vernacular retained, and “modern vernacular” as a rejection of the local vernacular forms, and a creation of a new, modern vernacular by updating functional forms through an evolutionary process (Gutshow 2010, p.166). This vision of Le Corbusier had an effect on many architects.

### 4.1.1. Le Corbusier (Charles-Édouard Jeanneret)

One of the most important architects of the 20<sup>th</sup> century is Le Corbusier who launched his famous Voyage d’Orient from Berlin in 1911 to the Balkans, Turkey, Greece, then South of Italy and Pompeii. After spending 10 years studying the art and architecture of Germany, he fell in love with the Mediterranean and its vernacular. After visiting Pompeii, he was fascinated by the gardens and the pergolas and spoke about the ordonnance of Roman architecture.

Le Corbusier believed that the houses of ordinary people are neglected with the belief that the grand palaces, monuments, and places of worship were the only significant buildings of the past. The sketches made on the journey to the east were of small rural dwellings. He was fascinated by their simplicity as a reaction against the decorative styles of the 19th century. His designs of 1910 and 1920 spoke of purity, order and rationality rather than of wealth and the desire to display it.

His designs of 1911 very often incorporated spaces such as balconies, verandas, loggias, and enclosed courtyards, which gave their users the protection of inside while enjoying the outside. These spaces were perfectly adapted to the hot climates which Le Corbusier visited. They incorporated ‘summer rooms’, like loggias and terraces, for example, the house which he built for his parents in 1912–13, the Felix Klipstein house of 1914–15, and the Villa Stein-de Monzie at Vaucresson, which was called ‘Les Terraces’ after its spatial arrangement, which takes the visitor on a journey between inside and outside with its terraces and roof gardens.

He was fascinated by the way vernacular architecture in the western extremes of Europe dealt with the chilling effects of prevailing winds. This was shown in his description of the Breton village of Ploumanach:

*“The street curves amid the rectangular alignment of the houses. The direction of the prevailing wind determines the orientation of all the houses”* (Cofaigh, Olley and Lewis 1996, p.20).

Le Corbusier also applied white plaster facades to display his love for traditional whitewash. In the 1925 book, *The Decorative Art of Today*, he stated:

*“whitewash exists wherever peoples have preserved intact the balanced structure of a harmonious culture... In the course of my travels I found whitewash wherever the twentieth century had not yet arrived”* (Le Corbusier 1925, p.189).

Another influence of Le Corbusier's journey to the East was the vernacular builder's connection with the natural environment, especially in the Greek island architecture, and which he carried into his own work (Goldfinger 1969, p.18). This connection, he felt, had been completely lost in the West, creating a situation in which fresh air, sunlight, and greenery had become inaccessible to most people.

The white volumes, the outdoor spaces, the connection to nature in rural architecture were stamped in his memory and would always return in his projects. In many examples of Le Corbusier's work, we can see the influence of his travels which remained engraved in the deepest of his memory and kept resurfacing throughout the entire adventure of his ideas and designs. That was proved in the autobiographical notes written in July 1965 in his *cabanon* overlooking the Mediterranean Sea:

*"Along those years I have become a man of everywhere. I have traveled across the continents. Yet, I have only one deep attachment: The Mediterranean. I am a Mediterranean, strongly... Mediterranean, Queen of form and light. Light and space.... My recreations, my roots, they must be found in the sea that I have never ceased to like.... The sea is movement, and endless horizon"* (Le Corbusier 1965).

#### **4.1.2. Alvar Aalto**

Alvar Aalto was also a pioneer of vernacular architecture but this passion of his started long before his voyages to the Mediterranean. He was deeply committed to indigenous Finnish culture and its devotion to nature. He understood the landscape, its measurement and description and this helped him establish his skills at siting and landscaping. He had an intimate relationship with the Finnish wilderness and this formed his sensibility for natural form, materials and space (Trencher 1998, p.7).

After his short enthusiasm for the Modern Movement, Alvar Aalto began thinking that the task of architecture was to mediate the relationship between man and technology and support the social and cultural needs of man (Pallasmaa 2007, p.133). His designs became known for their sense of rootedness and Finnishness and gave an impression of environments formed by tradition and history (Pallasmaa 2007, p.133). He used motifs of history and vernacular tradition, combined with a modern language which resulted in an architecture remarkably rooted in place and time. Aalto's work gives faint hints of archaic history, antiquity, vernacular Mediterranean building, and anonymous Finnish peasant tradition (Pallasmaa 2007, p.134). He was one of the architects who combined traditional materials and building technologies with modern ones and embraced both figuration and abstraction (Sabatino 2010, p.45).

This deep commitment to indigenous architecture became even deeper after his voyages to the Mediterranean and he was inspired by the vernacular characteristics. One of these characteristics was the textural contrasts which are formed by the different periods of masonry construction. He often composed wall surfaces with overlapping textures of white painted slatted boards or brickwork, render and treated concrete (Parkyn 1991, p.144).

Aalto's interest in the climatic dwelling is displayed in his writings:

*"Light and sun. Under extreme conditions one can no longer leave the dwelling's access to the sun to chance. Light and air are such important preconditions for living that the haphazard conditions that prevail today must be changed. The norms should...require that each dwelling get sun... The sun is a source of energy; but only if we use it in a scientific way... nor can we afford to allow the sun's and the light's energy to remain unused. And at the same time we have to eliminate the inconveniences that these same factors, under favourable circumstances, can lead to"* (Cofaigh, Olley and Lewis 1996, p.20).

His summer house at Muratsalo, in the far North, shows his interest in the climatic dwelling. The plan is L-shaped consisting of rooms which turn away from the north and east, while opening to a lake view terrace on one side protected by a slatted screen to the west (Cofaigh, Olley and Lewis 1996, p.28).

Villa Mairea (1938) is one of the examples where the influence of the Mediterranean is displayed. He employed the cubist collage technique and combined overlapping layers of materials, colours, textures and forms which reflect the modern and the historical, the natural and the industrial. It is a combination of organic, modern and cultural characteristics (Trencher 1998, p.8). The white rendered cubic volumes came in contrast with the wooden poles cladding the lower level and terrace. The L-shaped villa frames a courtyard which is bordered from the opposite side by a walled garden (Schildt 1998, p.61). Aalto employed the courtyard in other works like the Saynatsalo Town Hall of 1949 (Schildt 1998, p.81).

He was also inspired by the Mediterranean balcony as a design and social element like the Factory Housing at Kauttua (1938-1940) which responds to natural contours with an ingenious building section (Parkyn 1991, p.174). The arrangement of the buildings is stepped according to the south facing slopes. In this way, the roof of the apartment below is a terrace for the apartment above it and every apartment looks out to the forest (Fleig 1974, p.229).

Aalto was also influenced by the “white Style” which is displayed in The Church of the Three Crosses (1955-58), an example of a white rendered exterior (Trencher 1998, p.9).

Barrel vaulting which was also common in the whitewashed villages is also seen repeatedly throughout his work (Parkyn 1991, p.178).

#### **4.1.3. Jose Antonio Coderch**

Jose Antonio Coderch was another Spanish architect who was inspired by vernacular architecture and the work of the indigenous people. In his 1960 text *It Isn't Geniuses We need Right Now*, he wrote trying to spread awareness about the importance of tradition:

*“Something of the living tradition is still within our reach, as well as many old moral doctrines having to do with ourselves and with our discipline or profession as architects (and I use these words in their best traditional sense). We need to make good use of the little that remains of constructional and above all moral tradition in an era in which the most beautiful words have practically lost their real and true meaning”* (Coderch 2005, p.134). He continues by saying:

*“We need thousands and thousands of architects who're out there in the world to think less about Architecture, money or the cities of the year 2000 and more about their occupation as an architect. To work with a rope tied around their ankles so that they can't get too far away from the land their roots are in, and from the people they know best, always relying on a firm basis of dedication, goodwill and honour”* (Coderch 2005, p.134).

His first domestic works appeared to evolve out of the Catalan vernacular, and at times, out of the ground itself. A few examples are the proposals for Le Forques development project for Sitges near Barcelona, and the Ferrer Vidal House where it is difficult to distinguish between the earth and the main body of the house (Frampton 2005, p.4). His projects followed the rules of respect for the landscape, where minimum earth movements are introduced and the natural vegetation preserved (Diez 2005, p.27).

One of his important projects is the Casa Ulgade near Sitges which became an icon for Spanish modernity. The house is described in the book Jose Antonio Coderch, *Casas Houses* with the words:

*“The house is as organic in its plan as the undulating, pine-studded promontory on which it stands. It is a house that derives much of its special form from the rough stone, whitewashed podium on which it sits; a stepped earthwork that is countered and controlled by the knife-edge of a shallow pitched, concrete roof whose wide span is achieved with the aid of a single, free-standing tubular column”* (Frampton 2005, p.6).

In many of Coderch’s houses we can see the intimate relationship with the surrounding landscape with their single-storey, flat roofs, projecting over a terrace (Frampton 2005, p.8) and the famous sliding louvered external floor to ceiling screens (Frampton 2005, p.7) These characteristics are found in the Catus House in Sitges Barcelona (1956) and four successive houses completed during the first half of the 1960s (Frampton 2005, p.8). Depending on the orientation and topography of the site, two of these houses, the Uriach House (1961) and the Rozes House (1962) were erected in the form of independent wings (Frampton 2005, p.8) with the rooms forming a series of incremental steps down the rock face as it descends towards the sea (Frampton 2005, p.9). The Luque and Gili houses (1965) are structured around an internal square courtyard (Frampton 2005, p.9) and his coastal houses followed a Mediterranean tradition with their white painted walls like the Casa Ulgade (1952).

Coderch was associated with the group Team 10, whose members generally adopted the avante garde attitude, while he strove to design modest and indigenous paradigms (Frampton 2005, p.11). His works with architect Manuel Valls respected the urban traditions of the city while developing a unique urban approach to the modernization of the vernacular (Lejeune 2010, p.88). In the 1960s, they designed a number of medium rised apartment buildings in and around Barcelona. The one which is considered a model is the Torre Valentina development in Girona (1959) which is a high density housing project in a heavily wooded site on the Costa Brava. This project has ecological character due to the care that Coderch and Valls took in their attempt to saving every existing pine tree on the site. With the number of trees between three and five thousand, the house could not be seen from the sea (Frampton 2005, p.11).

In many of their projects in the countryside or the city, Coderch and Valls used the modern louvers to screen the interiors from the sun. This “vernacular skin” was filed as a patent for the modern persiana (originally the Arab Mashrabiya and a defining element of the Spanish vernacular) by Coderch, Valls, and the owners of the Llambi company who became the manufacturers of the wooden shutters (Lejeune 2010, p.88). These examples show the interest in a sustainable architecture inspired by the Mediterranean vernacular.

#### **4.1.4. Alvaro Siza**

*“Viewing the past as irretrievable as a whole and that the future remains uncertain, Siza's works paradoxically suggest the possibility of a creative historical continuity* (Testa 1984, p. 177).

Alvaro Siza’s architecture was based on principles and models marked by cooperation with his teacher and first employer Fernando Tavora, a Portuguese modernist architect who was interested in Portuguese and Mediterranean vernacular architecture. Working at Tavora’s studio from 1955 to 1958, Alvaro Siza’s interest in vernacularism has seen a constant value as a result of the human needs and conditions, completely independent from the settings of current style that have replaced throughout history. During that period, Tavora was a principal investigator in the study of Portuguese traditional architecture. Siza described this investigation in the words:

*“It was an effort to understand the relations between a way of life and architecture, not as a source for proposals of spatial organization but in order to understand the concrete problems of society”* (Siza 1978) (Testa 1984, p.182).

His inspiration with Mediterranean vernacular architecture is represented through purely geometric design devoid of decorations, whitewashed walls, rational composition, open plan, fluid penetration of open and closed areas. The clarity of pure form in Siza’s architecture clearly represent the lack of tendency towards satisfying the aesthetic or fashion trends (Zoranić 2012, p.21).

Alvaro Siza’s Mediterranean modernism is deeply rooted in the experience and tradition, while free from the dictates of current styles. His inspiration with the rich traditions of the Mediterranean landscapes is reflected in the spatial conceptualization, design, proportions, and composition of material. His designs are new and modern, but at the same time associated to the context with integration of ecological element which are a fundamental need, and not a trendy addition to the house (Zoranić2012, p.22). In an interview with architect and author Vladimir Belogolovsky in 2017, Siza stated that:

*“Tradition does not mean closure, immobility. Quite the opposite, the value of traditions is in being open to innovations. Tradition is not the opposite of innovation, it is complementary. Tradition comes from successive interchanges”* (Siza 2017)<sup>159</sup>.

By closely studying Siza’s first works, we can find evidence of significant influence of the works of Alvar Aalto, such as the Banco Pinto & Sotto Mayor, Oliveira de Azeméis, Portugal (1971-1974) (Testa 1984, p.35).

In his 1977 project Quinta da Malagueira, he works the site by adding another layer to what already exists in an operation where *"the new results from the old but the old also changes in the light of the new."* (Testa 1984, p.153). Siza’s attitude of change without loss is reflected in all his work and is based on obeying the laws of conservation of energy<sup>160</sup> (Testa 1984, p.153). Simple building methods are also employed in an effort to mediate technology like the use of a massive masonry system and lack of heavy machinery use and inflexible construction systems (Testa 1984, p.129). In his own country in 1988, he first attracted the attention he deserved after the fire in the Chiado Quartre in Lisbon. He was then entrusted to rebuild the central area and the result was a simple renewal and modernisation with few but decisive changes<sup>161</sup> (Fleck and Pfeifer 2013, p.262).

Another project which displays Mediterranean inspiration is the Serralves Museum (1997) in Porto. Its plain white facades, straight lines and courtyards reflect Mediterranean characteristics. Another one of his Mediterranean inspired designs is the house in Mallorca (2004-2007) with its straight lines, white cubic forms and simple facades. It was also inspired by the rocky landscape surrounding it, resulting in a deeply rooted design belonging in its urban context. The spaces are organized into three blocks, two of them facing the sea and the third north block opening into a small intimate courtyard.

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<sup>159</sup> <https://www.archdaily.com/803250/interview-with-alvaro-siza-beauty-is-the-peak-of-functionality>

<sup>160</sup> Examples are Quinta da Conceicao (1958-65) where an existing irrigation tank is reappropriated for a public swimming pool, and in Berlin (1980) where Siza proposes to build a corner building over a row of existing shops (Testa 1984, p.153).

<sup>161</sup> These changes included enhancing the pedestrian routes through the creation of two patios, reopening the ancient links between the baixa shelf and the hills of chiado and carmo, restricting traffic and car parking into the neighbourhood through the redesign of public space and the planning of new commercial zones (<http://www.designboom.com/architecture/alvaro-siza-restores-the-district-of-chiado-in-lisbon/>).

#### 4.1.5. Jorn Utzon

Jorn Utzon derived his earliest inspiration from foreign architects such as Swedish architect Gunnar Asplund who he worked under the influence for three years then in 1946 he started his apprenticeship at the office of Finnish architect Alvar Aalto. He spent the next decade travelling extensively worldwide to destinations like Morocco, Mexico, United States, China, Japan, India, and Australia. These travels left solid marks on his career and inspired his work. Though most of his projects were Denmark based but it was the Sydney Opera House that gave him unbeatable recognition around the globe<sup>162</sup>.

He was influenced by Frank Lloyd Wright, whose organic conception of architecture was of great significance for Utzon's own expressive and sculptural nature-inspired architecture<sup>163</sup>. This can be seen in the Kingo Houses in Helsingør (1956-60) and the Houses of Fredensborg (1959-63) with their low courtyard houses blending with the environment. His interest in courtyard housing typology also grew after studying Chinese and Turkish courtyard houses<sup>164</sup>.

His own house in Majorca (1971-73), Spain facing the Mediterranean Sea is built with yellow sandstone inspired by the local materials in the area. A small courtyard is also incorporated into the design of the house in addition to the terraces facing the sea.

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<sup>162</sup> <http://www.famous-architects.org/jorn-utzon/>

<sup>163</sup> <http://denmark.dk/en/meet-the-danes/great-danes/architects/joern-utzon/>

<sup>164</sup> <https://www.thoughtco.com/jorn-utzon-architecture-portfolio-177921>.

## 4.2. Mediterranean Vernacular Inspired Settlements

Two modern and vernacular inspired settlements were chosen to be analyzed in the same way as the two vernacular settlements. The first example in Evora, Portugal is Quinta da Malagueira by Alvaro Siza. It is a very good example of a sustainable modern settlement with a climate similar to Mediterranean climate. The second example in North Zealand, Denmark is Fredensborg Housing by Jorn Utzon. It is an example with a colder climate than those on the Mediterranean coast.

### 4.2.1. Quinta da Malagueira, Evora (1977-1998)

Architect: Alvaro Siza



Figure (4.1) Location of Evora, Portugal

Source: Google maps



Figure (4.2) Areal Photo of Quinta da Malagueira

Source: Google maps





Figure (4.3) Areal Photo of Quinta da Malaguera<sup>165</sup>

## Project Summary

### Evora

The old city of Evora is the capital of the Alentejo region and is located about 100 miles east of Lisbon (figure 4.1). Its history goes back as far as Celtic times. It still retains ruins from the Roman domination and the Visigoth period when the Roman walled was reconstructed. Further improvements were made to the fortified gate during the Moorish domination which ended 1165. Evora's golden age began in the 15<sup>th</sup> century when remarkable monuments which were either entirely new buildings or constructed within already existing establishments. Evora became Portugal's second city in the 16<sup>th</sup> century. It was a time of major urban planning and the unique quality of the city arises from the architecture of the 16<sup>th</sup>, 17<sup>th</sup> and 18<sup>th</sup> centuries. It was characterized by the low whitewashed houses decorated with red Dutch roof tiles and wrought-iron balconies, and the narrow cobblestone alleyways of medieval configuration<sup>166</sup>. One of the greatest 16<sup>th</sup> century building projects in the Iberian Peninsula is the Evora aqueduct. It provided clean drinking water to Evora by connecting the city to the nearest constant flowing river, 9km to the north. The Alentejo region has minimal rain throughout the year and with the very hot summers and mild dry winters, there was a constant fear of drought. Therefore a decree was established that Evora should have a constant supply of fresh water by the construction of the Aqueduto da Água

<sup>165</sup> <https://www.area-arch.it/en/malagueira-district-complex/>

<sup>166</sup> <http://whc.unesco.org/en/list/361>

de Prata<sup>167</sup>. The water from the river flowed unassisted into the main plaza of Evora through a complex set of structures that included long tunnels, deep valleys and most important, the stone aqueducts. The construction of the aqueduct started in 1531 and took 6 years to complete<sup>168</sup>. The great earthquake of 1755 destroyed many towns in Portugal, including Lisbon, however Évora remained mainly undamaged<sup>169</sup>.

### **Malagueira**

Malagueira is a large, low-rise, high density complex of about 1200 dwellings built over a period of about 20 years on a 27-hectare site. Starting in 1977, it is one of three housing projects Alvaro Siza designed between 1973 and 1977. Two of these projects, Bouca and São Victor were low cost projects designed for the SAAL organization in Porto<sup>170</sup>. Malagueira, however, was designed as a suburban community during the desperate conditions of Portugal, and would eventually be owned by the residents in a cooperative organization. The Evora City Council wanted this project to be built on the landscape west of the old city along the road to Lisbon<sup>171</sup>.

#### **Site (figure 4.4)**

The site for the new community was to be between two existing *barrio* communities, Santa Maria and Nossa Senhora da Gloria, which had grown along one of the radial roads leading out of the old city, creating an east-west axis. A stream running in a general north-south direction passes between these two villages and a system of paths had developed over time as people walked to different destinations between the villages to shop, get water, or walk to the hilltop of the old city of Evora. Other existing buildings to the south of Santa Maria were the high-rise buildings of Cruz da Picada which started in the 1960s and some of them were still under construction at the time (Fleck 2013, p.28).

The gridiron structure of Santa Maria was the model for the layout of the new quarter, creating bigger and smaller groups of parallel rows of streets and back to back patio houses. The largest of these groups extends along the north edge of Santa Maria from one side and opening to the large public space along the stream. Other groups were sited at different angles according to the existing topography of the landscape. The open public spaces between the neighbourhoods follow the pre existing paths and other features in the landscape (Pfeifer 2013, p.242). The six-meter-wide streets do not accommodate on-street parking. Separate structures adjacent to each residential sector provide garages with chimneys which reinterpret the rural tradition of out buildings used to keep animals and for cooking (Testa 1984, p.129).

The houses of Malagueira are arranged in clusters. Each cluster forms a simple geometric shape by laying out the houses in back to back rows. The advantage of this strategy is that the clusters form precise blocks clearly defining and separating the public spaces from the private (Pfeifer 2013, p.242). The separated groups of residential clusters are connected together by a system of raised concrete aqueducts supported on columns which provide the infrastructure for water and electricity. Other than its function as a water and electricity supply, it is a large-scale planning device which connects neighbourhoods, forms public arcades and defines entrances to groups of

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<sup>167</sup> This decree was established under the reign of King John III (Joao III 1502 –1557) who selected a military architect, Francisco de Arruda, to design the water system.

<sup>168</sup> <http://www.evora-portugal.com/Attractions/agua-de-Prata-Aqueduct-Evora-Aqueduct.html>

<sup>169</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)

<sup>170</sup> The SAAL organization is the workers' council that addressed severe housing conditions in Portugal after the 1974 revolution.

<sup>171</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)

shops and other public facilities. It also relieves the monotony of the repetitive white walls of the dwellings<sup>172</sup>.

When entering the settlement of Malagueira, the picture of Evora is repeated and revealed in so many ways. The white walls, the terracing and curving layers of stone in Evora continue in Malagueira. Although the courtyard housing typology chosen by Siza does not exist in Evora, the alignment of the buildings and branching of the alleyways are repeated in Siza's settlement. The grey concrete aqueducts are an interpretation of the historical *conduta* at Evora (Pfeifer 2013, p.251).

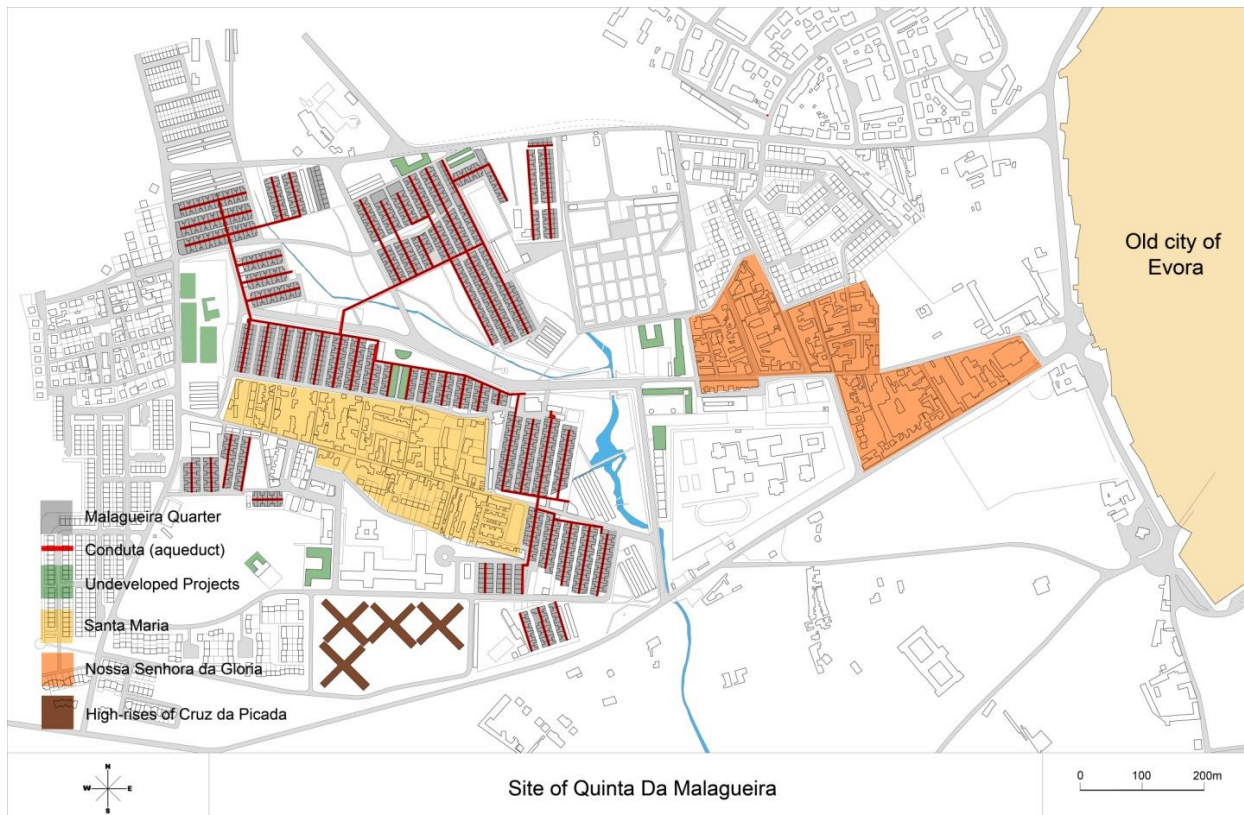


Figure (4.4)  
Source: (Woodman 2015)

Another example of a transformational process underlying Siza's works is found in the fountain proposed for the Malagueira district at Evora. Siza's proposal reinterprets the fountain which sits in the main square of the old city of Evora<sup>173</sup>. In Siza's fountain, the water arrives from the landscape by means of an open channel, crosses a rectangular basin, and descends into a stepped square container with an open side where the water is collected in a negative hemisphere excavated from a solid block of stone. This reinvention not only draws from the old fountain in Evora, but it is also inspired by traditional irrigation systems of stone channels (Testa 1984, p.163).

<sup>172</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)

<sup>173</sup> The fountain is from the 16<sup>th</sup> century and was designed by the Portuguese architect Diogo de Torralva. As noted by Jean Paul Rayonll, the marble sphere represents the world which dispenses its wealth of water over an ordered domain; in the form of a square stone basin, and subsequently over everything, represented by the rectangular basin in which it sits (Testa 1984, p.162).



## **Mediterranean and Portuguese Influence**

It is very important to note that Alvaro Siza made the characteristics of Evora the basis of his design, but by respecting the historical value without duplicating them. Gunter Pfeifer described it as: “*Transformed memories of a local identity*” (Pfeifer 2013, p.251).

Influence of Mediterranean vernacular architecture is visible through the white facades (which is also typical to the Alentejo region), flat roofs, cubic forms and lack of decoration and the courtyards with orange and lemon trees<sup>174</sup>. Another traditional characteristic of the Mediterranean is the social and outdoor lifestyle of the people. We can see this in the Malagueira neighborhoods in many ways. The public area between the neighborhoods is a meeting place for the members of the community. The openings of the doors, windows and terraces are located toward the street, enhancing the contact among neighbours and the limits of their visual control. This contributes to the use of the street as a semi-private area or domestic extension and its constitution as a social space. Siza’s interest in Adolf Loos’ work could also have inspired his design, when looking at his projects like the unbuilt 1923 design for the house of the actor Alexander Moissi on Venice’s Lido (Woodman 2015). As for the indigenous architecture of the Alentejo region, it is seen through elements like the placement of doors and windows of equal size on smooth flat walls, the tall chimneys that extends above the line of the eaves, and the steep staircases from the courtyard to the roof (Pfeifer 2013, p.241). Back to back houses are a traditional way of arranging houses in Southern Portugal with the inward patio and the solid outside wall which separated the public spaces from the private<sup>175</sup> (Pfeifer 2013, p.242). Another Portuguese influence is the shared chimney that carries exhaust air from two adjacent houses together (Pfeifer 2013, p.247).

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<sup>174</sup> ([http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)).

<sup>175</sup> The back to back typology was a concept of mass housing and was very common in 19<sup>th</sup> century England. This English version was economical with the reduction of service roads but was built without paying attention to natural ventilation and light (Pfeifer 2013, p.242).

#### 4.2.1.1. SITE: General Characteristics of the Site of Quinta da Malagueira

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##### A. General Climate of Evora, Portugal

Latitude: 38 34N

Longitude: 007 54W

Evora is classified under the Köppen Climate Classification as a "dry-summer subtropical" climate which is often referred to as "Mediterranean" (C). The subtype is Csa which is "hot, dry summer". This climate zone has relatively mild winters and hot summers. The precipitation in the driest month of summer is less than 30 mm and less than 90 mm in the wettest month of the winter. The temperature of warmest month is 22 °C or above<sup>176</sup>.

The highest recorded temperature in Evora is 107.6°F (42°C), which was recorded in July. The lowest recorded temperature in Evora is 26.8°F (-2.9°C), which was recorded in January<sup>177</sup>.

The summer sun angle at noon in Evora is 64° and the winter sun angle at noon is 28°<sup>178</sup>.

The prevailing winds are from the west and the northwest (Atlantic) (Pfeifer 2013, p.242) in the summer and from the east and northeast in the winter<sup>179</sup>.

##### B. The Effect of Different Elements on the Climate of Quinta da Malagueira

###### a. SOLAR FACTOR

- **Topography:**

The housing project of Malagueira lies on a gently rising slope with a grassy upland at its foot by the stream which separates the old city of Evora from Malagueira. The construction follows the topography so the houses step along the street or perpendicular to the street and the narrow, cobbled streets along which the houses are distributed always follow the slope (Figure 4.5-4.6).

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<sup>176</sup> <https://www.britannica.com/science/Mediterranean-climate#ref1092481>

<sup>177</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=75580&cityname=Evora%2C+Evora%2C+Portugal&units=>

<sup>178</sup> These sun angles were calculated from the online application (<http://susdesign.com/sunangle/>).

<sup>179</sup> These average wind directions were estimated from the historical weather records from (<https://www.worldweatheronline.com/evora-weather-history/evora/pt.aspx>).

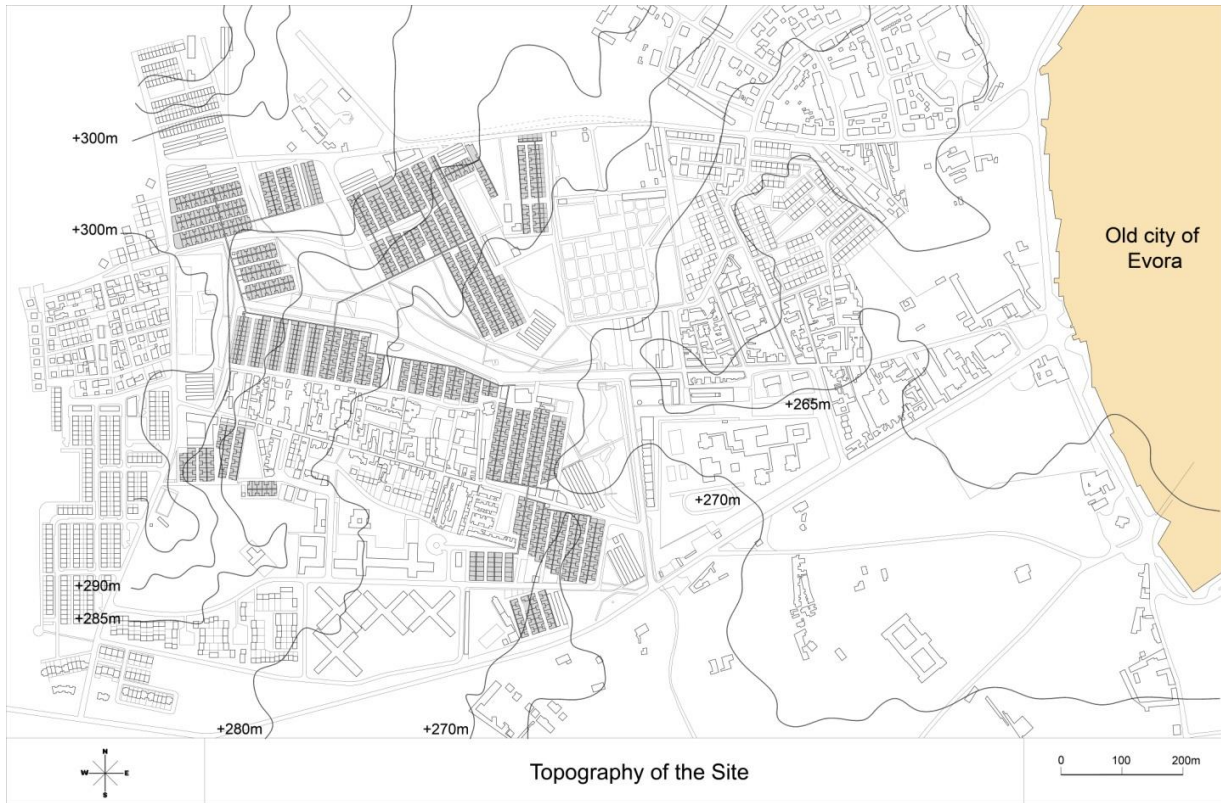
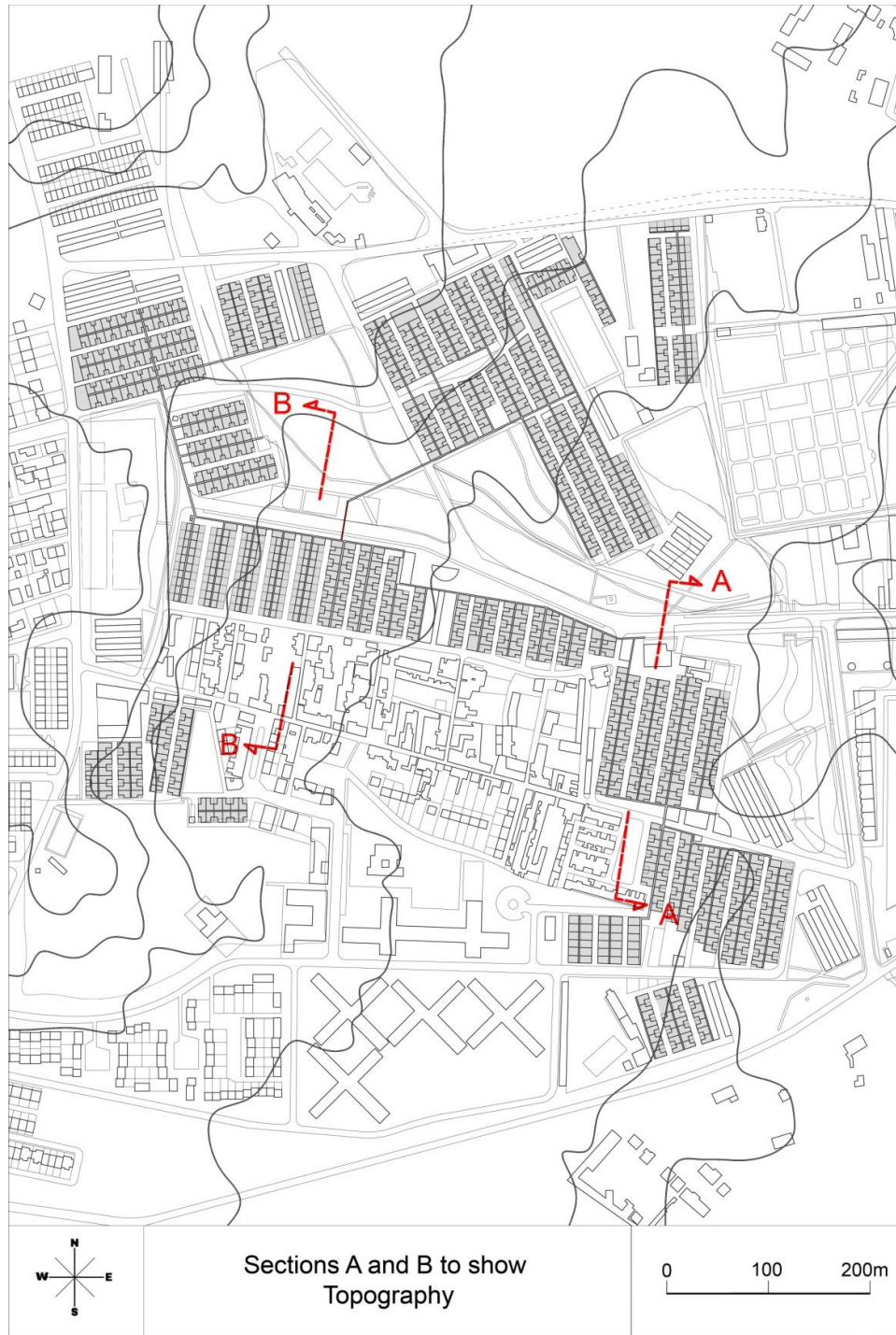


Figure (4.5)  
Source: (Li 2013, p.23)



Sections A and B to show Topography

Figure (4.6)

Source: (Woodman 2015)

The topography of the settlement of Malagueira caused most of the building blocks to be built stepped up towards the north, and resulted in increased exposure to the low southern sun in winter (Figure 4.7-4.8). In the summer, the sun is high; therefore, the topography does not affect the solar penetration.

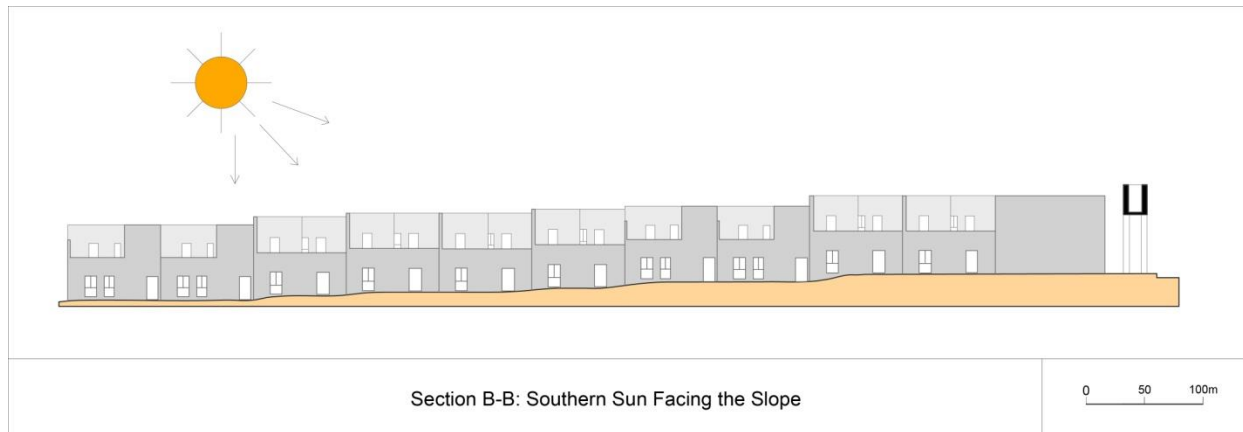


Figure (4.7)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

According to figure (2.2)<sup>180</sup> when the slope angle is 2°, the spacing to height ratio should be around 2.5. (figure 4.8). However, in the dense neighbourhoods of Malagueira, when spacing is available, the ratio is only around 1. This means that the blocks receive partial benefit from the southern sun, not the maximum.

