WAGENINGEN UNIVERSITEIT
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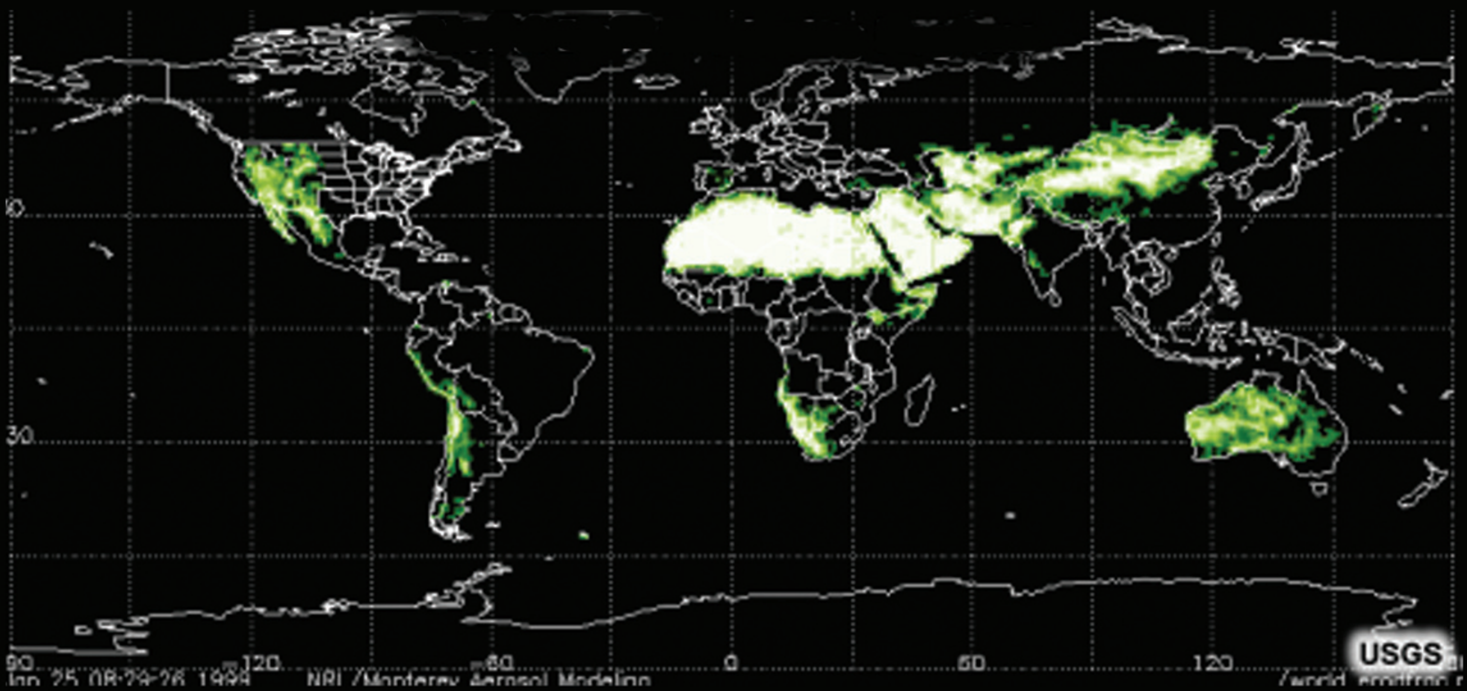
Master's Thesis:

Landscape Architecture for Micro-Climate Improvement and Energy Conservation in Egypt.

Design Principals and Guidelines applied for the American University in Cairo.



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Landscape Architecture for Micro-Climate Improvement and Energy Conservation in Egypt.

Design Principles and Guidelines
Applied for the American University in Cairo.

Major thesis in Landscape Architecture

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بسم الله الرحمن الرحيم

عن الرسول صلى الله عليه وسلم أنه قال:

إذا مات ابن آدم انقطع عمله إلا من ثلاث: صدقة جارية، أو علم ينتفع به، أو ولد صالح يدعو له.

رواه الترمذي.

In de naam van Allah de Barmhartige de Genadevolle.

de profeet Mohammad (vrede zij met hem) zegt:
"Wanneer de zoon van Adam sterft, houden zijn beloningen voor zijn daden op, behalve de volgende drie daden: Een onophoudelijke liefdadigheid, achtergelaten kennis die voor mensen nuttig zal zijn en een oprecht kind dat smeekbede voor hem doet."

Tiermiedhie onder nr 1297

In the Name of Allâh, the Most Gracious, the Most Merciful.

The Prophet Mohamed (peace be upon him) said:
"If the son of Adam dies, all his works are stopped except three: A charity that is continuous, useful knowledge or a righteous child who supplicates for him."

Tiermiedhie inder nr 1297

Content

Preface

Nowadays, I have the feeling that Egyptians are not smiling any more. In 2026 the Egyptian population will be 90 Million and in 2030 it will reach 100 Million. In the meantime, the growth of population negates the potential of continuing to live on and utilize only 5 percent of the land area of Egypt. For centuries geopolitical factors played a key role in conditioning the people of Egypt to depend on a strong, central authority to govern the long strip of agricultural land alongside the river Nile. While this central authority was needed for a society whose basic activity was simply farming of the fertile land through artificial irrigation, it has now become a constraint. It is not possible to foresee establishment of a modern country within the confines of the Nile Valley and its Delta, because that would reduce agricultural land. The fertile soil within the inhabited strip of Egypt was deposited by the Nile River over millions of year, and it is irreplaceable. Thus, it is imperative to open new vistas for expansion outside of the inhabited strip. But Egypt suffers from the tradition of singular political regime. A highly centralized political organization dominated by an oligarchy wielding absolute power. Centralization and the corrupt oppressive regime impeded development and growth because it did not suit the complexity of modern life. Consequently, urbanization has taken place in the fertile valley and delta of the Nile River, a ribbon of territory that made up only 5 percent of present-day Egypt's total land area, while the remainder of the country is a barren and unpopulated desert. The urbanization of the narrow valley lead directly to high building concentrations reaching a density more than 460 dwelling/ha in a city like Cairo.(figure p.01).

After staying almost two years in the Netherlands I was always questioning my self about the key factors that are missing in Egypt. I found that the reasons that made a country like the Netherlands prospers and blossomed is mainly based on the fact that Dutch people are collectively able to achieve the following: (1) Production of excess of

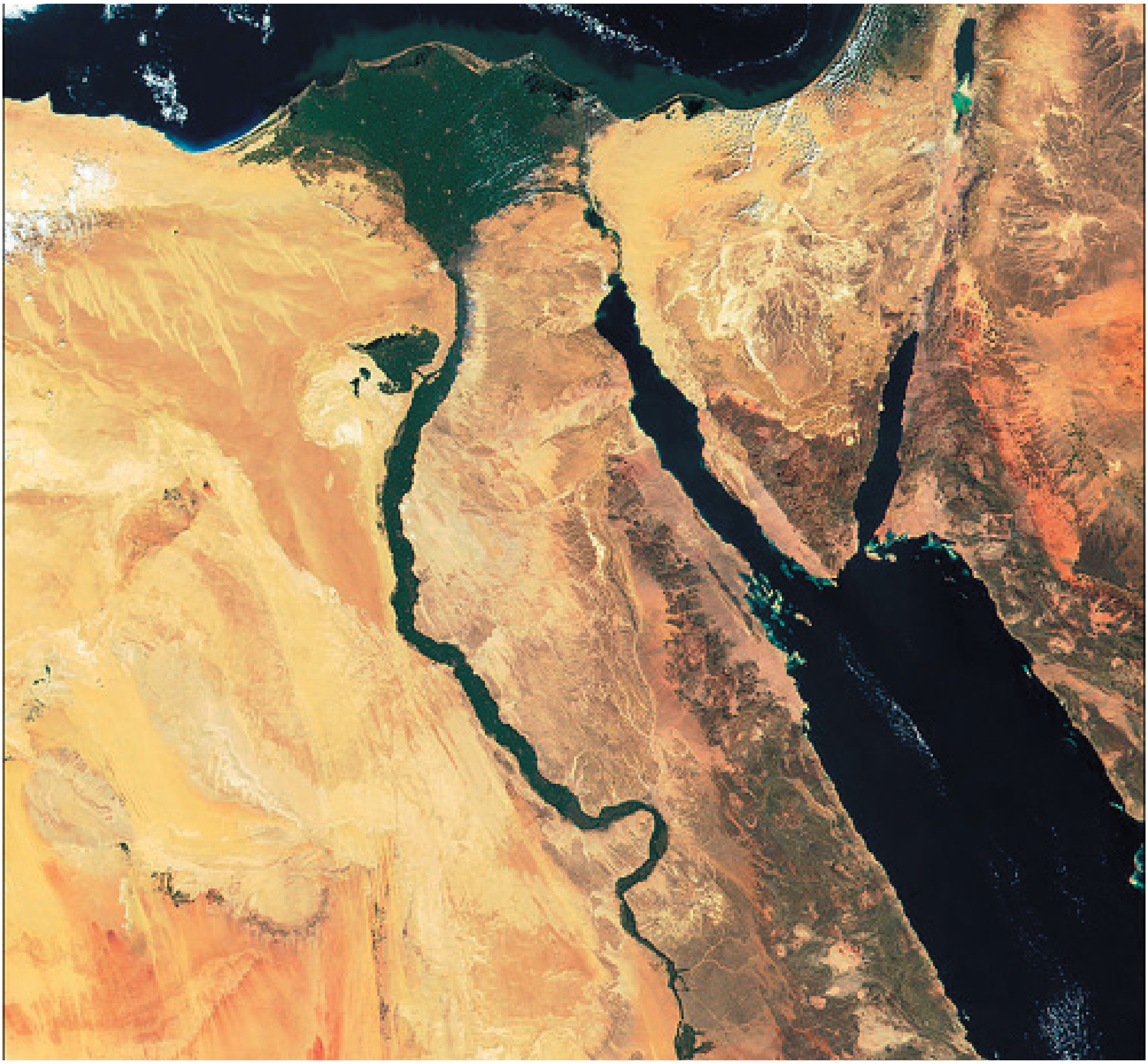

Fig. p.01, Egypt Satellite map, 2000 (www.gesource.ac.uk).

food, for the growth of their bodies and minds, (2) division of labor among the society, in a fair and well organized manner and (3) easy living in urban areas, where some of them could create and innovate. Therefore, we need in Egypt a comprehensive strategy to change our reality. We need creativity and ideas. We need innovation and creation. We need researches and books. But above all, we need to broaden our scopes and expand the land we live on. We need high hopes and new prospects. We need visions and initiatives and more importantly we need a leadership and the spirit of team work. We need an innovative solution to the numerous problems that face Egypt today.

As the Egyptian population is growing rapidly, there is increasing pressure to develop our arid lands, development that will tax these regions natural resources to their ultimate. In a time of global energy consciousness and concern for safeguarding natural systems, the real test for our desert communities will be to encourage growth and promote the unique quality of life that arid environments offer, while simultaneously preserving the very fabric of the desert ecology. We can best accomplish this by working within the limits of the natural carrying capacities of arid lands. Physical planning must acknowledge the necessity to preserve water resources. Drought-tolerant vegetation must be chosen for landscapes over high water-demanding exotic species, and even rainwater must be captured and used as an important source of freshwater. Our dwellings need to be energy efficient, using passive solar energy designs that will eliminate our dependency on energy intense cooling and heating systems. Microclimates must be put to work for us, creating natural buffers against extremes of heat, cold, and desert winds.

From here, I wanted to start my research. During the last 50 years Egypt turned its back to the desert. Now, it is not possible any more. The importance of desert lies in its potential for agriculture, recreation, supplying energy (especially solar and wind), good air navigation, mining of natural resources, and most importantly the establishment of new settlements. There are three corner stones or as the Dutch call it "*hoeksteen*" for a sustainable desert development. The first are renewables. For example, solar energy is the most freely readily available and most unlimited energy. While wind is blowing over the Egyptian Sahara almost the whole years and there is a high potential to harvest wind energy. Also the solar thermal potentials of the desert qualifies is to produce Hydrogen. The second key stone is water. Farouk EL Baz, (Director of the Center for Remote Sensing at Boston University, U.S.A), assures that the Egyptian Western desert is floating over a lake of potable water, which can supply an extensive development for at least 200 years. Sea water desalination plants can be also considered as the backup for water supply. Finally, the last key stone for sustainable development of the Egyptian desert is based on materials. Sand is considered as most freely available recyclable building material. The characteristic of the Egyptian desert sand allows it to be the best raw material for glass, silicone, ceramics and sandstone production.