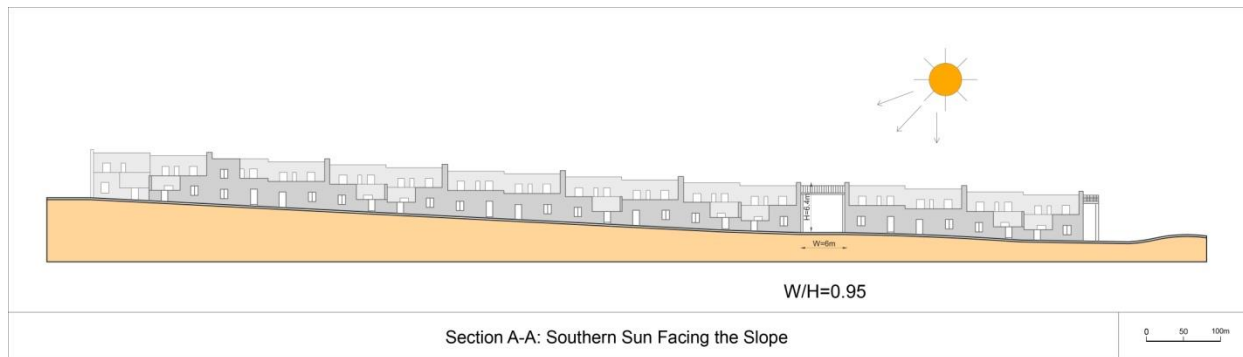


Figure (4.8)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

- **Vegetation:**

The housing settlement of Malagueira was designed to allow large green areas to be left open and undeveloped which find their way through the settlement in an organic way and act as a mediator between various points in the neighborhood. The residential sections are also surrounded by green spaces creating a relationship with the landscape similar to the relationship of the rural settlements scattered across the landscape<sup>181</sup> (Molteni 2013, p.94) (figure 4.9). There are also undeveloped spaces which were intended for various projects throughout the site, but were left undeveloped and eventually became open spaces with a small amount of grass and trees.

<sup>180</sup> See 2.2.1. Site, a. Solar Factor – Topography, pg.36.

<sup>181</sup> See 2.2.1. Site, a. Solar Factor - Vegetation, pg.37.





Figure (4.9)  
 Source: (Siza 2013, p.168)

- **Water Bodies:**

The main open spaces separating the building blocks are determined by the presence of streams and brooks running through the green areas. The streets follow the existing topography and lead water to the stream (Molteni 2013, p.94). In addition, a lake exists on the southeast corner of the project and the construction of a garden with fountains wells and canals (Zapatel 2001, p.125) (Figure 4.10). Due to the small size of the water bodies, they do not significantly contribute to the overall climate of the site.

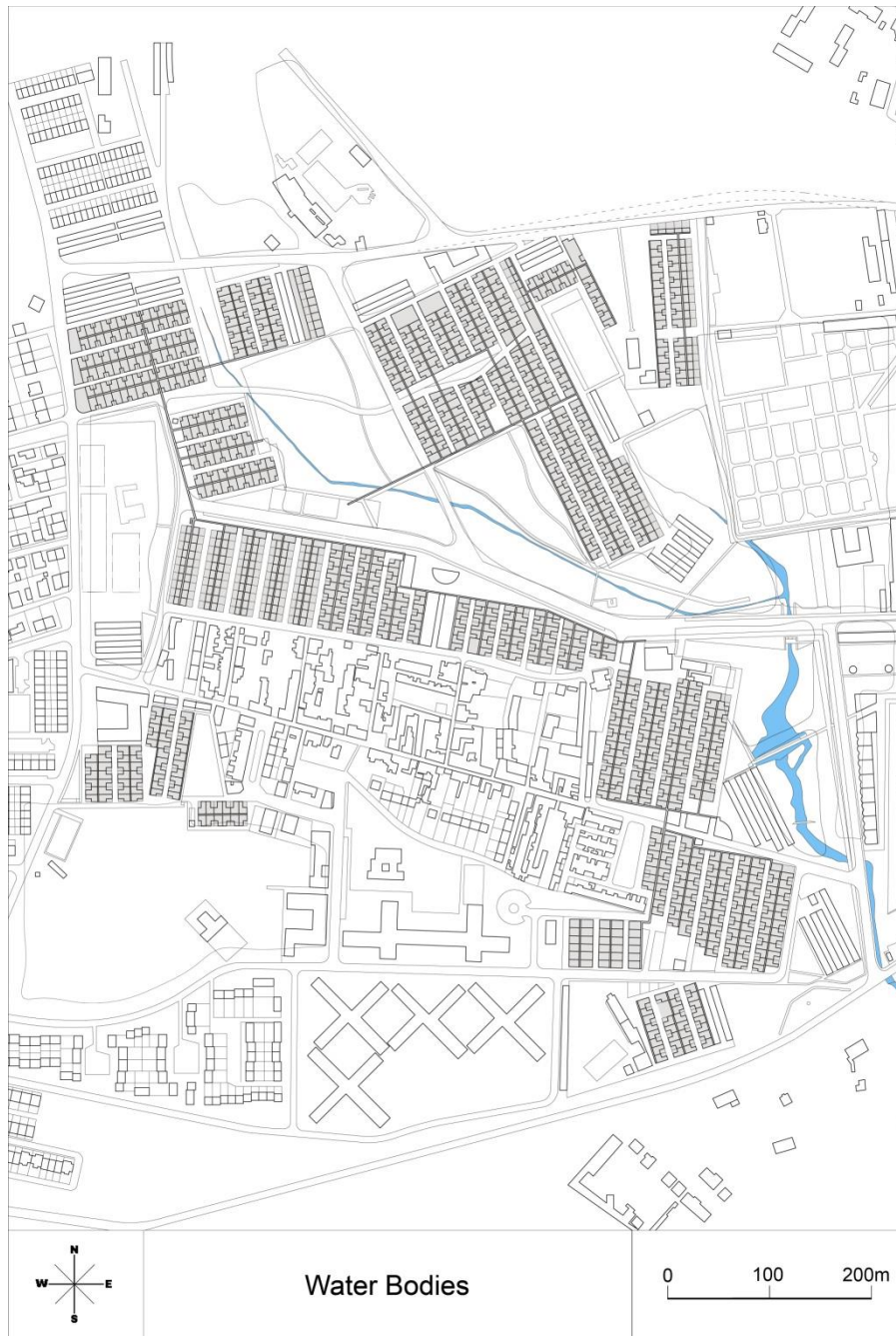


Figure (4.10)  
Source: (Woodman 2015)

## b. WIND FACTOR

- **Topography**

Considering the topography and the western and north-western prevailing winds, the settlement relatively turns its back to these winds and receives the eastern winds, however the small angle of the slope does not result in a significant relationship between the topography and the wind factor.

- **Vegetation**

The trees surrounding the Malagueira settlement aid in providing a barrier to the winter winds coming from the east and north east<sup>182</sup> (figure 4.11).



Figure (4.11)  
Source: Google maps

- **Water Bodies**

The small area of water bodies does not contribute to the climate of the site.

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<sup>182</sup> See 2.2.1. Site, b. Wind Factor – Vegetation, pg.39.

### c. Comparative Analysis Matrix

The SITE of Quinta da Malagueira was analysed based on the matrix found in chapter 2<sup>183</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The score was determined as a percentage based on the following:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (4.1) Evaluation for Existing Situation of Tools (EE)

#### 1. Topography

According to the sun factor, most of the building blocks step down towards the south making them benefit from the winter sun. However, since the angle of the slope is small, this tool was given “good” for the sun factor. As for the wind factor, the slight slope does not significantly effect the reception or blockage of the desirable or undesirable winds and only creates a small breeze, therefore, it was given “average” for the wind factor.

#### 2. Vegetation

The large amount of vegetation surrounding the site of Quinta da Malagueira affects the overall climate positively with regards to the sun factor through process of evapotranspiration and wind factor through creating a wind barrier. It was given “very good” for both factors.

#### 3. Water Bodies

The lake and river running through the site does not have a significant effect on the climate of the site and could only effect the temperature of the area directly around it. It was given “below average” for both factors.

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<sup>183</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, pg.42.

<b>Site (SI) – QUINTA DA MALAGUEIRA</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SI 1. Topography</b>	12	6	6	75%	50%	7.5
<b>SI 2. Vegetation</b>	16	8	8	100%	100%	16
<b>SI 3. Water Bodies</b>	16	8	8	25%	25%	4
<b>Total for SI Category: 44                      Final Points for SI – Malagueira: 27.5</b>						

Matrix (4.2) Malagueira SITE Evaluation



#### 4.2.1.2. SETTLEMENT: Urban Structure and Density

Malagueira consists of a low-rise, high density complex of about 1200 distributed into sets of blocks forming neighbourhoods throughout the site. Each neighborhood was built in dense urban conditions and was made up of rows of back to back houses in a repetitive order but at the same time achieving a high level of architectural variety due to the topography of the site<sup>184</sup> (figure 4.12). Narrow pathways separate the parallel blocks in each neighbourhood, but the basis of the main system of streets was the existing pathways formed from the movement of the people between the two existing villages.

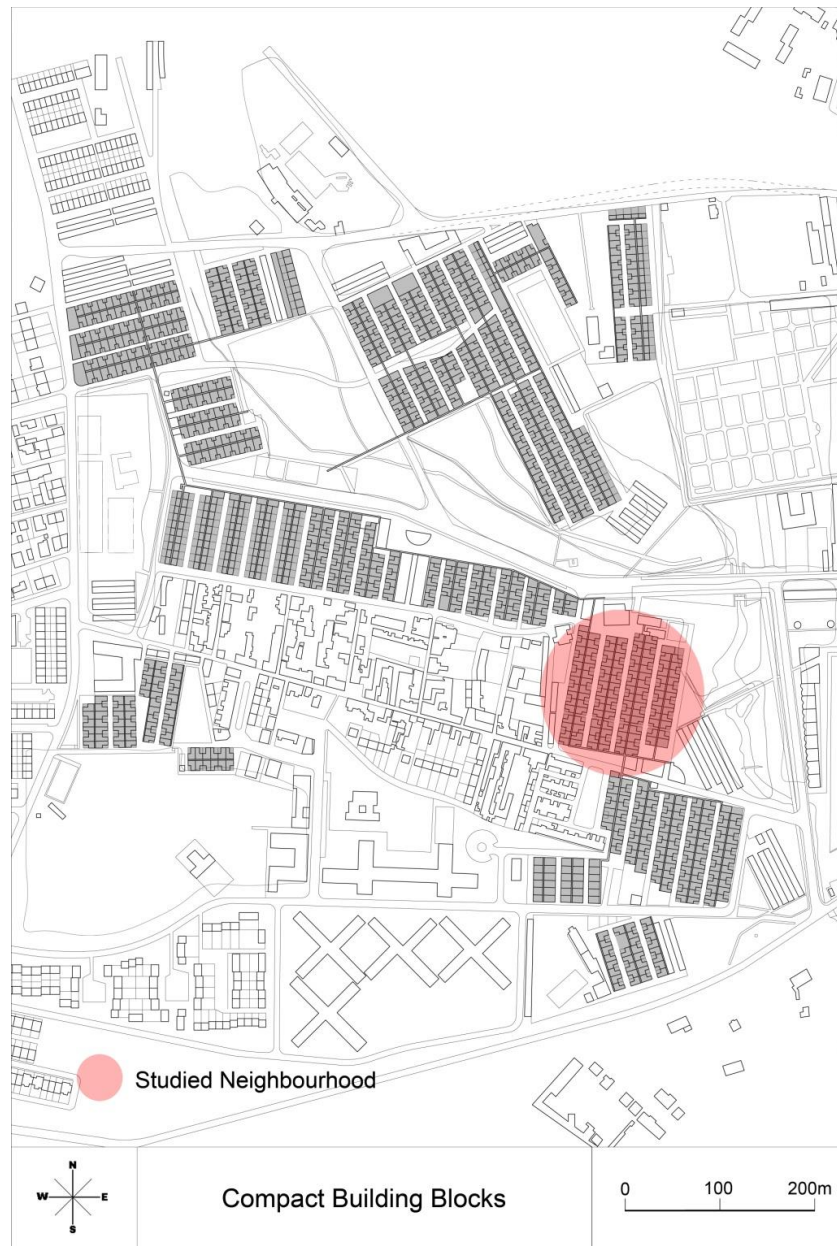


Figure (4.12)  
Source: (Woodman 2015)

<sup>184</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)

## a. SOLAR FACTOR

### • Compact Geometry

Despite the modern urban structure of the settlement of Malagueira, the density of the building blocks gives it the characteristic of a sustainable fabric due to the decreased surface to volume ratio and less heat gain and loss<sup>185</sup>.

**Surface to Volume Ratio** (Figure 4.13).

**Block 1:**

$$1514/14311=0.1$$

**Block 2:**

$$750/5145=0.14$$

The smaller block with the higher surface to volume ratio means increased heat gain and loss.



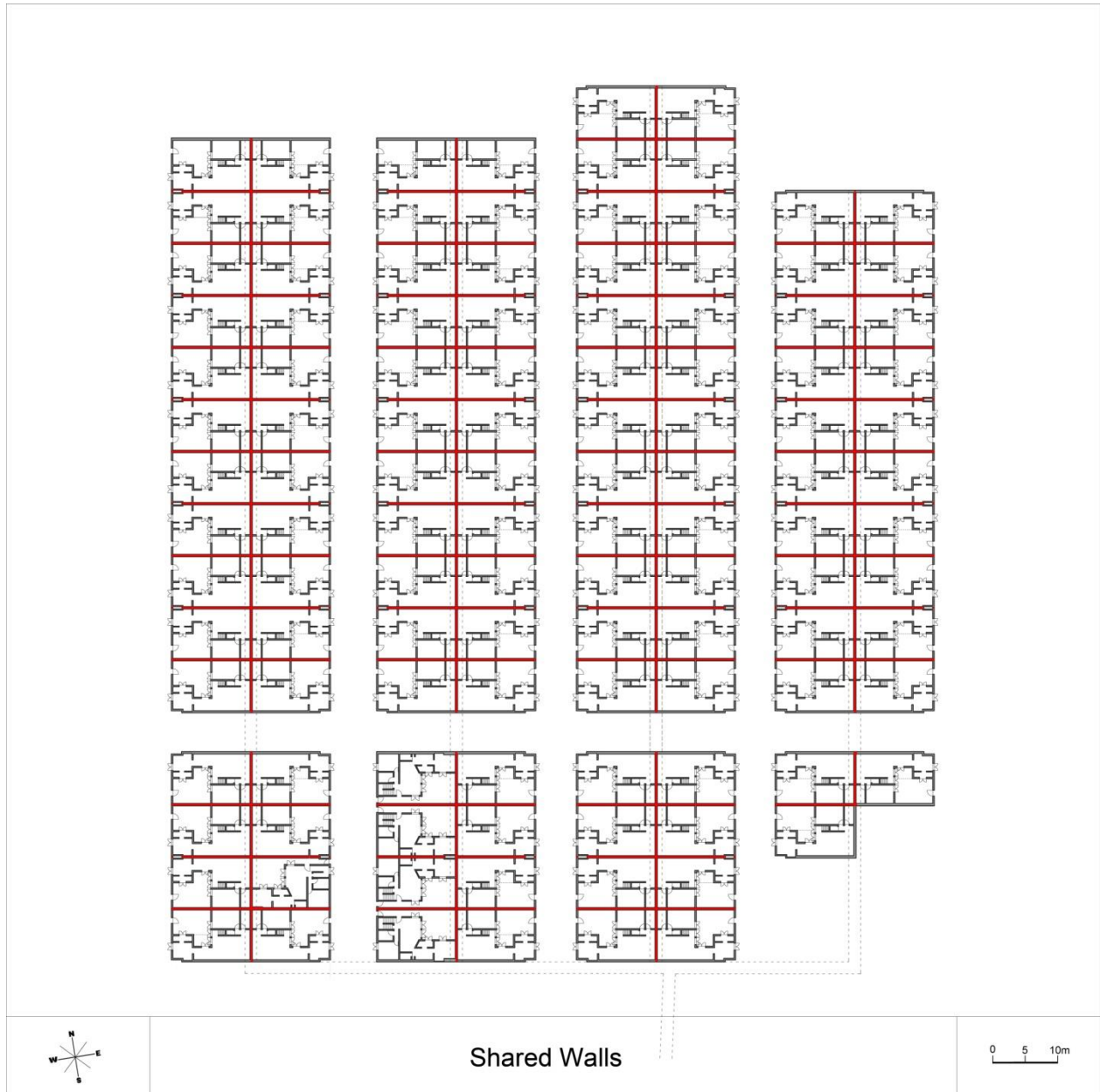
Figure (4.13)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

<sup>185</sup> See 2.2.2. Settlement, a. Solar Factor - Compact Geometry, pg.44.

## Shared Walls

The dense structure in the building blocks of Malagueira results in the increased number of shared walls for each house, making each house open to only one side. This decreases the heat gain and loss (Figure 4.14).



Shared Walls

Figure (4.14)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>



- **Block Orientation**

Most of the building blocks in the settlement run along a north-south axis with a slight angle towards the east or west. A few run along the opposite orientation. This is not the most desirable orientation due to the lack of southern exposure in addition to the excessive exposure to the east and west<sup>186</sup>. This problem however is solved by shade which is mentioned in the following section (figure 4.15).

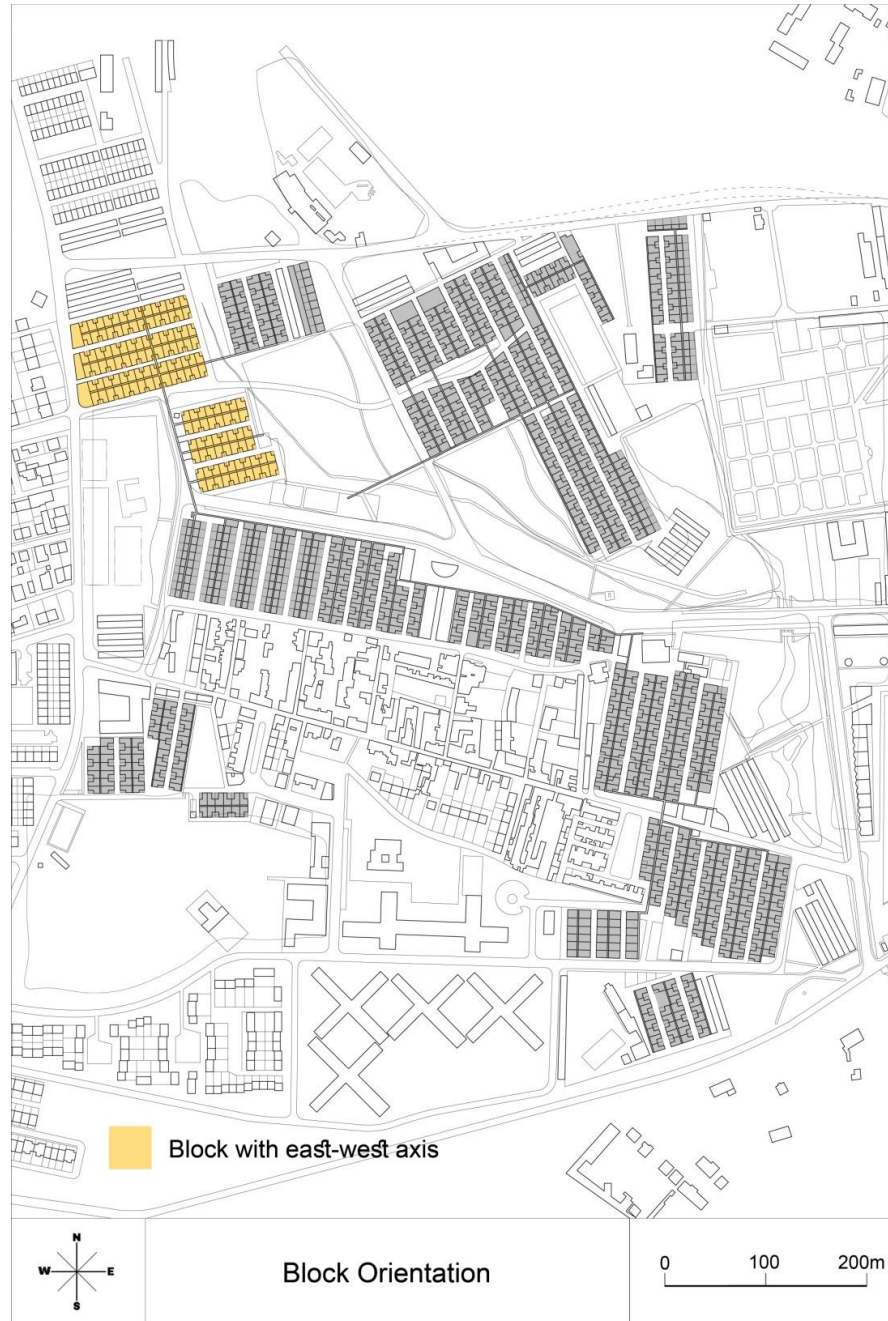


Figure (4.15)  
Source: (Woodman 2015)

<sup>186</sup> See 2.2.2. Settlement, a. Solar Factor – Block Orientation, pg.45.

- **Street Orientation**

From the first sketches of the project, the layout of the settlement was clearly oriented towards the city of Evora on an east-west axis with a slight angle towards the south (Molteni 2013, p.97). This orientation is not ideal because it results in solar penetration of the streets for most of the day in summer. The axis constitutes the main road and pedestrian route from which all the secondary streets in the neighborhood branch off (Molteni 2013, p.100). The secondary streets have an approximate NE-SW axis which is the optimum orientation<sup>187</sup> (figure 4.16).

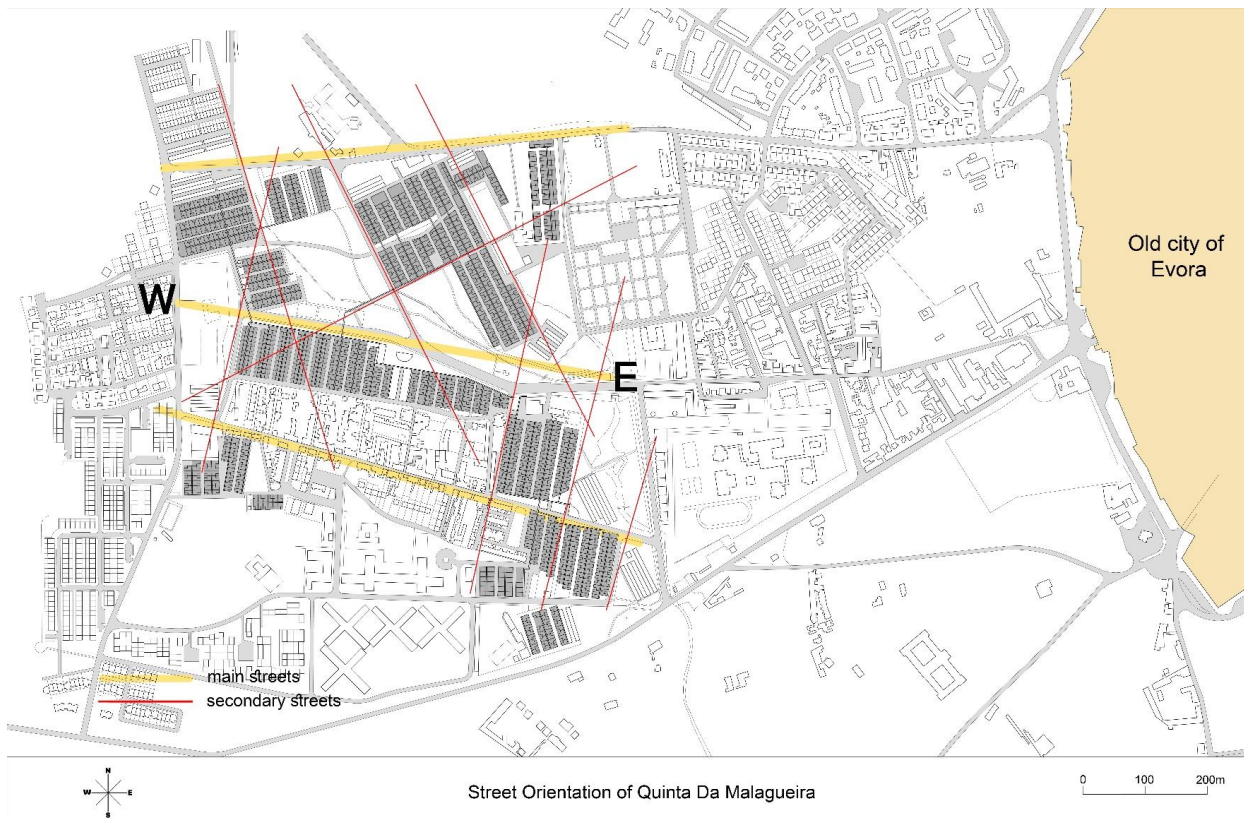


Figure (4.16)

Source: (Woodman 2015)

- **Narrow Streets**

The streets running north-south result in the eastern and western exposure of the blocks. The narrow streets in proportion to the height of the walls create shade and allow the pedestrians to walk along the street even on the hottest of days (Molteni 2013, p.96). The building blocks which are mostly oriented on a north-south axis provide shade for each other protecting the buildings from the excessive summer sun on the eastern and western facades (figure 4.17). The amount of shade depends on the time of day and can be calculated from the Lateral Distance of Shade which depends on the angle of the sun at different times of the day<sup>188</sup>(figure 4.18). This amount is less when comparing this settlement to a vernacular one due to the wider streets in proportion to the building height.

<sup>187</sup> See 2.2.2. Settlement, a. Solar Factor – Street Orientation, pg.46.

<sup>188</sup> See 2.2.2. Settlement, a. Solar Factor – Narrow Streets, pg.47.

$$L = H \times \cot \theta$$

**Summer:**

$$L = 6.6 \times .48 = 3.17\text{m}$$

**Winter:**

$$L = 6.6 \times 1.88 = 12.4\text{m}$$

**L:** Lateral Distance of shade on street surface

**H:** Height of building

$\theta = 64^\circ$  (Summer Solstice in Evora)

$\theta = 28^\circ$  (Winter Solstice in Evora)

$\cot 64^\circ = .48$ ,  $\cot 28^\circ = 1.88$

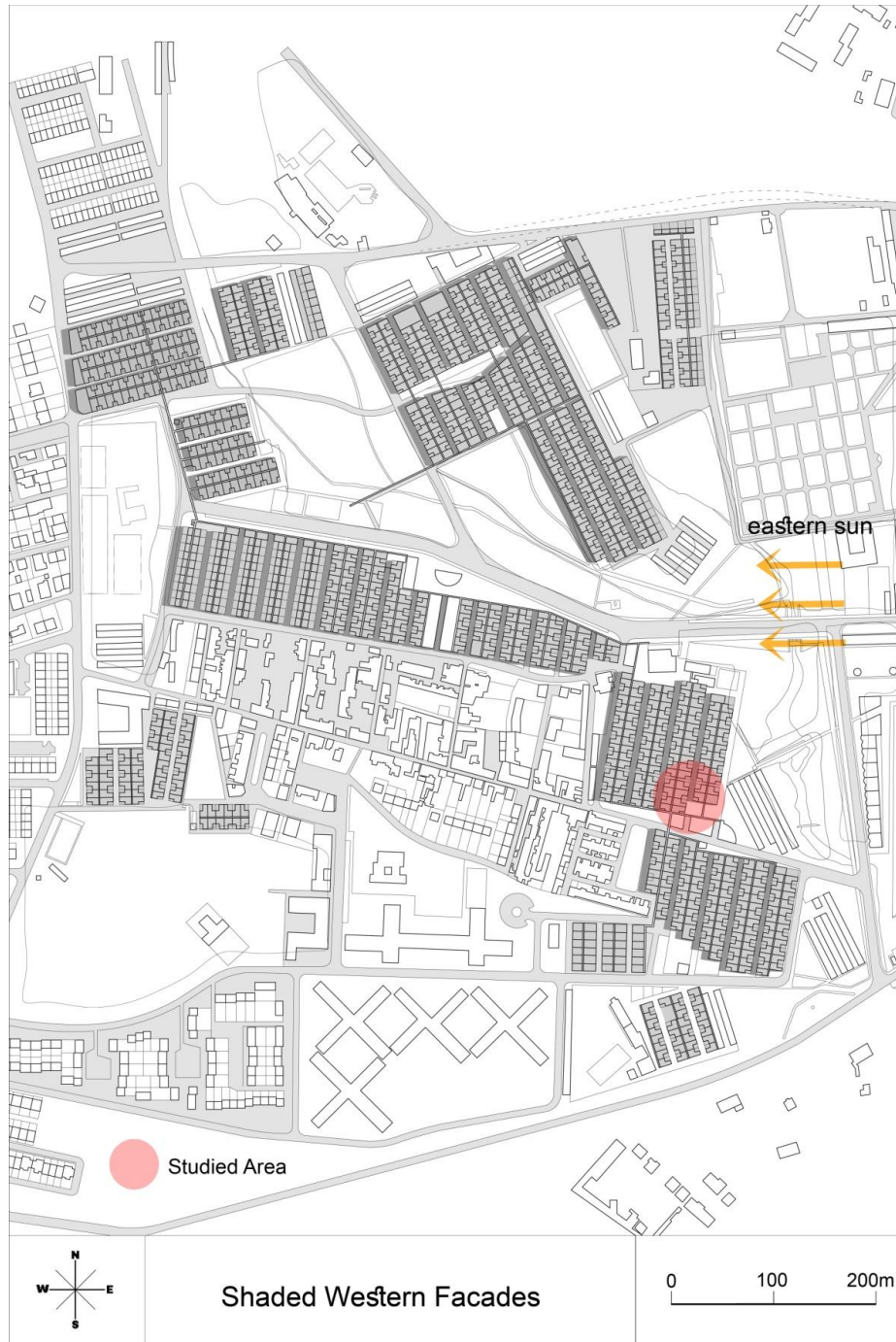


Figure (4.17)  
Source: (Woodman 2015)



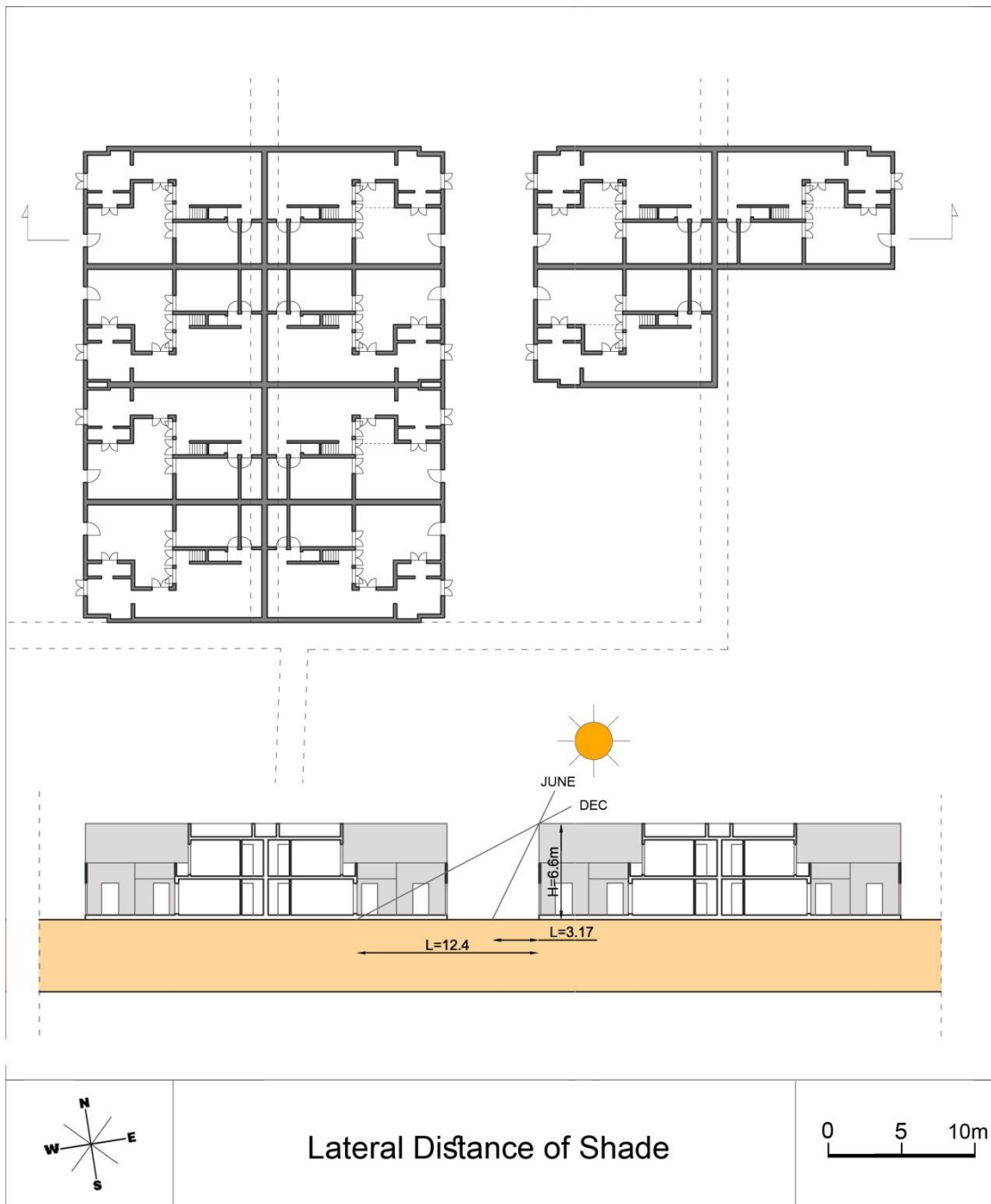


Figure (4.18)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Open Spaces**

The settlement of Malagueira consists of sets of blocks forming neighbourhoods and open spaces randomly scattered between them. These spaces are used for meeting, walking and playing. The two most important spaces are described in detail (figure 4.19).

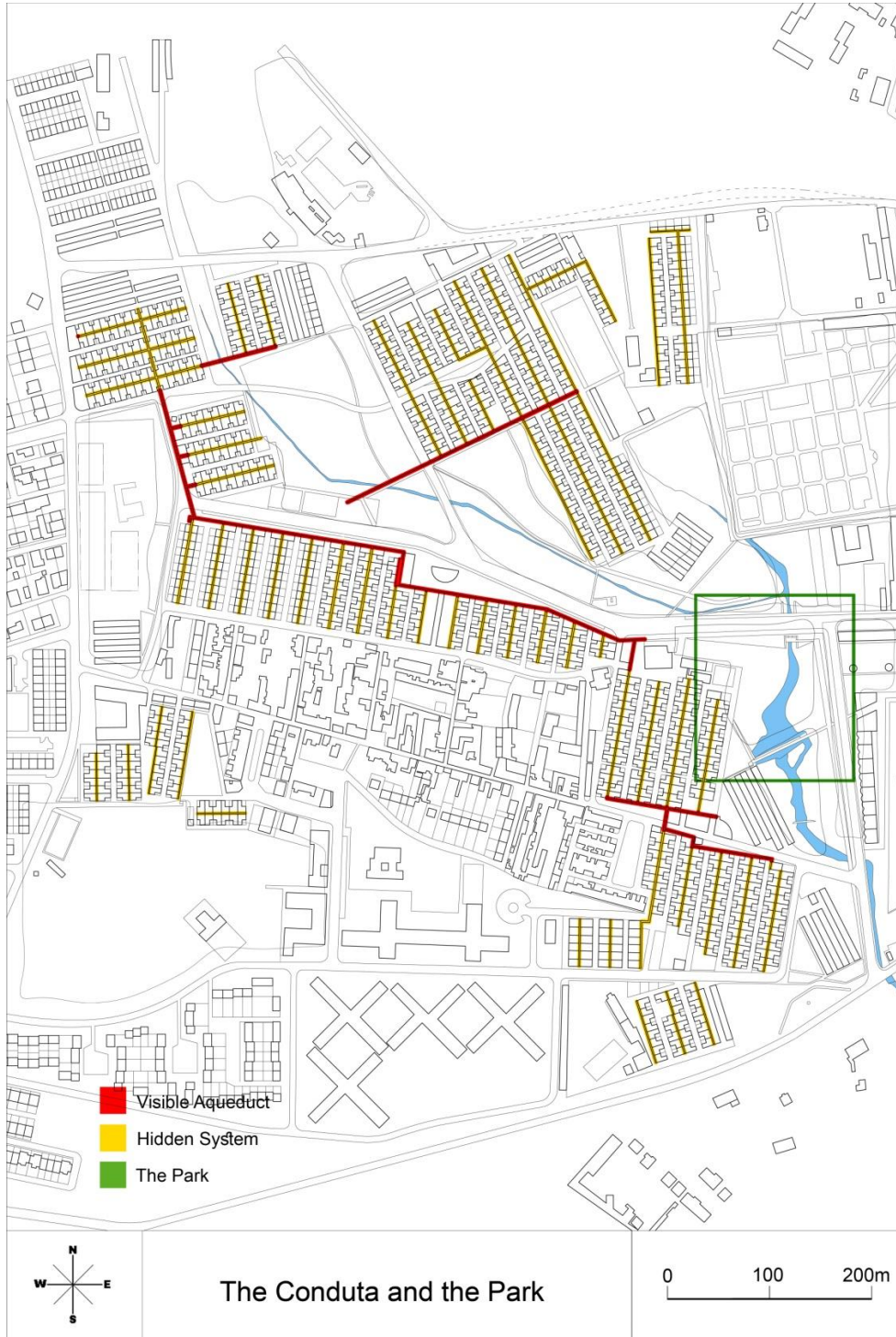


Figure (4.19)  
Source: (Woodman 2015)

### Open Space 1: The Conduto

The Aqueducts (conduta) is a combination of arcade and canal<sup>189</sup>. It is an elevated canal which acts as a supply line for the houses and service infrastructure, branching out across the whole area in different directions and connected to all the communal facilities such as shops, cafes and parking areas (Fleck 2013, p.46). The hidden system passing through the building is united by three ducts which connect the different limbs of the large planning area and define the open spaces. The ducts are supported by gateways and pillars creating a covered walkway which protects the pedestrians from the sun and rain (figures 4.20, 4.21, 4.22, 4.23).

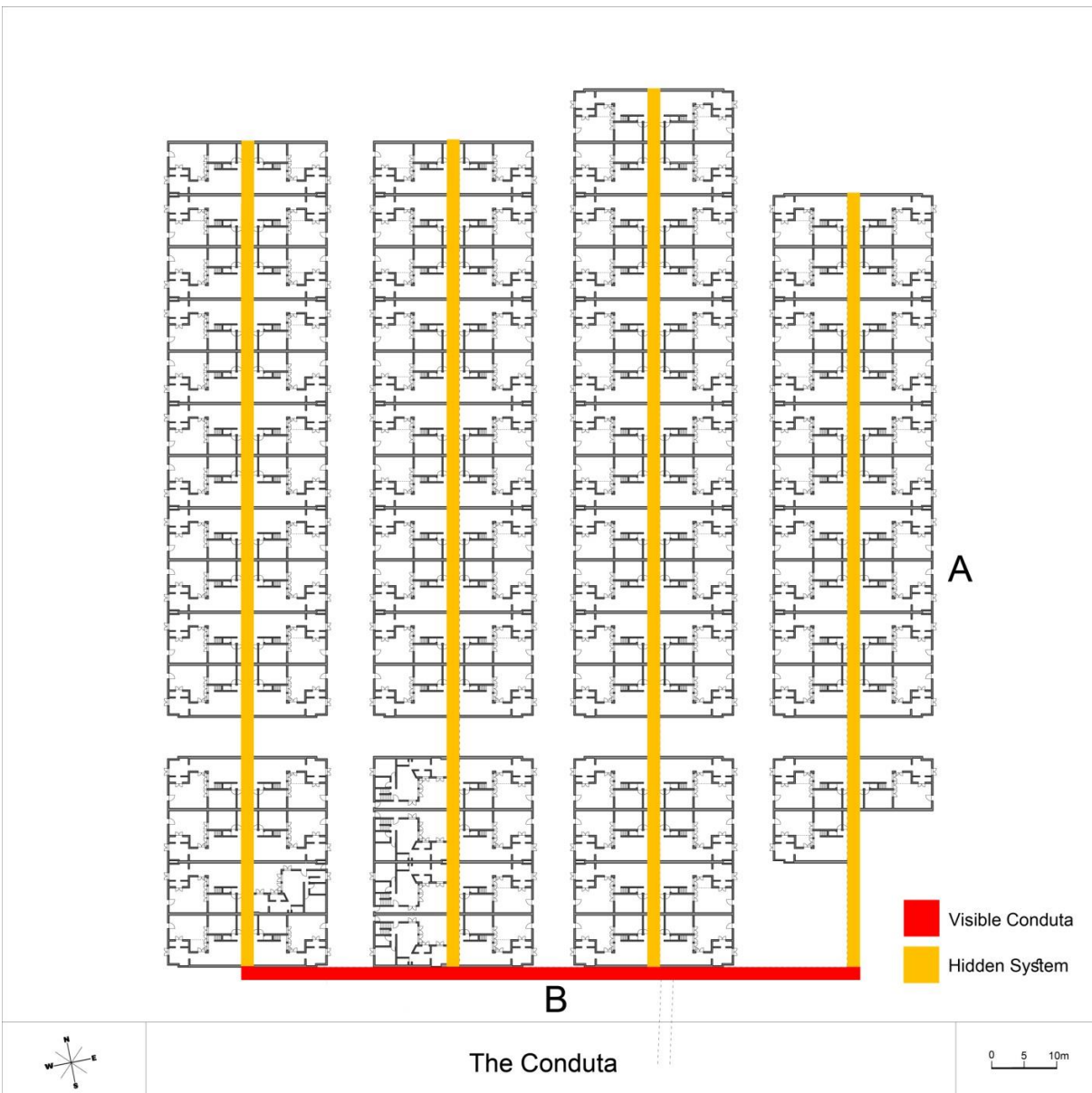


Figure (4.20)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

<sup>189</sup> It is an interpretation of the 16<sup>th</sup> century aqueduct which crosses the open country from the north and enters the old town of Evora (Fleck 2013, p.46) It is “like an umbilical chord (Molteni 2013) joining the new project to the old city of Evora.

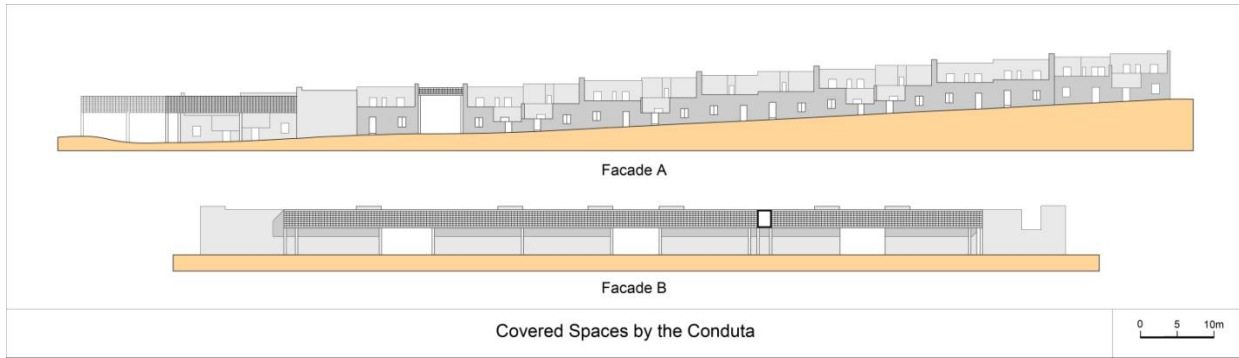


Figure (4.21)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

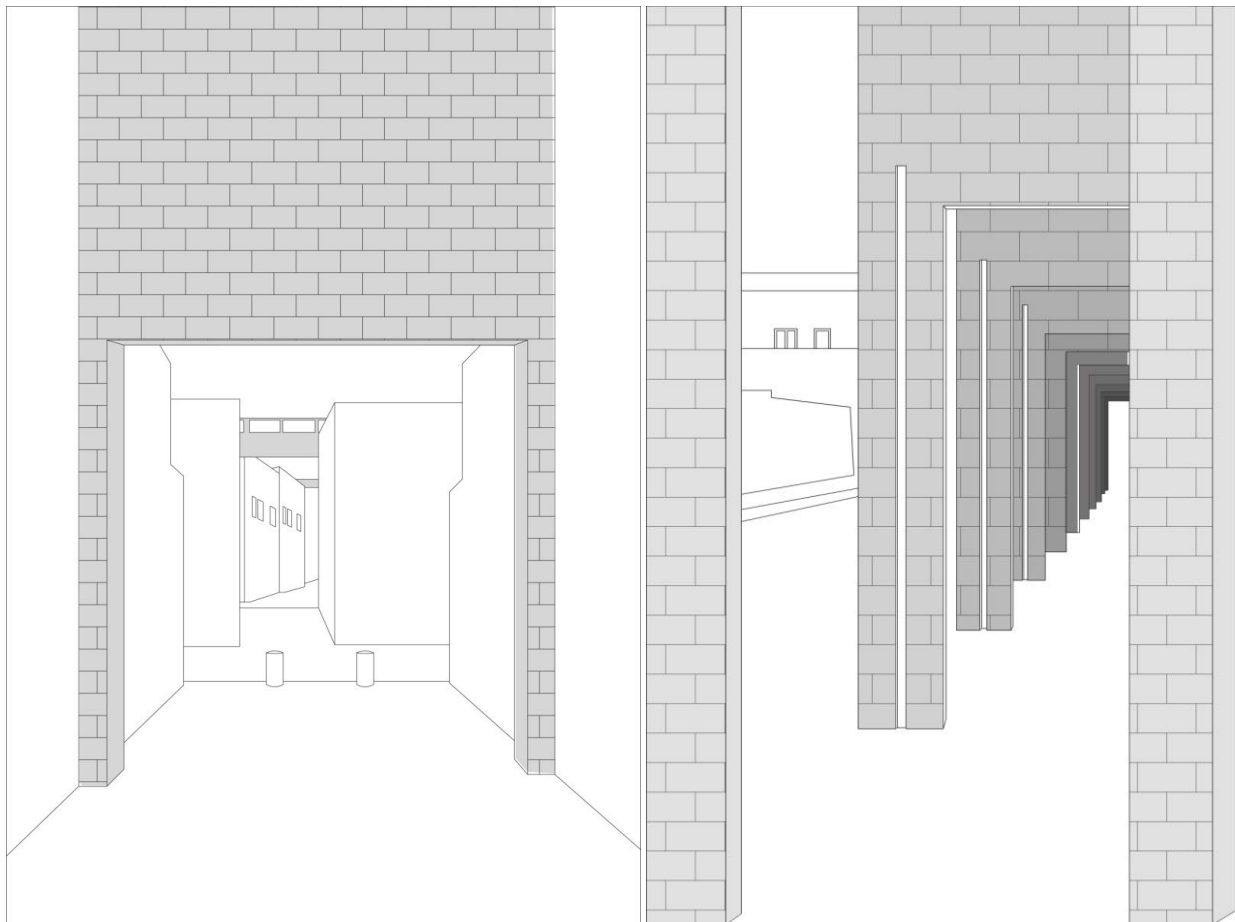


Figure (4.22, 4.23) Shaded Spaces by the Conduto

Source: (Pfeifer 2013, p.111, 103)

### Open Space 2: The Park

This space is the most common meeting space in the area. It contains the most commonly used walkway which was an existing path, a lake, an open air theatre and an underground path. Surrounded by green areas, this space is ideal as a thermally comfortable meeting space during the summer and winter (Molteni 2013, p.97) (figure 4.24).

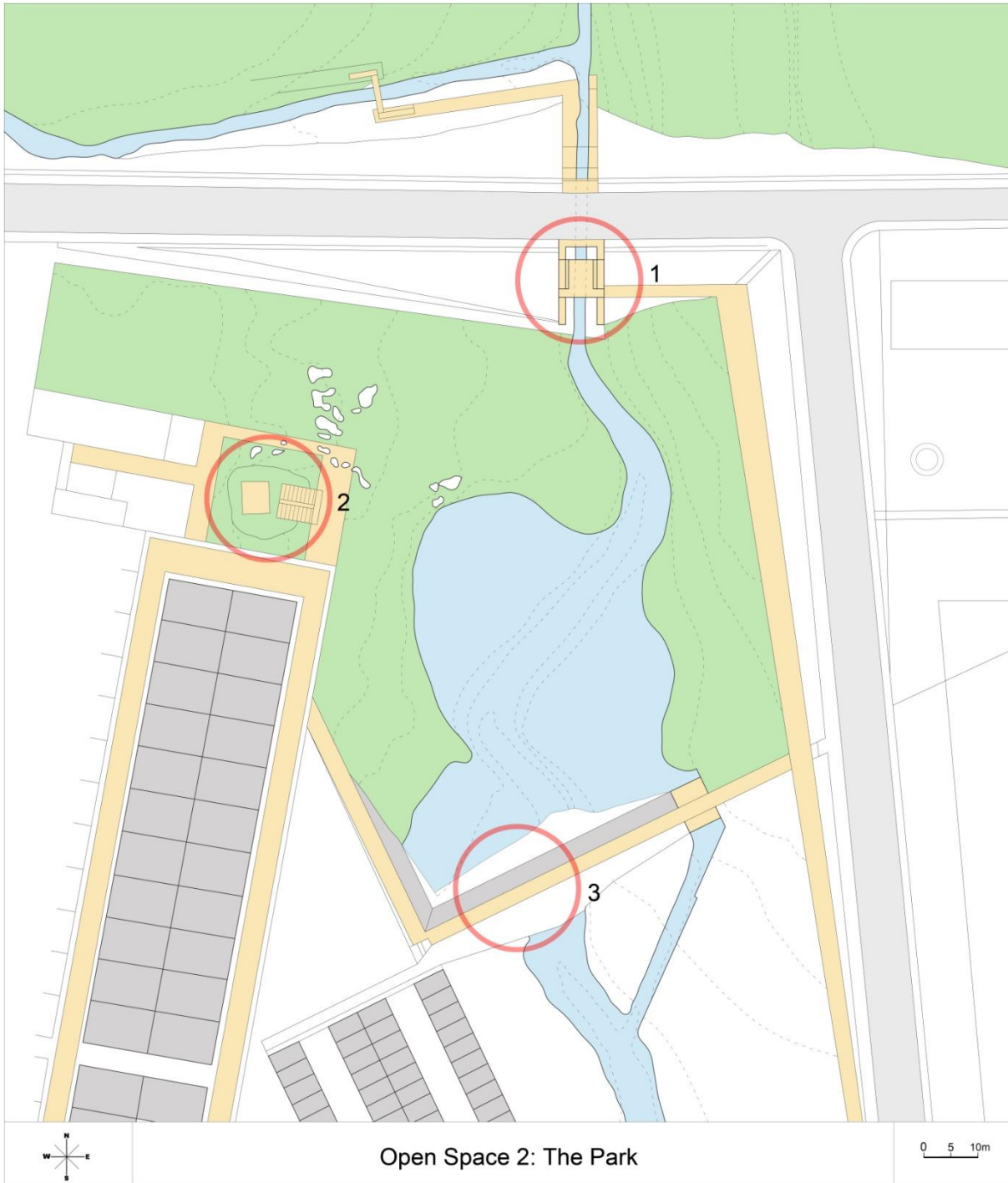


Figure (4.24)  
Source: (Molteni 2013, p.125)



### **Detail 1: The Bridge**

Many connections are achieved through this bridge. First it connects the park to the main road through the stairs. Second it connects the pedestrian to the other side of the river by climbing half the staircase. Finally, it takes the pedestrian to the other side of the park past the main road through a shaded underground pathway along the river (figure 4.25).

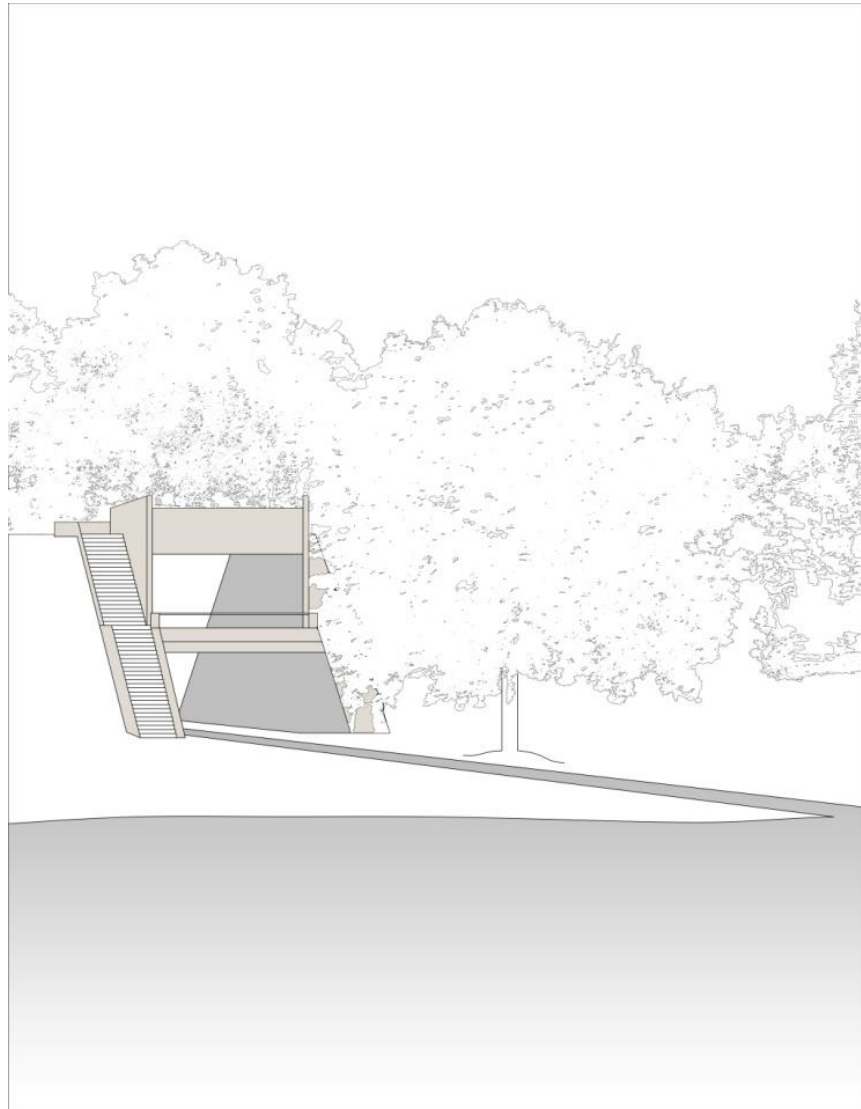


Figure (4.25) The Bridge  
Source: (Pfeifer 2013, p.140)

### **Detail 2: The Open Theatre**

This space allows the residents to enjoy shows during the warm summer evenings, in addition to providing a shaded sitting area under the theatre steps (figure 4.26).

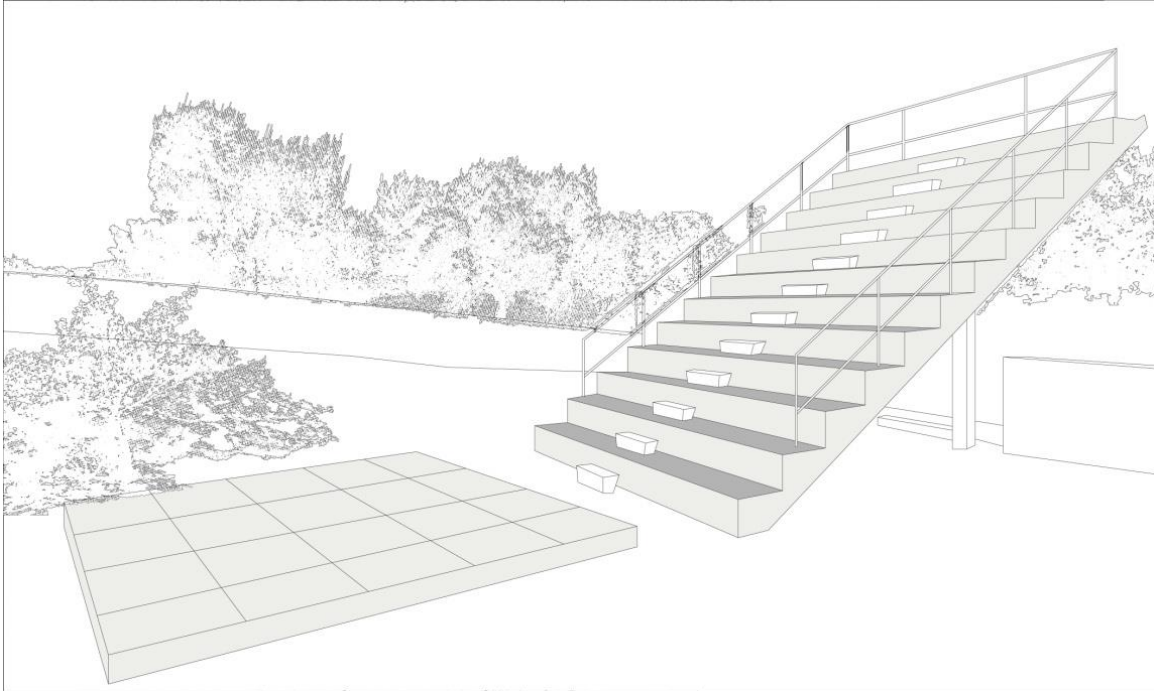


Figure (4.26) The Open Theatre  
Source: (Pfeifer 2013, p.125)

### Detail 3: The Dike

The dike emphasizes a pre-existing pathway<sup>190</sup> and now defines the most commonly used pedestrian walkway overlooking the lake (figure 4.27).

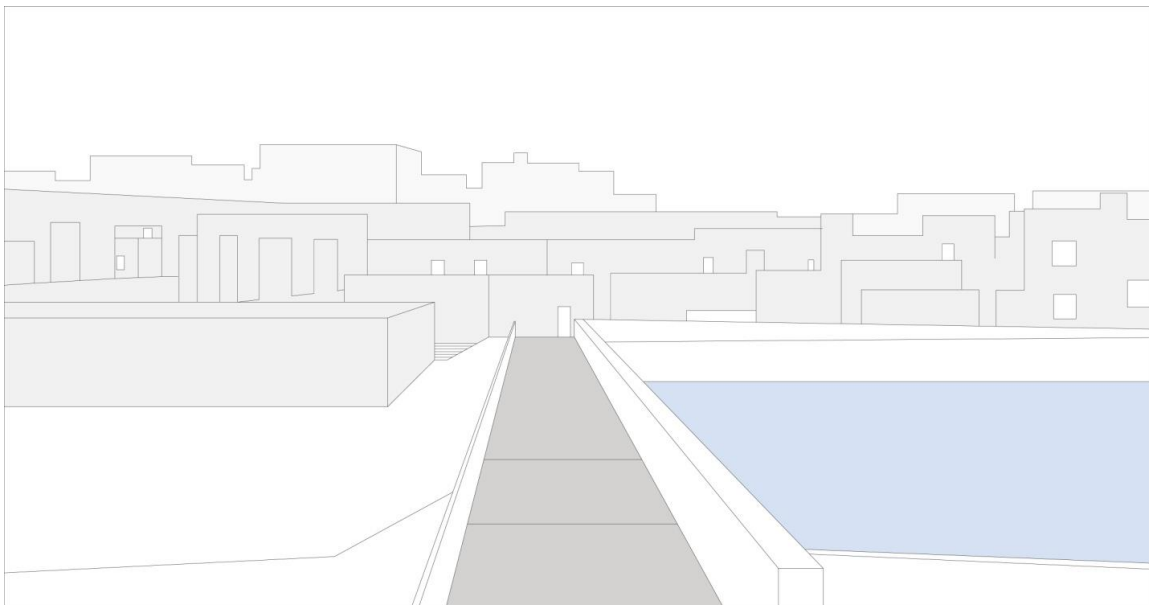


Figure (4.27) The Dike  
Source: (Pfeifer 2013, p.99)

<sup>190</sup> This walkway linked the neighbourhood of Santa Maria with Nossa Senhora da Gloria, and was used by children going to school and mothers going to the supermarket (Molteni 2013, p.97).

- **Vegetation**

In addition to the vegetation surrounding the settlement, the spaces between the blocks are dense with vegetation and trees which create shade for the open spaces and buildings and affect the overall temperature of the settlement<sup>191</sup> (figure 4.28).



Figure (4.28)

Source: (Woodman 2015)

- **Public Fountains and Wells**

On a smaller scale the small lake and connected river could have the effect of a water fountain in the open spaces of a settlement<sup>192</sup> (figure 4.29).

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<sup>191</sup> See 2.2.2. Settlement, a. Solar Factor – Vegetation, pg.49.

<sup>192</sup> See 2.2.2. Settlement, a. Solar Factor – Public Fountains and Wells, pg.50.

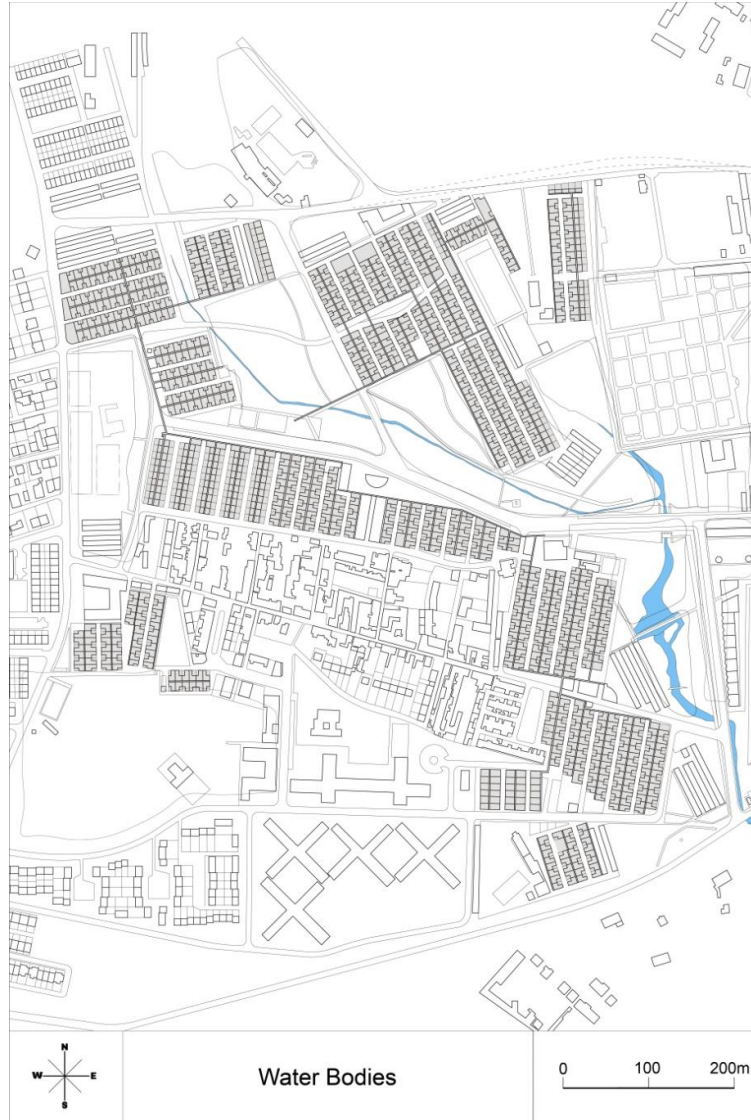


Figure (4.29)  
Source: (Woodman 2015)

- **Surface Materials:**<sup>193</sup>

**Ground Surface Materials**

The streets of Malagueira are covered with a natural cobblestone which has a solar reflectance of 0.21. This reduces the heat island effect and the overall temperature.

**Building Surface Materials**

The exterior of the settlement dwellings is covered with a white plaster which has an albedo of 0.80, also reducing the heat island effect.

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<sup>193</sup> See 2.2.2. Settlement, a. Solar Factor - Surface Materials, pg.50.



## b. WIND FACTOR

- **Compact Geometry**

The compact geometry and decreased S/V ratio of Malagueira building blocks aids in protecting the dwellings from the harsh winter winds and from heat loss during the winter<sup>194</sup>.

- **Block Orientation**

Most of the building blocks are orientated on a north-south axis. That means that the long elevation receives the winter winds coming from the east and the summer winds coming from the west<sup>195</sup> (figure 4.30).

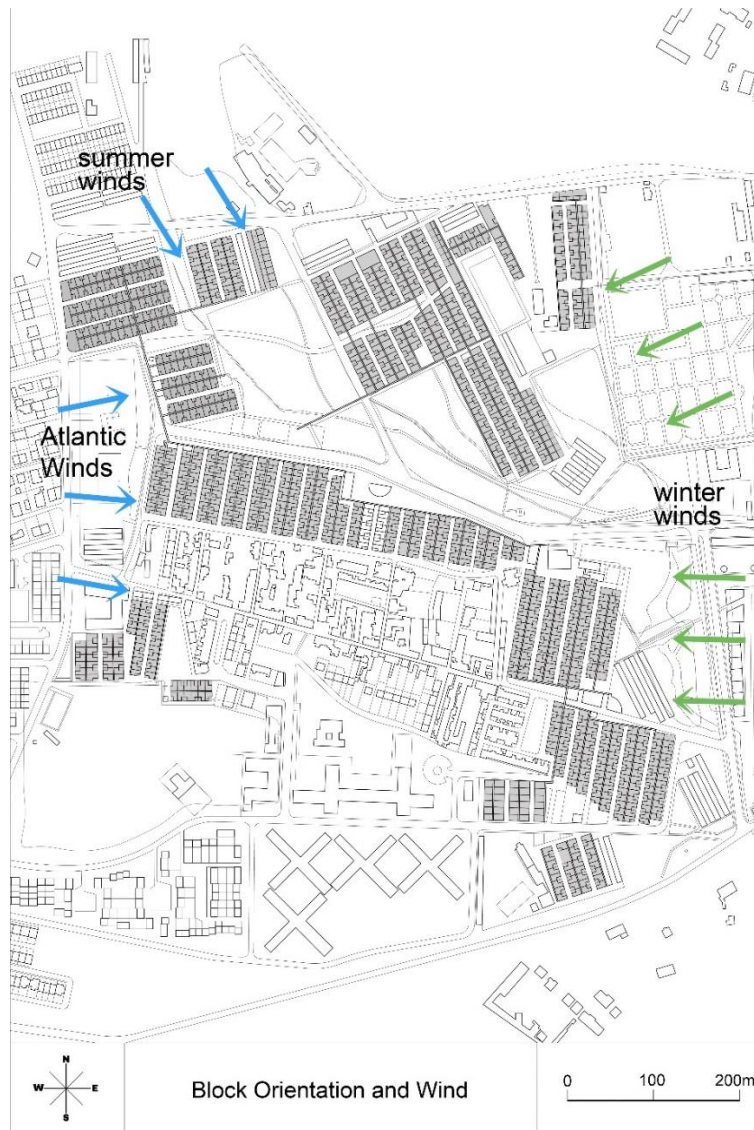


Figure (4.30)  
Source: (Woodman 2015)

<sup>194</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.

<sup>195</sup> See 2.2.2. Settlement, b. Wind Factor – Block Orientation, pg.51.

- **Street Orientation**

The main streets of the settlement of Malagueira are oriented on an east-west axis. This results in the creation of a passage for the western Atlantic winds to be channeled through the public spaces and pathways of the settlement. The winter winds are blocked by the buildings in some areas and received in other areas where it can be blocked by trees as mentioned previously<sup>196</sup> (figure 4.31).



Figure (4.31)  
Source: (Woodman 2015)

<sup>196</sup> See 2.2.2. Settlement, b. Wind Factor – Street Orientation, pg.53.

- **Narrow Streets**

The airflow in the narrow streets depend on the street and building dimensions. To determine whether the winds are blocked or received in the narrow streets of the neighbourhoods, the H/W ratio is calculated. The results are that the H/W is approximately 1 meaning winds pass over the buildings with some ventilation entering the streets<sup>197</sup> (figure 4.32).

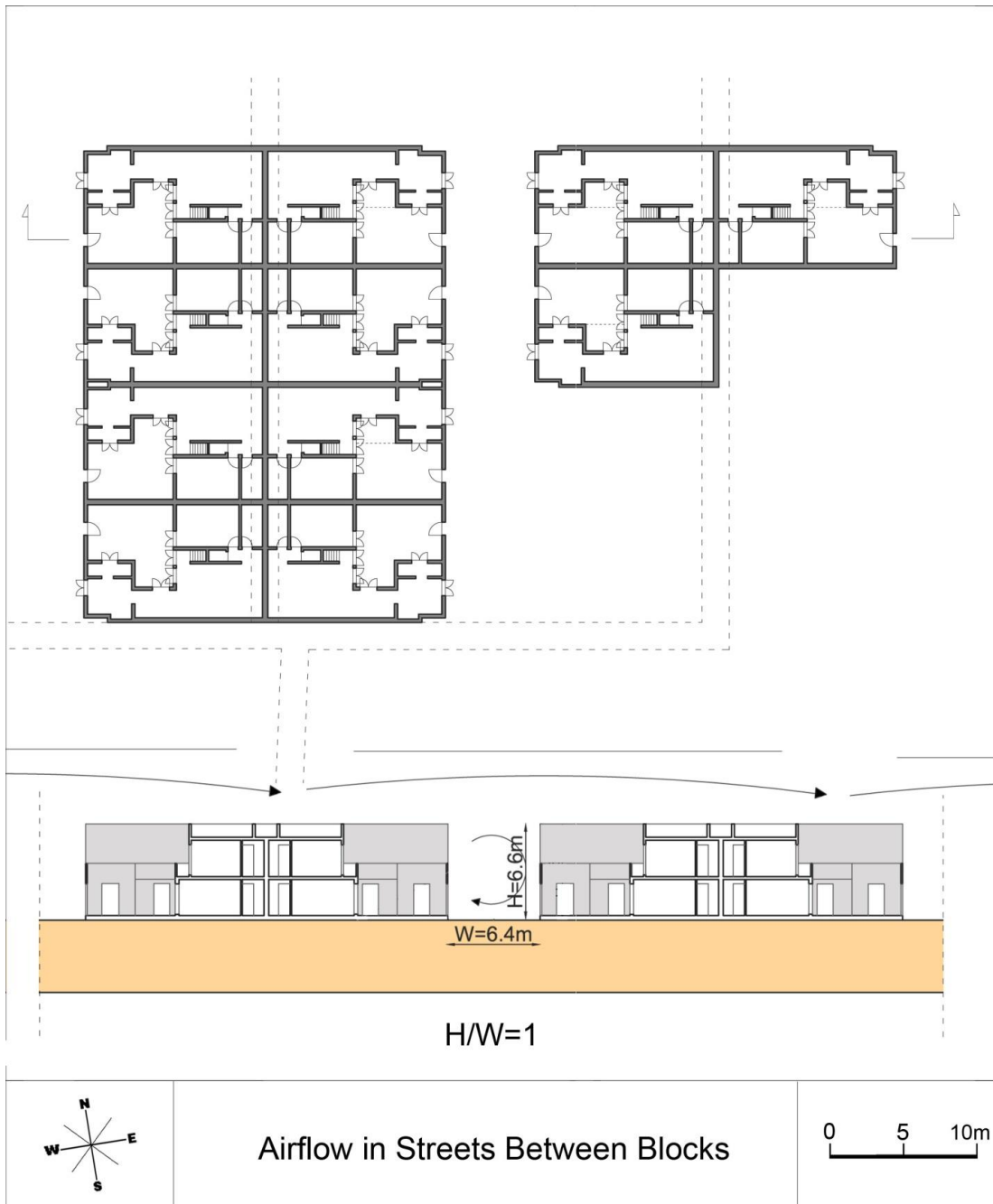


Figure (4.32)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

<sup>197</sup> See 2.2.2. Settlement, b. Wind Factor – Narrow Streets, pg.54.

- **Open Spaces**

Due to the wide streets and large area of the open spaces between the neighbourhoods, the winds coming are channeled through the open spaces of the settlement. This is a benefit in the summer but a disadvantage in winter when trees can be used as barriers.

- **Vegetation**

The open spaces throughout the settlement and the areas by the buildings are dense with various types of vegetation. The vast grassy areas give maximum ventilation conditions and the trees in the central area reduce the wind speed. The trees near the buildings improve the indoor ventilation<sup>198</sup> (figure 4.33).



Figure (4.33) Dense Vegetation throughout the Settlement  
Source: (Pfeifer 2013, p.202)

- **Public Fountains**

The rivers and lake in the settlement of Malagueira aids in cooling the passing winds through the settlement<sup>199</sup>.

- **Surface Materials**

In addition to their material and colour, surfaces of the buildings of Malagueira are cooled due to the cool winds passing through the settlement especially since the settlement is more open when compared to a vernacular settlement.

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<sup>198</sup> See 2.2.2. Settlement, b. Wind Factor – Vegetation, pg.55.

<sup>199</sup> See 2.2.2. Settlement, a. Solar Factor – Public Fountains, pg.50.



### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the SETTLEMENT of Quinta da Malagueira based on the matrix found in chapter 2<sup>200</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The number of points was determined as a percentage according to Matrix (4.1)<sup>201</sup>.

#### **1. Compact Geometry**

The geometry of Quinta da Malagueira consists of compact building blocks distributed in several neighbourhoods in the site. This resulted in a decreased S/V ratio which decreases heat gain and loss. When compared with a vernacular settlement, the building density is less. Therefore, it was given “good” for both factors.

#### **2. Block Orientation**

Most of the blocks are orientated on a north-south axis, giving this tool a “below average” rating for the sun factor. As for the wind factor, the orientation of most of the blocks exposed them to the desirable winds from the long elevation but at the same time exposed them to the winter undesirable winds. That is why this tool was given “average” for the wind factor.

#### **3. Street Orientation**

According to the sun factor, the orientation of the main streets exposes them to the sun for most of the day in summer, however the secondary streets have an almost ideal orientation. Therefore, it was given “good” for the sun factor. According to the wind factor, the orientation of the streets receives the desirable winds from the western side. From the eastern side, the undesirable winds are blocked from some streets by the buildings and are received by others. This gave it a “good” rating for the wind factor.

#### **4. Narrow Streets**

The narrow streets between the building blocks in each neighbourhood create shade which protects the facades from the excessive heat. When compared with a vernacular settlement, the streets of Malagueira are wider and overall density is less, therefore, this tool was given “good” for the sun factor. According to the wind factor, the H/W ratio allows more air to enter the streets creating more ventilation. It was also given a “good” rating.

#### **5. Open Spaces**

There is a variety of open spaces in the settlement of Malagueira where residents can enjoy the sun, shade and breeze. This tool was given “very good” for both factors.

#### **6. Vegetation**

The amount of vegetation between the neighbourhoods of Quinta da Malagueira has a positive effect on the buildings energy savings by shading the buildings, reducing wind speed and improving ventilation. Therefore, it was given “very good” for both factors.

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<sup>200</sup> See 2.2.2. Settlement, c. Comparative Analysis Matrix, p.57.

<sup>201</sup> See 4.2.1.1. Site, c. Comparative Analysis Matrix, Matrix (4.1) Evaluation for Existing Situation of Tools (EE) p.209.

## 7. Public Fountains

On the settlement scale, the lake and connected rivers have an effect on the thermal comfort of the outdoor spaces for the sun and wind factors, therefore it was given “very good”.

## 8. Surface Materials

The light colours of the buildings of Quinta da Malagueira protect buildings from excessive summer heat. It was given “very good” for the sun factor. From the wind factor, winds aid in cooling surface temperatures especially in a more dispersed settlement when compared with a vernacular one. Therefore, this tool was given “good” for the wind factor.

<b>Settlement (SE) - QUINTA DA MALAGUEIRA</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SE 1. Compact Geometry</b>	16	8	8	75%	75%	12
<b>SE 2. Block Orientation</b>	12	6	6	25%	50%	4.5
<b>SE 3. Street Orientation</b>	4	2	2	75%	75%	3
<b>SE 4. Narrow Streets</b>	16	8	8	75%	75%	12
<b>SE 5. Open Spaces</b>	4	2	2	100%	100%	4
<b>SE 6. Vegetation</b>	16	8	8	100%	100%	16
<b>SE 7. Public Fountains</b>	4	2	2	100%	100%	4
<b>SE 8. Surface Materials</b>	16	8	8	100%	75%	14
<b>Total for SE Category: 88                      Final Points for SE – Malagueira: 69.5</b>						

Matrix (4.3) Malagueira SETTLEMENT Evaluation

#### 4.2.1.3. DWELLING: Passive Design Strategies of Courtyard Houses in Quinta da Malagueira

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##### Case Studies: Type A and B Houses

The Malagueira residential units are courtyard type and two storeys high, with an L-shaped plan connected back to back forming long rectangular blocks which create a clear and strong separation between public and private spaces (Pfeifer 2013, p.241). Each dwelling has a courtyard or atrium with a group of rooms surrounding two sides of the patio<sup>202</sup>. Plot sizes are eight meters along the street and 12 meters back and step up the hill perpendicular to the contour lines. This system allows the compacting of the units and minimum necessary change to the topography (Zapatel 2001, p.126). The back to back system allows a compact structure where all houses share three walls and one elevation facing the street. However, this system results in some houses with an eastern elevation and some with a western elevation, and the patio with the L-shaped plan resulted in some houses receiving southern exposure and some northern exposure. Therefore, not all of the houses have the desired orientation with regards to the sun and wind.

Siza designed a system that allowed the generation of different houses, where he allowed the residents to participate in the design process and each have their unique home. He designed two basic types of boxes, one with a front courtyard, Type A (figure 4.35) and one with a back courtyard, Type B (figure 4.36). Each type allowed different options according to the placement of the staircase and the number of rooms from one to five, while both types have the kitchen and living rooms on the patio level and the bedrooms and terraces above. According to this system, Siza designed 35 different house solutions (Duarte 2013, p.212). These houses can also be added on to over time by the occupants so that they can begin with a simple two room house built on one level that can be transformed into a larger dwelling depending on the owner's necessities (figure 4.35, 4.36). This characteristic of an incomplete dwelling helps break down the strict repetition typical of most low cost housing<sup>203</sup>.

The two types of houses are scattered all over the settlement, however the studied houses were chosen from the set of blocks highlighted in figure (4.34) with the same orientation.

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<sup>202</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003)

<sup>203</sup> [http://www.housingprototypes.org/project?File\\_No=POR003](http://www.housingprototypes.org/project?File_No=POR003).