As an Egyptian architect studying landscape architecture at Wageningen University I wanted to react on the vision that I described above. First of all, I started to define the role of landscape architecture in Egypt. Then I discovered that in Egypt's high density populated cities, the outdoor environment is very important. Later, and during conversations with Meto Vroom and Frank de Josseling de Jong I decided to go for an analytical study about existing urban squares in the form of a minor thesis. During this study, I was interested to experience the design vocabulary of the urban outdoor environment. This minor study provided me with a good theoretical design and research background. But I was still asking how can we design in hot arid climates as long the land we can only expand on is desert? The high temperatures, humidity and dusty hot winds of the desert lead to excessive discomfort for people. Therefore, I found that the most important objective for a sustainable desert landscape design should be mainly aiming to improve the microclimate in an energy efficient way.

I started my research trying to provide landscape architects with a consistent study about landscape design principles and guidelines for micro climate improvement and energy conservation in Egypt. The new American University Campus in Cairo was my design case study. I used it as a verification tool for my design. Under Ingrid's Duchhart's supervision I went for a month to Cairo for a field visit and it was one of the most intensive and fruitful source for data collecting. Also I followed a simulation course with Jan Hensen in TU-Eindhoven aiming to excel some validation software tools to verify my design and proof the microclimate improvement and cooling load reduction, consequently energy conservation.

This research by design study is a result of 6 months' work in which I researched about design guidelines and design principals trying to apply them in a real case. I had the opportunity to publish my first research paper during this study. More importantly I would like to state that I gained a deep insight about research and design which will help me to presume my carrier.

Shady Attia
Wageningen, June 2005

Acknowledgments:

First and foremost, praise and thanks be to God the Almighty that the achievement of this study has been made possible.

The basic theme of this thesis originated in May 2005 during my participation in the Energy Valley design Charette held in Groningen, May 24th-30th 2005 and is a part of the Grounds for Change project. The project is part of the international project Bridging to the Future, which is the second phase of the international Union Initiative on Sustainable Urban System Design. During the Charette we were looking for design strategies that will help making the energy system as sustainable as possible. When the Charette came to an end I realized the importance of landscape in conserving energy and I started to research on this topic until I visited Alterra Building in Wageningen. Alterra Building is a pilot project based on an ecological design approach, which integrated landscape architecture as a part of the energy-climatic design concept. I was fascinated with the use of vegetation and water to improve the microclimate and conserve the energy consumption in this building (Behnisch, 2004). It was with these overwhelming feelings that I knew that I should spend several month studying landscape architecture Landscape architecture for building's micro climate improvement and energy conservation in Egypt.

Through the period of this research, I have been helped by many people who have presented invaluable assistance through one way or another. There is firstly Professor Ingrid Duchhart who supervised this thesis with a great interest and enthusiasm to say but the least. Her criticisms and remarks have been very educational, and have enabled me to strengthen my argument. I would like to thank her for the books, papers and contacts the she provided me throughout the course of the research. I wish to take this opportunity to extend the deepest and warmest of my regards an appreciation to her.

I also wish to extend my thanks to Professor Peter Germeraad for his help that he had gave me. I would also like thank Professor Jan Hensen from the Building Physics Department at the Technische Universiteit Eindhoven who helped and introduced me to simulation softwares that can validate my design. I would also like to add that I have enjoyed and greatly profited from my association with other members of staff of the School of Landscape Architecture of Wageningen University such as Professor Jusuck Koh, Klaas Kerkstra, Meto Vroom, Frank de Josselin de Jong, Sanda Lenzholzer and Rudi van Etteger. It is at this university and in this school to be precise that my idea found a home.

During the field work and survey of new American University Campus in Cairo (AUC), I was assisted by a number of colleagues, friends and members of staff of the following project participants: (1) New AUC Campus Development (Owner), CDC-Abdelhalim (Architect), Sites International (Landscape Architect) and the Desert Development Centre (DDC) (Nursing). Most special thanks, however, are due to my friend Hesham Youssry and my colleague Yehia El Alaily for their help in surveying, and to Ezzedine Barakat, Dr. Maher Stino and Dr. Hussein El Sharkawy for the material they provide me with. I would like to thank my friends and colleagues, who helped me in Netherlands, Byoung Wook, Asier Larretxea, Harro Wieringa, Abdelhalim Ouahid and Liesbeth de Jong. Without them many things would not have been done.

It would not be just to end this acknowledgement without making grateful appreciation to those who have financially support my stay: In the Netherlands having been assisted by the Netherlands Fellowship Programme for two years without which I would not have been able to complete my work; in Egypt having been granted a leave-of-absence for almost 2 years from the department of Architecture, Faculty of Fine Arts, Helwan University in Cairo.

Though last not least, to my family in Egypt, I lovingly dedicate this work; I am eternally grateful to them for their encouragement and patience throughout this period and I sincerely hope to find other ways than mere words to show them my gratitude.

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ONDERWERP

'S-GRAVENHAGE

June 23 2006

PALEIS NOORDEINDE

Dear Mr. Attia,

On behalf of Her Majesty the Queen I would like to thank you for your kind letter and for the perfume bottle she received from you.
It is very nice to read that you have enjoyed your stay in the Netherlands, during your studies landscape architecture at the Wageningen University, both on an intellectual as on a personal level.

I would like to wish you success in the completion of your studies and a safe return to your beautiful home country.

Yours sincerely,

(Henk A.C. van der Zwan)
Principal Secretary to
Her Majesty the Queen

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Summary:

Landscape Architecture for Micro-Climate Improvement and Energy Conservation in Egypt.

In Egypt, high temperatures, humidity and dusty hot winds lead to excessive discomfort for people. Contemporary designers do not integrate landscape architecture as a way to improve the micro climate of the outdoor built environment, in addition to the inappropriate use of energy resources ,while in Egypt's hot arid climates, it is essential to ameliorate the microclimate in an energy efficient way. Landscape architects must fully understand that Egypt has one of the harshest and most limiting environments on earth. Therefore, the role of landscape architect is essential in creating a more favourable outdoor environment for people with regard to their inner living space: adequate shade, cooler temperatures, light breezes, protection from glare and wind blown sand.

The main aim of this thesis was to provide landscape architects with design principals and design guidelines to improve the microclimate and conserve energy in Egypt. The thesis could be described as horizontal overview that describes historical and recent design solutions that tackle with the problem of aridity and resources scarcity. The research was guided by a design problem that was intended to steer the research in order to come out with the knowledge needed in correspondence to the design problem. The location of the case study or design was in Egypt's eastern desert and the selection was made based in the aridity and harshness of the project location. This study was divided into 6 parts: (1) Research Design, (2) Background, (3) Lessons from historical landscape design examples, (4) Contemporary Landscape design principals and guidelines, (5) Case Study and (6) Conclusion.

In the first chapter, the research structure is clearly determined or "designed". Here, the research objective, questions and limitation were defined. "Research by Design" was the research methodology applied in this thesis. Moreover, this chapter addressed the cyclic research approach in which the design played an important role as a verification tool.

Chapter 2 basically described the Egypt's Biotic and Aboitic aspects. The chapter was called background not only because it was providing elementary introduction to Egypt but because it also addressed the main definitions and terms that will have been dealt with in the thesis. For example, general information about comfort and micro climate were described.

In chapter 3, the traditional landscape designs of Egypt's history were explored. Because Egypt witnessed two golden ages I selected the Ancient Egyptian and Islamic civilisation as examples for my study. During both ages landscape architecture prospered and important design concepts such as the oasis and walled garden were well adopted in their built environment. Moreover, this chapter includes and comparative analysis of traditional landscape designs, conducted by the author that identified the main landscape design elements and passive cooling techniques that had been applied in the Islamic history.

Next in chapter 4, the recent and contemporary landscape design principals and guidelines were presented in detail. Chapter 4 was classified based on three aspects: (1) Site Design, (2) Architecture and Urban Fabric Design and (3) Landscape Design. The chapter is full of illustrations that are corresponding to the role of landscape architecture in improving the microclimate in an energy conservative way. Finally, the chapter reached interesting findings about the importance of shading and ventilative cooling. The relation between all three mentioned aspects was illustrated on a so called Landscape Architecture Climatic Circle.

Then, chapter 5 represents the case study. A new university campus for the American university in Cairo's was selected as a show case or design problem. The work on this chapter started simultaneously with chapter 1.The chapter documents a field study and design inventory that was prepared before reaching an extensive design analysis phase. The analysis phase addressed the functional, biotic, abitoic, spatial and aesthetical aspects of the site as a preparing phase for the final design. The final design concept was presented at the end of this chapter as an experimental case and verification tool for the developed design principals and guidelines. Chapter 5 was rounded up by the a list including 7 strategies or research findings that were tested and applied in the design concept.

Finally, the concluding chapter dealt with the possibilities of testing the design as a way of empirical verification. The possibilities of applying verification techniques such as shade studies, simulation runs and field measures were discussed. Finally, the chapter sums up and list the design principals and guidelines and that the study came out in order to improve the micro climate and conserve energy in Egypt.

Introduction:

There is a plenty of examples in Egypt and Arab world of designs (for buildings, open spaces, urban neighbourhoods, and roads) derived directly from European styles and standards, absolutely inappropriate to the climate and traditions of these arid Arab countries. However, previous generations adapted the traditional ways to their climatic situation. Many traditional landscape designs were concerned with environmental optimization through landscaping and the use of water bodies. Landscaping was an essential condition with a prime goal of altering the microclimate of a place. Landscape architecture provided shading the exterior spaces as well as facades and courtyards, filtering dusty winds and preventing undesirable hot air to penetrate the buildings. Such design solutions were principal elements in ancient builder's design toolbox. They were considered as the basic vocabulary of any building design. These traditional designs for controlling the microclimate of a place, are traced chronologically in many examples of vernacular (Pharonic and Islamic) architecture.

The microclimate of a building site can make or break a project. Shadows cast by nearby buildings, trees, or any design elements are important considerations in orienting or designing a passive solar building. Using climate assessments in design involves more than creating a building or solar system within the context of a specific environment. The landscape design and building structures can enhance solar system performance. For instance, overhangs and eaves can shade windows when solar heating is not desired. Deciduous trees and shrubs can strategically place outside to help keep buildings cooler and more comfortable during the warmer months. Courtyards filled with trees, flowering vines, shrubs and a large fountain can create a cool oasis even in the hottest desert climate.

The landscape site-layout can improve the microclimate around a building, taking advantage of existing topographical features, adjacent buildings and vegetation for solar protection. Good site layout can also take greater advantage of local breezes by the formation of air funnels and also aid natural ventilation by organizing the building layout. The presence of water and vegetation on the site can also be used for natural cooling. Good site layout can reduce cooling loads appreciably by optimising natural solar protection and local breezes.

But what would a city be without landscape architecture? It is precisely these landscape design elements that can ameliorate the microclimate of a building site and reduce it cooling load. But how can we design to improve the microclimate in an energy conservative way? What are the design guidelines and principals to achieve such a goal in the hot arid climate of the Egyptian desert?

In order to answer such questions, I will use a broad methodology position based on 'research by design'. The research by design is a cyclic research approach, which considers the design process as the main entry point for the research. This thesis will be a research driven design presupposed by an empirical study. The research driven design will process in a cyclic approach, including inner research loops and will enable observing, checking and predicting. The new American University Campus in Cairo (AUC) will be my design case study. The design will include major steps like, collection and analysis of relevant data. Research by design will be a plan that guides the investigator in the process of collecting, analyzing, and interpreting observations. It will be a logical model of proof that allows me as a researcher to draw inferences concerning causal relations among the variables under investigation.

Based on a AUC design brief and design problem, the work in this thesis will interweave five phases in a cyclic process, all focusing on Landscape architecture for micro climate improvement and energy conservation in Egypt. Firstly, by reviewing, ordering and classifying the natural physical conditions affecting landscape design and energy consumption in Egypt. Secondly, by reviewing, classifying and analyzing the traditional design types and solutions in similar climatic areas in order to develop design guidelines. Thirdly, by reviewing, classifying and developing theoretically and visually the basic design guidelines and principals for micro climate improvement and energy conservation in Egypt. Fourthly, by developing a design concept as proof that provide support for the application of different landscape design guidelines that demonstrate how to integrate them, in the design. Finally, by verifying the design concept in relation to the guidelines through the developed design decisions.