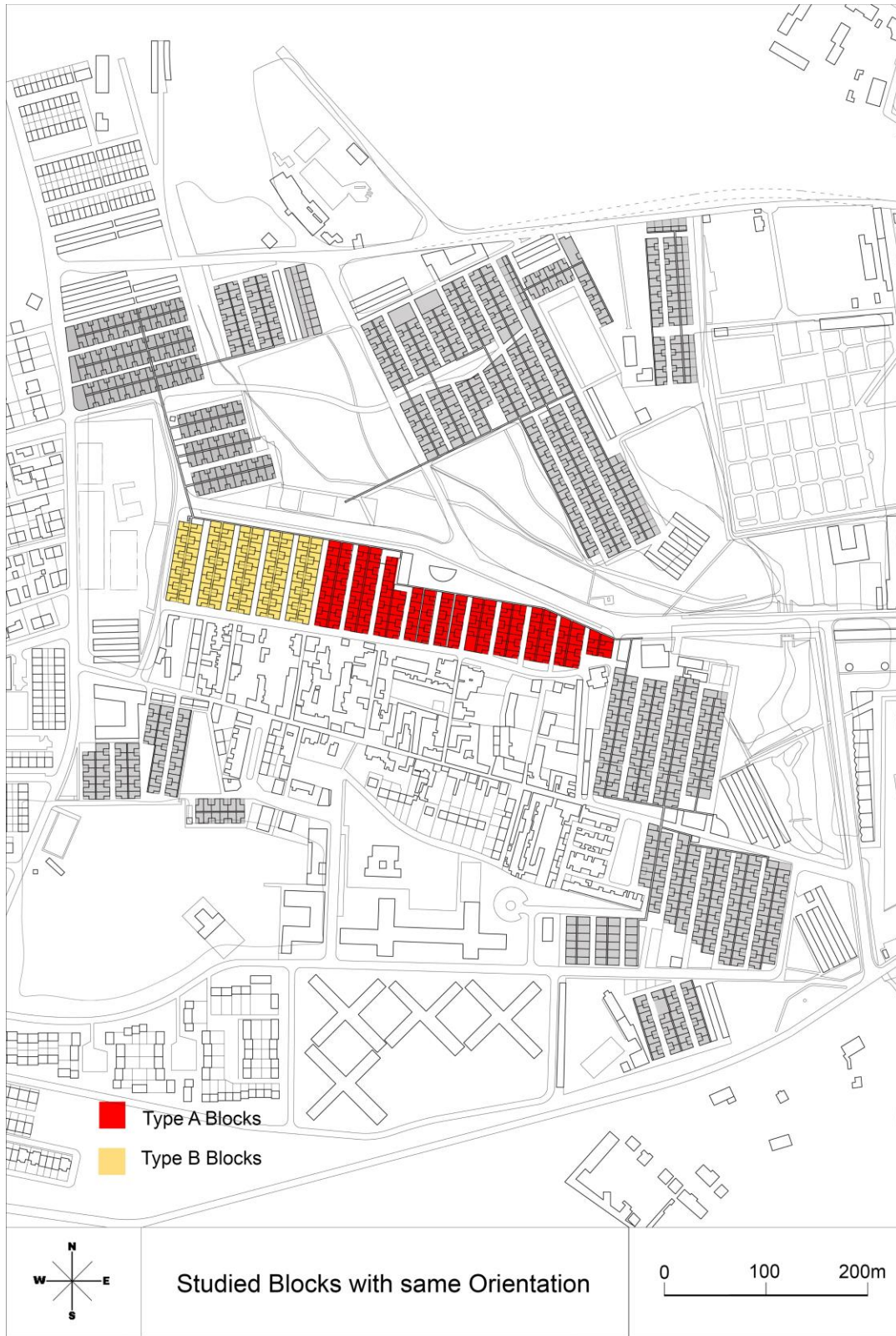


Figure (4.34)



Figure (4.35)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>



Type B Houses

Figure (4.36)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

## Type A Houses

### A. The Thermal Response of Type A Courtyard House:

The back to back system in the Type A houses caused the generation of 4 differently orientated houses (figure 4.37). That resulted in the different thermal response of each house with regards to sun and wind.

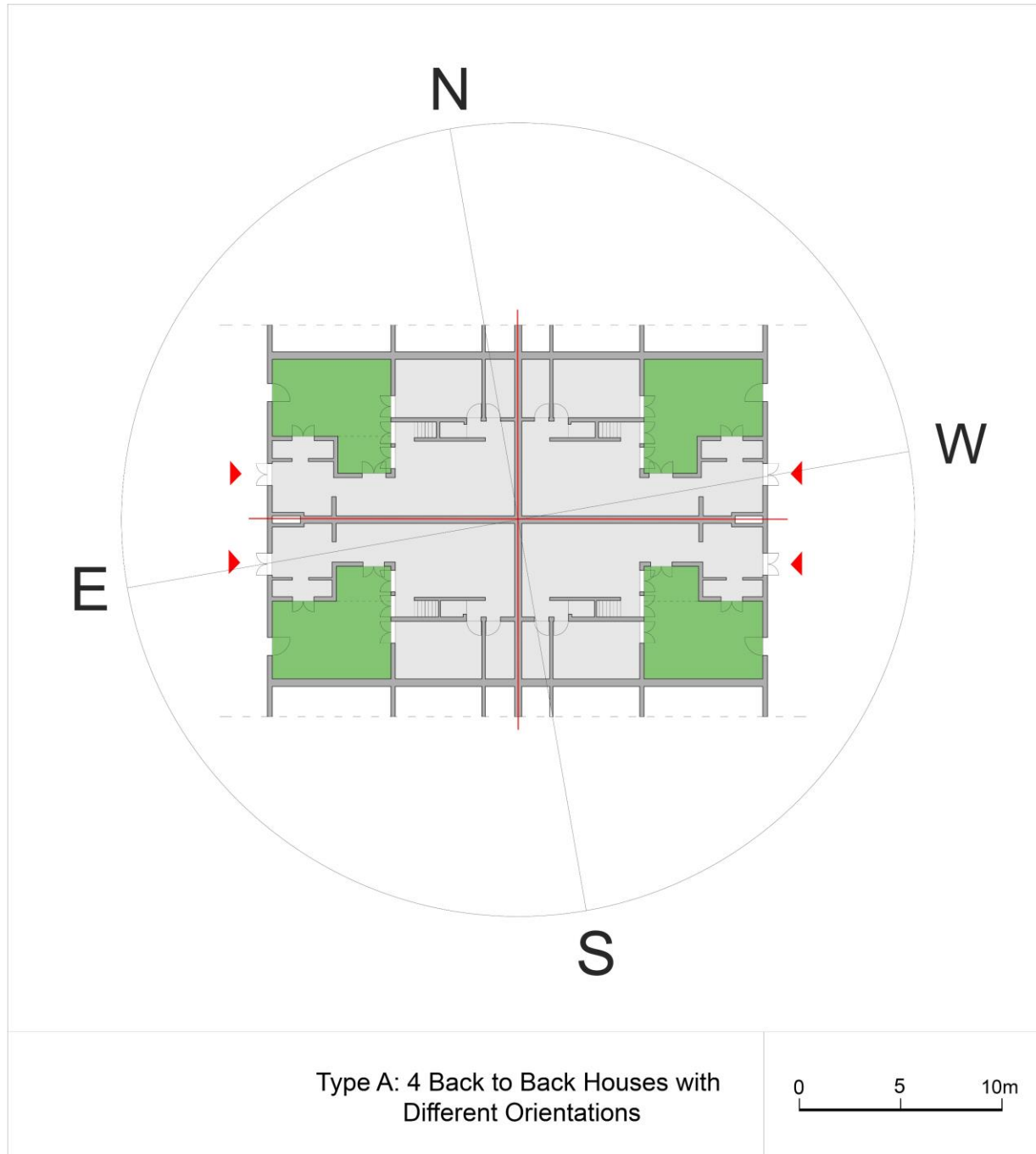


Figure (4.37)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

**a. SOLAR FACTOR**

Each one of the four back to back houses of type A has a different relationship with the sun (figure 4.38). This affects the thermal response of the house in many ways.

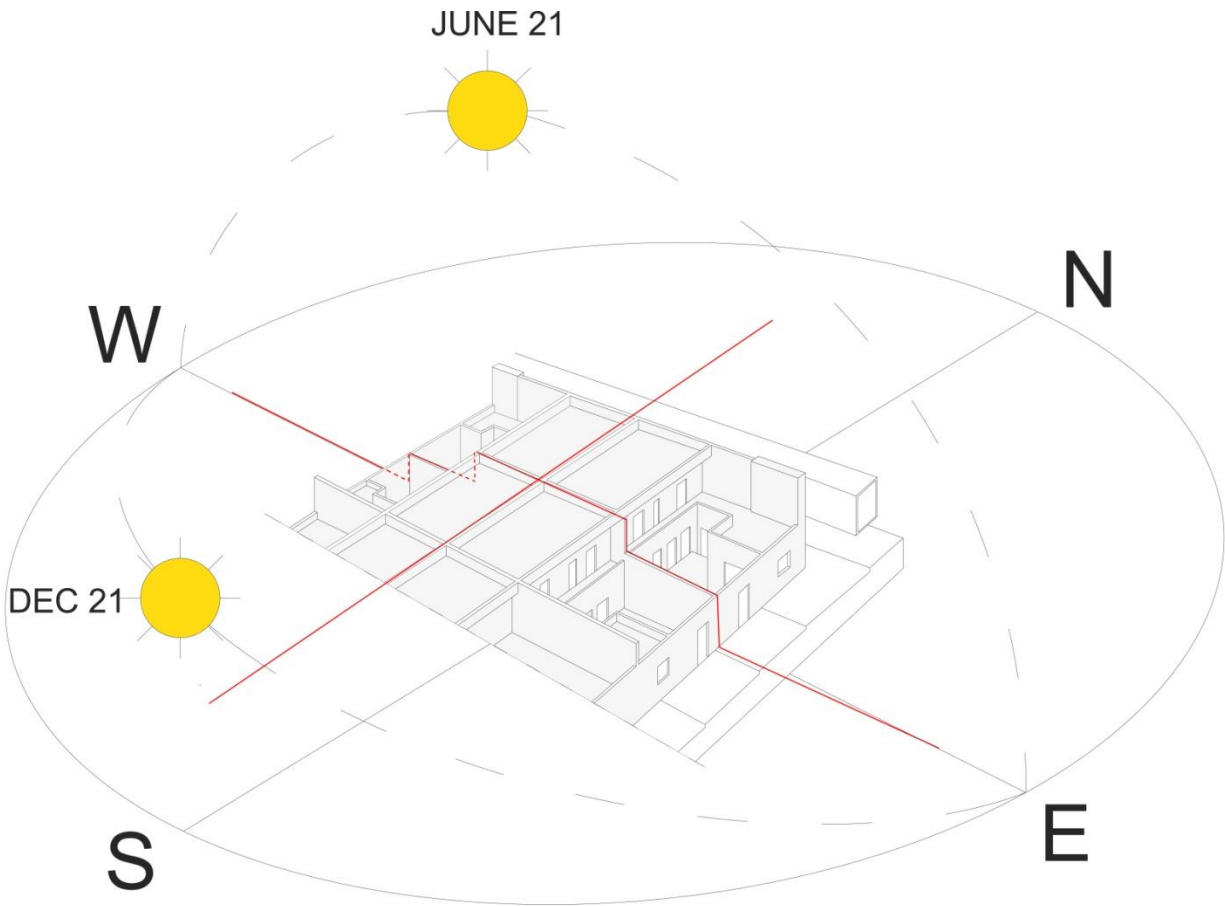


Figure (4.38)

Relationship of 4 Back to Back Houses with the Sun

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>



- **Shape and Form**

All type A houses have an L-shaped plan surrounding a courtyard. This gives it a benefit of self shading. In addition, the irregular form of the courtyard creates extra shade for the courtyard occupants (figure 4.39). The amount of shade depends on the position of each house and the sun angle and this is studied in the “Dimensions and Shade” section.

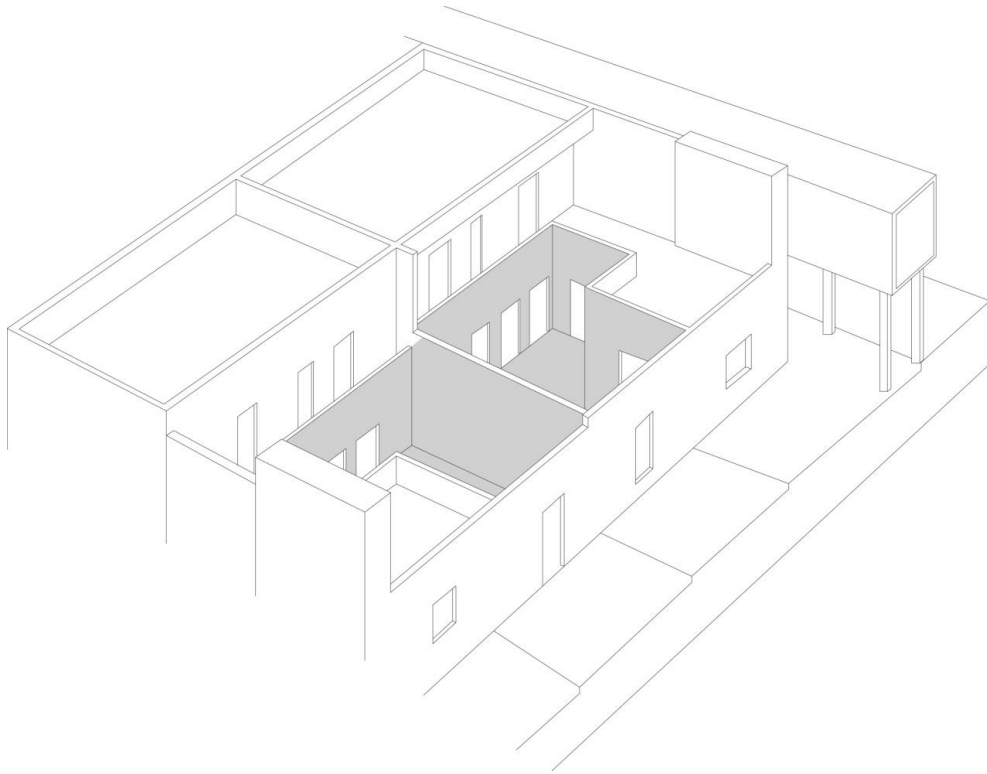


Figure (4.39) Self Shading due to Form

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Orientation:**

The general orientation of the type A houses is east-west, however the integration with the existing topography causes the houses to turn a little more to the southeast, and sometimes a little towards the northwest. Only a few houses are oriented in a north-south direction. However, in the east-west orientated houses, due to the back to back system, the position of the courtyard changes and therefore the effect of the sun changes significantly (figure 4.40).

In winter, the rooms overlooking the courtyard in two of the four houses benefit from the southern sun, and the other two only receive the winter sun on the courtyard wall. In summer, two of the houses receive the eastern sun from morning to noon and the other two receive the western sun from afternoon to sunset.

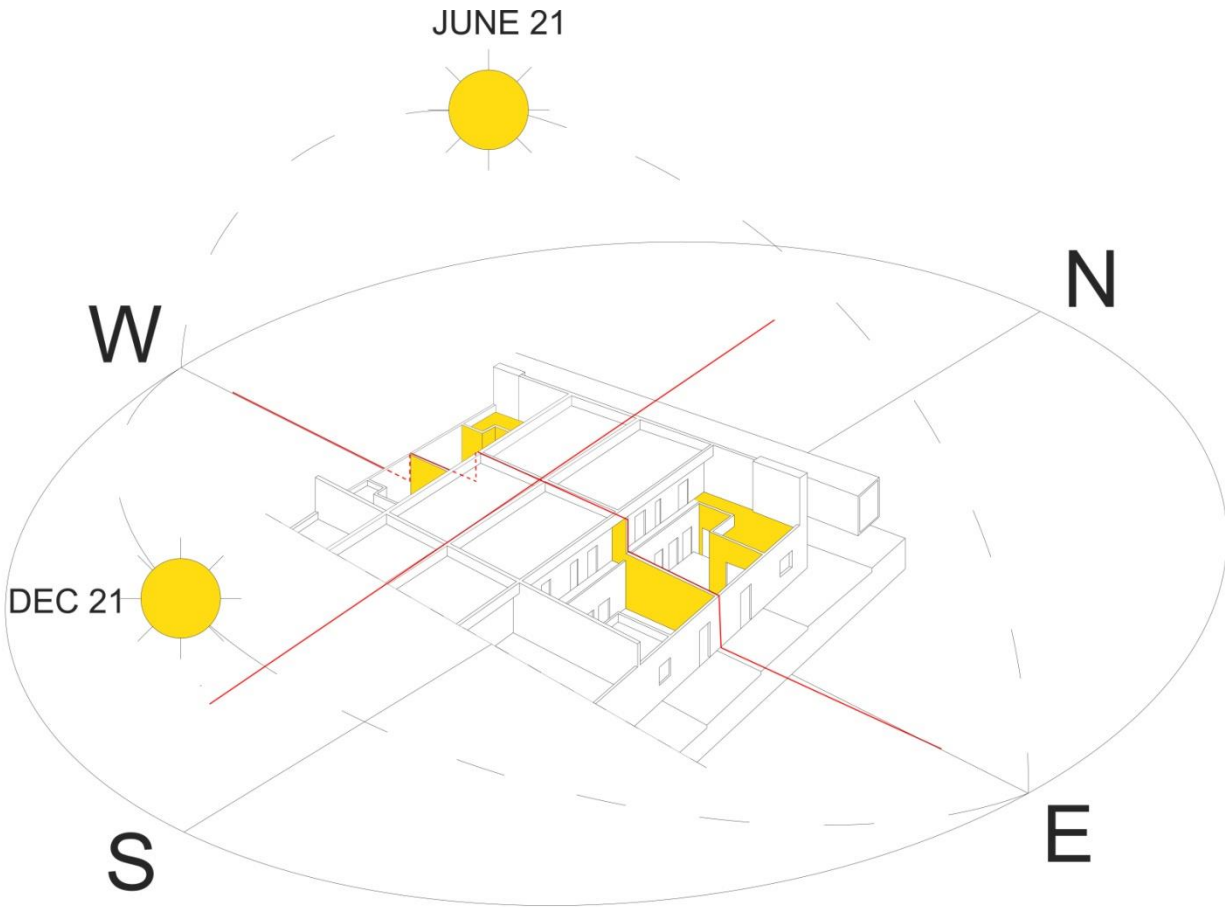


Figure (4.40) Southern Exposure of the Houses  
 Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

• **Dimensions and Shade**

The amount of shade produced in type A depends on the different options of the second level. In the option where the second floor covers the whole first floor, the amount of shade increases. In some units, the exterior courtyard wall was 3 metres high as initially planned, but in most units this was reduced to the height of the courtyard gate which was 1.8m<sup>204</sup> (Zapatel 2001, p.126). This decreased the amount of shade from the eastern and western courtyard walls (figure 4.41).

**Lateral Distance of Shade<sup>205</sup>**

$L=H \times \text{COT}\Theta$

$\Theta = 64^\circ$  (Summer Solstice in Evora)

$\text{Cot } 64^\circ = .48$

$\Theta = 28^\circ$  (Winter Solstice in Evora)

$\text{Cot } 28^\circ = 1.88$

<sup>204</sup> This was a sign of the social interaction to address neighbourhood contact. Vegetation was used to preserve the privacy of the inhabitants.

<sup>205</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Dimensions and Shade, pg.62.

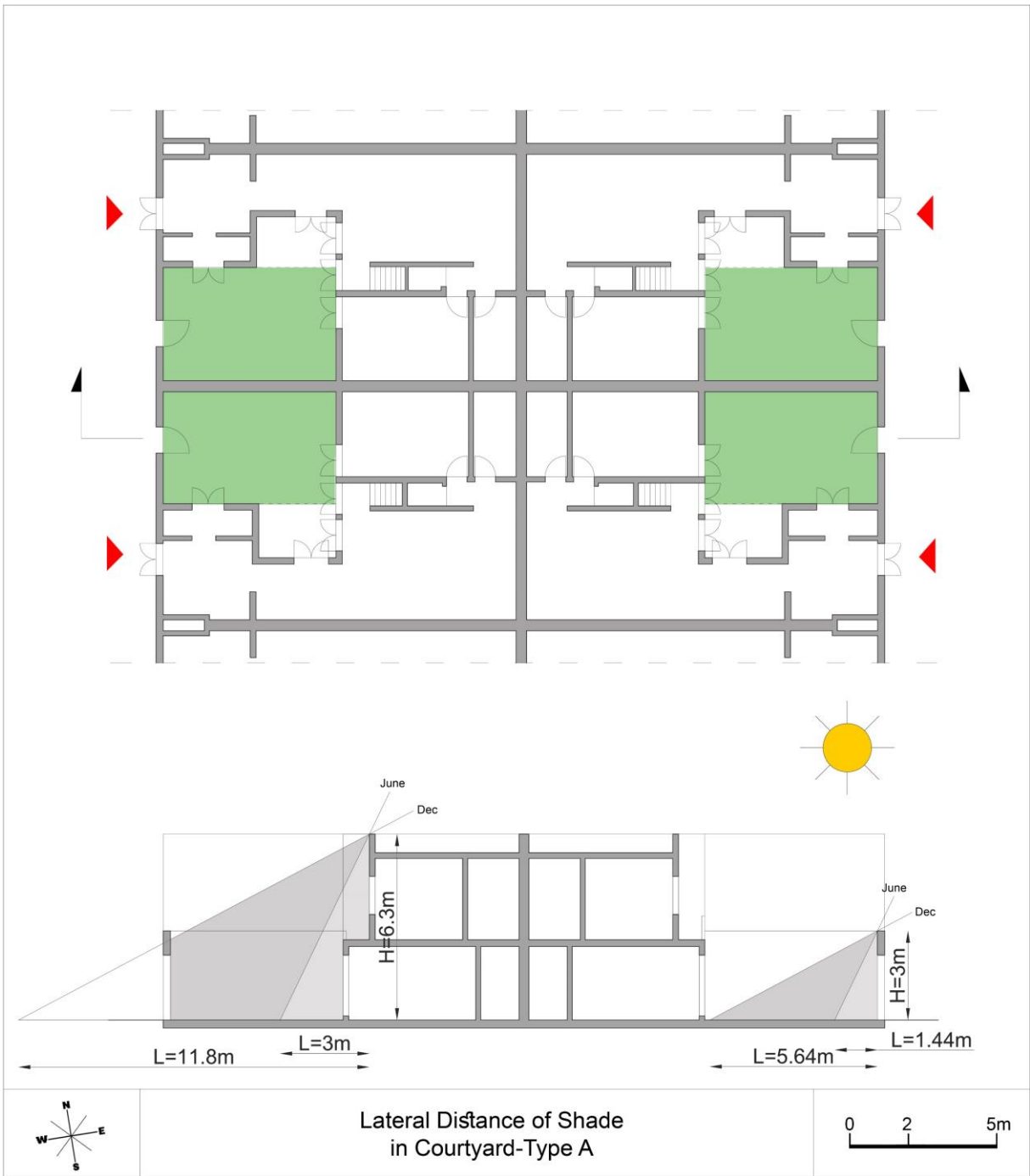


Figure (4.41)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

## b. WIND FACTOR

### • Shape and Form

As mentioned previously in the courtyard houses of Sidi Bou Said and Algiers, ventilation by convection is one of the most important characteristics of the courtyard house form. In the Type A houses of Malagueira, the courtyard is surrounded by rooms from 2 sides (in the full 2 storey option) giving them the benefit from the stored coolness and the process of reradiation in Mediterranean climate<sup>206</sup>. However, the lower courtyard wall could result in the cool air to escape before reaching the upper floor windows (figure 4.42).

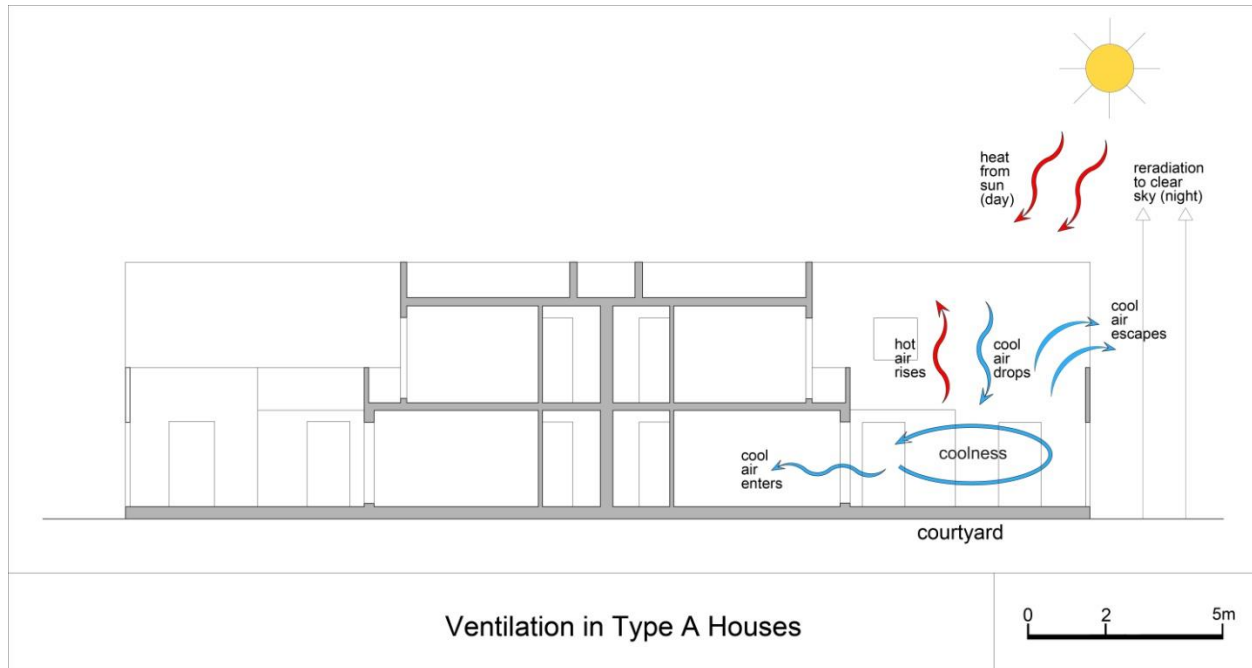


Figure (4.42)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

### • Orientation

The orientation of the building blocks and the back to back location of the houses resulted in some of the houses being orientated towards the eastern winter winds and some to the western summer winds. The existence of the adjacent buildings blocks these winds from both sides (figure 4.43).

<sup>206</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Shape and Form, pg.63.

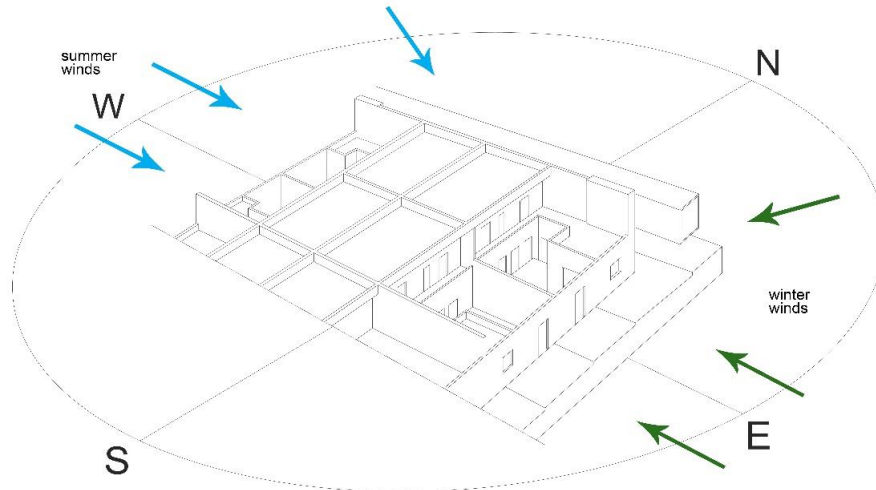


Figure (4.43) Orientation of Type A Houses to Wind

- **Dimensions and Airflow**

When studying the airflow in the courtyard, the two courtyard orientations should be considered. The western courtyard welcomes the prevailing winds due to its lower wall and medium aspect ratio  $0.3 < H/W < 1$ <sup>207</sup>. Therefore, recirculation of air happens in the western courtyard. The eastern courtyard however, has less air recirculation due to the higher aspect ratio considering the direction of the prevailing winds (figure 4.44).



Figure (4.44)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

<sup>207</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Dimensions and Airflow, pg.65.

## B. Additional Thermal Regulating Spaces in Type A houses:

As mentioned before, the Malagueira houses were designed in a way that would allow the resident to choose between many options for each type. Differences are mostly found in the second floor, however in all options, there are spaces which aid in the thermal comfort of the house. They are: the terrace and a covered space in the courtyard (figure 4.45).



Figure (4.45)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

### a. SOLAR FACTOR

#### • The Terrace

The terrace in options 1 and 2 benefit from the winter sun, however in the summer they should be shaded for protection from the eastern sun in the east orientated house and from the western sun in the opposite house (figure 4.35). This was achieved in some houses by installing a pergola with vegetation allowing the residents to use the terrace more during the hot summer days (figure 4.46).



Figure (4.46) Terrace covered with Pergola  
Source: (Leger 2013, p.237)

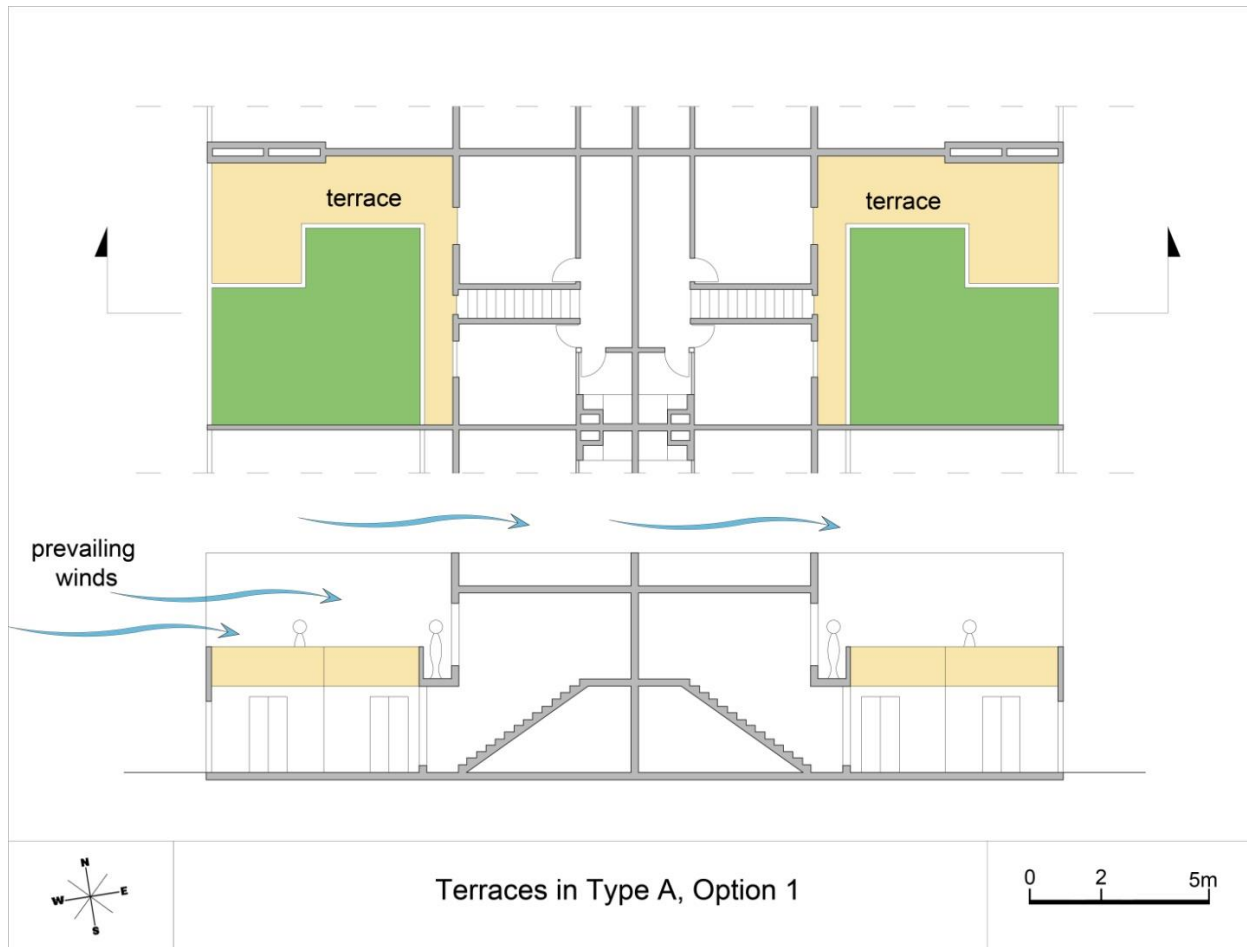
- **The Covered Space**

The covered space in the courtyard is present in options 2 and 3. It provides a shaded sitting space during the day when the temperatures are higher and the sun more excessive (figure 4.45).

**b. WIND FACTOR**

- **The Terrace**

The terraces found in all options overlook the courtyard and benefit from the coolness provided by the courtyard, especially the small inner terrace. The airflow is also determined by the orientation of the house. The terraces in the western houses benefit from the prevailing winds (figure 4.47).



Terraces in Type A, Option 1

Figure (4.47)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>



### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the DWELLINGS in Quinta da Malagueira based on the matrix found in chapter 2<sup>208</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This was based on Matrix (4.1)<sup>209</sup>.

#### **1. Shape and Form**

The courtyard form contributes to the energy savings of a house due to the benefit of self shading from all four sides. However, in Type A houses, the courtyard is not enclosed from all four sides, and the rooms do not get maximum benefit from the courtyard shade. The courtyard shape also has the function of thermally regulating the dwelling by convection but the lower gate resulted in the escape of some of the air. This tool was given “good” for both factors.

#### **2. Orientation**

The back to back system of Type A houses resulted in some houses benefiting from the winter sun and others not. In addition to their exposure to either the east or the west. The same case applies for the wind factor, some houses face the desirable winds and some the undesirable winds. Therefore, this tool was given “average” for both factors.

#### **3. Dimensions**

The lower gate wall resulted in the different amount of shade between the two back to back houses making each of the two houses benefit from the shade at different times of the day. According to the wind factor, the amount of air flow in the courtyard of the western houses is more than the eastern houses, however it is still satisfactory in the latter due to the H/W ratio. This tool was given “good” for both factors.

#### **4. The Covered Area**

In Option 2 and 3, a covered shaded area is found in the courtyard which provides a shaded space for sitting and creates a small buffer area protecting part of the house from heat. It was given “good” for the sun factor.

#### **5. Terrace**

Depending on its position in the back to back houses, the terrace receives the sun differently during different times of the day, however, the pergolas makes it a shaded pleasurable place for the residents. For the wind factor, the terrace in all cases is ventilated due to the courtyard function and the western terraces receive the prevailing winds. This tool was given “good” for both factors.

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<sup>208</sup> See 2.2.3. Dwelling, c. Comparative Analysis Matrix, p.72.

<sup>209</sup> See 4.2.1.1. Site, c. Comparative Analysis Matrix, Matrix (4.1) Evaluation for Existing Situation of Tools (EE) p.209.

<b>Dwelling (DW) - QUINTA DA MALAGUEIRA-TYPE A</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>DW 1. Shape and Form</b>	16	8	8	75%	75%	12
<b>DW 2. Orientation</b>	16	8	8	50%	50%	8
<b>DW 3. Dimensions</b>	12	6	6	75%	75%	9
<b>DW 4. Liwan</b>	8	4	4	0	0	0
<b>DW 5. Arcade/Covered Space</b>	8	4	N/A	75%	N/A	3
<b>DW 6. Loggia</b>	8	N/A	4	N/A	0	0
<b>DW 7. Terrace/Roof/Garden</b>	8	4	4	75%	75%	6
<b>Total for DW Category (-N/A): 68      Points for DW-TYPE A– Malagueira: 38</b>						

Matrix (4.4) Malagueira DWELLING – TYPE A Evaluation

## Type B Houses

### A. The Thermal Response of Type B Courtyard Houses:

As in Type A, the back to back system of the houses results in four houses with different orientations (figure 4.48).

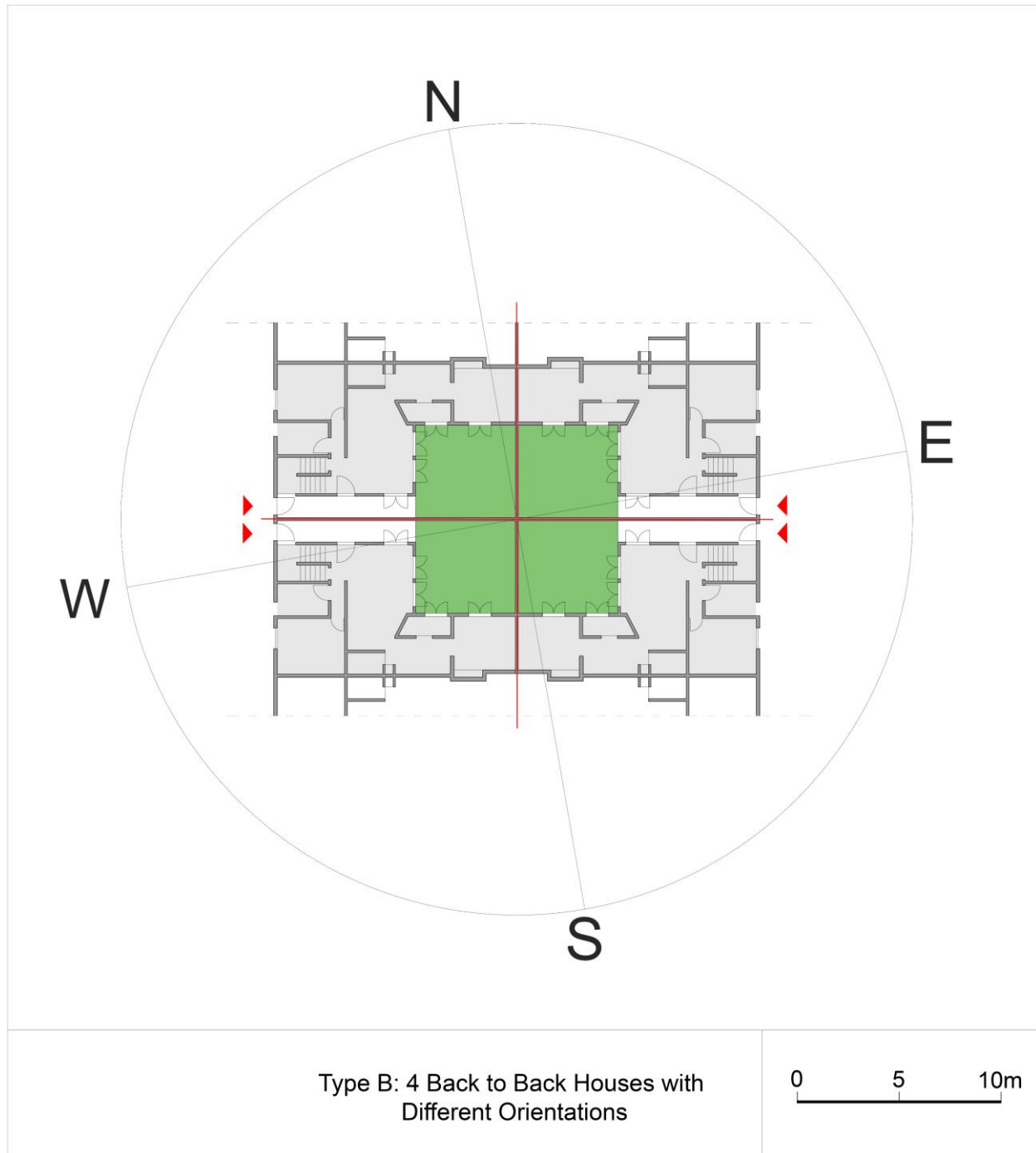


Figure (4.48)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

**a. SOLAR FACTOR**

Due to the four different orientations of the houses, the thermal response of each house is different as a result of the solar factor (figure 4.49).