List of Illustrations:

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Chapter 1

Research Design

Chapter 1

Chapter 1: Research Design

1.1 The Aims of Scientific Research and the Research Aim

In his book 'Methodology' De Groot (De Groot, 1969) defines the aim of scientific research as follows: " A scientific discipline seeks to generate and assess knowledge pertaining to the particular sector of reality covered by this discipline." What is meant by 'gaining knowledge' is processing the experience of the phenomena encountered in the specific research sector in one or more of the following ways; to describe, to order, to record (measure), to understand, to explain, to predict and to control. But the previous mentioned ways should be processed with great precision, systematic treatment and should be associated with consistent adherence to logical and methodological standards of landscape architecture discipline. To achieve our scientific aim, adherent to logical and methodological standards the scientific research rely on the empirical cycle, which constructs this basic shape of scientific inquiry.

1.2 The Aim of This Thesis

Before explaining the aim of this thesis I would like to mention that this thesis is a part of the fulfilment requirement to obtain the Master's degree of landscape architecture at Wageningen University. Some views see a thesis as a piece of scholarly enquiry, deliberately limited in scope, but perfectly executed. The other view of a thesis is that it is a worthwhile learning experience. These two views might be better regarded as two extremes of a scale, and that in reality a thesis will often exhibits characteristic of both models. In either case a master's thesis is seen as a part of a training programme, which is designed to demonstrate competence as a researcher within a limited field (Anderson and Poole, 1997). But the Dublin descriptors agreed that a Master's student should:

(1) Have the knowledge and understanding beyond Bachelor level,
(2) Demonstrate originality in developing and applying ideas,
(3) Be able to solve problems for new and unfamiliar environments,
(4) Can communicate conclusions to specialist and non specialist,
(5) Has the learning skills to study in a manner that is self directed and autonomous.

These qualities should also be present in the Master's thesis. Therefore, the aim of this 6-month 'research by design' master's thesis is to generate design guidelines related to landscape architecture in order to improve the micro-climate and conserve energy consumption of buildings in Egypt. Through an adequate formulation of a research problem and by following a research methodology for data gathering, processing and analysing of empirical data, this research will draw a design-concept relevant conclusions in this specific field of study. During the study, a design concept will be developed. The cyclic process will allow the development of the design through several internal scientific loops that will be followed by visual and spatial design translations. Finally, the design concept will guide the study and provide support and proof for the application of different landscape design guidelines that demonstrates how to integrate them, in the design.

1.3 Thesis Research Problem

In Egypt, high temperatures, humidity and dusty hot winds lead to excessive discomfort for people. Contemporary designers do not integrate landscape architecture as a way to improve the micro-climate of the outdoor built environment, in addition to the inappropriate use of energy resources ,while in Egypt's hot arid climates, it is essential to ameliorate the micro-climate in an energy efficient way. But in practice, there is a plenty of examples for landscape designs derived directly from Western styles and standards, utterly inappropriate to the climate and traditions of Egypt and the Arabian region. For example, the oversized open spaces, the oversized lawns and the oversized water bodies next to the inappropriate use of plants, potable water, irrigation systems and mismanagement of natural resources. Landscape architects must fully understand that Egypt has one of the harshest and most limiting environments on earth. Therefore, the role of landscape architect is essential in creating a more favourable outdoor environment for people with regard to their inner living space: adequate shade, cooler temperatures, light breezes, protection from glare and wind blown sand.

In my opinion, landscape architecture should be functional, beautiful, people friendly, in addition to creating good atmosphere. But we should also consider the resource management during creating our urban landscape designs because resources, which are the basement of society, are depleting soon. Obviously, urban landscape-design interferes with three major resources: (1) materials, (2) energy (3) and above all water. Therefore, it is wise to create and ameliorate our urban outdoor environment in an energy conservative way. However, the problem facing the Egyptian landscape architects lies in the lack of the suitable knowledge and examples that could be followed to improve the micro-climate and conserve energy in response to geographical and socio-cultural context. There is still a gap in the existing knowledge, specifically the applicable knowledge, related to the design principles and guidelines.

1.4 Hypothesis

Landscape architecture is an integral component for the environmental optimization of the built environment. This means that landscape design should spontaneously connect the climatic improvement of the outdoor environment to the comfort in the internal environment. With appropriate landscape, there is a greatly reduced need for fans and air conditioning. For example shade trees have been shown to be seven times as effective as interior curtains, shades, or blinds in maintaining cool interior temperatures. The rooted knowledge and principals provided guidelines for ancient builders, to achieve thermal comfort in and around their buildings passively. Even in the face of restrictive technology and building materials, the performance of their outdoor environment proved incredibly good, even when judged in the light of modern technology. Based on this fact, we can claim that proper landscape design can help to improve micro-climatic conditions and conserve energy consumption of the built environment.

1.5 Research Objective & Questions

An efficient landscape design deals with means: (1) micro-climate improvement (2) energy consumption conservation. These two research objectives move us to the following research questions:

- How can landscape architects design a landscape that improves the micro-climate in an energy conservative way?

Before answering such a question, we should mention (1) the landscape design elements that influence the micro-climate and (2) the micro-climate elements that need to be controlled.

Figure 1.01 shows the three main elements that influence the micro-climate of the outdoor environment as Robinette (1983) classifies them. The site, the buildings and the landscape can all together ameliorate the outdoor environment. While the micro-climate element that need to be controlled are sun radiation, wind and water evaporation. Based on Fig 1.01 a matrix produced the following a specific research questions:

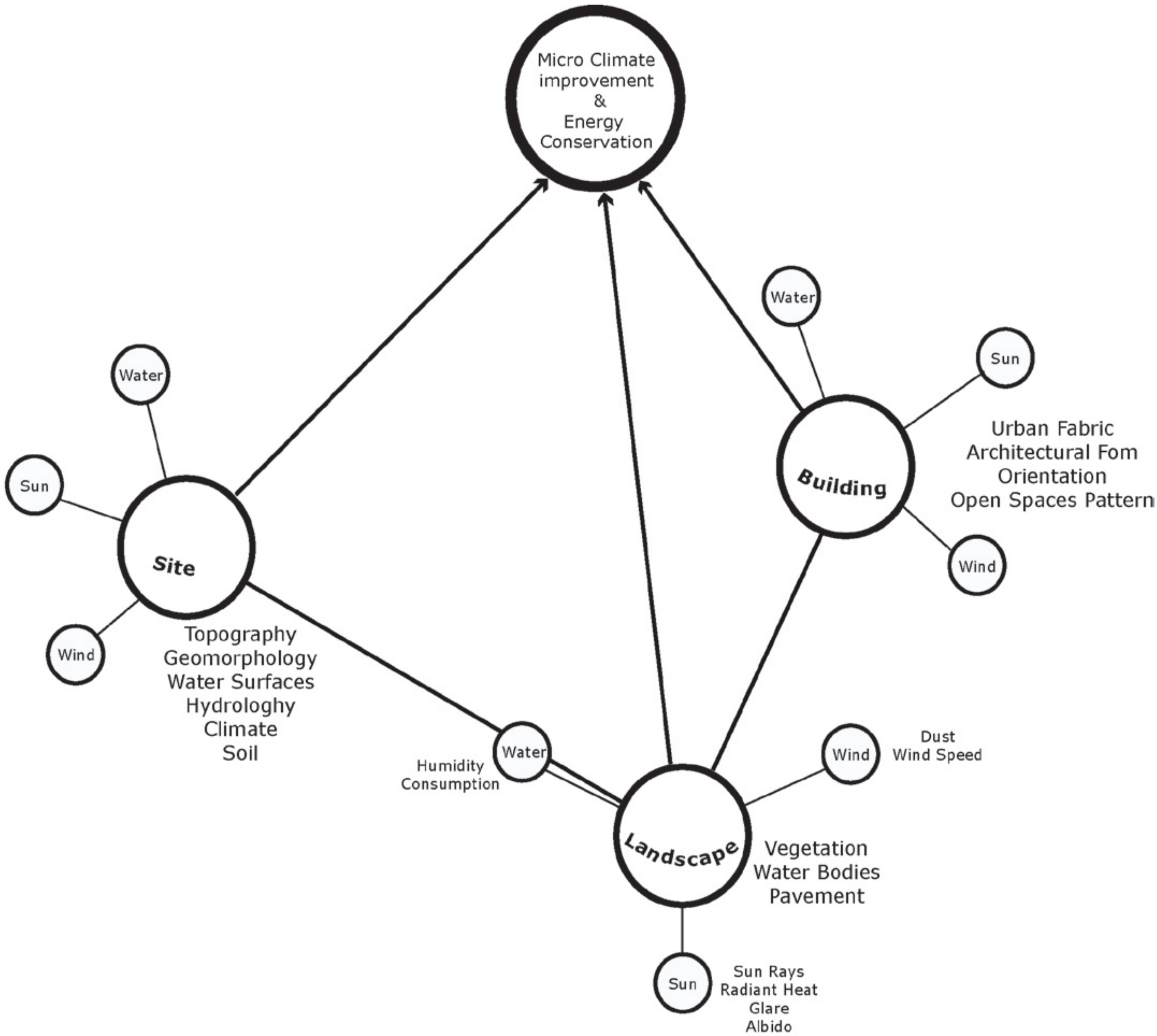

Fig. 1.01, Landscape Design Elements, by author.

- What are the site selection criteria?

- What are the design guidelines for the urban fabric?
- What are the design guidelines for open spaces pattern designs?
- What are the design guidelines considering the architectural forms?
-
- How can landscape reduce the direct sun from striking and heating up building surfaces?
- How can landscape prevent the reflected light carrying heat into a building from the ground or other surfaces?
- How can landscape create different airflow patterns and can be used to direct or divert the wind advantageously by causing a pressure difference?
- How can the shade created by trees and the effect of grass and shrubs reduce air temperature adjoining the building and provide evaporative cooling?
- How can landscape filter the dusty winds and prevent undesirable hot air to penetrate buildings?
- How can landscape avoid glare and albedo?
- How to locate water bodies to lower air temperatures in buildings?
- How can water bodies used for natural ventilation and energy conservation?

To answer such questions and to reduce the gap between knowledge and application, first of all, landscape architects should be provided with basic design guidelines and principal knowledge about the landscaping techniques and the utilization of water elements in contemporary design programs. Secondly, they should be supported with traditional visualizations of a successful design example, which followed these principles and guidelines.

1.6 Research Methodology

The broad methodological position of this thesis is based on what (De Jong and Van der Voordt, 2002) call 'research by design'. The research by design is a cyclic research approach, which considers the design process as the main entry point for the research. In figure 1.02, research and design are featuring two different realms, while they both overlap. At that point, one may imagine research activities without design and design without activities of research. But as landscape architects we consider research and design as two sides of one coin. Because design is a step by step process in which the conceptual idea goes through a testing process by every design decision. Often these design decisions are based on design inventories and analysis. Therefore, we can claim that this thesis is a research driven design, presupposed by an empirical study. The research driven design will be processed in a cyclic approach, including inner research loops and is enabling observing, checking and predicting of the gained knowledge (fig. 1.03).

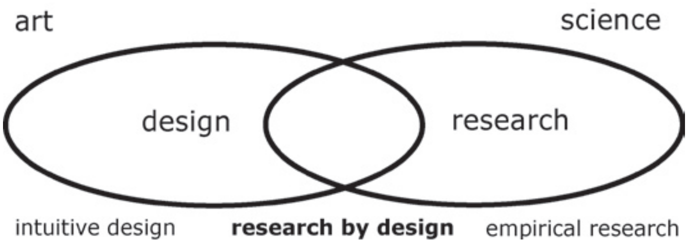

Fig. 1.02, Research by design scheme, adapted from De Jong 2002 by author.

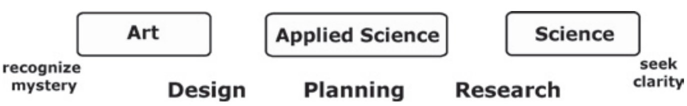

Fig. 1.03, Landscape between art and science, Jusuck Koh Lectures, Wageningen 2005.

Research by Design
In the most elementary sense, the research is the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions. On the other hand, the design is including major steps like, collection and analysis of relevant data. Research by design is a plan that guides the investigator in the process of collecting, analyzing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation.

Figure 1.04 shows how the research by design starts with a design assignment and problem statement passing on the data collection then analysis and classification phase, before making generalisations that could be proved through a design concept. In the beginning, the research process will be conducted in an inductive way until reaching the design concept phase where the research way turns to be deductive (Hoggart et al., 2002). The research by design will provide strong guidance in determining what data to collect and the strategies for analyzing the data.

The work in this thesis will interweave five phases in a cyclic process, all focusing on Landscape architecture for micro-climate improvement and energy conservation in Egypt:

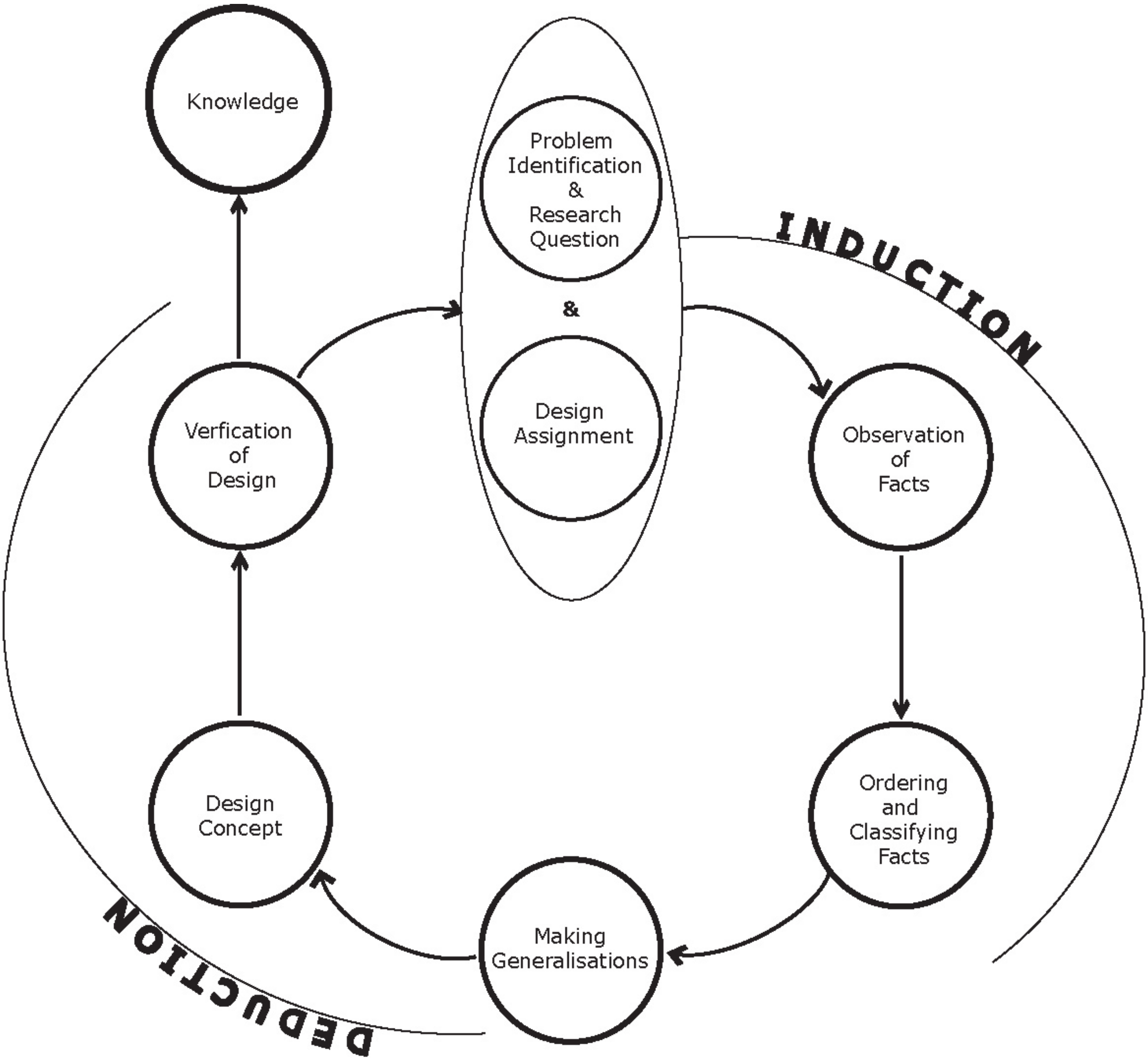

Fig. 1.04, Research by design and the cyclic process, by author.

1 Reviewing, ordering and classifying the natural physical conditions affecting landscape design and energy consumption in Egypt.
2 Reviewing, classifying and analyzing the traditional design types and solutions in similar climatic areas in order to develop design guidelines.
3 Reviewing, classifying and developing theoretically and visually the basic design guidelines and principals for micro-climate improvement and energy conservation in Egypt.
4 Developing a design concept as proof that provide support for the application of different landscape design guidelines that demonstrate, how to integrate them, in the design.
5 Verifying of the design concept in relation to the developed design guidelines.

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6 Verify the developed design concept through simulation softwares (CFD and SOALARIS) (not in this study see 1.9).

1.7 The Design Case-Study and Expected Research Results

This research will provide landscape architects with knowledge and examples of successful landscape designs, integrating landscape techniques and water surfaces. The objective of this study is to provide basic guidelines and principals, for the integration of landscape architecture techniques driven from successful, ancient examples to increase the application of traditional landscaping techniques in the Egyptian built environment.

In order to achieve this idea, a design case-study will be conducted in the hot arid desert environment of Cairo. On a 260-acre site in the centre of New Cairo, approximately 35 kilometres east of the Nile, the home of the new American University in Cairo (AUC) will be implemented in 2008. A large scale project (260 acre), recently designed in Egypt. As stated in the master-plan competition-brief of the AUC campus, this master plan should reflect the desire to create "spaces and places that facilitate, encourage, and celebrate the interactive learning process"; to translate "the university's mission into its campus setting" and to create "a showcase for ecological design." Furthermore, the designer will and tries to integrate landscape architecture and green measures to achieve an environmental optimization in his design.

1.8 Research Tools

Under the previous mentioned methodological assumptions, specific techniques will be applied in this research for data collection. The methods used in this research will not be applied in a sequential order as listed below due to the cyclic approach of the research and due to the nature of the Design Study, which generates inner research loops for each chapter in accordance to the design. The following methods are the specific techniques, which will be applied for data collection:

Literature Review

As a first step, for the research and after determining the research problem and research questions, an extensive research through digital search catalogues and web engines on the subject will be conducted to find suitable journals and books. The following key word were used: landscape design – landscape - comfort - vegetation-plants - energy conservation– energy efficient –arid climate – hot arid -passive cooling – outdoor environment – micro-climate – shading, water pond.

Observation (direct and Indirect)

As a resident of Cairo I am able to perceive reality from the viewpoint of someone ‘inside’ the site. In addition, the field observation will allow me to feel and sense the site as a step before design. Finally, indirect observations through reporting of others will another source for data.

Interviewing and Questionnaire

Interview is an important tool for data generating. A group open ended questions formed in a focused interview will be answered by interviewed Egyptian and Dutch designers (face to face) together with local plant specialist (in field) in order to stand on the latest design guidelines and considerations. This study will also refer to a questionnaire made for the users of the project describing their wishes and preferences.(see Appendix)

Site and Nursery Visit

The 113 hectares (271 feddan) site is owned by the American University in Cairo and is strictly secured and surrounded by watched fences. At least three guided tours will be conducted for data collection in coordination with the owner representative in the site. The data collection activities will basically focus on direct observation including, field interviews, photographing, soil inspection, visual and topographical study, climatic measurements and sketching. Next, the Desert Development Centre (DDC) in South Tahrir (150 north from Cairo) will be visited for being the project nursery. The visit to the DDC nursery will focus on the plants types, plants growth and plants transport in addition to the irrigation and fertilizing.

Measurements Recording

During the field trip to Cairo, some temperature and humidity measurements will be taken in some remaining traditional houses of Islamic Cairo. Temperatures and relative humidity on the roofs and in house rooms will be recorded and compared with measurements in the courtyard gardens of the same house. Next, several measurements will be taken on several locations of the project’s site. On the project site, records will be made for temperatures difference between sunny and shaded areas.

Comparative Analysis of Traditional Plans

A comparative analysis will take place for useful historical references of vernacular Islamic landscape designs like Alhambra, Moorish Spain and the Al-Suhaymi House in Islamic Cairo will be analysed. The layout and plant material of Alhambra, Generalife courts and Al-Suhaymi court in Islamic Cairo will be examined and evaluated. This study will come with a research paper that presents an overview of landscape design considerations for the composition of vegetation and water in addition to initial observations of their influence in controlling and improving the micro-climate in courtyards buildings as a way of passive cooling in the Arab world.

Inventory & Analysis

This step in the research will involve the collection of information concerning the physical, biological, and social elements of the site. The major aim of this step is to obtain insight about the natural process and human plans and activities that will take place on the new university campus. This step is an interdisciplinary collection effort that involves search, accumulation, field checking, and mapping data. But to ensure that this inventory will respond to the relevant historical, social and cultural contexts of the site together with the biophysical context the following classification systems will be followed to guide the inventory.

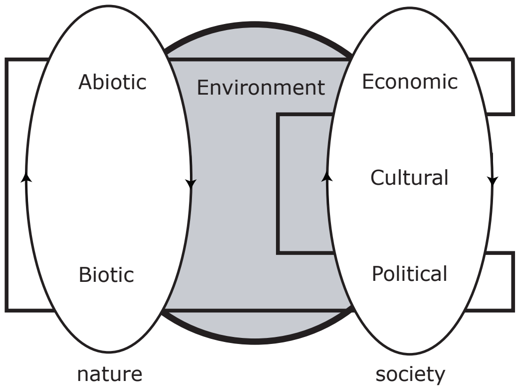

Fig. 1.05, In a balanced sustainable environment natural and social forces work in the same directions. Adapted from Kleefman by Ingrid Duchhart.

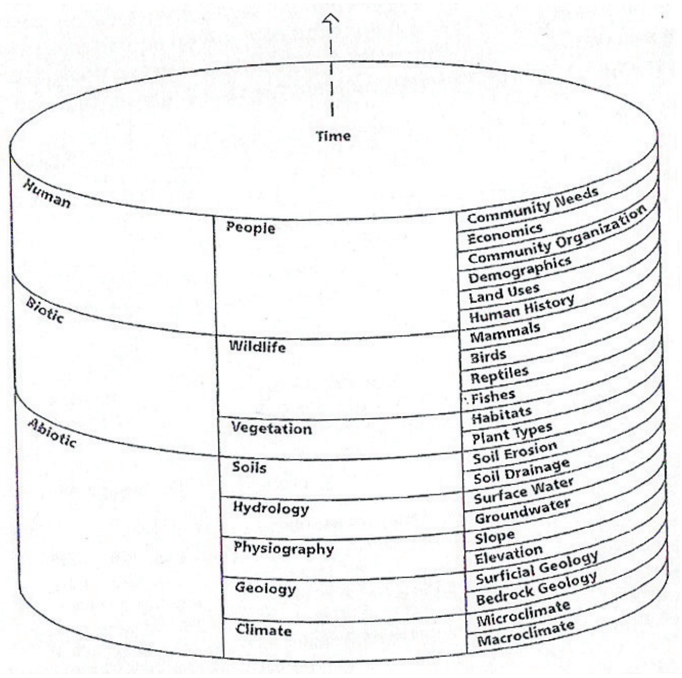

Fig. 1.06, Layer model cake, adapted by Ian McHarg.

There are several classification methods for design inventory and analysis. One of them is made Ian Macharg. McHarg and his collaborators have developed a layer-cake model 1.06 that provides a classification system for the inventoried data on needs for analysis. Similarly, in figure 1.05 Duchhart illustrates another classification system for the inventoried data.(Steiner, 2000) (Duchhart, 2000). Referring the two diagrams, the project owner and architect will be interviewed and asked for data material. An overview of the design project will be made firstly by collecting and analysing the drawings and reports related to the biophysical nature of the project. Secondly, the interviews will mainly focus on obtaining an insight to the social activities.

Schematic Design & Design Development
During and after inventorying and analysing the collected data the design process will take place. As described in figure 1.02 the design process will circulate between two poles. The first pole is inspirational, artistic and intuitive; the second is technical and empirical. The design process investigates different design alternatives or scenarios before going to the final design concept. After that, the design concept will be developed and presented on 3 A1 or 3 A0 panels, in addition to visual, spatial and technical design illustration.

Simulation & Visualizations (manual & computer aided)
Perspective drawings, sketches, impressions and photography will be used to simulate the consequences of the design plan. Computer aided three dimensional models, and a shade study will be made to determine consequences of the landscape plan.
Moreover, to evaluate the impact of the design concept on the micro-climate quantitatively I will try to use simulation software. I will follow a course called ‘Building performance simulation’ in TU-Eindhoven to analyse the design using computational fluid dynamic (CFD) software.