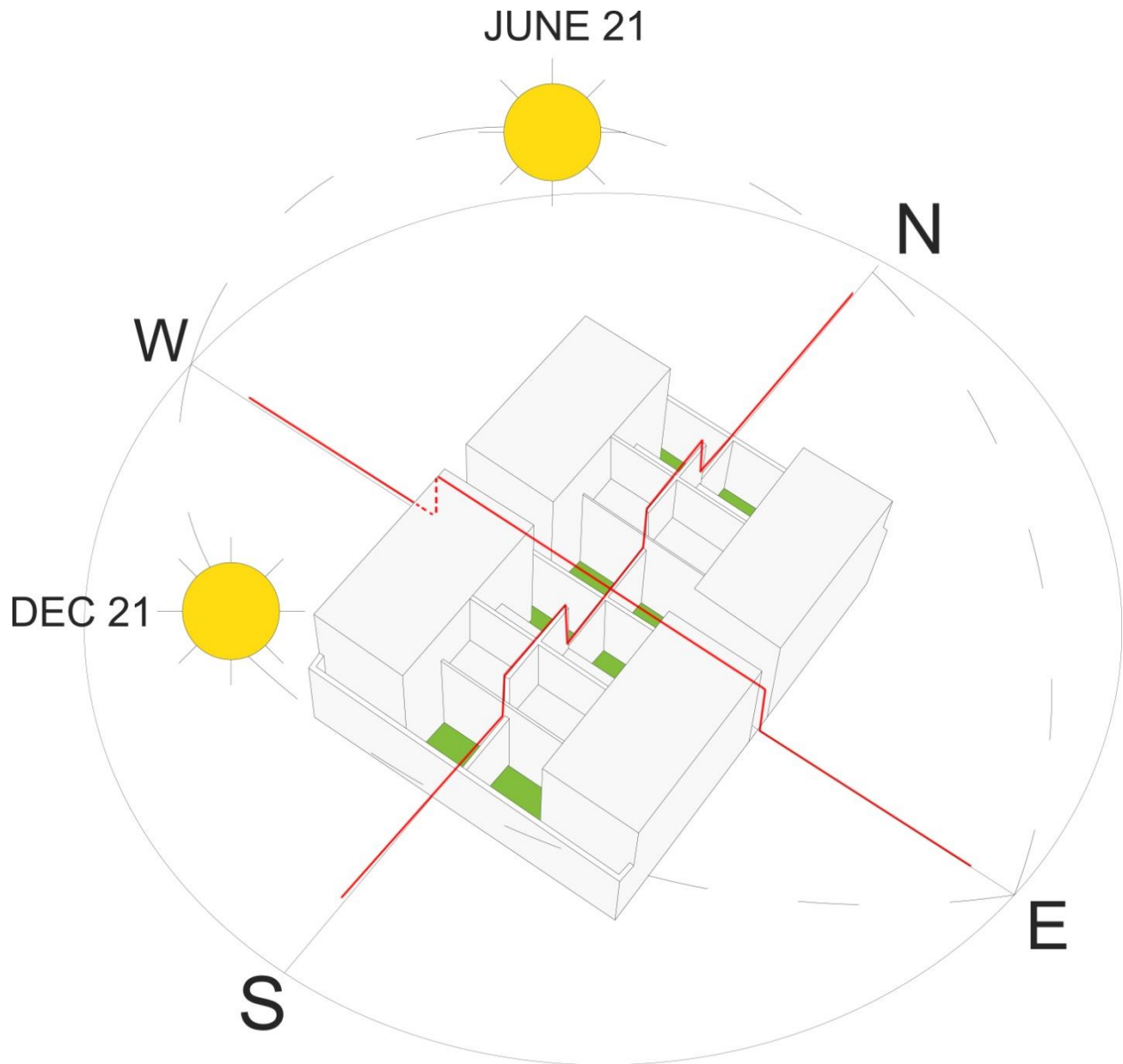


Figure (4.49)  
Relationship of 4 Back to Back Houses with the Sun

- **Shape and Form**

Type B houses have the same L-shaped plan as Type A houses, resulting in the same relationship to the courtyard and benefit from self shading. However, the internal position of the courtyard gives it more protection from the sun and causes more shade from the neighbouring houses and therefore acts as a traditional courtyard surrounded by rooms from all four sides (figure 4.50).

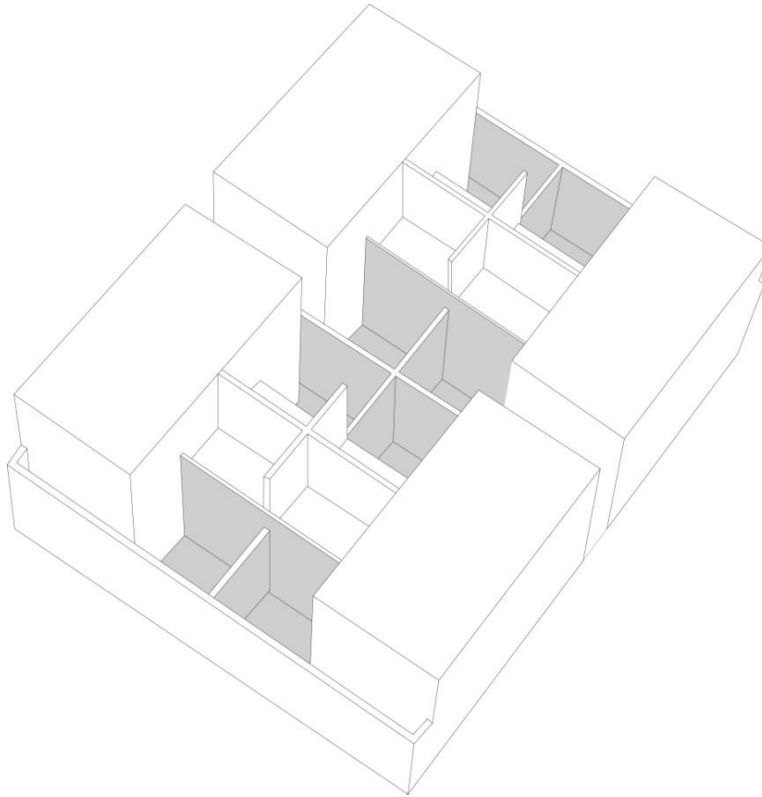


Figure (4.50)  
Self Shading in Courtyard Houses Type B

- **Orientation:**

The orientation of the type B houses is similar to that of type A. The general orientation of it is east-west, with slight angles towards the southeast, or the northwest depending on topography and a few oriented north-south. When studying the east-west orientated houses, the back to back system changes the effect of the sun on the courtyard of the houses.

In winter, the rooms overlooking the courtyard in two of the four houses benefit from the southern sun, and the other two only receive the winter sun on the courtyard wall. In summer, two of the houses receive the eastern sun from morning to noon and the other two receive the western sun from afternoon to sunset (figure 4.51).

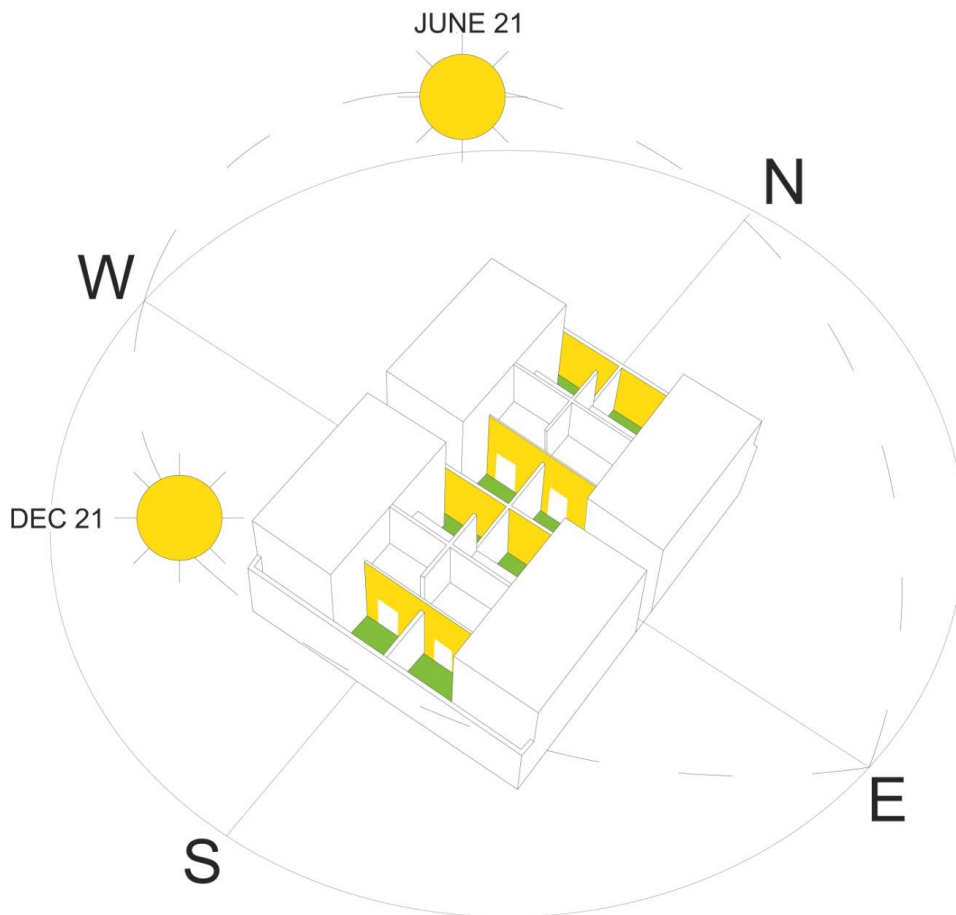


Figure (4.51)  
Southern Exposure of Back to Back Houses

- **Dimensions and Shade**

The amount of shade produced in type B depends on the different options of the second level. In the option where the second floor covers the whole first floor, the amount of shade increases (figure 4.52).

### Lateral Distance of Shade<sup>210</sup>

$$L=H \times \text{COT}\theta$$

$\theta = 64^\circ$  (Summer Solstice in Evora)

$\text{Cot } 64^\circ = .48$

$\theta = 28^\circ$  (Winter Solstice in Evora)

$\text{Cot } 28^\circ = 1.88$

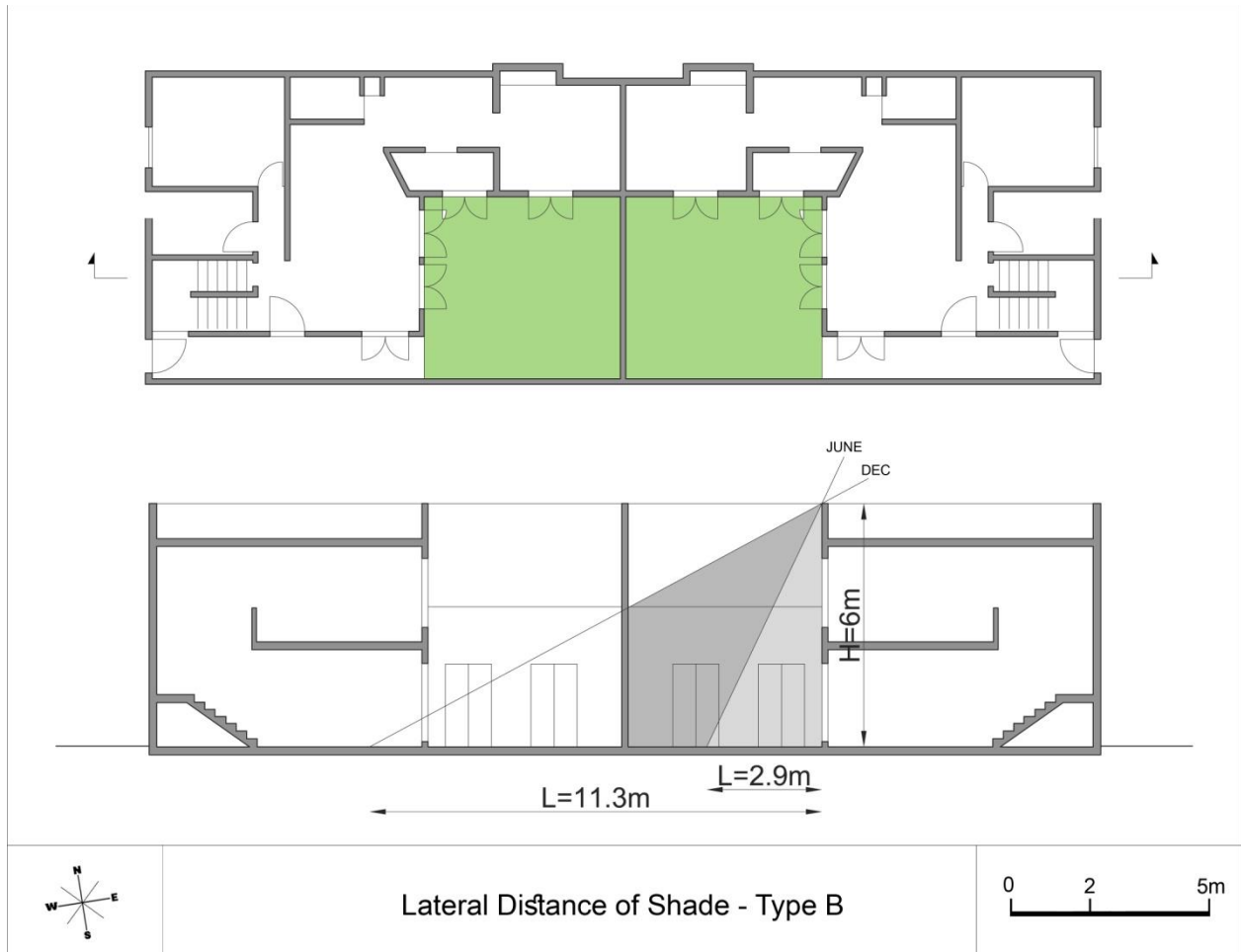


Figure (4.52)

Source: <http://uptaller3.blogspot.ac/2011/05/quinta-da-malagueira.html>

### b. WIND FACTOR

#### • Shape and Form

In the Type B houses of Malagueira, the courtyards have an internal position in the building block. The two storeys and the higher walls makes it act as a better reservoir of coolness which can then enter the rooms surrounding two sides of the courtyard<sup>211</sup> (figure 4.53).

<sup>210</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor- Dimensions and Shade, p.62.

<sup>211</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Shape and Form, p.63.

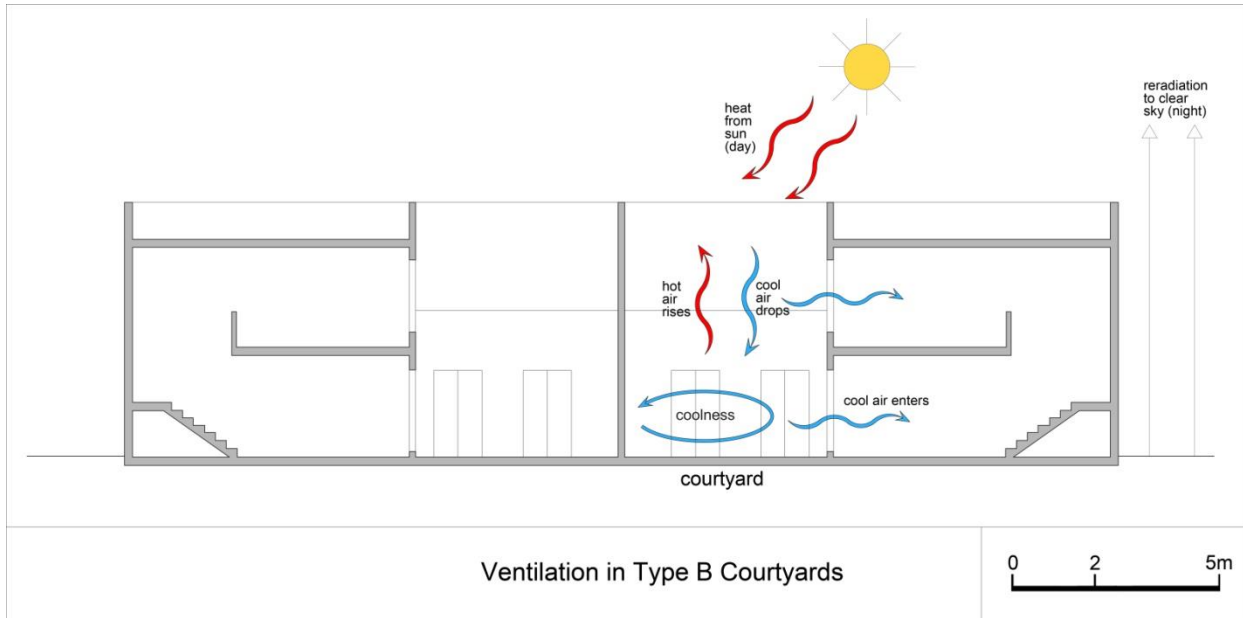


Figure (4.53)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Orientation**

The orientation of the building blocks and the back to back location of the houses resulted in some of the houses being orientated towards the eastern winter winds and some to the western summer winds. The existence of the adjacent buildings blocks these winds from both sides (figure 4.54).

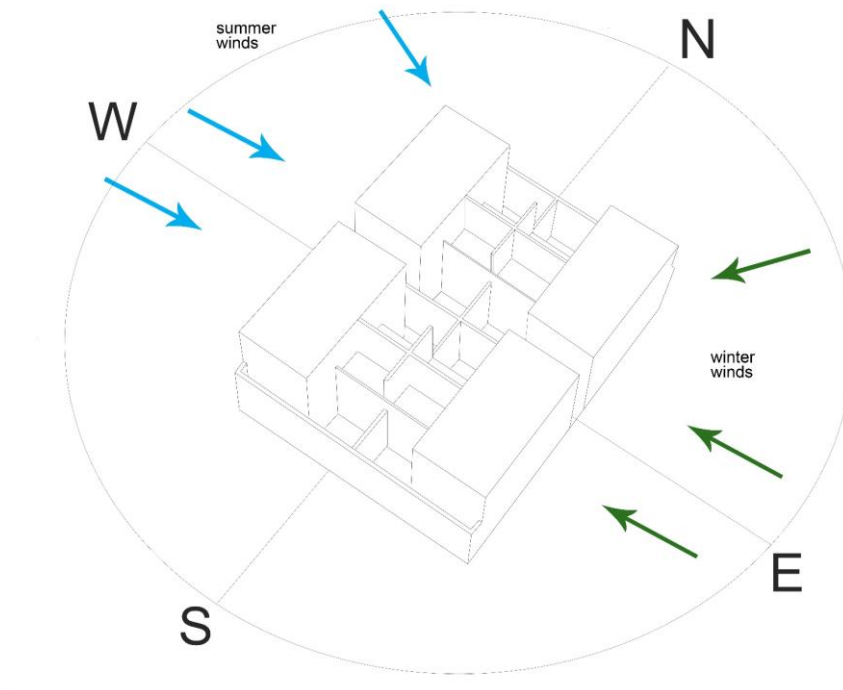


Figure (4.54) Orientation of Type B Houses to Wind



- **Dimensions and Airflow**

Comparing with type A courtyard houses, the recirculation in the courtyard is less due to its enclosed position, making it under the category c ( $H/W > 1$ )<sup>212</sup>. This means that most of the air flows over the courtyard with a swirl entering the courtyard (figure 4.55).

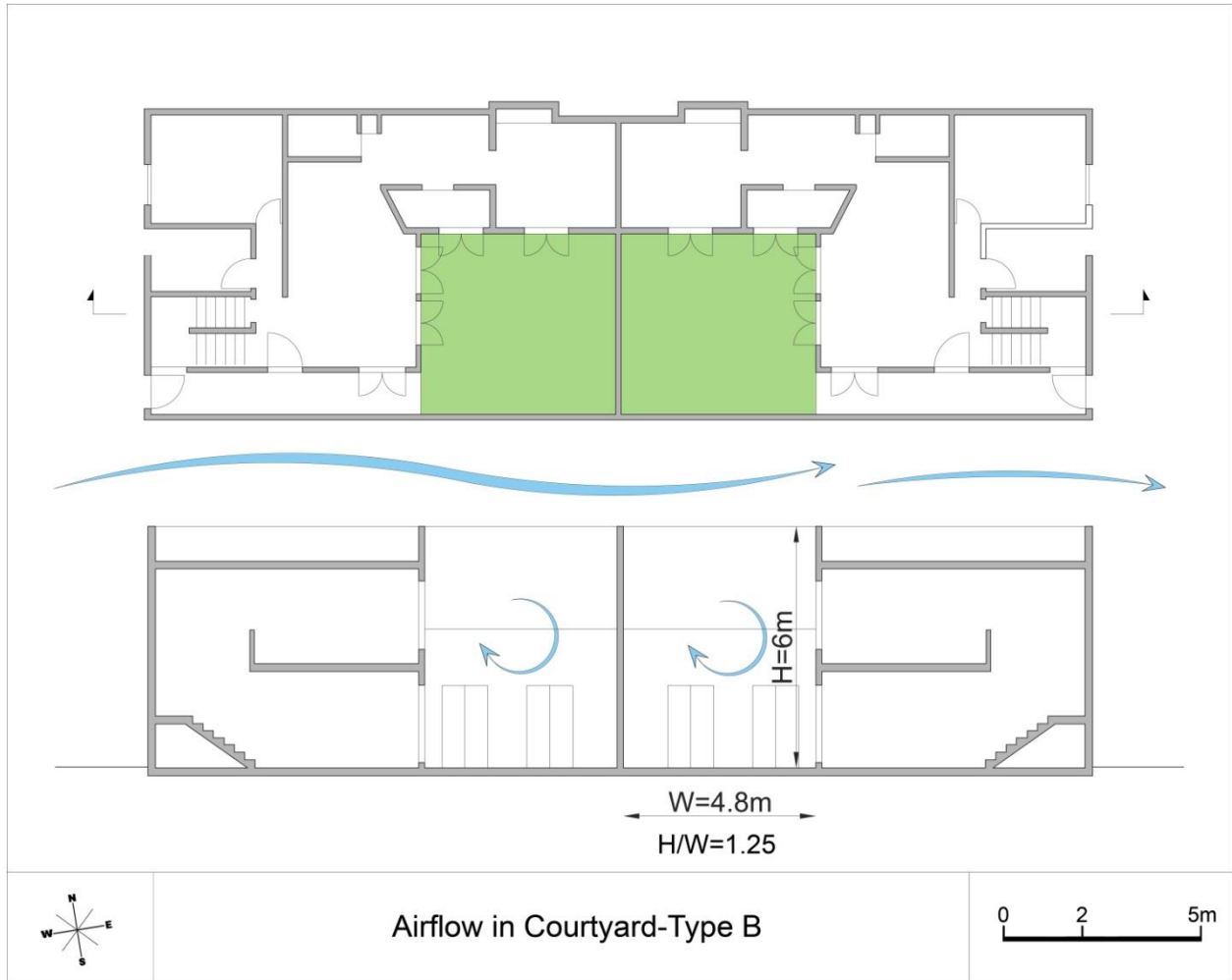


Figure (4.55)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

<sup>212</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Dimensions and Airflow, pg.65.

## B. Additional Thermal Regulating Spaces in Type B houses:

### a. SOLAR FACTOR

- **The Terrace**

In all Type B options, a terrace is present overlooking the courtyard and it creates a shaded meeting space for the residents in the summer protected by the high courtyard walls from the east and west. In the winter, the terrace receives the southern sun. In options 2 and 3 there is a terrace overlooking the street. Many of these terraces were covered with pergolas to protect them from the eastern and western sun (figure 4.56).



Figure (4.56)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

## b. WIND FACTOR

- **The Terrace**

The enclosed terrace in type B benefits from the coolness and ventilation of the courtyard. The terrace overlooking the street receives wind according to orientation and the prevailing western winds.

- **The Loggia**

In options 2 and 3 where there are 2 terraces, the room between them could act as loggia which benefits from ventilation by convection. The internal terrace overlooking the courtyard is considered more shaded than the external one which receives more sunlight from the east during the morning hours. At this time the internal courtyard would still have stored coolness from the evening before. This difference in temperatures causes air to be drawn through the loggia creating a pleasant sitting area<sup>213</sup> (figure 4.57).

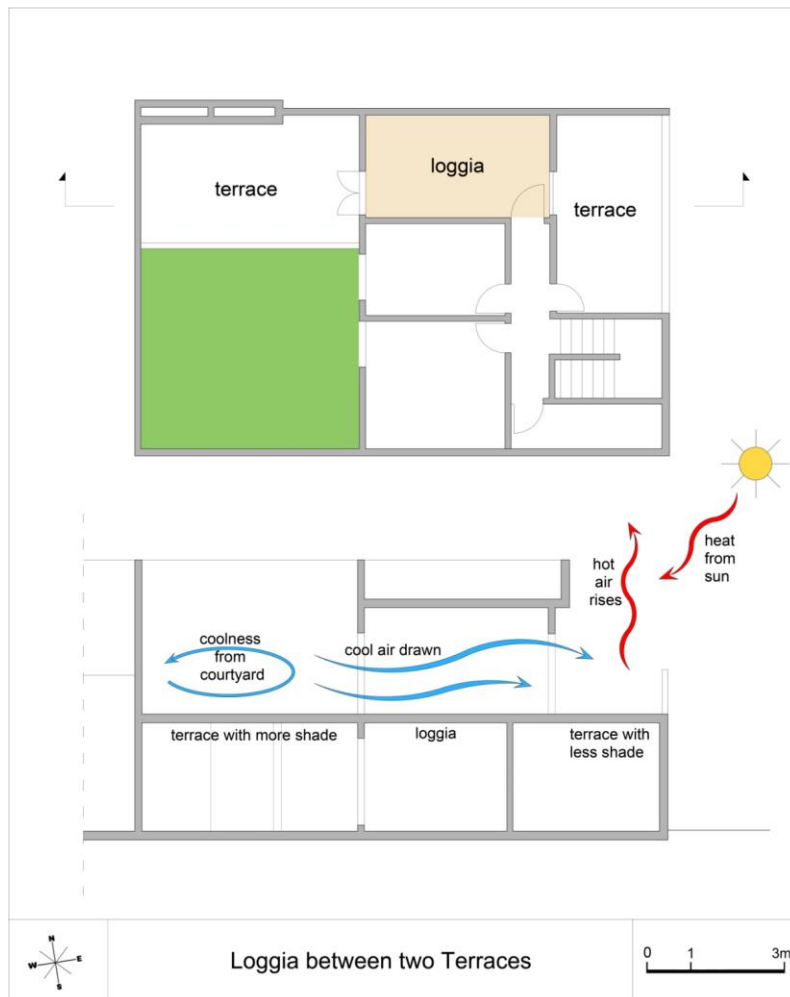


Figure (4.57)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

<sup>213</sup> See 2.2.3. Dwelling, 2.2.3.3. Additional Thermal Regulating Spaces, b. Wind Factor – The Loggia, p.69.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the DWELLINGS of Quinta da Malagueira based on the matrix found in chapter 2<sup>214</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This score was determined as a percentage based on Matrix (4.1)<sup>215</sup>.

#### **1. Shape and Form**

When compared with type A houses, type B houses are enclosed from all four sides. In addition, the courtyard provides a reservoir of coolness through the process of convection and its deepness protects the cool air from escaping. This tool was given “very good” for both factors.

#### **2. Orientation**

The back to back system of type B houses resulted in some houses benefiting from the winter sun and others not. In addition to their exposure to either the east or the west. The same case applies for the wind factor, some houses face the desirable winds and some the undesirable winds. Therefore, this tool was given “average” for both factors.

#### **3. Dimensions**

The amount of shade increases due to the internal position of the courtyard and the high walls from all side giving it “very good” for the sun factor. For the wind factor, the higher enclosed walls resulted in less air flow from outside, but protects from any cool air from escaping. Therefore, it was given “good” for the wind factor.

#### **4. The Loggia**

In type B houses, the space between the two terraces could act as a loggia where a breeze is created due to the difference in temperature. It is N/A for the sun factor and was given “very good” for the wind factor.

#### **5. The Terrace**

The interior terrace in type B houses is protected from the sun due to its internal position. Some receive the southern sun and some don't. The exterior terrace has a western or eastern orientation but is covered by a pergola for shade. This tool was given “good” for the sun factor. For the wind factor, the internal terraces receive coolness from the courtyard, and the exterior terraces receive desirable or undesirable winds according to their orientation. This tool was given “good” for the wind factor.

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<sup>214</sup> See 2.2.3. Dwelling, c. Comparative Analysis Matrix, pg.72.

<sup>215</sup> See 4.2.1.1. Site, c. Comparative Analysis Matrix, Matrix (4.1) Evaluation for Existing Situation of Tools (EE) pg.209.

<b>Dwelling (DW) - QUINTA DA MALAGUEIRA-TYPE B</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>DW 1. Shape and Form</b>	16	8	8	100%	100%	16
<b>DW 2. Orientation</b>	16	8	8	50%	50%	8
<b>DW 3. Dimensions</b>	12	6	6	100%	75%	10.5
<b>DW 4. Liwan</b>	8	4	4	0	0	0
<b>DW 5. Arcade</b>	8	4	N/A	0	N/A	0
<b>DW 6. Loggia</b>	8	N/A	4	N/A	100%	4
<b>DW 7. Terrace/Roof/Garden</b>	8	4	4	75%	75%	6
<b>Total for DW Category (-N/A): 68      Points for DW-TYPE B– Malagueira: 44.5</b>						

Matrix (4.5) Malagueira DWELLING – TYPE B Evaluation

<b>DWELLING TYPE</b>	<b>DW POINTS</b>
<b>Type A</b>	<b>38</b>
<b>Type B</b>	<b>44.5</b>
<b>Average Points for DW-Malagueira</b>	<b>41.25</b>

Matrix (4.6) Malagueira DWELLING Average Score

#### 4.2.1.4. Element: Thermal Regulating Elements in Houses of Quinta da Malagueira

##### a. SOLAR FACTOR

- Windows

##### Type A and B Houses

In Houses type A and B, there are no windows on the perimeter of the house due to the attached structure of the building blocks. Only in type A-option 3, there is a window facing the streets. Similar to a traditional courtyard house, the only openings found overlook the courtyard. This protects the house from the excessive sun on the outside walls (figure 4.58, 4.59). In both types, the southern courtyard windows benefit from the winter sun, however, due to the height of the courtyard walls, only the upper floor windows benefit from it (figure 4.60). The eastern windows receive excessive sun at sunrise and should be shaded with vegetation and shutters. The opposite side receives the excessive western sun and also should be shaded.



Figure (4.58)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>



Figure (4.59)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>



Figure (4.60)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Courtyard Vegetation and Shade**

Most courtyard houses in Malagueira from all types are rich in vegetation and trees spread in the courtyard. Large lemon trees protect the courtyard from the excessive solar radiation producing shade for the walls of the house and for the residents sitting in the courtyard. In addition to increasing the humidity levels by evapo-transpiration<sup>216</sup> (Figure 4.61).

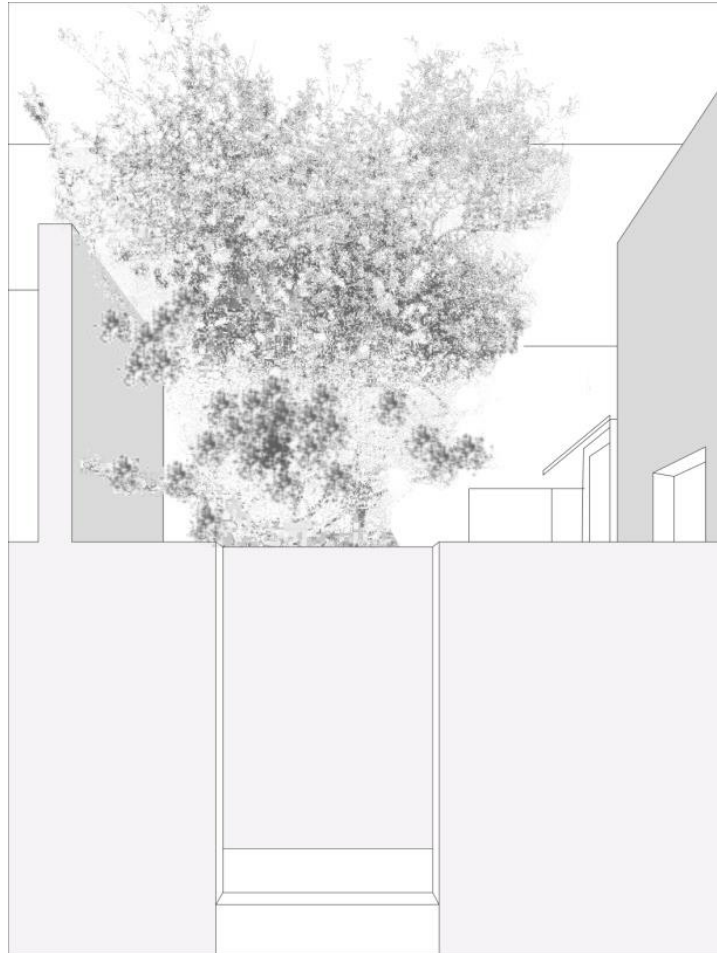


Figure (4.61) Lemon Tree in Courtyard  
Source: (Pfeifer 2013, p.250)

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<sup>216</sup> See 2.2.4. Element, a. Solar factor – Courtyard Vegetation, pg.77.



In order to create more privacy and shade, some of the residents installed hedges on top of the low walls (figure 4.62).

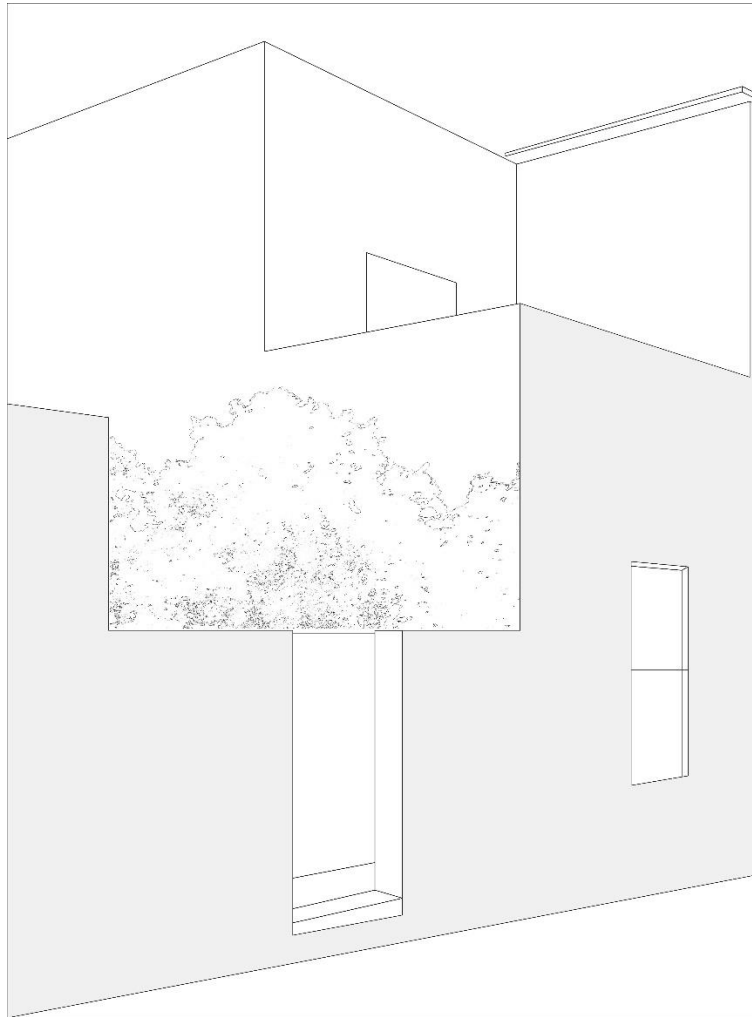


Figure (4.62) Hedges on Low Walls  
Source: (Leger 2013, p.232)

- **Thermal Mass**

The houses of Malagueira were made with sun-dried bricks (Siza 2013, p.163) with a width of 20cm (Pfeifer 2013, p.246) which have the advantage of high thermal mass<sup>217</sup>.

## **b. WIND FACTOR**

- **Windows**

The large windows on the ground floor of the type A and B courtyard house benefit from the natural ventilation and coolness caused by the courtyard thermal regulation (figure 4.63, 4.64).

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<sup>217</sup> See 2.2.4. Element, a. Solar Factor – Thermal Mass, pg.79.



Figure (4.63)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>



Figure (4.64)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Courtyard Vegetation**

Many houses in Malagueira have trees with large canopies which create a semi-barrier between the courtyard air space and the ambient air above reducing air exchange on windy days<sup>218</sup> (figure 4.65).

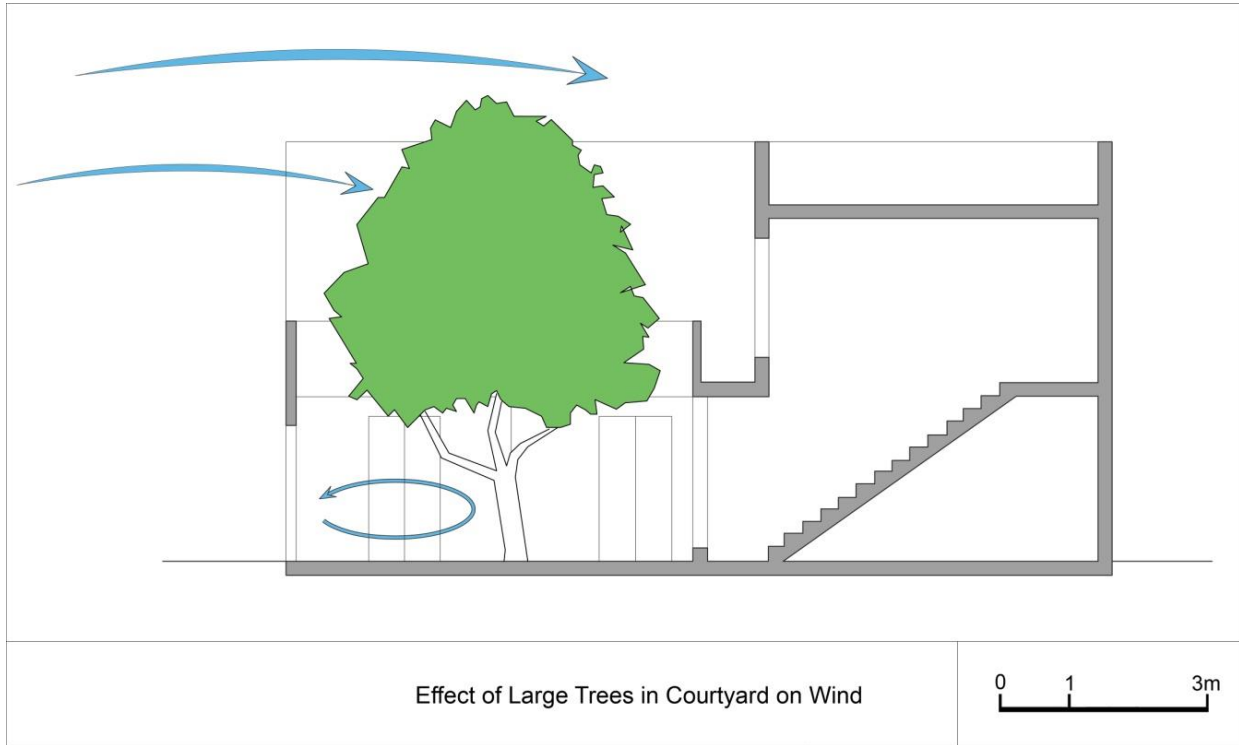


Figure (4.65)

Source: <http://uptaller3.blogspot.ae/2011/05/quinta-da-malagueira.html>

- **Thermal Mass**

The thermal mass of the sun dried brick also stores coolness from the wind and releases it to cool indoor temperatures<sup>219</sup>.

<sup>218</sup> See 2.2.4. Element, b. Wind Factor – Courtyard Vegetation, pg.80.

<sup>219</sup> See 2.2.4. Element, a. Solar Factor – Thermal Mass, pg.79.

### c. Comparative Analysis Matrix

The following matrix is the result of analysing the ELEMENTS found in the dwellings of Quinta da Malagueira based on the matrix found in chapter 2<sup>220</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This score was determined as a percentage based on Matrix (4.1)<sup>221</sup>.

#### 1. Windows

The only windows in the type A and B dwellings are the windows facing the courtyard (apart from one option where there is one small exterior window). These windows are large making it benefit from the southern sun, however most benefit is on the upper level due to the dimensions of the courtyard. Large windows also welcome the cool air from the courtyard. This tool was given “very good” for both factors.

#### 2. Vegetation

Type A and B houses are rich in vegetation which has a positive effect on the climate of the courtyard according to the sun factor by producing shade and cooling the atmosphere and according to the wind factor by creating a barrier. This tool was given “very good” for both factors.