1.9 Research Limits

The research objective is aiming to produce guidelines for landscape design that improves the micro-climate in an energy conservative way in Egypt. As a master's research thesis this research will follow the main four steps of the empirical cyclic process and will stop before the evaluation phase or the so called design verification phase. See 1.1 and 1.6.

On the ther hand, the AUC Master Plan will be my case study. I will use the existing buildings, already designed and located on the layout, as a constraint. Any changes to the buildings layout will not be allowed. This determination will be made in order to have a better control over the site and to focus on the landscape design task.

However, as a researcher, I will focus on conducting the research by design. The generated knowledge of this research should respond to the research problem and lead to a design concept as proof that provide support for the application of different landscape design guidelines. The simulation based verification of the design will be beyond the research limits. This does not mean that this sixth element of the empirical research cycle will be totally neglected, but it will not be the research focus.

1.10 Conclusion & Research Map

To sum up, this thesis is a combination between design and research. Both, the design and research are perceived and developed in a cyclic process. As shown in the research map (fig. 1.07), the design and research proceed parallel. The aim of the research is to provide landscape architect with design guidelines and design principals as highlighted in the grey window called 'Design Guidelines and Principals'. The research will go from a divergent brainstorming phase, including steps such as field visit, literature review, and comparative analysis, while the design is narrowing this phase to a convergent phase.

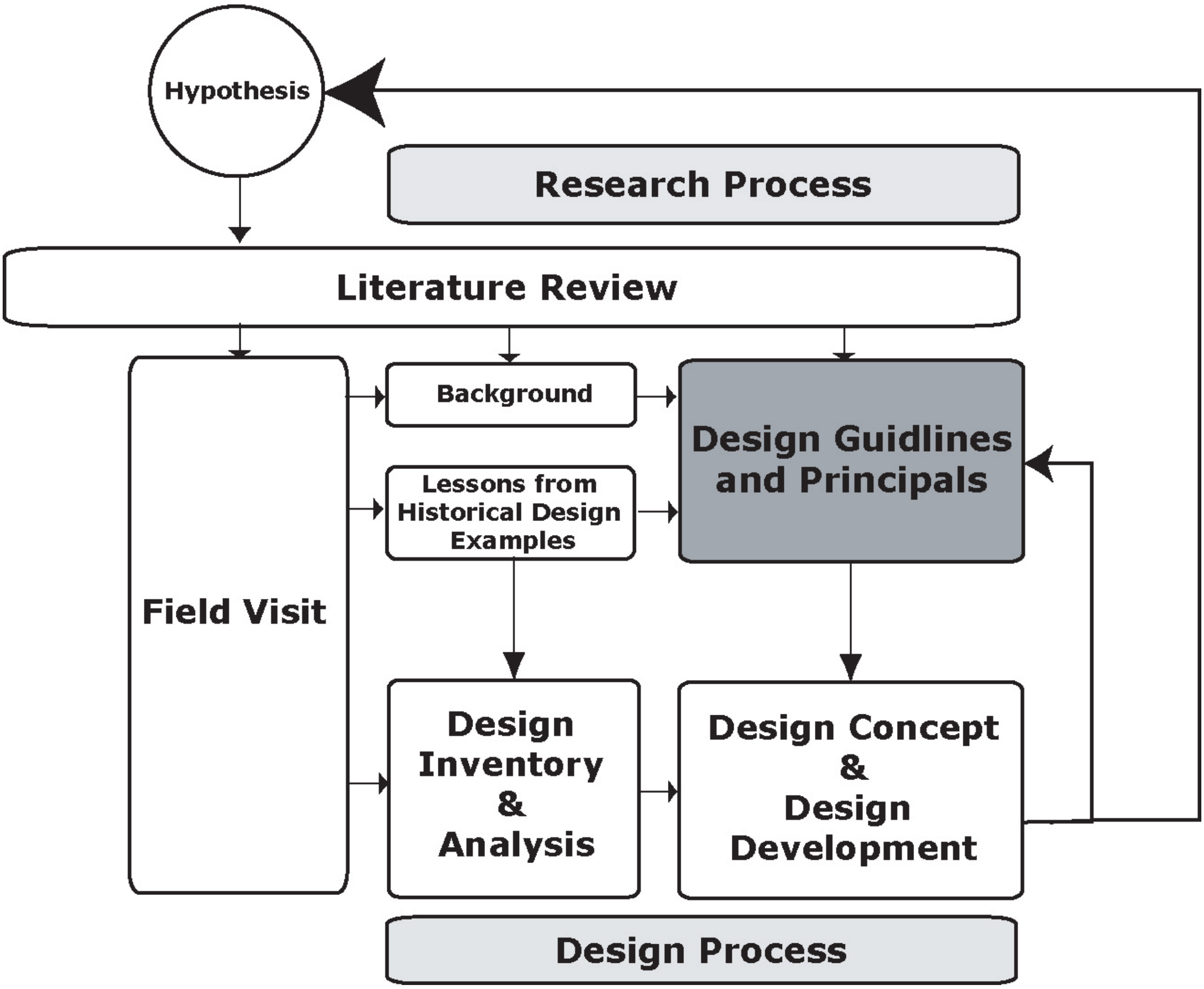

Fig. 1.07 showing the research map, by author.

Chapter 1: References

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Chapter 2

Background

Chapter 2

Chapter 2: Background

In the very cradle of all human civilisations is a land which from the peculiar character of its soil and climate was bound to show an early and important development in garden cultivation. This land is Egypt. Here the Nile by its own independent work has wrested from the desert a valley, narrow and long. Every year its waters, pouring forth blessing and fruitfulness, take on themselves that work which in other places has to be carried out by the care and pains of men the work of conveying to the earth the nourishment obtained from the earth.

The following pages I shall be presenting the natural physical conditions within Egypt's hot arid environment. Before starting to describe Egypt's abiotic conditions a short introduction will explain the relation between the climate and comfort and its types in arid environments. It should be understood that the notes and maps which follow can only give a generalised background to Egypt, and for more detailed information the reader is referred to the bibliography.

2.1 Man in the Arid Environment

There are few places in the world where man can live in relative comfort without relying on a built environment for protection. The desert is no exception. Deserts have average temperatures above 0^{o}C in the winter and above 18^{o}C. a hot arid climate has a strong sunshine with a large portion of direct radiation. The clear night sky can cause great differences between day and night temperatures, and the potential for radiative cooling. Winter nights are cold in certain regions.

The structures that we build and their impacts on the immediate surroundings like the landscaped outdoor areas, paving for sidewalks, parking lots etc. impose themselves on the existing natural conditions. Excessive or unprotected paving can cause hot spots and unwanted glare around our buildings. Cold winter winds may be inadvertently channelled through the courtyards, or cold air can surround the property at night. Negative impacts such as these not only create uncomfortable living conditions but they can be costly, requiring more energy to cool or heat our buildings. Proper placement of a simple shade tree, for example, can reduce wall and roof temperatures by as much as 6 to 16 ^{o}C even in temperate climate(Miller, 1980).

The location and nature of structures, landforms, plantings, and surface materials can either aggravate or ameliorate climatic problems for any site by the microclimates they create. On of the primary objectives of responsive environmental design is to modify the extremes of any particular environment, to increase or decrease the effects of prevailing conditions. We may wish to make the environment cooler or warmer, less windy or breezier, drier or more humid. In essence we are attempting to create zones of comfort through the modification or creation of various microclimates for a given situation.

2.2 Comfort and Climate

2.2.1Comfort Types

Thermal comfort
Thermal comfort is affected by measurable, personal and psychological factors. Personal factors included metabolic rate and cloth choice. Psychological pr perceived comfort factors can override measurable factors; people often feel cooler near a body of water, despite negligible differences in measurable factors.

Measurable comfort factors include air temperature, radiant surface temperature, relative humidity and air movement. Figure 2.01 shows a simplified psychometric chart as quantified by the American Society of Heating and Refrigeration Engineers (ASHRAE). The comfort zone in Cairo may shift slightly to the right, about 3 degrees C, as indicated by the yellow oval, because Egyptians are more comfortable at higher temperatures. In the outdoor environment, people tolerate more variation in thermal conditions, and are comfortable over a wider range of temperatures. Acceptable air temperature for Cairo, range between 23 degree C and 31 degree C, with relative humidity between 20% and 72%. When temperatures fall below 23 degrees C, solar exposure is desirable; above 31 degree C, shade is required for comfort. The solar radiation is desirable in most of December, January and February, as well as in the morning and late evening in November, March, April and May. Conversely, shading and cooling strategies such as air movement and evaporative cooling, in lower humidity conditions, are needed during midday and afternoon hours in May through October.

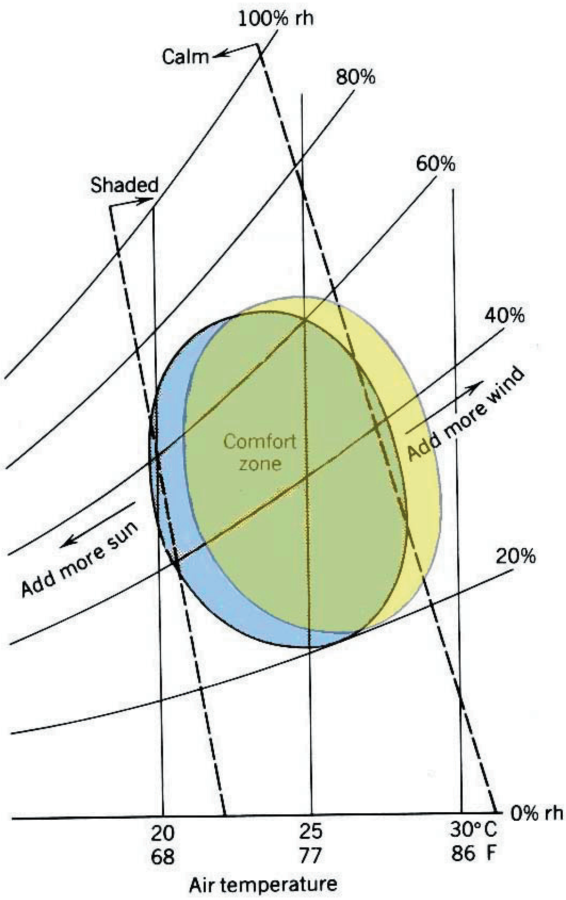

Fig. 2.01, Psychometric chart as quantified (ASHRAE).

Hygienic comfort
Adequate hygiene requires an adequate and convenient supply of clean air. The hygienic comfort means the quality of the outdoor air in terms of the absence of dust and presence of nice odours.

Visual comfort
The sun has been the main source of light and heat on our planet. Man has, through evolution, become to depend on daylight and sun light. The beauty, but also the challenge to the landscape architect and engineer, comes with the fluctuations in light levels (glare or darkness), colours and the direction of the natural light.

Psychological comfort
The attention must be drawn to the psychological aspect that plays a major role, especially the landscape architecture that is keen microclimate improvement. The “Pleasant” natural conditions that positively affect our psychological disposition are the prime characteristic of the landscape architecture that is generally believed to be non-quantifiable. However, the number of studies demonstrates tangible results, for example, the conditions that affect our behavioral aspect and subsequently lead to varying degrees of compliance to the circumstances that is widely known as Adaptive Behavior - the capacity of a person to adjust in varying climatic conditions.
So when the well executed natural conditions (e.g. the sight and the sound of water, the extent of lush green sprawl, the innate fragrance of the soil and the plants or the wind that is made to channel through the building etc.) are integrated within the design, the outdoors are transformed into highly desirable zones. And also the fact that such measures help to contemplation, relaxation, and spiritual rejuvenation.

2.2.2 Climatic elements

Temperature
The dry bulb temperature (°C, °F or K), is probably the most commonly used unit to describe climate. Air temperature is measured with a dry bulb thermometer protected from solar and heat radiation. This data is generally available in meteorological records as monthly means, maximum and minimum values. The wet bulb temperature (wbt) is the temperature at which vapour saturation occur.

Humidity
Air contains a certain amount of vapour, which is called air humidity. Humidity can be specified as absolute humidity in grams per kg or m^3, or as partial vapour pressure (kPa). But the expression 'relative humidity' is more common (RH %), which express the amount of vapour in relation to saturation. Hot air can contain vapour more than cold air. When the air is cooled to the limit, or dew point, the surplus condenses. Relative humidity can be measured with electronic hygrometers or with simple sling hygrometer including a dry bulb and wet bulb thermometer.

Winds
At local level wind is the most irregular and varying component of the climate. It is affected by topography, vegetation and surrounding buildings, closeness to the large water surfaces may create onshore and offshore winds. Wind is described by its speed and direction and is measured by an anemometer. Frequency diagrams, wind roses, are often drawn for each month of the year or for the main seasons.
There are three general classifications of airflow (Fig 2.02)

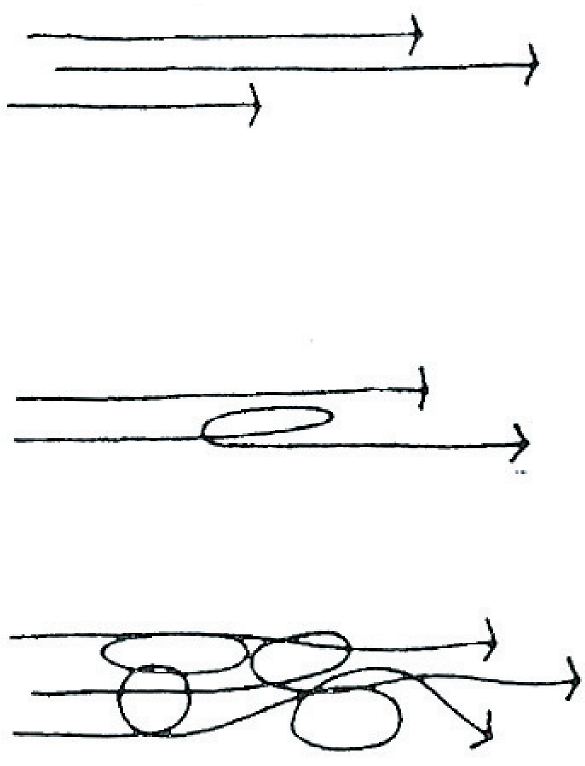

Fig. 2.02, Three types of wind flows (Miller 1980).

1.Laminar airflow, where parallel layers of air flow smoothly one on top of another in a predictable pattern.
2.Separated airflow, where a separation of layers may result in some turbulence between layers.
3. Turbulent airflow, where air masses travel in the same direction but with a random pattern and with unpredictable velocities.

Laminar airflow, being more predictable, is the easiest to control. Turbulent airflow is the most difficult to control. Turbulent airflow is the most difficult to control.
Air has a viscosity coefficient of zero, which simply means it flows freely when unobstructed. Obstacles placed in its path will generate forces between air layers and can lead to separation and turbulence. If the obstacles, or barriers, are streamlined, the air will flow freely around it relatively unimpaired. The air layers next to the surface will speed up, but no real turbulence between layers results and the flow quickly resumes its original path. On the other hand, if wind strikes a non-streamlined or bluff barrier, such as a building, the air layers have a difficult time following the contours and separation of the air layers and turbulence will result. The degree to which airflow changes from laminar to turbulent, therefore, is a function of the roughness of the surface over which the air is flowing. (Fig 2.03)

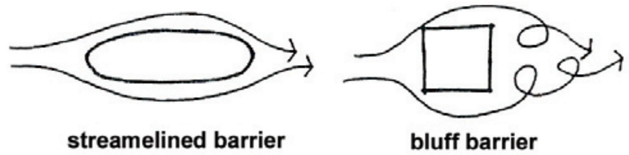

Fig. 2.03, Air flow changes in relation to obstructions (Miller 1980).

Precipitation
Rains are very rare in Egypt. Precipitation is almost neglected but in the winter seasons, some heavy showers occur.

Solar radiation and sky conditions
Solar radiation is the driving force for systems of our biospehere. It is the most influential climatic factor that powers global weather systems. In hot arid climate it can be intolerable to live with the sun and a searing hot sun can send one on research for shady retreat.
In general, the sun's path is regular and depends on the latitude and the time of the year. The season also determines the total amount of irradiation through the length of the day. High altitudes give more intense solar radiation, because there is less absorption in the relatively thinner layer of atmosphere.
The position of the sun is determined with the help of solar diagrams. There is one diagram for each latitude, making it possible to read the altitude (vertical angle) and the azimuth (horizontal angle) and the azimuth (horizontal angle) of the sun at every hour of every day of the year.
Short-wave solar radiation is divided onto direct (I_D) and diffuse (I_d) and the sum of these is global radiation (I_{GL}). These are often measured on a horizontal surface (W/m^2), but normal (I_N) radiation, facing the sun, is commonly used. Also values for vertical surfaces in various directions may

be found. The relation between direct and diffuse radiation varies with sky conditions. Humid air or overcast skies increase the diffuse part. Overlays to the solar diagram may be give data on solar radiation on horizontal or other surfaces, but corrections for cloudiness and humidity must always be considered. Reflections from the ground and adjacent buildings, and shading from adjacent buildings and vegetation, affect the total solar radiation. (Rosenlund, 2000)

Dust and sandstorms

Winds blow across the desert landscape with varying intensities, temperatures, and directions throughout the year. Uncontrolled, wind can be both annoying and destructive to the human environment. Large quantities of erodible silt and clay are transported by the wind and deposited throughout urban areas contributing to air pollutants. Also, because of its abrasive nature, windblown sand can be damaging to anything in its path. (Miller, 1980)

Comfort

The human being, like other bodies, exchanges heat with its environment through conduction (by direct conduct), convection (transported by air), radiation (mainly short-wave visual light and long-wave heat) and evaporation/ condensation (heat released through change of state of water, also called latent heat). Factors influencing the heat balance are environmental, such as air and mean radiant temperatures, vapour pressure and air motion, but also individual, such as metabolic rate and clothing.

Comfort is subjective experience, and not all people agree optimal comfort. To handle comfort, it was necessary to define some kind of index, or ‘comfort zone’ where the majority of people experience well-being. This is normally done by the votes of a population in an experimental situation. A number of scales are developed, and some are shown in Table 2.01.

Table 2.01 including the thermal sensation scales (Based in part on Markus and Morris 1980).

	ASHRAE	Fanger (PMV)	Rohles Nevins	Gagge's DISC	SET (oC)
Painful			+5	+5	
Very hot			+4	+4	37,5-
Hot	7	+3	+3	+3	34,5-37,5
Warm	6	+2	+2	+ 2	30,0-34,5
Slightly warm	5	+1	+1	+1	25,6-30,0
Neutral	4	0	0	±0.5	22,2-25,6
Slightly cool	3	-1	-1	-1	17,5-22,2
Cool	2	-2	-2	-2	14,5-17,5
Cold	1	-3	-3	-3	10,0-14,5
Very Cold			-4	-4	

Gagge’s DISC index expresses degrees of discomfort rather than comfort. The most common definition of the ‘comfort zone’ is DISC ±0,5, which means that 80% of the population is satisfied, though extending limits to DISC ±1, where 70% are satisfied, could be proposed when resources are limited.

The Standard Effective Temperature (SET) developed by Gagge et al. (Markus and Morris 1980) describes a uniform environment with:

- 50% relative humidity,
- Air speed of 0.125 m/s,
- Activity level of 1 met (sitting) and
- Clothing of 0.6 clo (‘indoor clothes’).

An air temperature of 20^{o}C in these conditions results in a SET of 20^{O}C. A change in any of the parameters will result in a change of the SET.

2.4 Geography of Egypt:

The land of Egypt occupies the north-eastern corner of the African continent. The area of Egypt constitutes 3 % of the total area of Africa. It is bordered on the north by the Mediterranean Sea, on the south by Sudan, on the west by Libya, and on the east by the occupied lands of Palestine, the Gulf of Aqaba and the Red Sea. Egypt appears as a quadrangle whose length from north to south is about 1073 kilometres, and whose width exceeds its length by about 189 kilometres. Thus the total area o Egypt is a little more than one million square kilometres (1.019, 600 sq. km.).

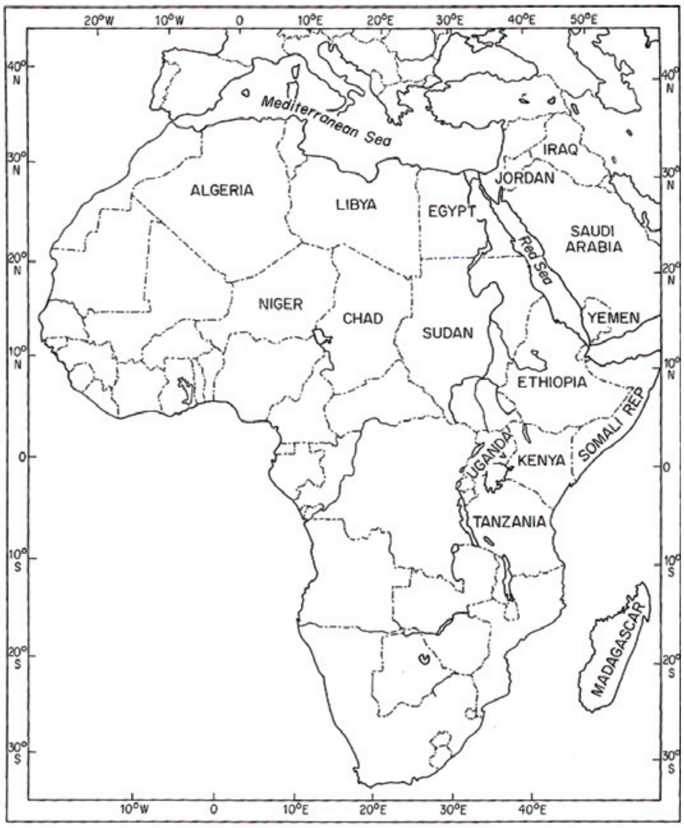

Fig. 2.04, Egypt in the African context (Zahran M, Willis A. 1992).

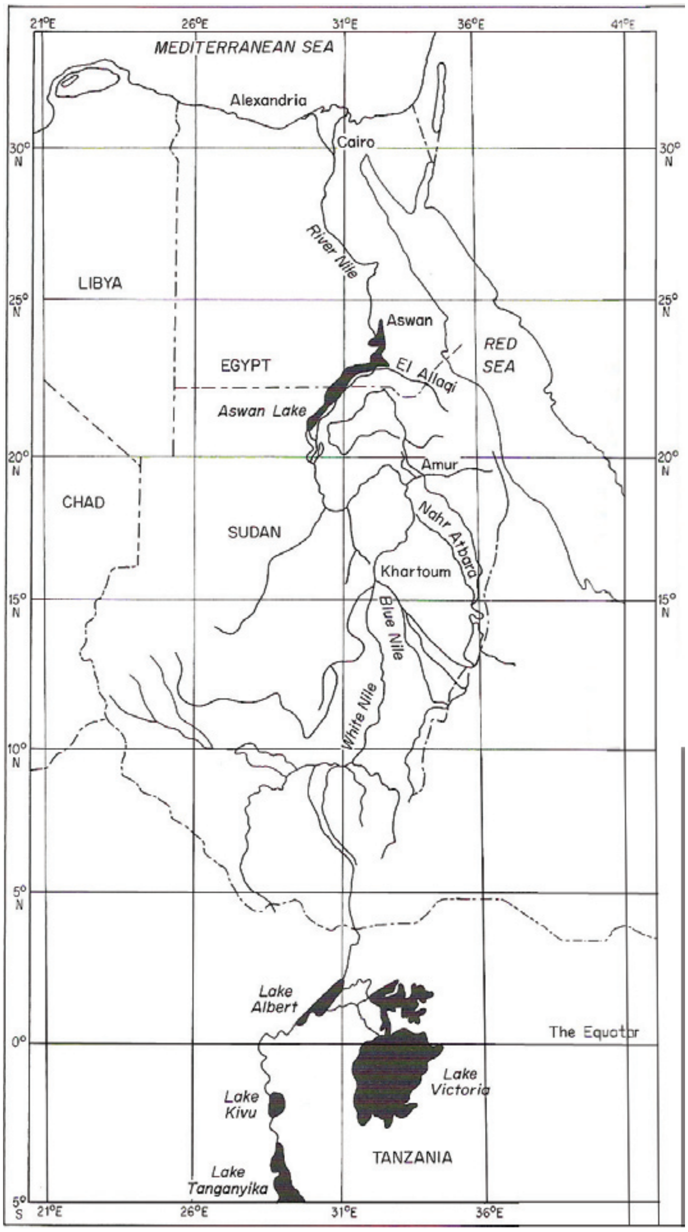

Fig. 2.05, The Nile Basin (Zahran M, Willis A. 1992)

Egypt extends over about ten degrees of latitude, being bounded by latitudes 22o N and 32o N. about a quarter of its area lies to the south of the Tropic of Cancer. This latitudinal location means that most of Egypt falls within Africa's dry desert region, excepting a narrow strip of land far north, which experiences a Mediterranean type of climate. The empty, barren deserts occupy more than 96% of the total area of the country. The only inhabited part of Egypt is a longitudinal oasis corresponding to the lower Nile Valley. This setting is where Egypt's inhabitants have concentrated since the dawn of human history.