#### 3. Thermal Mass

The walls of the houses are made with sun dried brick which have a high thermal mass. The thickness of 20cm however is small when compared to that of a dwelling in a vernacular settlement. Therefore, this tool was given “good” for both factors.

Element (EL) - QUINTA DA MALAGUEIRA	Total Points	Sun 50%	Wind 50%	Sun EE*	Wind EE*	Final Points
EL 1. Windows	16	8	8	100%	100%	16
EL 2. Mashrabiya	12	6	6	0	0	0
EL 3. Courtyard Vegetation	16	8	8	100%	100%	16
EL 4. Water Features	12	6	6	0	0	0
EL 5. Thermal Mass	16	8	8	75%	75%	12
EL 6. Malqaf	12	N/A	6	N/A	0	0
<b>Total for EL Category (-N/A):</b>		<b>78</b>	<b>Final Points for EL – Malagueira:</b>		<b>44</b>	

Matrix (4.7) Malagueira ELEMENT Evaluation

<sup>220</sup> See 2.2.4. Element, c. Comparative Analysis Matrix, p.83.

<sup>221</sup> See 4.2.1.1. Site, c. Comparative Analysis Matrix, Matrix (4.1) Evaluation for Existing Situation of Tools (EE) p.209.

<b>CATEGORY</b>	<b>POINTS</b>
<b>Site (SI)</b>	27.5
<b>Settlement (SE)</b>	69.5
<b>Dwelling (DW)</b>	41.25
<b>Element (EL)</b>	44
<b>FINAL SCORE</b>	<b>182.25</b>

Matrix (4.8) Quinta da Malagueira FINAL SCORE

**4.2.2. Fredensborg Housing. Denmark (1962-1965)  
Architect: Jorn Utzon**

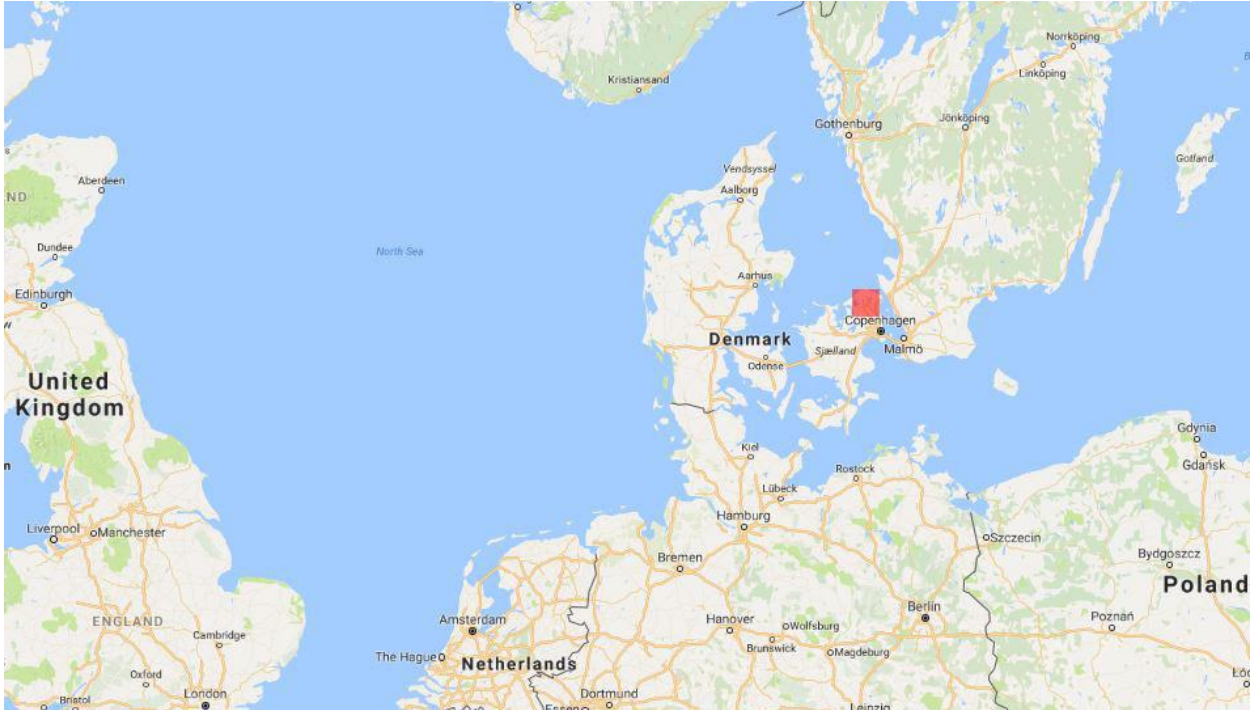


Figure (4.66) Location of Fredensborg, Denmark  
Source: Google maps

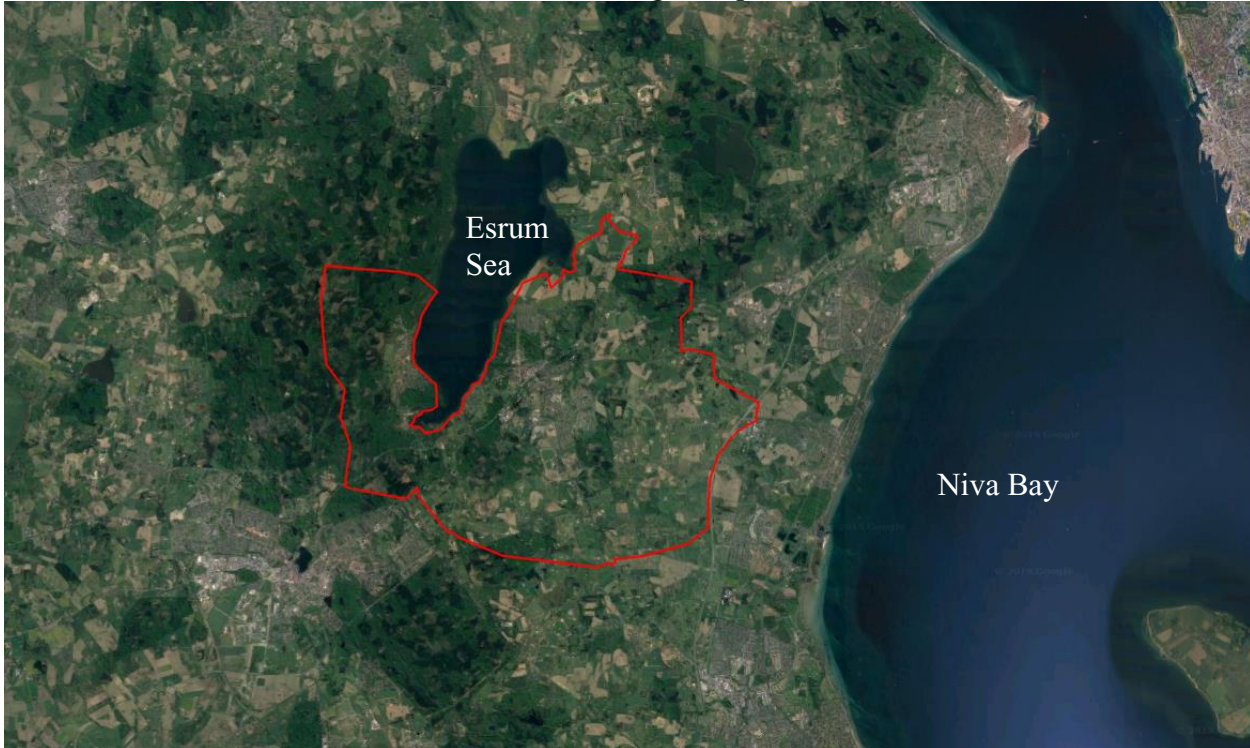


Figure (4.67) Areal Photo of Fredensborg, Denmark  
Source: Google maps





Figure (4.68) View of Fredensborg Housing  
Source: <https://utzon.dk/portfolio-item/fredensborg-housing/>

## Project Summary

### Location

Fredensborg Housing is located in the town of Fredensborg, 30 km from Copenhagen, Denmark (figure 4.66). The Royal Castle of Fredensborg stands only a few hundred metres away to the north of the site (Weston 2002, p.95).

### Design Process

Fredensborg housing is a self-governing housing development derived from a support organization “Dansk Samvirke” and was designed for Danish engineers who lived most of their lives abroad and wished to return to Denmark after retirement. It was linked to and legally independent of Dansk Samvirke who approached Utzon in 1962 requesting him to find a suitable programme and site for the project, which he did, near the Royal Castle of Fredensborg.

The land was cut by a conservation line beyond which no building was to be allowed. It slopes south-west towards farmland and a golf course. Utzon explored possible layouts using an L-shaped rubber stamp. A first proposal was to place the communal building at the head of a continuous chain of courtyard houses, however, Utzon found it too strictly organized that he persuaded the authorities to accept the proposal of three chains of courtyard houses serviced by three cul de sacs which extended past the conservation area with the communal facilities at the head of the two longest terraces. This proposal made far better use of the site and did not exceed the total built area permitted by the conservation strategy (Weston 2002, p.95). It provided 49 courtyard houses and a communal building where residents would meet, eat, celebrate and entertain family and friends.

The communal building also included a mini hotel which consisted of twelve rooms to serve the needs of the community. To the north-east, a further 30 units were accommodated in two storey terraced buildings (Weston 2004, p.144). Initially, these terraced houses were three storeys high, but were later reduced to two storeys to avoid overpowering the one-storey development (Weston 2002, p.95). The principles in designing the individual courtyards were similar to what was designed in the Kingo Houses where both enclosure and view were provided. At Fredensborg, there was a specific allowance for a standard number of bricks included in the builder's price, and as Utzon demonstrated to his assistant Birger Schmidt, each wall was determined by sitting in the courtyard and determining by eye the most appropriate configuration in terms of possible views, orientation, privacy, overlooking and exposure. The dimensions of the required panels were then coordinated by measurements taken from Le Corbusier's modular system and this resulted in the unique configuration of each dwelling and created a variety in the façade of the chain of houses. Each house garden was sketched by Jean Palle Schimdt with various ideas, but only a few were implemented, and the rest were arranged by the residents (Weston 2002, p.106).

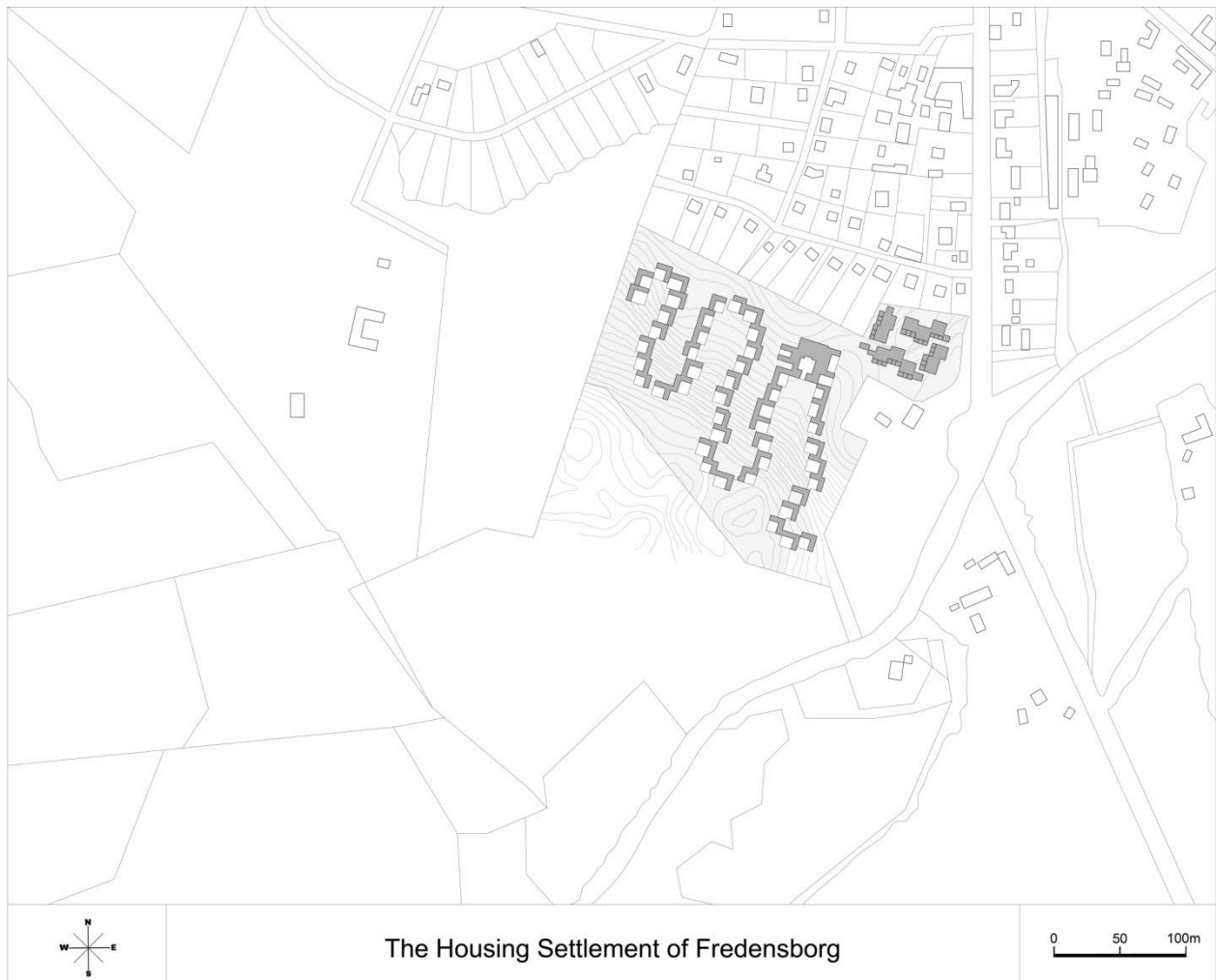


Figure (4.69)  
Source: (Utzon and Weston 2004, p.110)



#### 4.2.2.1. SITE: General Characteristics of the Site of Fredensborg Housing

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##### A. General Climate

Latitude: 55.97N

Longitude: 12.40E

Fredensborg is classified under the Köppen Climate Classification: Temperate Continental Climate (Cf). The subtype is the Temperate Oceanic Climate (Cfb). Temperatures in the winter tend to be mild, while summer temperatures are moderate. The warmest month is July with an average temperature of 16.1°C. The coolest month is January, with an average temperature of 0°C. The month with the most precipitation is December with 25.0 days and the least precipitation occurring in May with 18.0 days<sup>222</sup>.

In Fredensborg, the maximum sun angle at noon is 50° in summer and 10° in winter<sup>223</sup>.

The prevailing winds are from the north and west in the summer and the east, northeast and southeast in winter<sup>224</sup>.

##### B. The Effect of Different Elements on the Climate of Fredensborg

###### a. SOLAR FACTOR

- **Topography:**

The land on which the Fredensborg project was built slopes south-west towards farm land and a golf course. Three cul de sacs stepped down the slope with the communal facilities at the head of the two longest terraces (Weston 2002, p.95) (figures 4.70, 4.71).

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<sup>222</sup> <http://www.weatherbase.com/weather/weather-summary.php3?s=6160&cityname=Gladsaxe%2C+Capital+Region%2C+Denmark&units=>

<sup>223</sup> These sun angles were calculated from the online application (<http://susdesign.com/sunangle/>).

<sup>224</sup> These average wind directions were estimated from the historical weather records from (<https://www.worldweatheronline.com/fredensborg-weather-history/hovedstaden/dk.aspx>).

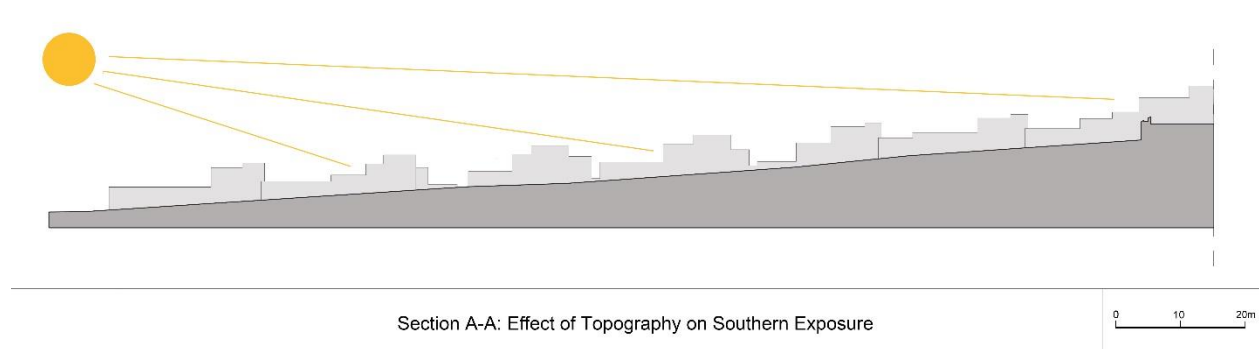


Topography of Fredensborg Housing Settlement

Figure (4.70)

Source: (Utzon and Weston 2004, p.111)

The stepped terraced houses towards the south make it receive the maximum benefit from the southern sun<sup>225</sup> (figure 4.71).



Section A-A: Effect of Topography on Southern Exposure

Figure (4.71)

Source: (Weston 2002, p.102, 103)

<sup>225</sup> See 2.2.1. Site, a. Solar Factor – Topography, pg.36.

- **Vegetation:**

Fredensborg housing settlement is surrounded by a vast area of vegetation from all sides. In addition to a park from the north and a golf course directly from the south, a dense forest of trees surrounds the settlement from the northeast and southwest, while the spaces between the houses were planted with grass only<sup>226</sup> (figure 4.72).

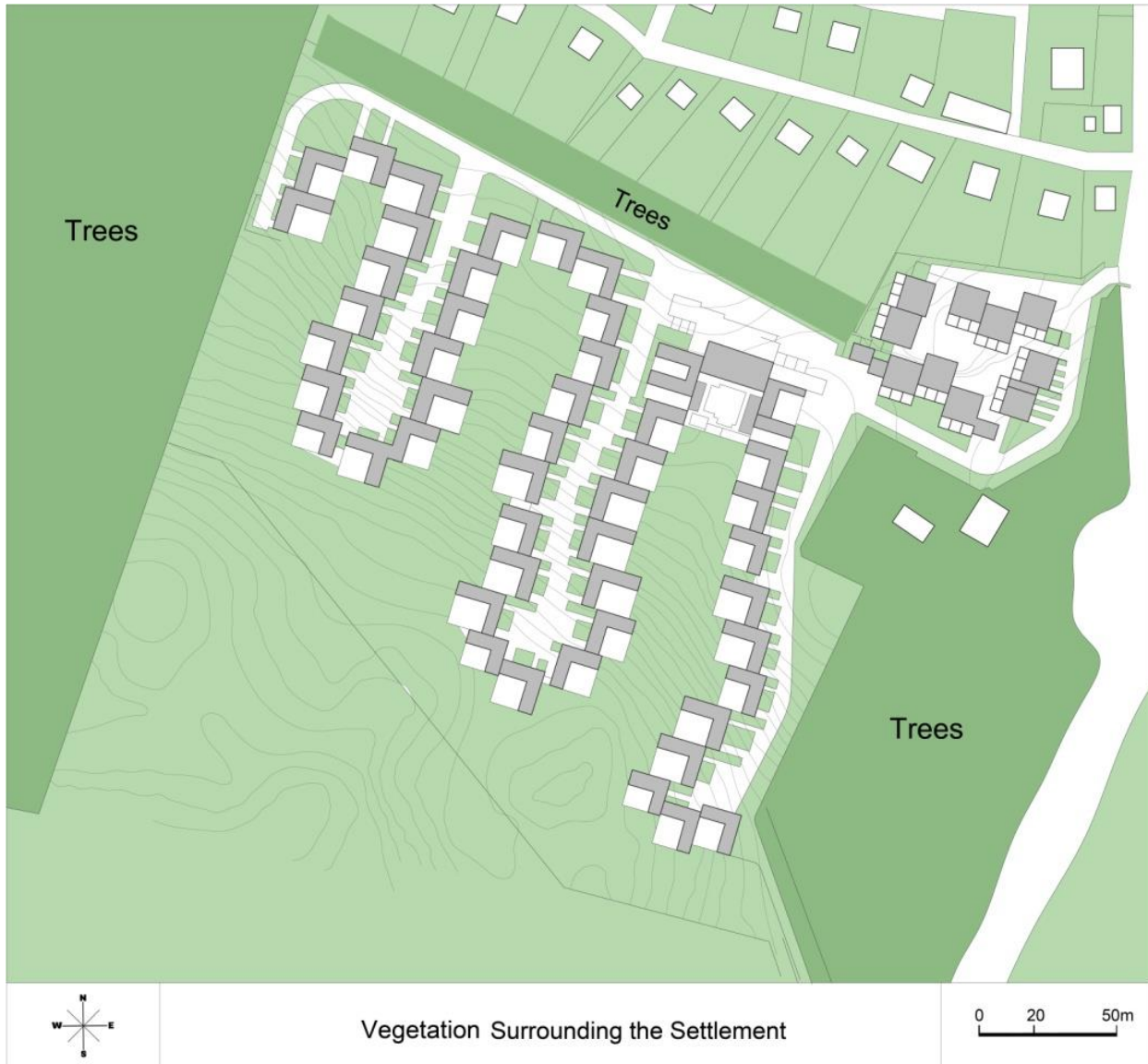


Figure (4.72)  
Source: (Utzon and Weston 2004, p.111)  
and Google Maps

<sup>226</sup> See 2.2.1. Site, a. Solar Factor – Vegetation, pg.37.

- **Water Bodies:**

North Zealand is surrounded by water from three sides, in addition to a lake less than one km away from Fredensborg settlement (figure 4.73). Although not directly next to the settlement, the nearby lake affects the climate and creates more humidity and more rain throughout the year<sup>227</sup>.

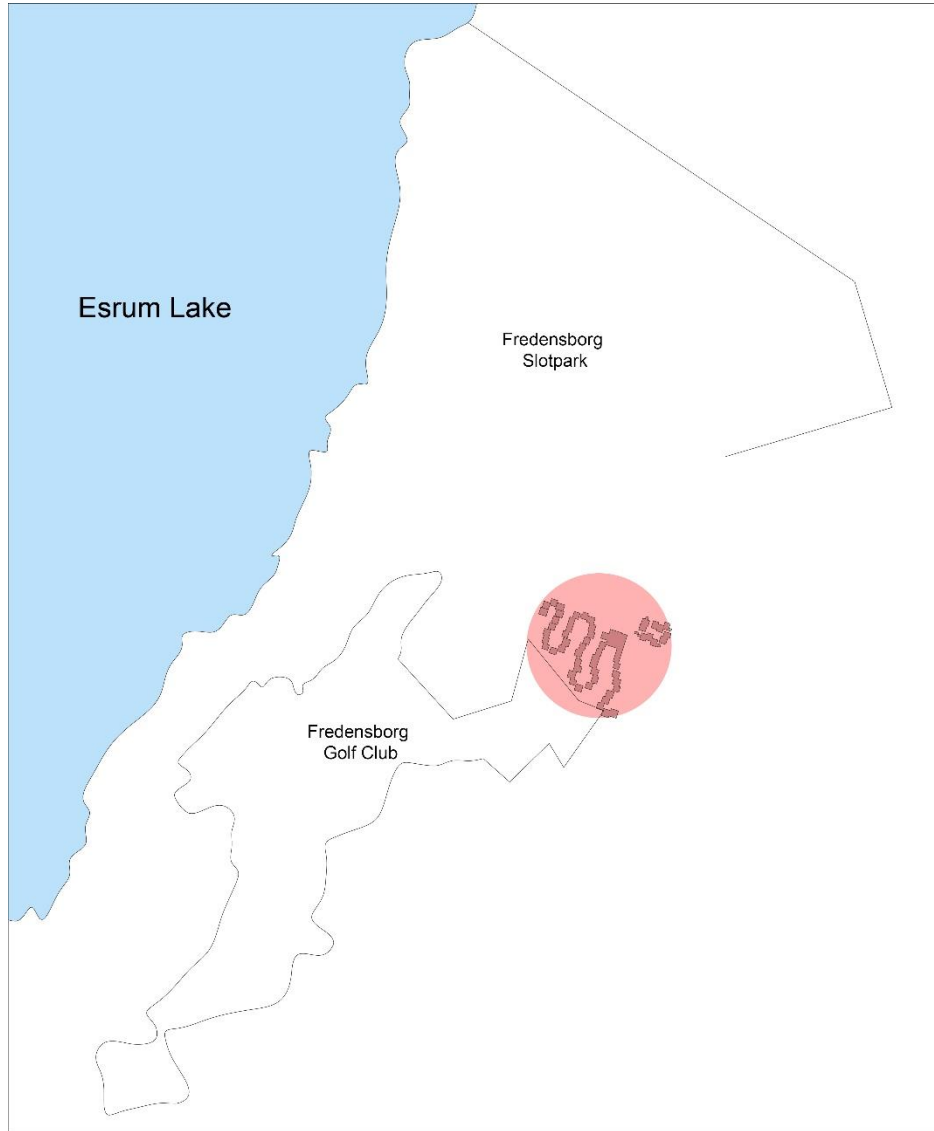


Figure (4.73) Water Bodies Surrounding Fredensborg Housing Settlement  
Source: Google maps

<sup>227</sup> See 2.2.1. Site, a. Solar Factor – Water Bodies, pg.38.

## b. WIND FACTOR

### • Topography

In the summer, the prevailing winds in Fredensborg come from the west. The slope running towards the west and southwest make the stepped houses benefit from the desirable winds in the summer. In the winter, however, the winds come from the east and northeast, so the settlement turns its back against the undesirable winds (figure 4.74). The topography also results in the creation of a wind flow up and down the slope.

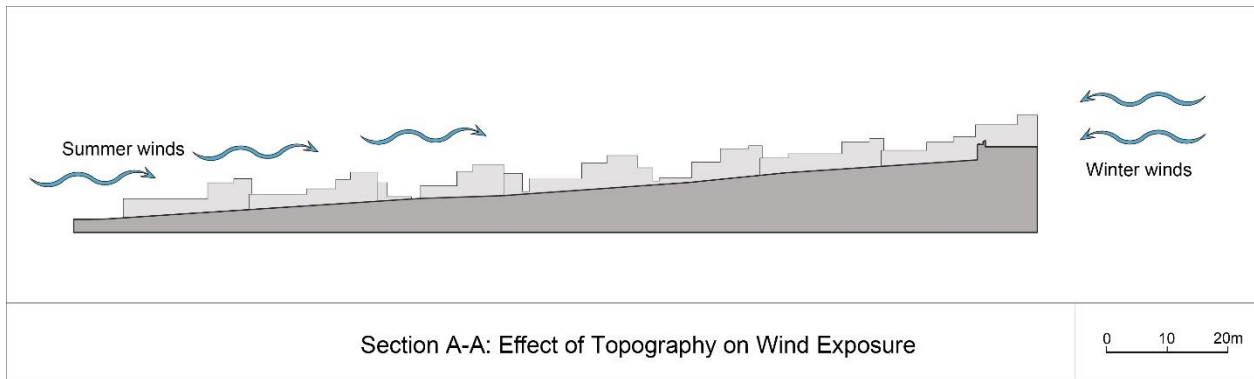


Figure (4.74)

Source: (Weston 2002, p.102, 103)

### • Vegetation

Trees surround the settlement from three sides, north, southeast and northwest. The trees surrounding the settlement from the northeast protect the settlement from the cold winter winds<sup>228</sup>. In addition, since summer temperatures are not very high in North Zealand, it is sometimes favourable to block the summer winds coming from the west by the dense forest on the west and northwest of the settlement (figure 4.75).



Figure (4.75) Trees surrounding Fredensborg from three sides

Source: (Weston 2002, p.106, 107)

### • Water Bodies

Since the distance of the nearby lake is farther and the size of the lake is smaller than that of the vernacular case studies facing the Mediterranean Sea, the water body effect is significantly less. However, the existence of this water body still contributes to creating the western prevailing winds<sup>229</sup>.

<sup>228</sup> See 2.2.1. Site, b. Wind Factor – Vegetation, pg.39.

<sup>229</sup> See 2.2.1. Site, b. Wind Factor – Water Bodies, pg.40.

### c. Comparative Analysis Matrix

The following matrix is the result of analysing the SITE of Fredensborg Housing based on the matrix found in chapter 2<sup>230</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. This score was determined as a percentage based on the following Matrix:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (4.9) Evaluation for Existing Situation of Tools (EE)

#### 1. Topography

The slope of Fredensborg Housing faces the southwest making the stepped houses benefit from the southern sun which is very desirable in the winter. As for the wind factor, the slope turns it back to the undesirable winds and receives the summer winds. This tool was given “very good” for both factors.

#### 2. Vegetation

The site of Fredensborg housing is rich in vegetation and trees affecting the climate positively in addition to creating a barrier to protect the settlement from harsh winds. Therefore, this tool was given “very good” for both factors.

#### 3. Water Bodies

Although the lake is a kilometer away from the settlement, it does effect the climate of Fredensborg. This tool was given “good” for both factors.

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<sup>230</sup> See 2.2.1. Site, c. Comparative Analysis Matrix, p.42.

<b>Site (SI) – FREDENSBORG HOUSING</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SI 1. Topography</b>	12	6	6	100%	100%	12
<b>SI 2. Vegetation</b>	16	8	8	100%	100%	16
<b>SI 3. Water Bodies</b>	16	8	8	75%	75%	12
<b>Total for SI Category: 44                      Final Points for SI – Fredensborg: 40</b>						

Matrix (4.10) Fredensborg SITE Evaluation

#### 4.2.2.2. SETTLEMENT: Urban Structure

The Fredensborg Housing settlement consists of a chain of 49 houses in the shape of three fingers and serviced by three cul de sacs (figure 4.76). In addition to the courtyard housing typology, Utzon's choice of materials, the buff brick and similar coloured roof tile were used to unify the units into a cohesive whole. They seem like they were cut out from a solid block (Weston 2004, p.144). The walls were interrupted only a few times resulting in a continuity which gives the feeling of a small city wall enhanced by the sentinel-like chimneys (Weston 2002, p.110).



Figure (4.76)  
Source: (Utzon and Weston 2004, p.111)



## a. SOLAR FACTOR

### • Dispersed Geometry

Fredensborg Housing was designed in a way that the houses are linked together from a small wall only, resulting in a dispersed configuration of the settlement. The surface to volume ratio is very high due to the high surface of facades compared to the volume. It is almost as though each house is standing alone with no shared walls with other house (figure 4.77).

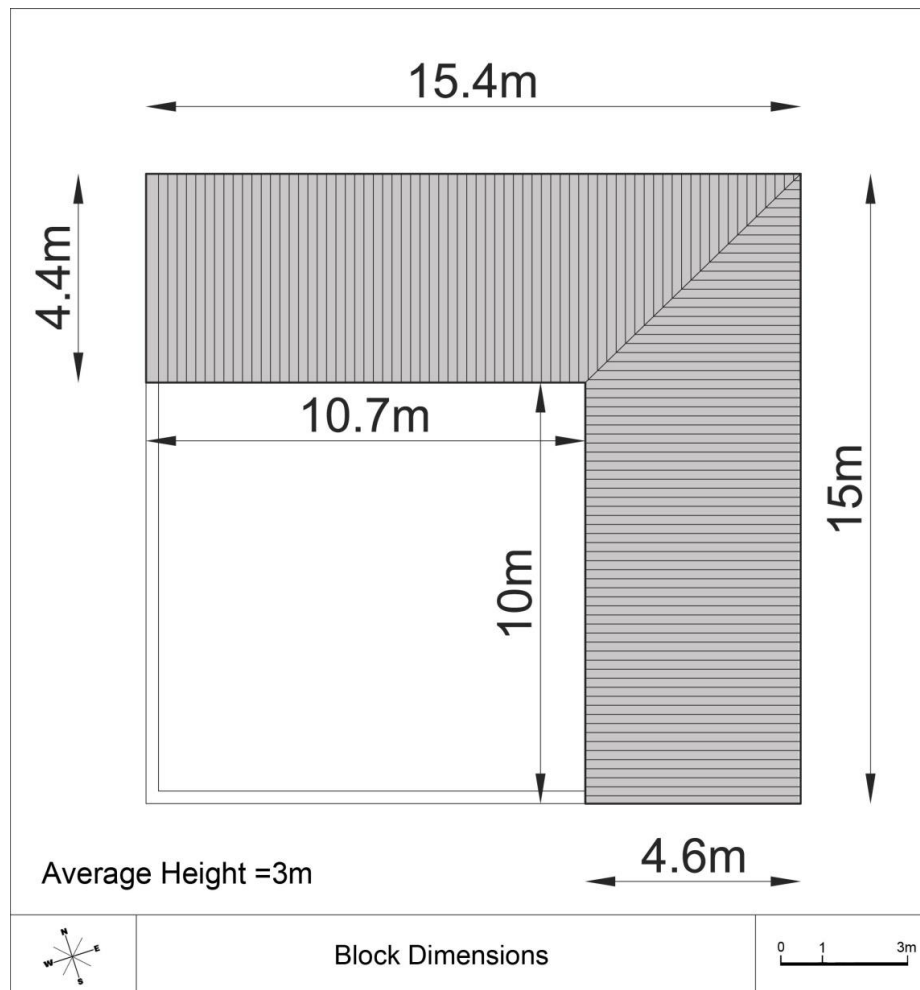


Figure (4.77)

Source: (Utzon and Weston 2004, p.112)

**Surface to Volume Ratio** = 285.27/348.24

$$S/V = 0.82$$

The high surface to volume ratio means a very high thermal exchange between the building and the external atmosphere. This is an advantage for maximum exposure to the sun from all sides throughout the year in colder climates<sup>231</sup>.

<sup>231</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.

- **Block Orientation**

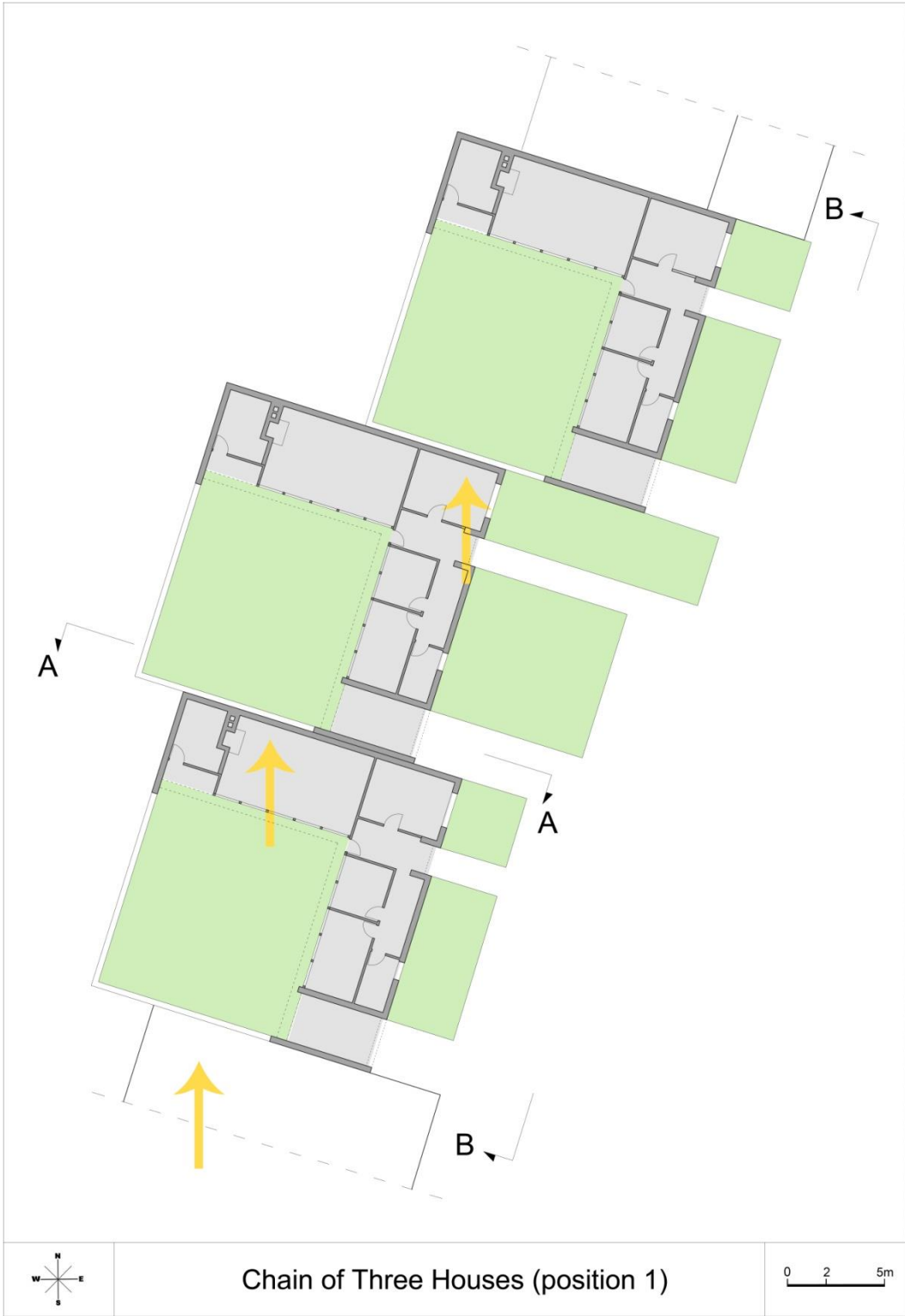
The distribution and orientation of the chain of houses, in addition to the topography, gives the houses benefit from the southern sun, especially since all the courtyards have a southern orientation (figure 4.78).



Figure (4.78)

Source: (Utzon and Weston 2004, p.111)

The chain of houses in figure (4.79) shows how all houses with position (1) receive the southern sun due to orientation. The houses with the mirror position (2) are exposed to the sun even more as both facades are exposed as shown in figure (4.80).



Chain of Three Houses (position 1)

Figure (4.79)  
Source: (Weston 2002, p.96)



Figure (4.80)  
Source: (Weston 2002, p.96)

Each individual house receives the southern sun to its courtyard in a different way as a result of Utzon's idea of sitting on the patio of each house and deciding which arrangement of walls would allow the sun in, protect from the wind, achieve possible views and prevent overlooking by neighbours (Weston 2004, p.144). As a result, each unit had a unique configuration and allowed the maximum possible amount of the sun in the courtyard (figures 4.81, 4.82, 4.83).