The Nile enters the land of Egypt, flowing from the south, at the village of Adinan on the Egyptian-Sudanese frontiers. The river flows across Egypt for a distance exceeding 1530 km. until finally discharging its water into the Mediterranean Sea./ the Nile in its lower course in Egypt has no tributaries to supply it with water other than a few dry wadis entering from both banks. These wadis are rarely filled with water.

Egypt comprises four main geographical units (Said, 1962):

1-The Nile Valley and the delta
2-The Western Desert
3-The Eastern Desert
The Sinai Peninsula

The Nile is more than 6650 km long from its source near Lake Tanganyika to its mouth in the Mediterranean Sea, but only about 1530 km lies within Egypt and in the whole of this part there is

Fig. 2.06, Satellite image for Egypt, Feb. 2000 (www.gesource.ac.uk).

2.4 Geology of Egypt:

In early geological time, Egypt was invaded on several occasions by the Sea of Tethys. This old geologic sea is the antecedent of the Mediterranean Sea and has always invaded on Egypt from the north. During late geological periods, the land of Egypt was uplifted, such uplift leading to a retreat of the Sea of Tethys. The retreating sea must have left behind sediments and remnants of the living organisms which it contained(Abu Al-Izz, 1971). Proof of this is the great quantity of sea shells spread over the surface of the Egyptian inland desert and the recently discovered nearly complete 18 meter long Whale skeleton in Wadi Hitan desert.

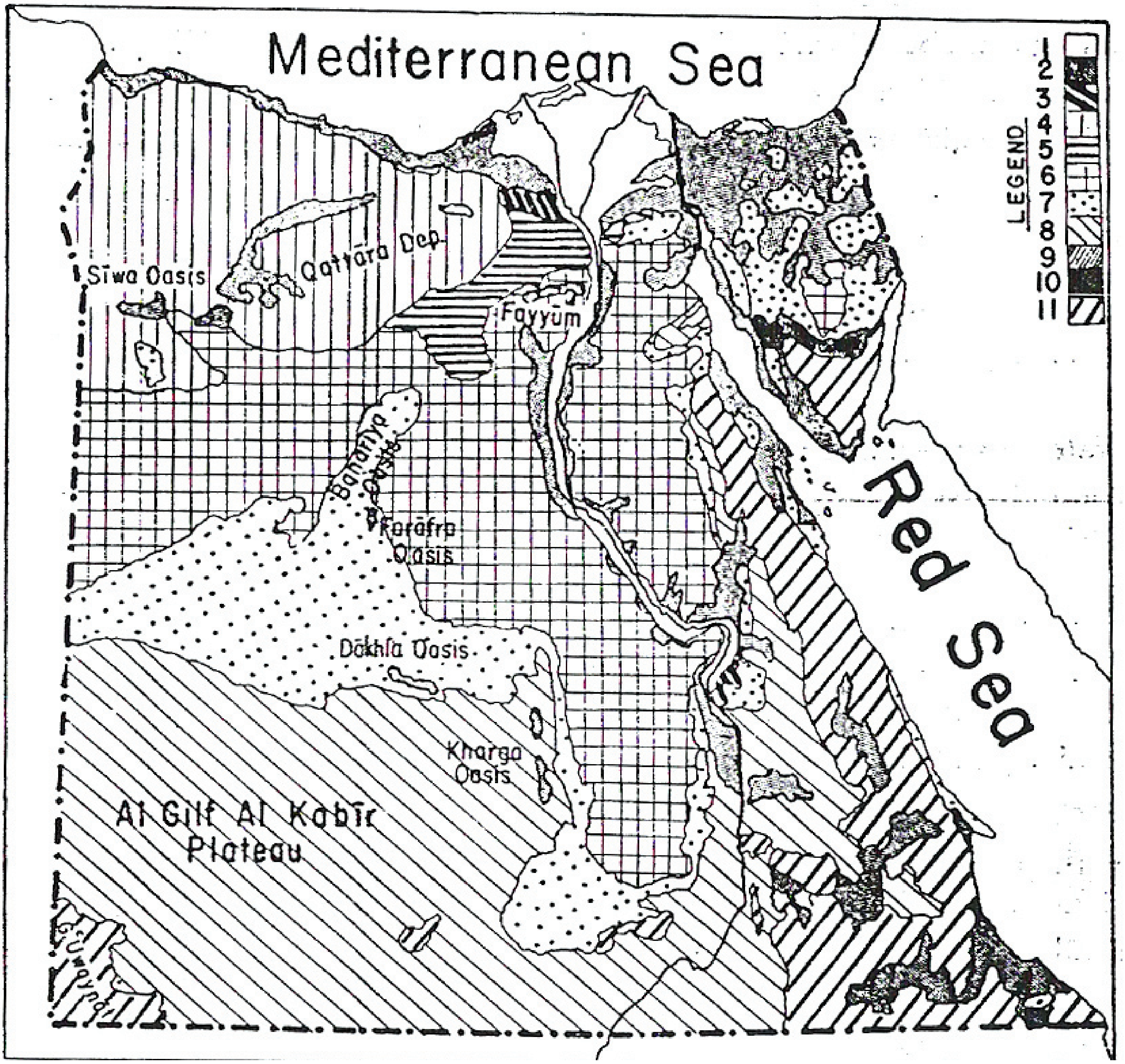

Fig. 2.07, The geological formation of Egypt (Abu Al-Izz M. 1971).

2.5 Climate of Egypt

Egypt is an arid country. The earlier European glaciations seem to have left the Egyptian desert dry, but the long span of drought was broken by at least two rainy interludes; the first when the desert, both east and west of the Nile, was habitable in Middle Palaeolithic times, the second, with light rainfall, from about 8000-4000 BC. An occurrence of subsoil water near the surface in the southern part of the Western desert permitted people to live there in oases till about 3000 BC when a drop of the water-table turned these places inhabitable.

The source of water all over the Eastern Desert is the rainfall on the chains of the Red Sea Mountains. These mountains seem to intercept some orographic rain from the continental northerlies which absorb their moisture through passage over the warm water of the Red Sea. The mountain rains may feed the wadis of the Eastern Desert with considerable torrential flows.(Hassib, 1951)

According to Ayyad and Ghabbour (Ayyad and Ghabbour, 1986), Egypt can be divided into two hyper arid and two arid provinces as follow:

1. Hyper arid provinces

a. Hyper arid with a mild winter (mean temperature of the coldest month between 10^{o} and 20^{o} C) and a very hot summer (mean temperature of the hottest month more than 30^{o} C), including the south western part of the Western desert.

b.Hyper arid with a mild winter and a hot summer (mean temperature of the hottest month 20-30^{o} C) covering the Eastern desert and the north eastern part of the Western Desert and Gebel Uweinat area.

Arid provinces

a.The northern section with winter rainfall which extends along the Mediterranean coast and the Gulf of Suez. This section is divided into two provinces by the UNESCO/FAO map of 1963: the coastal belt province under the maritime influence of the Mediterranean, with shorter dry period (attenuated), and a more inland province with a longer dry period (accentuated) and an annual rainfall of 20-100 mm. Both provinces are characterized by a mild winter and a hot summer.

b. A southern section with winter rainfall which includes one province – Gebel Elba area of the Red Sea coast of Egypt.

Another classification of Egypt climatic provinces was made by the Egyptian Organization for energy planning (OEP, 1998). Based on the data collected from 45 weather station all over Egypt the below illustrated map classifies Egypt's weather into 7 climatic zones (Fig. 2.08).

Wind

Winds in Egypt are generally light. The climate is cloudless with a prevailing north wind assuring a reasonable temperature. But violent dust storms and sand pillars are not rare. El-Khamassin winds blows occasionally for about 50 days during spring summer. Fig 2.09 shows a Khamassin wind storm in spring 2000 over Egypt where the visibility reached 3 meters.

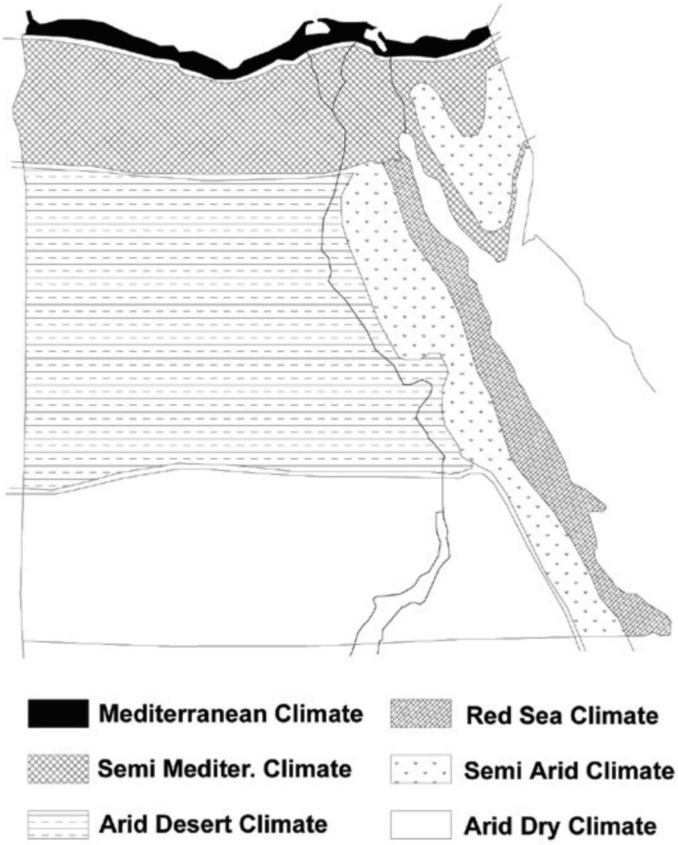

Fig. 2.08, Climatic zones of Egypt (OEP 1998).

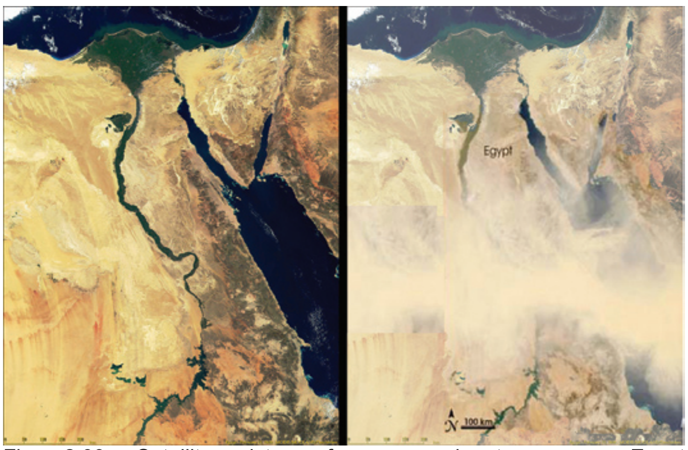

Fig. 2.09, Satellite picture for a sand storm over Egypt (www.gesource.ac.uk).