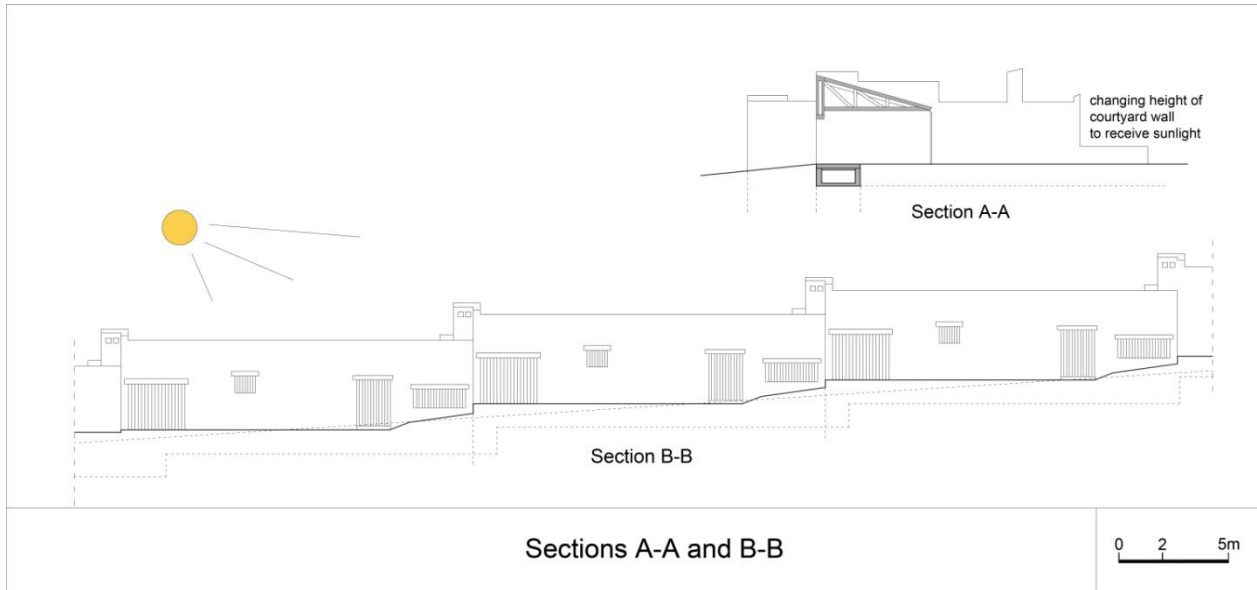


Figure (4.81)

Source: ([http://architectures234.blogspot.ac/2011\\_02\\_01\\_archive.html](http://architectures234.blogspot.ac/2011_02_01_archive.html))

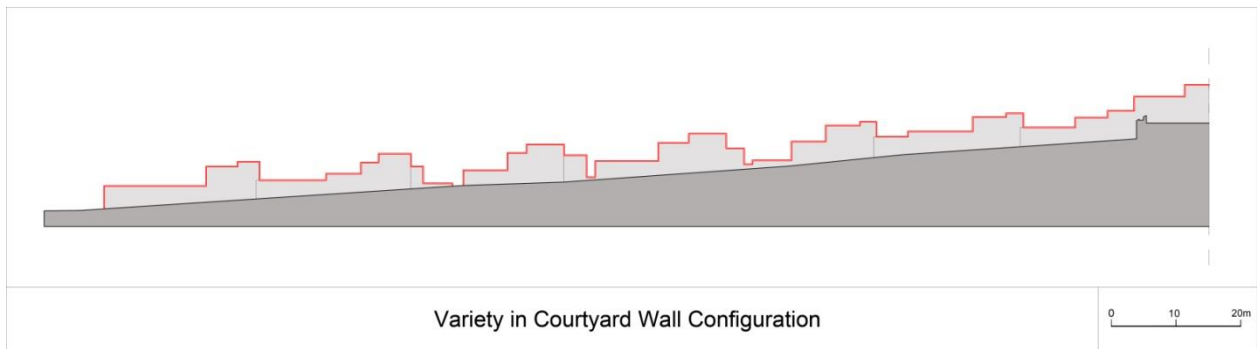


Figure (4.82)

Source: (Weston 2002, p.102, 103)

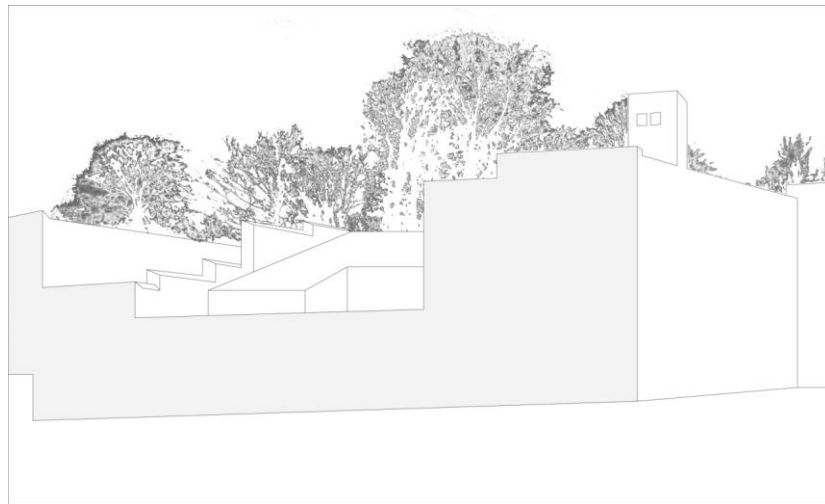


Figure (4.83) Difference of Heights of Courtyard Wall

Source: (Weston 2002, p.97)

- **Street Orientation**

The streets of Fredensborg only reach the back of the chain of houses. The main street has an approximate NW-SE orientation with the cul de sacs branching out at an approximate NE-SW<sup>232</sup> (figure 4.84). This would have been an advantage in the hot climates of previous case studies. Since this orientation is closer to the south, the streets somewhat benefit from the winter southern sun.



Figure (4.84)  
Source: (Utzon and Weston 2004, p.111)

<sup>232</sup> See 2.2.2. Settlement, a. Solar Factor – Street Orientation, pg.46.



- **Wide Streets**

Due to the dispersed structure of the settlement, the dimensions of the streets that affect the amount of shade are very large (and the one storey height of buildings), resulting in a decreased amount of shade and more exposure of the buildings to the sun. This is an advantage in this region, as shade is not desirable due to the cool temperatures even in summer<sup>233</sup>.

- **Open Spaces**

**Cul De Sacs**

The vast green areas between the chains of houses create large cul de sacs for the residents to meet. These spaces are not shaded due to their large width and the small height of the surrounding buildings; therefore, the desirable sun is received throughout the year whether in the moderate summers or cold winters (figure 4.85).



Figure (4.85) Wide Cul de Sacs  
Source: (Weston 2002, p.94)

- **Vegetation**

On a smaller scale, the type of vegetation inside the three cul de sacs is grass. Vegetation in the warmer seasons of the area could aid in raising humidity levels which can increase temperatures (figure 4.85).

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<sup>233</sup> See 2.2.2. Settlement, a. Solar Factor – Narrow Streets, pg.47.

- **Surface Materials**<sup>234</sup>

### **Ground Surface Materials**

The material of the streets leading to the houses is asphalt which has an SRI of 0. The high absorption of asphalt is a disadvantage in hot climates, however the cooler climate of Fredensborg and the small area of the asphalt roads comparing to the vegetation, makes its thermal effect small unless there is an increase in the usual summer temperatures. The remaining surfaces are grass which has an SRI of 0.18.

### **Building Surface Materials**

The houses of Fredensborg were built with a buff brick and same colour roof tile. The solar reflectance of buff brick is 0.55<sup>235</sup> which means less reflectance when compared to a whitewashed surface. This is an advantage in cooler climates.

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<sup>234</sup> See 2.2.2. Settlement, a. Solar Factor – Surface Materials, pg. 50.

<sup>235</sup> <http://www.brickform.com/ResourceDownload.aspx?id=4184>



## b. WIND FACTOR

- **Dispersed Geometry**

The dispersed geometry results in a high S/V ratio and consequently more heat loss due to cold winter winds and even in summer where temperatures only reach around 16°C<sup>236</sup>.

- **Block Orientation**

The orientation of the chain of houses is towards the southwest where three open spaces are created. This results in a partial reception of the summer winds (which is not always desirable) while the houses turn their back to the harsh winter winds<sup>237</sup> (figure 4.86). The configuration of the individual courtyard walls also took into account protection from the harsh winds.



Figure (4.86)

Source: (Utzon and Weston 2004, p.111)

- **Street Orientation**

The main street is exposed to the harsh winter winds but the streets leading to the houses do not receive them.

<sup>236</sup> See 2.2.2. Settlement, a. Solar Factor – Compact Geometry, pg.44.

<sup>237</sup> See 2.2.2. Settlement, b. Wind Factor – Block Orientation, pg.51.

- **Wide Streets**

The cul de sacs are considered low aspect ratio where  $H/W < 0.3$ . The wind therefore enters the cul de sac but does not recirculate<sup>238</sup>.

- **Open Spaces**

**Passageways between the houses**

The continuous chain of houses is breached a few times creating shaded passages which frame glimpses of a beautiful landscape beyond the walls (figure 4.87, 4.88, 4.89). These passages can be used for the residents to meet and be protected from any harsh weather like the winter winds coming from the northeast (Weston 2002, p.108). In summer, these spaces can also become a ventilated area located between a more shaded area (the narrow cul de sac) and the less shaded area (the wide green areas)<sup>239</sup> (figures 4.90). This could be more desirable during the warmest days of the summer.



Figure (4.87)

Source: (Utzon and Weston 2004, p.111)

<sup>238</sup> See 2.2.2. Settlement, b. Wind Factor – Narrow Streets, pg.54.

<sup>239</sup> See 2.2.3. Dwelling, 2.2.3.3. Additional Thermal Regulating Spaces, b. Wind Factor – The Loggia, pg.69.



Figure (4.88) Open Space between Houses  
Source: (Weston 2002, p.108)

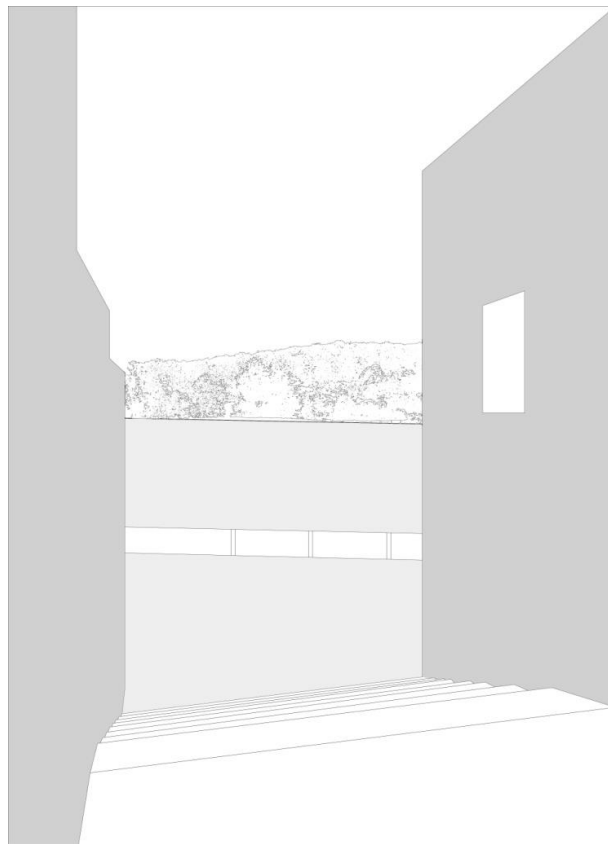


Figure (4.89) Open Space between Houses  
Source: (Weston 2002, p.109)

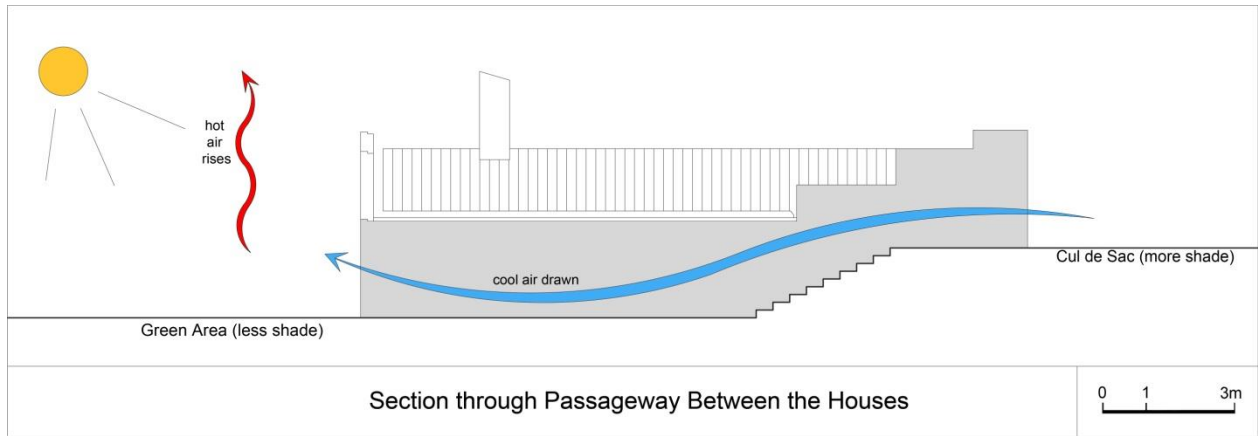


Figure (4.90)

- **Vegetation**

There are no trees in the cul de sacs between the neighbourhoods which could protect the building from the winds, however, the grass areas do affect the ventilation in the area in summer<sup>240</sup>.

<sup>240</sup> See 2.2.2. Settlement, b. Wind Factor – Vegetation, pg. 55.

### **c. Comparative Analysis Matrix**

The following matrix is the result of analysing the SETTLEMENT of Fredensborg Housing based on the matrix found in chapter 2<sup>241</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The score was determined as a percentage based on Matrix (4.9)<sup>242</sup>.

#### **1. Compact Geometry**

The geometry of Fredensborg Housing is a dispersed geometry which exposes almost all 4 sides of the buildings to the sun, giving it a “very good” rating for the sun factor. However, for the wind factor, this geometry increases the heat loss in winter, giving it a “below average” rating.

#### **2. Block Orientation**

All blocks are orientated in a way to receive maximum winter sun. The design of the garden and walls also took into consideration the ideal orientation for sun, views and wind. Summer winds are partially received and building blocks turn their backs to the winter winds. This tool was given “very good” for both factors.

#### **3. Street Orientation**

The orientation of the secondary streets is approximately south giving them some benefit from the southern sun. The main street benefits from the eastern and western sun. For the wind factor, the streets slightly receive the summer winds but the winter winds are blocked. This tool was given “good” for both factors.

#### **4. Wide Streets**

The wide streets allow the sun to penetrate and expose the buildings to heat. Therefore, this tool was given “very good” for the sun factor. The wide streets result in the winds entering the cul de sacs but do not recirculate giving the wind factor “good”.

#### **5. Open Spaces**

The grassy cul de sacs are considered pleasant open spaces in the summer and winter since they receive a good amount of sunlight. The spaces between the houses are also good open spaces in the summer for shading and ventilation and in the winter for protecting from harsh weather. This tool was given “very good” for both factors.

#### **6. Vegetation**

The areas between the chains of houses are rich with vegetation giving a “very good” rating for the sun factor. Grass improves ventilation but trees are not available to create barriers giving a “good” rating for the wind factor.

#### **7. Surface Materials**

The colour of the houses of Fredensborg has less reflectance than the white whitewash which is an advantage in cool climates, giving this tool a “good” rating for the sun factor. The cooling of surfaces due to the cold climate and dispersed geometry is not an advantage so it was given “below average” for the wind factor.

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<sup>241</sup> See 2.2.2. Settlement, c. Comparative Analysis Matrix, p.57.

<sup>242</sup> See 4.2.2.1. Site, c. Comparative Analysis Matrix, Matrix (4.9) Evaluation for Existing Situation of Tools (EE), p.275.

<b>Settlement (SE) – FREDENSBORG HOUSING</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>SE 1. Dispersed Geometry</b>	16	8	8	100%	25%	10
<b>SE 2. Block Orientation</b>	12	6	6	100%	100%	12
<b>SE 3. Street Orientation</b>	4	2	2	75%	75%	3
<b>SE 4. Wide Streets</b>	16	8	8	100%	75%	14
<b>SE 5. Open Spaces</b>	4	2	2	100%	100%	4
<b>SE 6. Vegetation</b>	16	8	8	100%	75%	14
<b>SE 7. Public Fountains</b>	4	2	2	0	0	0
<b>SE 8. Surface Materials</b>	16	8	8	75%	25%	12
<b>Total for SE Category: 88      Final Points for SE – Fredensborg: 69</b>						

Matrix (4.11) Fredensborg SETTLEMENT Evaluation

### 4.2.2.3. DWELLING: Passive Design Strategies of Courtyard Houses in the Fredensborg Housing Settlement

There were 3 plan types for the houses of Fredensborg. The courtyard houses had a common core with the kitchen and bathroom facilities, and around these, were the other living spaces and bedrooms which varied in each house in terms of size and configuration. There is also a variation in the number of bedrooms, either one or two, and the existence or non-existence of the garage. (Weston 2002, p.96) (figure 4.91).

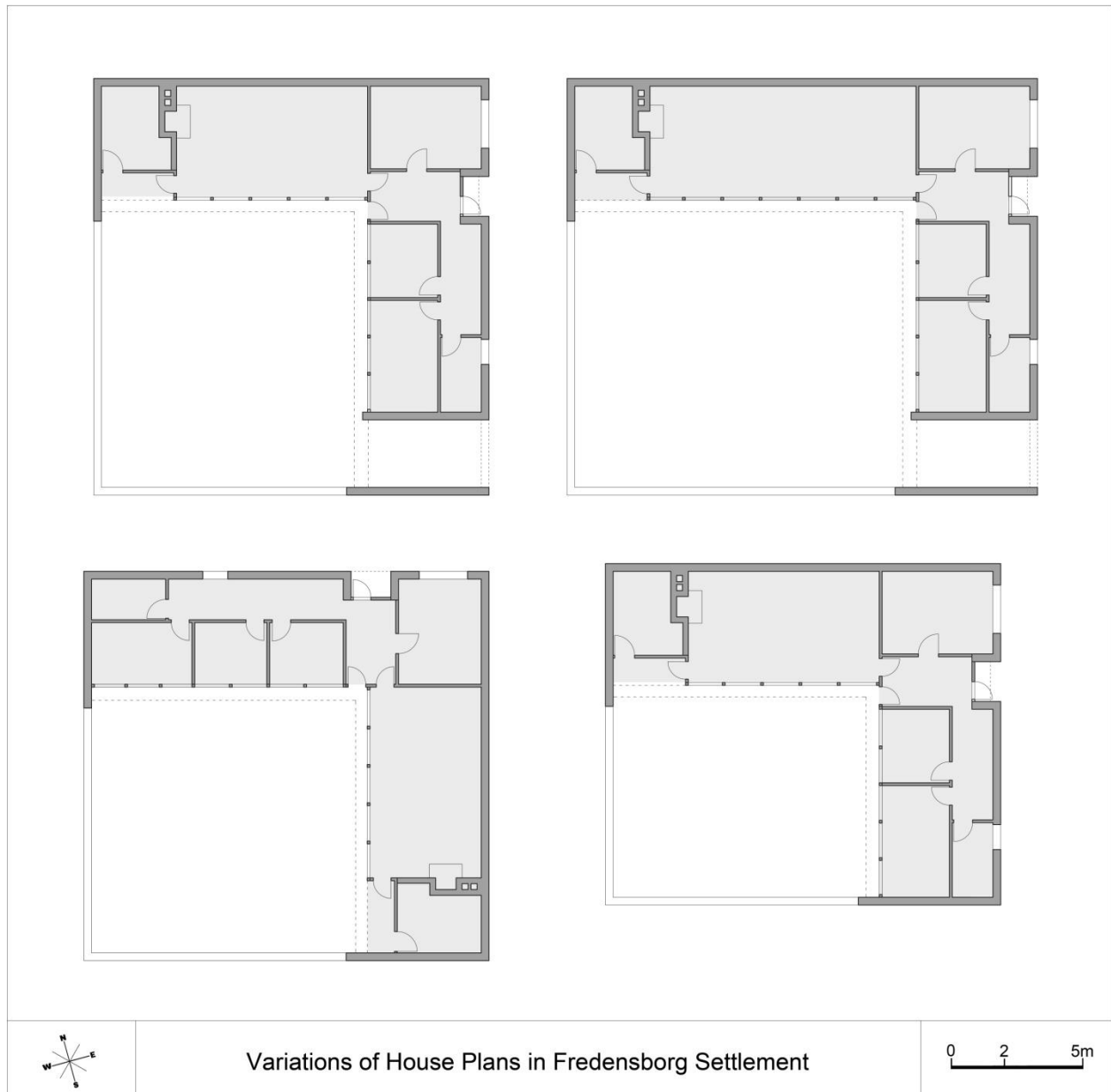


Figure (4.91)  
Source: (Weston 2002, p.96)

Type Studied:

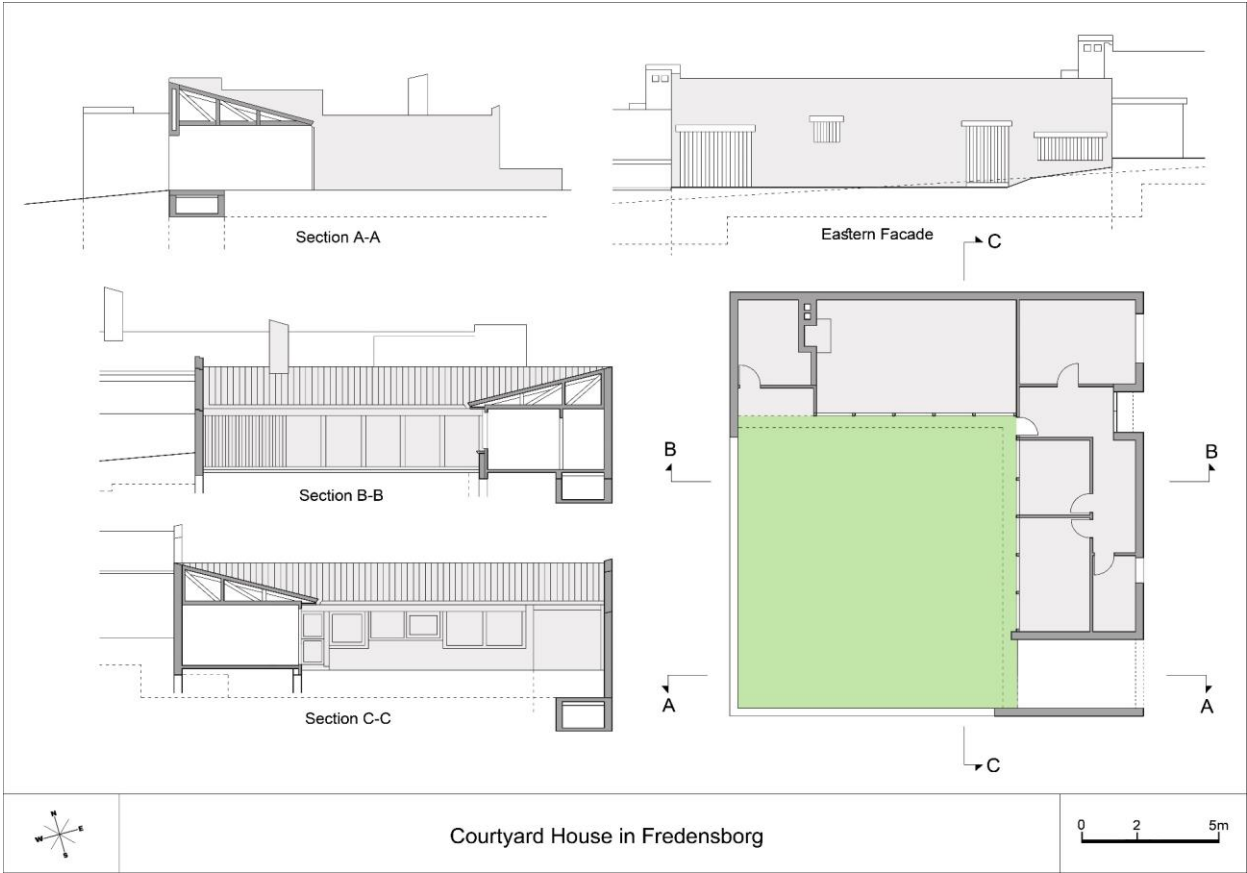


Figure (4.92)  
Source: (Utzon and Weston 2004, p.112, 114, 115)



**a. SOLAR FACTOR**

In addition to the environmental properties of courtyards in hot climates, it also aids in the thermal comfort of houses in cold climates.

• **Shape and Form**

The shape of the courtyard also improves the thermal comfort of houses in cold climates. In an analysis done by J. Mänty for the vernacular architecture of Sweden, Norway and Switzerland, he found that courtyards create “pockets of solar gain” (Mänty 1988) which subsequently balance the harshness of cold northern climates (Raydan, Ratti and Steemers 2005, p.192). This depends on the proportions of the courtyard (figure 4.93).

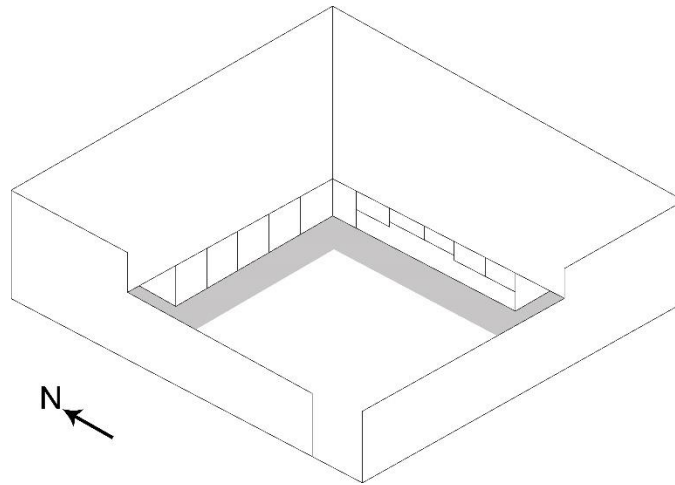


Figure (4.93) Shape of Fredensborg Houses

• **Orientation**

The courtyard houses in Fredensborg all have southern exposure and similar distribution of spaces. Most of the houses have the living spaces facing south and benefit from the winter sun (figure 4.94). A few of the houses have the bedrooms facing south with the living spaces facing west.

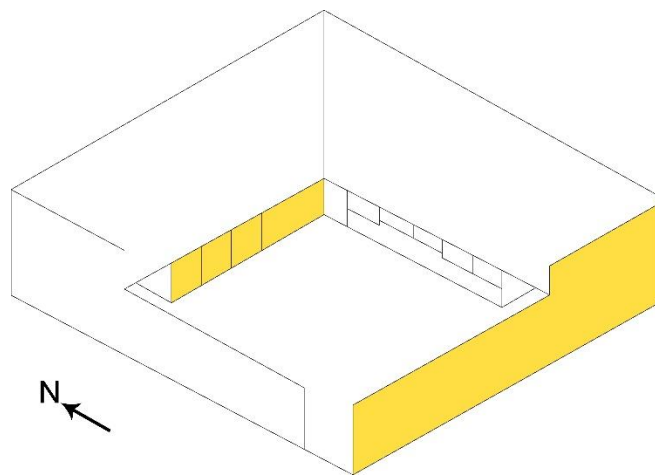


Figure (4.94) Southern Exposure of the House

- **Dimensions and Shade**

The decreased H/W ratio due to the wide dimensions of the courtyard and the one storey height of the dwelling result in a decreased amount of shade in summer and gives it a “sun concentrating character” (Raydan, Ratti and Steemers 2005, p.203).

**Lateral Distance of Shade:**  $L=H \times \text{COT}\theta^{243}$  (figure 4.95)

Summer:  $L=2.5 \times 0.63=1.5\text{m}$

Winter:  $L=2.5 \times 5.4= 13.5\text{m}$

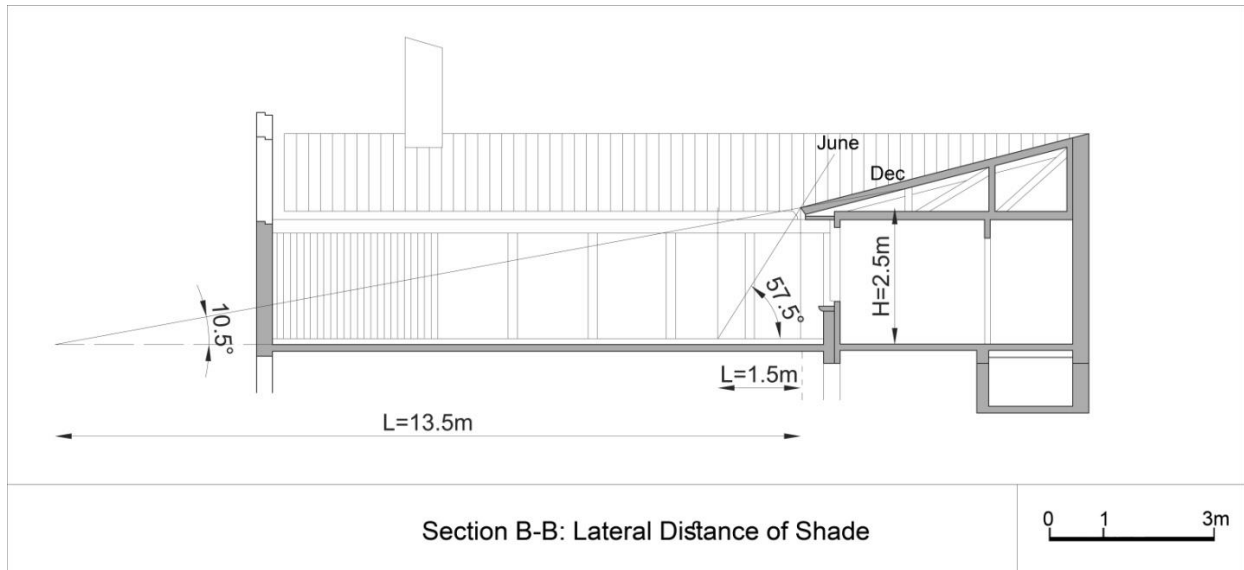


Figure (4.95)

Source: (Utzon and Weston 2004, p.115)

<sup>243</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, a. Solar Factor – Dimensions and Shade, pg.62.

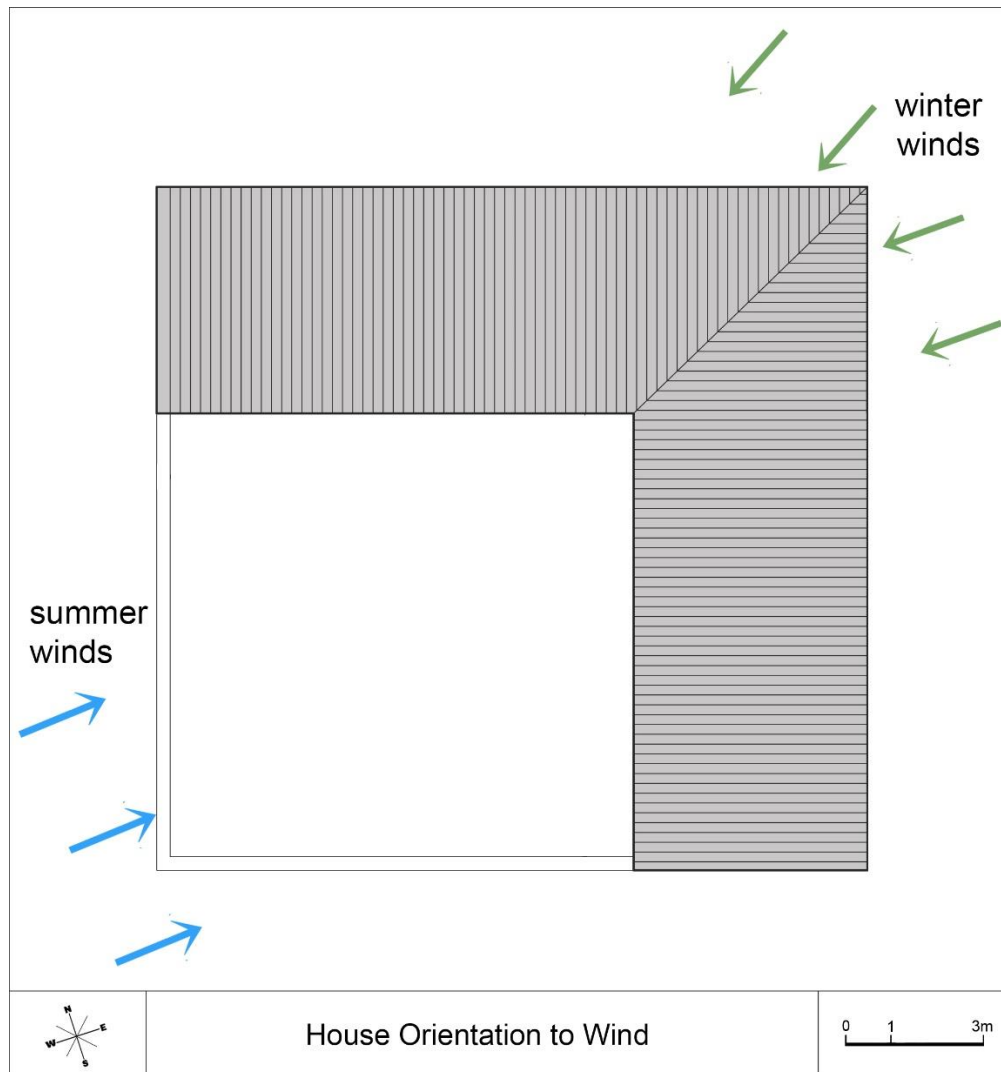
## b. WIND FACTOR

- **Shape and Form**

Another function of the courtyard shape in cold climates is wind protection which also depends on the H/W ratio.

- **Orientation**

All houses turn their backs to the harsh winter winds and some receive the summer winds depending on their location on the site (4.96).



House Orientation to Wind

Figure (4.96)

Source: (Utzon and Weston 2004, p.112)

- **Dimensions and Airflow**

The dimensions of the courtyard make it under the category (a) low aspect ratio when  $H/W < 0.3$ . This means that a great deal of outdoor air enters and the air does not recirculate very much<sup>244</sup> (figure 4.97). Vegetation aids in protecting from this wind.

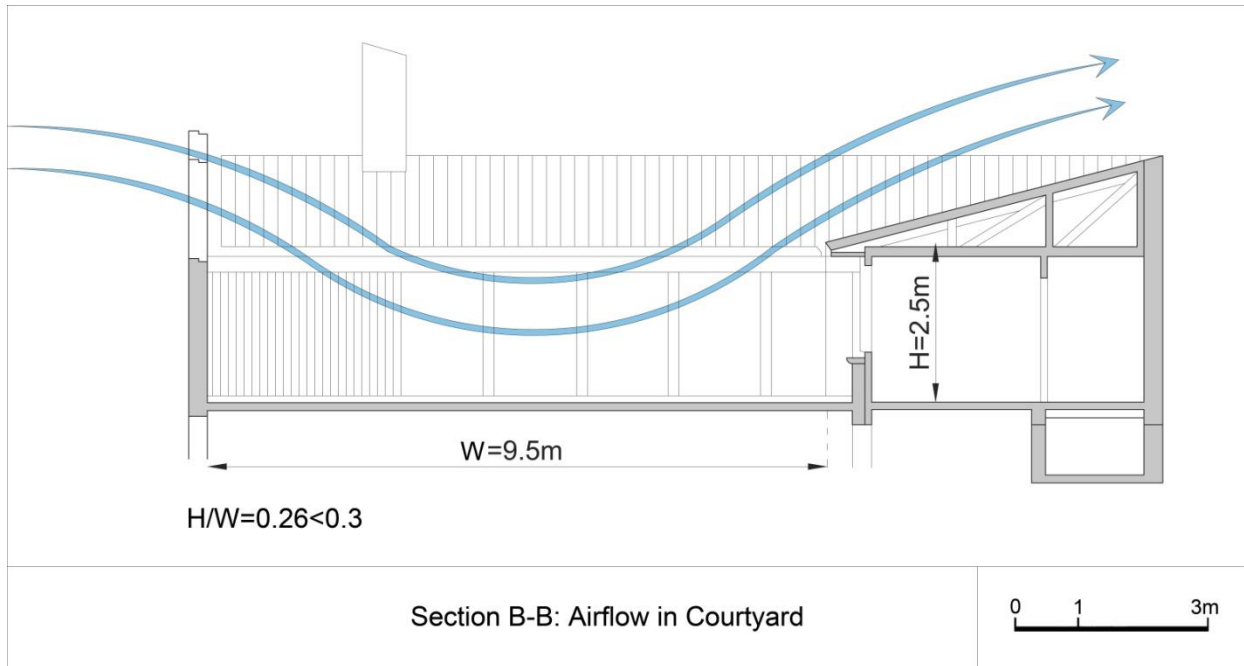


Figure (4.97)

Source: (Utzon and Weston 2004, p.115)

<sup>244</sup> See 2.2.3. Dwelling, 2.2.3.2. The Courtyard, b. Wind Factor – Dimensions and Airflow, pg.65.

### c. Comparative Analysis Matrix

The following matrix is the result of analysing the DWELLINGS of Fredensborg based on the matrix found in chapter 2<sup>245</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The score was determined as a percentage based on Matrix (4.9)<sup>246</sup>.

#### 1. Shape and Form

The courtyard shape aids in the thermal comfort and energy savings of the dwelling in cold climates as well as hot climates because it is a “solar collector”. This shape also aids in protecting the dwelling from the harsh winds. However, since its position is not internal like the courtyards of vernacular dwellings, it was given “good” for both factors.

#### 2. Orientation

All houses are orientated in a way that the living spaces receive southern sun in winter. All houses turn their backs to the winter winds and some receive the summer winds. Therefore, this tool was given “very good” for both factors.

#### 3. Dimensions

The low H/W ratio results in increased benefit from the solar energy in winter due to the decreased amount of shade giving this tool “very good” for the sun factor. According to the wind factor, the H/W ratio results in some protection from the wind, however not the maximum protection, giving it an “average” rating.

<b>Dwelling (DW) – FREDENSBORG HOUSING</b>	<b>Total Points</b>	<b>Sun 50%</b>	<b>Wind 50%</b>	<b>Sun EE*</b>	<b>Wind EE*</b>	<b>Final Points</b>
<b>DW 1. Shape and Form</b>	16	8	8	75%	75%	12
<b>DW 2. Orientation</b>	16	8	8	100%	100%	16
<b>DW 3. Dimensions</b>	12	6	6	100%	50%	9
<b>DW 4. Liwan</b>	8	4	4	0	0	0
<b>DW 5. Arcade/Covered Space</b>	8	4	N/A	0	N/A	0
<b>DW 6. Loggia</b>	8	N/A	4	N/A	0	0
<b>DW 7. Terrace/Roof/Garden</b>	8	4	4	0	0	0
<b>Total for DW Category (-N/A):</b>	<b>68</b>	<b>Points for DW- Fredensborg:</b>				<b>37</b>

Matrix (4.12) Fredensborg DWELLING Evaluation

<sup>245</sup> See 2.2.3. Dwelling, c. Comparative Analysis Matrix, p.72.

<sup>246</sup> See 4.2.2.1. Site, c. Comparative Analysis Matrix, Matrix (4.9) Evaluation for Existing Situation of Tools (EE), p.275.

#### 4.2.2.4. ELEMENT: Thermal Regulating Elements in the Courtyard Houses of Fredensborg

##### a. SOLAR FACTOR

- **Windows**

The houses open to the courtyard by two facades. The living areas open to the courtyard through full-height glazing, and the bedrooms are open through windows with a shorter height to the courtyard (figures 4.98, 4.99). These windows allow the desirable sunlight in winter to enter from the courtyard (figure 4.100).

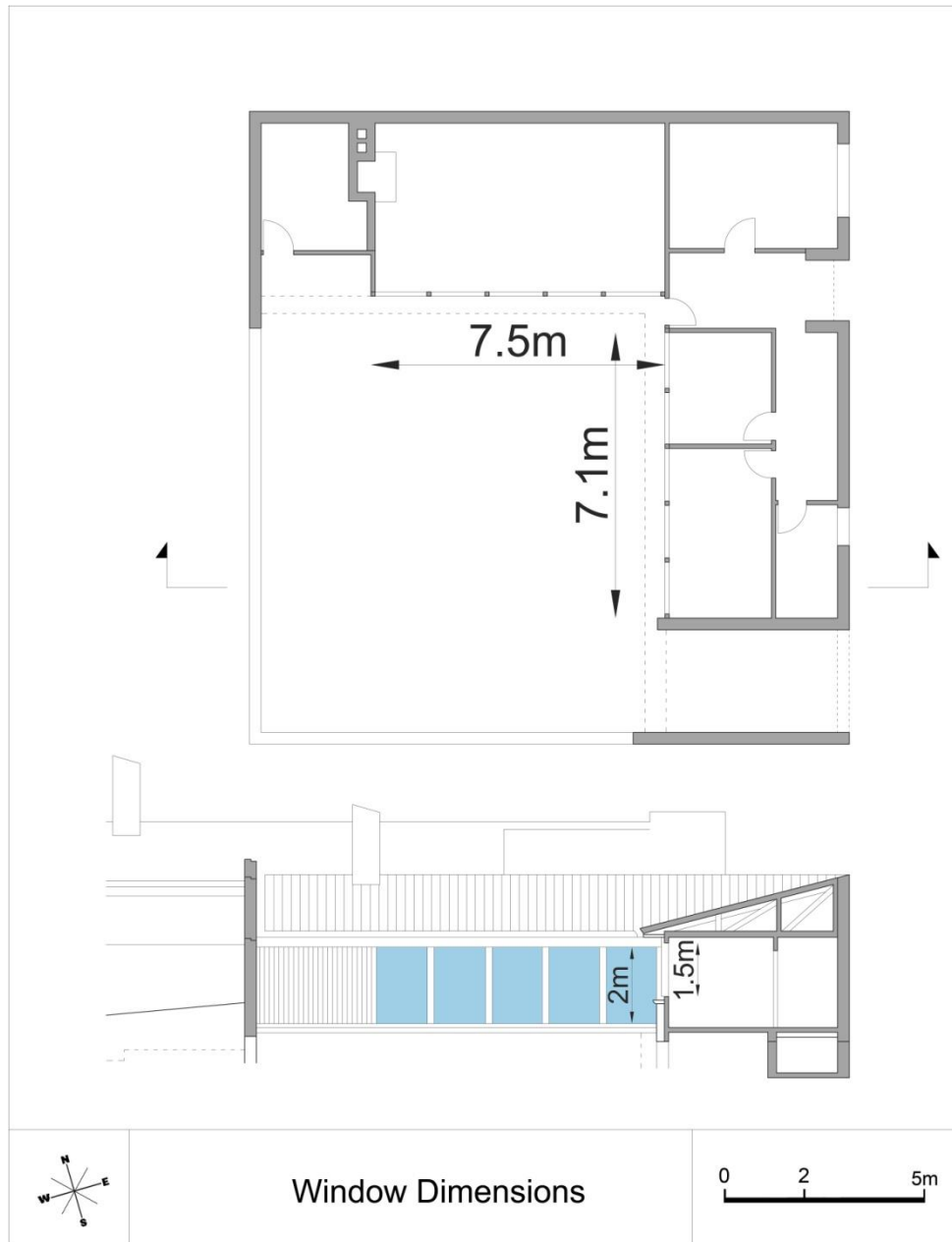


Figure (4.98)

Source: (Utzon and Weston 2004, p.112, 115)

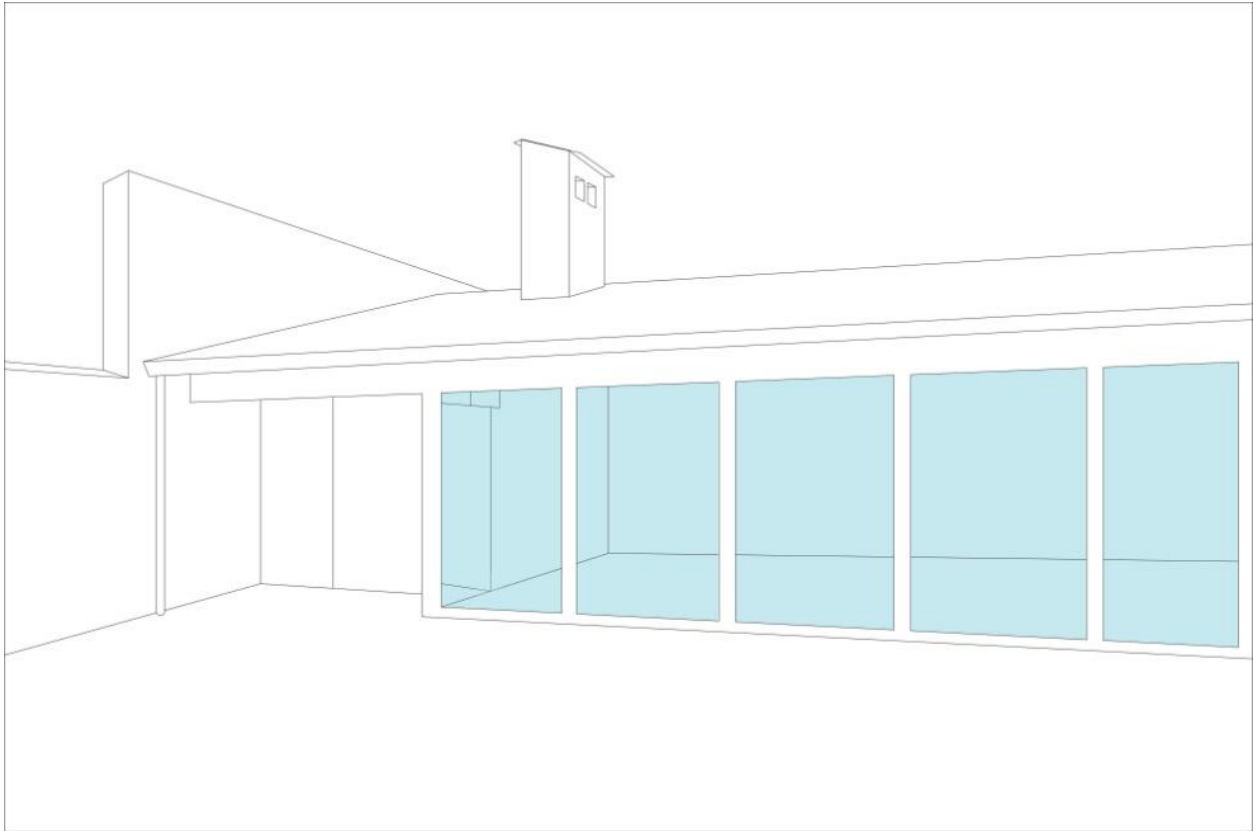


Figure (4.99) Southern Windows facing Courtyard  
 Source: (Weston 2002, p.98)

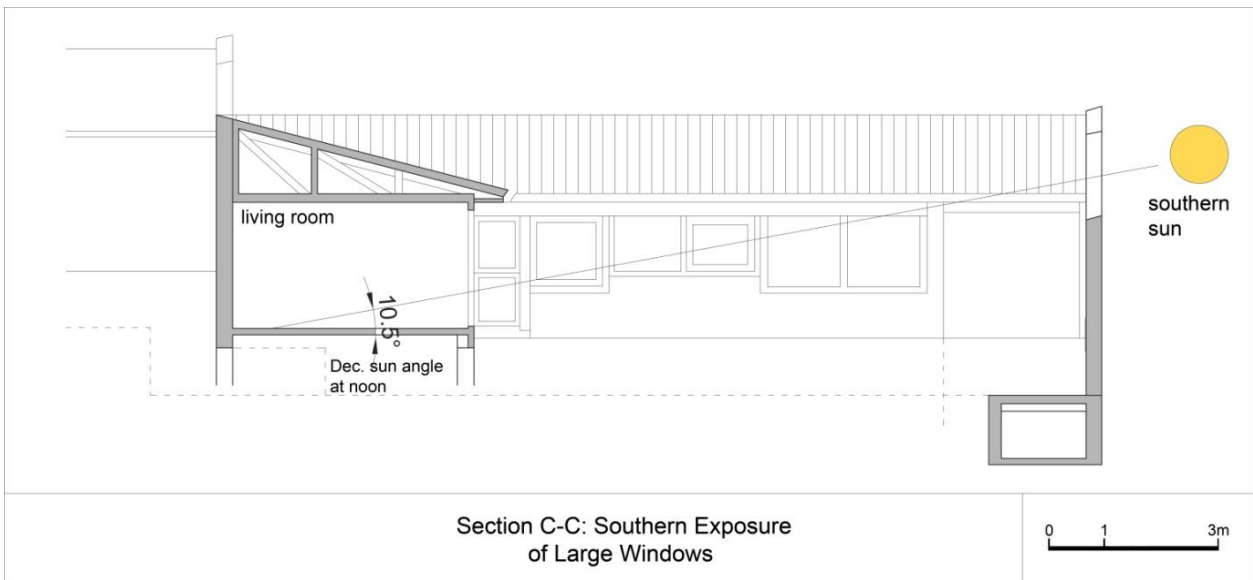


Figure (4.100)  
 Source: (Utzon and Weston 2004, p. 115)

- **Courtyard Vegetation**

The courtyards of all the houses are rich in a variety of vegetation, trees, grass and shrubs. In cooler weather, vegetation increases humidity which warms the atmosphere (figure 4.101).

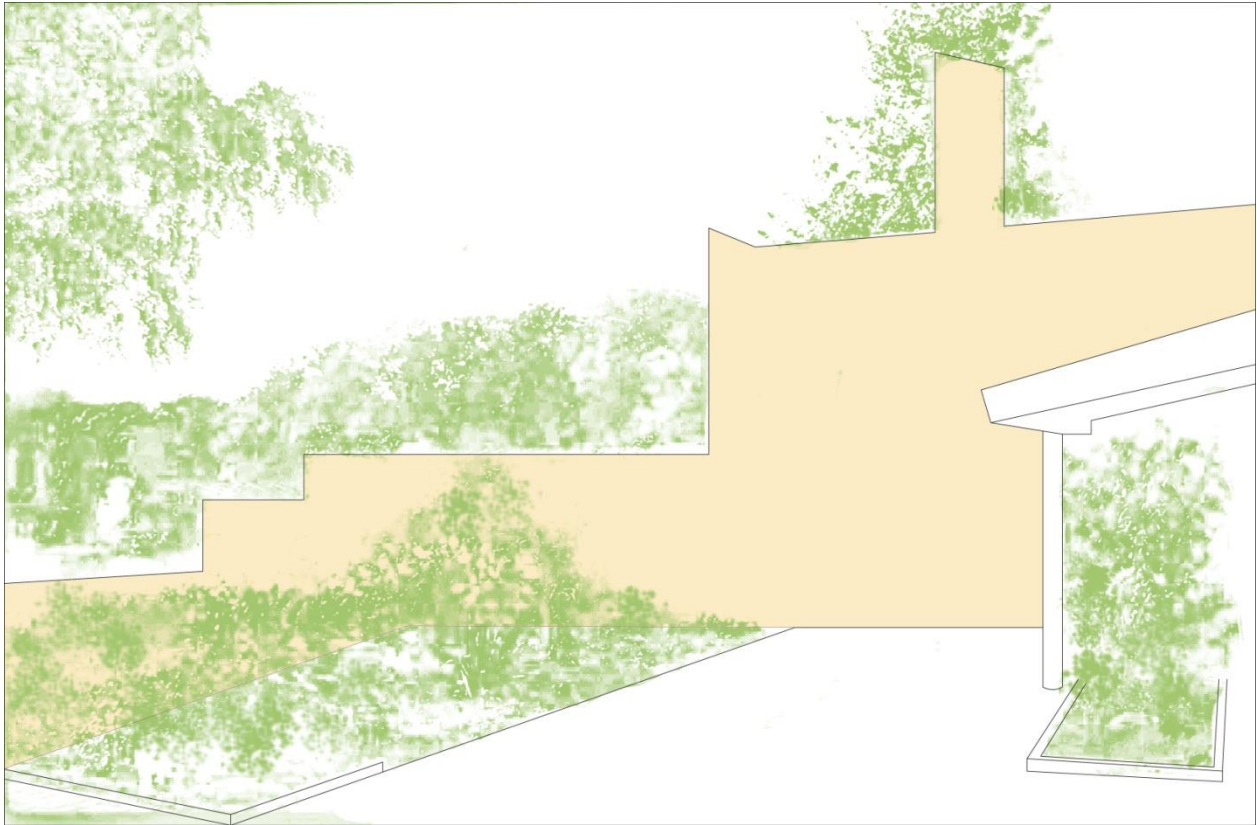


Figure (4.101) Courtyard Garden

Source: (<http://www.utzonphotos.com/guide-to-utzon/projects/fredensborghusene/>)

- **Thermal Mass**

The outer walls of the houses are about 30 cm thick and are built with buff brick. Buff brick absorbs almost 50% of the solar radiation making the dwelling benefit from increased indoor temperatures in winter<sup>247</sup>.

## b. WIND FACTOR

- **Windows**

The large windows allow ventilation of the rooms when needed but result in heat loss in winter.

- **Courtyard Vegetation**

Large trees protect the courtyard from harsh winter winds.

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<sup>247</sup> <http://www.brickform.com/ResourceDownload.aspx?id=4184>



### c. Comparative Analysis Matrix

The following matrix is the result of analysing the ELEMENTS found in the dwellings of Fredensborg Housing based on the matrix found in chapter 2<sup>248</sup>. Each tool was evaluated for its performance in this case study and given a number of points out of the amount given for each tool in the chapter 2 matrix. The score was determined as a percentage based on Matrix (4.9)<sup>249</sup>.

#### 1. Windows

The windows facing the courtyard are large resulting in maximum benefit from the southern sun in winter, therefore this tool was given “very good” for the sun factor. For the wind factor, large windows can provide ventilation during summer, but can result in increased heat loss in winter, therefore, it was given “average” for the wind factor.

#### 2. Vegetation

All courtyard houses in Fredensborg are rich with vegetation which increase humidity and increase temperatures in the cool summers. Trees in the courtyard which protect the courtyard from the harsh winds. This tool was given “very good” for both factors.

#### 3. Thermal Mass

The walls of the houses are made with buff brick 30 cm thick, with 50% absorption of radiation. Since brick has the property of high thermal mass it was given “very good” for both factors.

Element (EL) - FREDENSBORG HOUSING	Total Points	Sun 50%	Wind 50%	Sun EE*	Wind EE*	Final Points
<b>EL 1. Windows</b>	16	8	8	100%	50%	12
<b>EL 2. Mashrabiya</b>	12	6	6	0	0	0
<b>EL 3. Courtyard Vegetation</b>	16	8	8	100%	100%	16
<b>EL 4. Water Features</b>	12	6	6	0	0	0
<b>EL 5. Thermal Mass</b>	16	8	8	100%	100%	16
<b>EL 6. Malqaf</b>	12	N/A	6	N/A	0	0
<b>Total for EL Category (-N/A): 78                      Final Points for EL – Fredensborg: 44</b>						

Matrix (4.13) Fredensborg ELEMENT Evaluation

<sup>248</sup> See 2.2.4. Element, c. Comparative Analysis Matrix, p.83.

<sup>249</sup> See 4.2.2.1. Site, c. Comparative Analysis Matrix, Matrix (4.9) Evaluation for Existing Situation of Tools (EE), p.275.

<b>CATEGORY</b>	<b>POINTS</b>
<b>Site (SI)</b>	40
<b>Settlement (SE)</b>	69
<b>Dwelling (DW)</b>	37
<b>Element (EL)</b>	44
<b>FINAL SCORE</b>	<b>190</b>

Matrix (4.14) Fredensborg FINAL SCORE

# 5

## Conclusion

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The aim of this research was to show that it is possible to design modern sustainable dwellings by taking vernacular strategies and implementing them in modern dwellings. The methods used to answer the research questions were analyzing the sustainable characteristics and elements of the vernacular and modern case studies and comparing them for energy savings in the buildings. Some tools have more effect on energy savings than others. After viewing the results of this analysis displayed as a total number of points for each case study, it is possible to compare between the traditional and modern case studies, determine which case study has more energy saving strategies and which of these strategies can be used in modern dwellings to achieve energy savings and contribute to protecting the environment.

This analysis was done through a rating system which defines levels of Sustainability and gives the designer the goal of collecting points for each tool achieved and implemented in the correct way.

## 5.1. Analysis Results

After analysing the two vernacular case studies and the two vernacular inspired case studies, we are able to compare these four case studies for their response to the sun and wind and give them a level of Sustainability<sup>250</sup> according to the Passive Solar and Passive Wind Rating System (PSPW).

### 5.1.1. The Passive Solar and Passive Wind Rating System (PSPW)

The evaluation is the result of analysis of the four case studies which was based on the general physical facts in chapter 2.2. As mentioned in the methods, all tools and passive design strategies were evaluated for the level of influence on energy savings. This was done as a number of points given for each strategy according to its level of influence on energy savings<sup>251</sup> based on the following:

<b>CATEGORY (influence on building energy savings)</b>	<b>POINTS</b>
<b>Very high influence</b>	<b>16</b>
<b>High influence</b>	<b>12</b>
<b>Medium influence</b>	<b>8</b>
<b>Low influence</b>	<b>4</b>
<b>No influence</b>	<b>0</b>

Matrix (5.1) Evaluation according to Influence on Energy Savings

After that each tool was evaluated for its actual performance (or existence) in the four case studies and given a number of points out of the total, determined as a percentage based on the following:

<b>CATEGORY (existing situation)</b>	<b>POINTS</b>
<b>Very good</b>	<b>100%</b>
<b>Good</b>	<b>75%</b>
<b>Average</b>	<b>50%</b>
<b>Below Average</b>	<b>25%</b>
<b>Non-existing (element)</b>	<b>0</b>

Matrix (5.2) Evaluation for Existing Situation of Tools (EE)

<sup>250</sup> Sustainability in this research refers to energy savings in dwellings as a result of the reduced demand of hi-tech systems.

<sup>251</sup> This evaluation is a result of the estimation of the author based on the facts collected in chapter 2.

After assigning a score for each tool based on its situation in the case study, points were added for each of SITE, SETTLEMENT, DWELLING, ELEMENT for each case study to obtain a final score and rating for level of sustainability based on the following:

<b>SUSTAINABILITY LEVEL</b>	<b>POINTS REQUIRED</b>
<b>Not Sustainable</b>	<b>Below 140</b>
<b>C</b>	<b>140-164</b>
<b>B</b>	<b>165-189</b>
<b>B+</b>	<b>190-214</b>
<b>A</b>	<b>215-239</b>
<b>A+</b>	<b>240-274</b>
<b>Total points</b>	<b>274</b>

Matrix (5.3) PSPW Sustainability Levels

### 5.1.2. Final Score

The following tables display the individual scores for each category (Site, Settlement, Dwelling, Element) and the final score for each of the four case studies:

- **Vernacular Case Studies**

<b>CATEGORY</b>	<b>POINTS</b>
<b>Site (SI)</b>	37.5
<b>Settlement (SE)</b>	60.5
<b>Dwelling (DW)</b>	48.5
<b>Element (EL)</b>	56
<b>FINAL SCORE</b>	<b>202.5</b>
<b>PSPW RATING</b>	<b>B+</b>

Matrix (5.4) Sidi Bou Said FINAL RATING

CATEGORY	POINTS
Site (SI)	29
Settlement (SE)	59
Dwelling (DW)	54.5
Element (EL)	48
<b>FINAL SCORE</b>	<b>190.5</b>
<b>PSPW RATING</b>	<b>B+</b>

Matrix (5.5) Casbah of Algiers FINAL RATING

Both case studies received the same rating but the scores conclude that the settlement of Sidi Bou Said is more sustainable and generally carries more passive design strategies than the Casbah of Algiers. The detailed comparison between the two vernacular case studies and main differences which led to these ratings is explained in the following section.

- Vernacular Inspired Case Studies

CATEGORY	POINTS
Site (SI)	27.5
Settlement (SE)	69.5
Dwelling (DW)	41.25
Element (EL)	44
<b>FINAL SCORE</b>	<b>182.25</b>
<b>PSPW RATING</b>	<b>B</b>

Matrix (5.6) Quinta da Malagueira FINAL RATING

CATEGORY	POINTS
Site (SI)	40
Settlement (SE)	69
Dwelling (DW)	37
Element (EL)	44
<b>PSPW FINAL SCORE</b>	<b>190</b>
<b>RATING</b>	<b>B+</b>

Matrix (5.7) Fredensborg Housing FINAL RATING

Both vernacular inspired case studies have close scores but Fredensborg housing carries more (or better) sustainable features than Quinta da Malaguiera and received a better rating. A detailed comparison and reasons behind the higher score is explained in the following section.

### 5.1.3. Vernacular Case Studies Comparison

The vernacular case studies are the basis for the PSPW Rating System, created as a conclusion for this thesis. The comparison between them displays the advantages and disadvantages of both case studies in order to try to achieve the advantages and overcome the disadvantages in future developments.

In the comparison of the vernacular case studies, results prove that Sidi Bou Said carries more passive design strategies which contribute to energy savings than the Casbah of Algiers. The score of each category is displayed in Matrix (5.8) and the differences are explained in the following:

- **Site:**

When comparing site characteristics, Sidi Bou Said is more sustainable than the Casbah of Algiers due to the slope orientation and vegetation areas. The Casbah slope does not face south and has no vegetation areas surrounding it.

- **Settlement:**

When comparing settlement characteristics, both case studies have a very similar evaluation due to similar urban structures, amount of vegetation and surface materials. All of them elements which contribute to a large amount of points.

- **Dwelling:**

When comparing the dwelling characteristics, the case study chosen in the Casbah of Algiers carried more passive design strategies than the one chosen in Sidi Bou Said, especially regarding the thermal regulating spaces in the courtyard house.

- **Element:**

Finally, when comparing elements in these dwellings, Sidi Bou Said has a higher score due to the garden vegetation which significantly contributes to the overall score.

CATEGORY	SIDI BOU SAID	CASBAH OF ALGIERS
Site (SI)	37.5	29
Settlement (SE)	60.5	59
Dwelling (DW)	48.5	54.5
Element (EL)	56	48
<b>FINAL SCORE</b>	<b>202.5</b>	<b>190.5</b>
<b>RATING</b>	<b>B+</b>	<b>B+</b>

Matrix (5.8) Vernacular Case Studies Comparison

#### 5.1.4. Vernacular Inspired Case Studies Comparison

When comparing the two vernacular inspired case studies, both settlements have a close evaluation and same overall sustainability rating as per the PSPW Rating System, however the settlement of Fredensborg has a higher score and a closer evaluation to that of a vernacular settlement. The score of each category is displayed in Matrix (5.9) and the differences are explained in the following:

- **Site:**

The water body in the area of Fredensborg Housing gave the site a higher score than Quinta da Malagueira and a closer score to that of a vernacular settlement.

- **Settlement:**

The urban fabric is the main difference between the two settlements. The compact geometry of Quinta da Malagueira gave it the benefit of self shading and a lower surface to volume ratio giving it a higher score. In Fredensborg, the dispersed geometry results in more heat loss in a cooler climate. The two settlements are also different when speaking about block orientation. The blocks in Malagueira are orientated (north- south), a negative factor which was solved with strategies like the narrow streets which shaded the eastern and western facades. The Fredensborg Houses were all orientated south and benefited from the winter sun. As a result, the two settlements have very close evaluations where one tool would compensate for the lack of another.

- **Dwelling:**

The courtyard houses of Quinta da Malagueira carry more thermal regulating spaces when compared to Fredensborg Housing giving it a higher score.

- **Element:**

There is a general balance between the thermal regulating elements found in both settlements resulting in the same scores.



<b>CATEGORY</b>	<b>QUINTA DA MALAGUEIRA</b>	<b>FREDENSBORG HOUSING</b>
<b>Site (SI)</b>	27.5	40
<b>Settlement (SE)</b>	69.5	69
<b>Dwelling (DW)</b>	41.25	37
<b>Element (EL)</b>	44	44
<b>FINAL SCORE</b>	<b>182.25</b>	<b>190</b>
<b>RATING</b>	<b>B</b>	<b>B+</b>

Matrix (5.9) Vernacular Inspired Case Studies Comparison

### 5.1.5. Vernacular and Vernacular Inspired Case Studies Comparison

When comparing a modern settlement to a vernacular one, it can be seen that some tools are easier to implement nowadays due to the ability of modern architects to consider them from the design phase rather than in the past, when some design aspects just happened spontaneously in vernacular settlements. An example in the settlement category, is the irregularity of the building blocks making it impossible to achieve the ideal shape and orientation to the sun and wind. When looking at Matrix (5.10):

- In the Site Category, scores vary from case study to another due to the existing site that was chosen. This means that choosing the site depends on the availability of land and its suitability for development.
- In the Settlement category, the vernacular inspired case studies received a higher score than the vernacular case studies due to the flexibility of modern architects to design and choose appropriate shapes and orientation of building blocks.
- In the Dwelling and Element Categories, the vernacular case studies received a higher score due to the many thermal regulating spaces and elements incorporated into vernacular dwellings when compared to the modern dwellings.

This means that it is possible to achieve a much higher score and rating than both the vernacular settlements and the vernacular inspired settlement by utilizing the maximum amount of vernacular strategies possible and at the same time taking advantage of modern day tools which can be used to create almost ideal situations.

<b>CATEGORY</b>	<b>SIDI BOU SAID</b>	<b>CASBAH OF ALGIERS</b>	<b>QUINTA DA MALAGUEIRA</b>	<b>FREDENS-BORG</b>
<b>Site (SI)</b>	37.5	29	27.5	40
<b>Settlement (SE)</b>	60.5	59	69.5	69
<b>Dwelling (DW)</b>	48.5	54.5	41.25	37
<b>Element (EL)</b>	56	48	44	44
<b>FINAL SCORE</b>	<b>202.5</b>	<b>190.5</b>	<b>182.25</b>	<b>190</b>
<b>RATING</b>	<b>B+</b>	<b>B+</b>	<b>B</b>	<b>B+</b>

Matrix (5.10) Vernacular and Vernacular Inspired Case Studies Comparison

After displaying results of the case study analysis and comparing scores, it is important to return to the research questions in order to identify the answers and finally display the steps which guide the architect on how to work through the PSPW Rating System and achieve the highest score possible.

## 5.2. Research Questions and Conclusions:

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In order to display the research conclusion, it is important to remember the research questions:

**How can we learn from the Mediterranean vernacular to design sustainable modern dwellings?**

**Which passive design strategies used in vernacular architecture can be implemented in modern dwellings?**

**How can we innovate new methods which meet modern demands based on vernacular methods?**

Based on the analysis of the case studies, it can be concluded that we can learn from **Vernacular Sustainability** and at the same time meet the demands of **Modern Architecture** by the process of **Innovation and by avoiding Imitation**.

### **Mediterranean Vernacular Sustainability**

After analysing the Mediterranean vernacular case studies from their site characteristics to the urban structure, architecture of the dwellings and finally the elements in these dwellings, it has been proved that many simple and natural characteristics affect the climate (and consequently the amount of energy savings) in a positive or negative way depending on the method of applying this element, such as vegetation, topography, orientation, shape of the dwelling etc. It is evident that it is not possible to apply all elements in a positive way, however, when one characteristic cannot be applied positively, another element is there to reverse its negative impact. For example, a negative eastern façade in a hot climate can have small or no windows. If it is necessary to have windows, then trees can be the shading element. Another example, if a wide courtyard is receiving harsh winter winds, then large canopy trees can create a barrier for protection.

This explains why the vernacular case studies did not reach the ideal 274 points. In Algiers, the orientation of the slope towards the sea prevented it from obtaining the ideal slope orientation towards the south. The density in the urban structure in both vernacular examples means less vegetation when comparing them with the vernacular inspired case studies with large areas of vegetation. The ideal orientation for the wind cannot always be the ideal orientation for the sun. In the dwellings, only large houses can contain all thermal regulating spaces. This means that all the characteristics from Site to Element aid each other to create a favourable climate for the residents in a simple way without the need for any high-tech systems.

### **Modern Architecture**

The influence of Mediterranean vernacular architecture on Modern architects has been mentioned in detail and it is evident that this influence had a significant effect on their work. Their journeys to the Mediterranean are reflected in their projects and many books mentioned these journeys and inspiration, however the importance of climate was not the main goal of this inspiration. Seldom were the climatic elements in the Mediterranean vernacular noticed for their sustainability, instead they were admired for aesthetic reasons. However, after analysing the modern vernacular inspired case studies, both carried sustainable characteristics in terms of passive design methods and energy savings. These modern case studies were chosen because they were influenced by Mediterranean vernacular architecture, they were world widely known for their sustainability and finally for reasons of climate. Quinta da Malagueira has similar Mediterranean climate as the vernacular case

studies and Fredensborg Housing has a colder climate to show that the same analysis can be implemented to any climate to evaluate its sustainability.

### **Innovation not Imitation**

The analysis results show that the rate of sustainability in Quinta da Malagueira and Fredensborg Housing is close to that of the vernacular case studies. In both case studies, the matrices after each section show which characteristics and elements were applied in these settlements, meaning that it is possible to apply climatic elements from the Mediterranean vernacular architecture into modern architecture. It is important to note that the vernacular architecture was not imitated but it was done as an innovative approach by selecting the appropriate sustainable characteristics which are adaptable to the local climate, and implementing them in a way which meets the current modern demands, way of life and the increasing importance of sustainability. The matrices found after each section show which tools achieve this goal from the number of points given whether this tool has high influence on energy savings or low influence. It is even interesting to see how the low influence tools evolved from a vernacular settlement and are implemented in a modern settlement.

### **Quinta da Malagueira**

The tools which display Innovation not Imitation in the Quinta da Malagueira settlement are:

#### **1. SITE:**

- **Topography:** The topography of the site is a south facing slope, a characteristic found in a vernacular city like Sidi Bou Said. A modern approach is building the blocks in a way adaptable to this topography which is perpendicular to the contour lines, making it easier for construction and resulting in the least site interventions.
- **Vegetation:** Due to the partial open structure of the site, the amount of green areas in this settlement is more than any compact vernacular city, resulting in a positive effect on the climate of the site.

#### **2. SETTLEMENT:**

- **Compact Geometry:** The compact geometry is designed in a different way than the irregular vernacular settlements of Sidi Bou Said and Algiers. The urban structure was done by forming neighbourhoods which consist of a repetition of regular rectangles with an identical width and changing length depending on the existing topography.
- **Narrow Streets:** The rectangles are separated by narrow streets. In this case, the benefit of compactness and narrow streets was achieved in the neighbourhood, but the benefit of openness, increased ventilation and vast areas of vegetation was also achieved in the spaces between the neighbourhoods.
- **Surface Materials:** A characteristic which can be taken from vernacular settlements is the light coloured surface materials. The buildings in Quinta da Malagueira were whitewashed and the streets were covered with a light cobblestone.

#### **3. DWELLING:**

- **Shape and Form:** The courtyard type house was inherited from vernacular architecture, however, the design of the house is different from the traditional court with a series of rooms side by side on the perimeter, but the house has a regular modern design with the most important spaces overlooking the courtyard.

- **Dimensions:** The two storeys of the houses resulted in creating a significant amount of shade in the courtyard.
- **Ventilation:** The courtyards of houses A and B function as thermal regulators due to their dimensions and the climate of Evora.
- **Loggia:** The existence of this space between a shaded space and sunny space resembled the traditional loggia in vernacular architecture but integrated in a modern dwelling.

#### 4. ELEMENT:

- **Windows:** The large windows overlooking the courtyard in the houses of Quinta da Malagueira are a simple method used in vernacular courtyard houses to get maximum benefit from the heat in winter, coolness in summer and daylight produced by the courtyard.
- **Thermal Mass:** Although not as thick as the walls of vernacular dwellings, the material used in the houses of Quinta da Malagueira has high thermal mass.

### Fredensborg Housing

The tools which display Innovation not Imitation in Fredensborg Housing are:

#### 1. SITE:

- **Topography:** The topography of the site is a south facing slope, a characteristic found in a vernacular city like Sidi Bou Said. The dwellings were built stepped on slope in a way adaptable to this topography.
- **Vegetation:** The vast open spaces between the chains of houses allowed for a great amount of green areas when compared to a vernacular compact settlement affecting the climate positively.
- **Water Bodies:** Although the settlement does not directly face a water body, there is a large water body in the vicinity which affects the climate positively.

#### 2. SETTLEMENT:

- **Dispersed Geometry:** The dispersed geometry allows for sun penetration of all facades throughout the day, however, the high surface to volume ratio results in high heat loss in winter. This could have been solved by designing back to back housing as in the Malagueira settlement.
- **Block Orientation:** Vernacular settlements could never achieve the ideal orientation for all dwellings, however in modern settlements, it is possible to achieve the best possible orientation as in Fredensborg housing where all houses have a southern orientation.

#### 3. DWELLING:

- **Shape and Form:** The courtyard type house was inherited from vernacular architecture and the distribution of spaces is close to that of a vernacular courtyard house, however the L-shape design of the house (most vernacular courtyards are enclosed from three or four sides) and the sloped roof distinguishes it as a modernized form.
- **Dimensions:** The one storey of the courtyard house results in a low H/W ratio giving maximum benefit from the desirable sun.

#### 4. ELEMENT:

- **Windows:** The modern glazing covering the full southern facades gives the rooms maximum benefit from the southern sun.
- **Vegetation:** The amount of vegetation in the courtyard houses of Fredensborg exceeds that of vernacular dwellings creating a pleasant and thermally comfortable outdoor space.

After displaying the analysis scores and results in section 5.1 which showed the success of the vernacular inspired settlements analyzed and comparing them to a vernacular settlement, then displaying the areas where Innovation and not Imitation were achieved throughout the two vernacular inspired settlements in section 5.2, a guide to achieving the PSPW Rating System is shown in section 5.3.

### 5.3. The PSPW Rating System as a Guide to Creating an Innovative Sustainable Architecture

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After displaying the analysis results and answering the research questions, it is important to mention the methods used to analyze the case studies and evaluate the different characteristics.

The evaluation of the case studies was done by studying the climate of the settlement then studying the positive tools which make the site as a whole sustainable and gradually moving to the urban structure and what makes it sustainable, then to the dwelling itself and finally the elements in the dwellings. Each tool was evaluated by comparing the existing situation of the tool to the ideal sustainable situation as shown in the general facts in chapter 2.2. The number of points given to each tool was estimated according to its existing situation.

From this method, the PSPW Rating System was created. It can become a guide for sustainable modern design that depends on the strategies of vernacular architecture and can be used by urban planners and architects from the beginning of the design phase. The steps to using this rating system can be explained in the following:

1. The first step is defining the place, its climate and its surrounding environment. The existing materials and topography are also important factors to take into consideration before moving to the next step.
2. The second step is defining what simple methods are used in the local vernacular architecture of the place in order to achieve maximum thermal comfort possible with minimum need for high-tech systems for heating or cooling. Some methods or tools are specific for a certain place and therefore can replace some elements found in the Rating System score card. Example: The Mashrabiya and Malqaf are elements used in some regions and sometimes are not relevant for a specific project.
3. After adapting the Rating System to the relevant place, the design process can begin according to the sequence Site, Settlement, Dwelling, Element where the attempt to achieve each tool in its ideal situation according to the general guidelines in chapter 2.
4. In most situations, not all tools can be achieved in an ideal way. Therefore, in order to obtain the highest score possible, the architect can attempt to achieve the tools that have the higher influence on energy savings and therefore have the higher amount of points. Different tools and strategies aid each other in achieving a high level of sustainability, therefore a few tips can be used for the project to receive a good rating:
  - When choosing a **site**, some important elements cannot be changed or replaced like topography and water bodies, others can be installed like vegetation in case the site lacks it. Therefore, a site with existing topography and water body is essential for collecting a good amount of points.
  - When designing the **settlement** structure, design tools aid each other to create an almost ideal sustainable situation. For example, if all houses have either an eastern or western façade, the narrow streets inside the neighbourhoods protect the houses from the excessive sun. In addition, vegetation is a flexible tool which can solve many problems caused by the lack of some important tools.
  - When designing the **dwelling**, and the size is sufficient, it is possible to create an almost ideal courtyard house which carries all the thermal regulating spaces. A smaller dwelling will have less thermal regulating spaces, so attempting to include the elements with higher points is essential.

- When adding the **elements**, whatever the size of the dwelling, it is possible to include all or most thermal regulating elements into the design.
5. After the design phase is complete, an evaluation of the integrated tools and elements is done by the architect to give a score for each tool according to Matrix (5.2) Evaluation for Existing Situation of Tools (EE).
  6. The score card is completed to obtain a final score and rating (Matrix 5.11):

PSPW (The Passive Solar and Passive Wind) Rating System						Maximum Points Possible:			
Scorecard						274			
Project Name:					Location:			Area:	
SITE (SI)	Max. Pts.	EE* Sun	EE* Wind	Tl. Pts.	DWELLING (DW)	Max. Pts.	EE* Sun	EE* Wind	Tl. Pts.
SI 1. Topography	12				DW 1. Shape/Form	16			
SI 2. Vegetation	16				DW 2. Orientation	16			
SI 3. Water Bodies	16				DW 3. Dimensions	12			
<b>Total</b>	44	<b>SI Score</b>			DW 4. Liwan	8			
<b>SETTLEMENT (SE)</b>					DW 5. Arcade	8		N/A	
SE 1. Compact Geometry	16				DW 6. Loggia	8	N/A		
SE 2. Block Orientation	12				DW 7. Terrace/Roof	8			
SE 3. Street Orientation	4				<b>Total (-N/A)</b>	68	<b>DW Score</b>		
SE 5. Open Spaces	4				<b>ELEMENT (EL)</b>				
SE 6. Vegetation	16				EL 1. Windows	16			
SE 7. Public Fountains	4				EL 2. Mashrabiya	12			
SE 8. Surface Materials	16				EL 3. Courtyard Veg.	16			
<b>Total</b>	88	<b>SE Score</b>			EL 4. Water Features	8			
					EL 5. Thermal Mass	16			
					EL 6. Malqaf	12	N/A		
<b>Final Score</b>		<b>Rating:</b>			<b>Total (-N/A)</b>	74	<b>EL Score</b>		

\*EE Existing Evaluation of tools

Matrix (5.11) PSPW Rating System Scorecard

7. If the architect is not satisfied with his/her final score and rating, it is possible to review the design in order to make any changes that would improve the score and rating.



8. In this way, a new approach to sustainable architecture is developed. In addition to saving energy and the environment, the sense of place, culture and identity is achieved through the implementation of local methods and materials and the adaptation to the surrounding environment.

Further research can be done on integrating this guide with a renewable energy system which is considered integrating vernacular sustainable methods with modern sustainable methods to create even more sustainable buildings and more energy savings. In addition, the general analysis done in chapter 2.2 can be repeated for other climatic regions and its vernacular architecture in order to create a guide for sustainable design in all climatic regions worldwide. It could also be enhanced to include other sustainable tools like the use of local building materials, water systems and land intervention. Other cultural aspects which can be studied and aid in the sustainability of any settlement are the participation of the local people in the construction process and the livelihood of the settlement whether it be in the decision making, construction work or any skills that the local people may have to create a sustainable and culturally independent settlement.

The purpose of this guide and rating system is to provide architects with simple low-tech strategies to save energy where they themselves can design, review and evaluate their own project without the need for high cost systems and consultants. These low-tech strategies if implemented from the design phase will change the life of the buildings and do not need future maintenance, repair or replacement like the high-tech systems used nowadays for energy savings. These settlements and buildings will simply work in harmony with nature and the local climate like a plant would survive in its local habitat without the need for any human interventions.

With the increasing threat of climate change, simple low cost methods are even more significant. Modern technologies although effective for the future, still need manufacturing and complicated systems to operate them, increasing the energy load. However, with these simple strategies, the need for heating and cooling is decreased from the beginning of the building life and only during the event of excessive weather, do any high-tech systems become needed.

Learning from the Past, Designing for the Future is the main concept which this guide is built upon, in the hope of creating a system where past technologies will be revalued, reborn and recreated into innovative ideas that will adapt to our modern needs. Combining that with what vernacular builders lacked, like the help of modern and efficient design and construction tools, computer aided design programs and extensive architectural knowledge. All these factors combined together offer the architect of today and tomorrow a new and simple way of creating sustainable settlements and buildings which aid in saving energy and contribute to protecting the environment.

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Weather of Sidi Bou Said

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