2.6 Soil & Vegetation:

Soils of the hot arid regions are estimated to occupy 31.5% of the land of the world (excluding the polar deserts). Africa has the largest area (17.7 million km^2) while Australia has the greatest percentage (82.1%) followed by Africa (59.2%), with Asia 33.0% and Europe only 6.6%. In Egypt, the soils fall into two main categories or orders as recognized by the US Comprehensive System of soil classification(Dregne, 1976):

Aridisols (essentially desert soils) and Entisols (alluvial soils and soils of sandy and stony deserts). Aridisols, which are confined to arid regions, are mineral soils distinguished by the presence of horizons showing accumulations, e.g. carbonates, soluble salts, in the profile typical of development in dry regions. These horizons have been formed under recent conditions of climate or those of earlier pluvial periods. The horizon at the surface (the epipedon) of this soil is light-coloured and there may be a salic (salty) horizon near to the surface or an argillic (clayey) horizon. These saline soils are well represented in the coastal plain of the Red Sea. Most of the times when temperatures are favourable for plant growth aridisols are dry or salty, with consequent restrictions on growth. Entisols, the most common type in arid regions, are mineral soils with little or no development of horizons. This lack of pedogenic horizons is because the soils are young as a result of recent deposition of material, or the

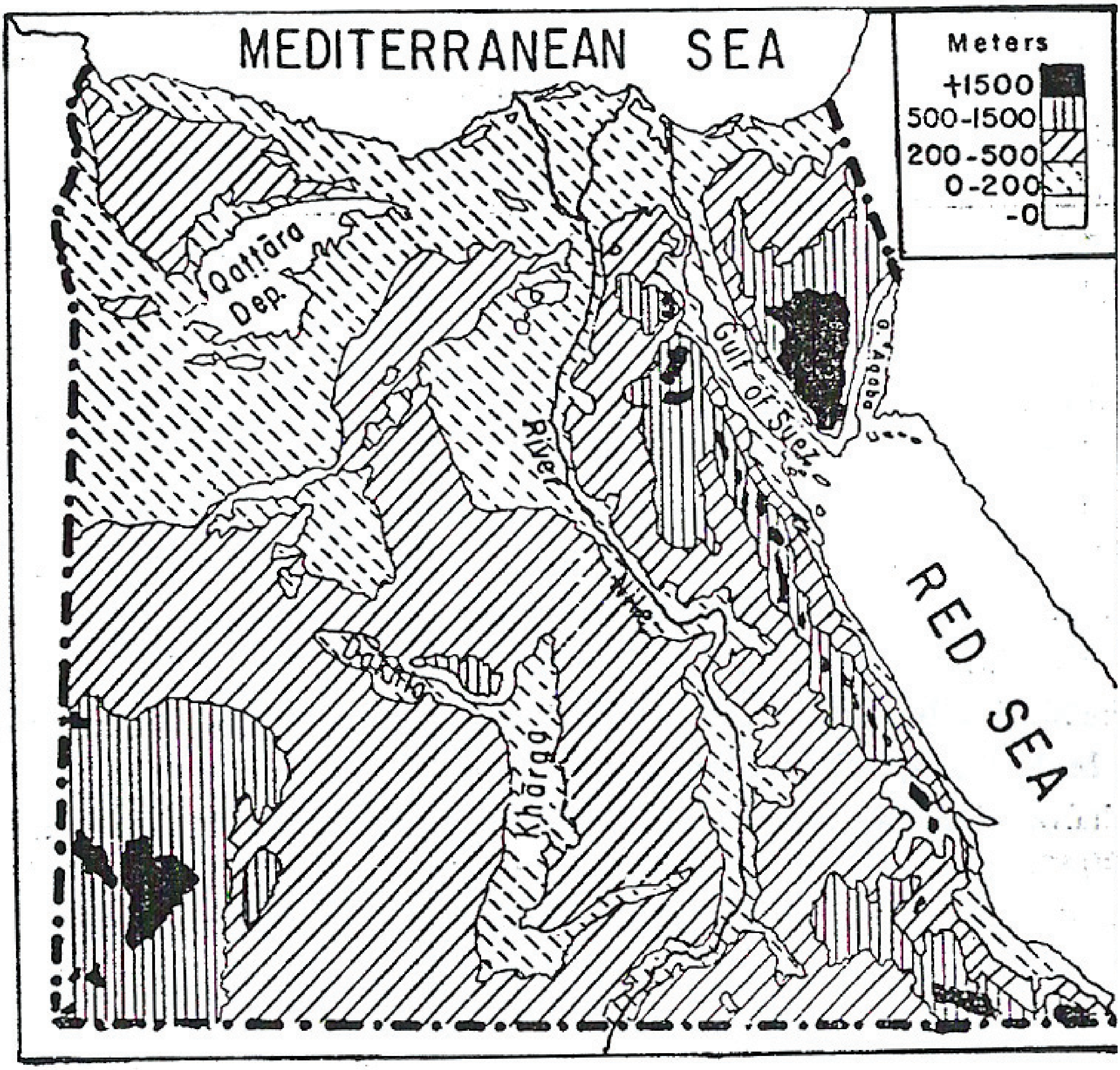

Fig. 2.10, Relief of Egypt (Abu Al-Izz M. 1971).

former surface has been lost by erosion. Saline soils of this type, with a water-table sufficiently near to the surface for salts to move upwards and be deposited at or near the surface at some time in the year, are represented in the lower Nile and the Qattara Depression of the Western Desert(Dregne, 1976).
The general characteristics of the soils of arid regions and their relationship with climate and vegetation are described by many authors, e.g (Dregne, 1976), (Ayyad and Ghabbour, 1986) and (Kassas and Imam, 1959).Such studies show that the soils of Egypt have many features distinguishing them from their better-known counterparts of humid regions. Usually, soils of arid lands have a low level of organic matter, are slightly acid to alkaline in reaction (McPherson et al.) at the surface, show an accumulation of calcium carbonate within the topmost 1.5m, have weak to moderate profile development, are of coarse to medium texture and have a low biological activity (Dregne, 1976). Frequently, and especially in upland area, aridisoils show a surface layer of stones, pebbles and gravels that constitutes a desert pavement, from which the fine particles have been lost by the action of wind and water. In some soils soluble salts may be present in sufficient quantities to influence the growth of plants significantly, particularly in poorly drained depressions, along coastal deserts and where there are appreciable amounts of gypsum. The lack of organic matter and the large particle size of some soils result in a low water holding capacity, with also relatively low levels of micro-organisms.
Variability of ecosystem structure and function is generally a product of interactions between its different components. In the extreme environmental conditions of arid lands these interactions are of high significance, so that slight irregularities in one component of the ecosystem are likely to lead to substantial variations in others, so creating distinct microhabitats. In arid lands, the interrelationships between soils, vegetation and atmosphere are so interconnected that, in an ecological perspective, they can hardly be considered as separate entities.

Climatically induced processes of weathering, erosion and deposition are continuously at work, dissecting the desert landscape into a variety of landforms and fragmenting the physical environment into a complex mosaic of microenvironments. The impact of rainfall is unmistakable. A decade or even a century may pass before a desert ecosystem experiences a heavy precipitation, but when rain does fall, it results in a great deal of erosion and deposition owing to the sparseness of vegetation which offers little or not protection to the soil. Major erosion forms now present in deserts generally result from fluvial action. Some, such as wadis and their affluent, are undoubtedly relict features derived from past periods of heavier rainfall, but many are attributed to occasional heavy rainfall at the present time. Because of the scarcity of rainfall, the high evaporation rate and the sparseness of vegetation in arid lands, salt accumulation close to the soil surface is a common phenomenon. This is obvious in the coastal belts affected mainly by maritime factors and in the inland depressions where the water-table is very shallow or exposed.

The role played by vegetation in the development of desert soils varies with the degree of aridity. In extremely arid regions with very scanty vegetation, as in most areas of the Egyptian deserts, the role of vegetation is insignificant and soil development is essentially a geomechanical process where calcareous, siliceous and gypseous crusts or subsurface pans are formed. As rainfall increases, as in the northern Mediterranean coastal belt in Egypt, the vegetation becomes denser and plants assume an important role in modifying edaphic conditions. In the book ‘the Vegetation of Egypt’ (Zahran and Willis, 1992) Batanouny and Batanouny show that desert plants may also play an active role in stabilizing surface deposits. Some are capable of building mounds and hillocks which form suitable micro-habitats for certain annuals, whereas others are instrumental in arresting the movement of large dunes, rendering them less mobile and more suitable for colonization by other plants.
The original natural vegetation included the palm, sycamore, fig, vine, reed and lotus; because of inundations there were no forest. The concept of environment was one of absolute stability, based on annual repetitive cycle of natural events (see appendix IV).

Water and hydrology

The River Nile is the main source of water for Egypt, with an annual allocated flow of 55.5 km3/yr under the Nile Waters Agreement of 1959. Internal surface water resources are estimated at 0.5 km3/yr. This brings total actual surface water resources to 56 km3/year. The Nubian Sandstone aquifer located under the Western Desert is considered an important groundwater source. The volume of groundwater entering the country from the Libya is estimated at 1 km3/yr. Internal renewable groundwater resources are estimated at 1.3 km3/yr, bringing total renewable groundwater resources to 2.3 km3/yr. The main source of internal recharge is percolation from irrigation water in the Valley and the Delta. The total actual renewable water resources of the country are thus 58.3 km3/yr.

All drainage water in Upper Egypt, south of Cairo, flows back into the Nile and the irrigation canals; this amount is estimated at 4 km^3/yr. Drainage water in the Nile Delta is estimated at 14 km^3/yr. Treated domestic wastewater in 2001/02 was estimated at 2.97 km^3/yr. There are several desalination plants on the coasts of the Red Sea and the Mediterranean to provide water for seaside resorts and hotels; total production in 2002 was estimated at 100 million m^3. Estimates of the potential of non-renewable groundwater in the eastern and western deserts, mainly from the Nubian Sandstone aquifer, vary from 3.8 km^3/yr to 0.6 km^3/yr; the latter estimate is defined as an indicator of exploitability over a period of time, where the time is not given.

The question of ultimate water supply resources in some parts of the Egyptian desert will be a crucial in the future. Water may be found in oases and sinking wells, but are necessarily limited and excessive pumping will result in the aquifer being invaded by brackish or saline water. The use of water must be controlled by successful thrifty way.

Conclusion:

Summing up the existing environmental conditions, it can be said that Egypt is an area of extremes, and sharp contrasts; strong sunlight and deep shadows; burning hot days and cool nights; dry months and sudden deluges; steep jagged *jebel* hills and flat sand plains, lush tropical vegetation where there is water and stony waste where there is non. Skies are blue and man-made colours are primary, but all natural elements, animals, soils and plants, take on the muted ochres of the sands themselves. It is a tranquil land. Its peace shattered only by the sudden violence of nature or man.

Considering the natural vegetation, the desert vegetation is by far the most important and characteristic type of the natural plant life of Egypt. It covers vast areas and is formed mainly of xerophytic shrubs and under-shrubs, e.g. *Anabasis, Hammada, Leptadeniua, Lycium, Thymelaea* and *Zilla,* robust grasses like *Panicum*, and a few trees of varied height and vigour , e.g. *Acacia* and *Balanites,* usually growing in the large wadis of the desert.

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Chapter 3

Lessons from Historical Landscape Design Examples

Chapter 3

Chapter 3: Lessons from Historical Landscape Design Examples

This chapter presents an overview of traditional landscape design types and solutions over Egypt's history. This chapter will also review considerations for the composition of vegetation and water and initial observations of their influence in controlling and improving the micro-climate in and around traditional buildings as a way of passive cooling in similar climatic and cultural areas. The objective is to identify the comfort improvements potential of successfully-planned and integrated landscape design of historical design examples. During this chapter I will focus on the Pharonic and Islamic era, while, a comparative analysis will take place. Useful historical references of vernacular Islamic landscape designs like Alhambra, Moorish Spain and the Al-Suhaymi House in Islamic Cairo will be analysed. The layout and plant material of Alhambra, Generalife courts and Al-Suhaymi court in Islamic Cairo will be examined and evaluated. This chapter demonstrates that in arid environments, the landscape planning, the composition of vegetation and water and choice of planting material all have important consequences in creating thermally-pleasant environments.

3.1 The Garden Concept in Ancient Egypt

Gardens and landscape in Ancient Egypt has a long and complex history. This chapter attempts only an overview. Because history is a source of inspiration and a drawer of lessons we should study the history of landscape architecture in Egypt.

The Egyptians created a complex and bewildering theology that drew on the sun and the sky as well as every form of life, and later included a pantheon of human gods and goddesses. Their beliefs greatly influenced the ancient world and have since been incorporated into many present day religions. Egyptian understanding and knowledge of plant and animal life was incorporated into both religion and art.

Gardens were not simply to create pleasant environments to the Ancient Egyptians. There were many symbolisms associated with trees, including to specific gods such as Osiris, Nut, Isis and Hathor. They also had creation overtones, as well as funerary. The Papyrus and Lotus plants were symbolic of the two regions of Lower and Upper Egypt. Of course, gardens also provided food including vegetables and wine, and in the final analysis, we might know much less about ancient Egypt if it were not for the papyrus paper used through most of Egyptian history. In general, houses, palaces, temples and chapels, whether funerary or private, when in the paintings of the tombs nearly always have a garden connected to the building. However, Egyptian's gardens are the founders of our present-day formal gardens which use plants as architectural elements. Because there was essentially no natural landscape, the Egyptians created one based on straight lines and symmetry. They represent human domination over plants and an ordered, artificial environment. It is the antithesis of the naturalistic gardens of Asia which strove to emulate the natural scenery.

The Development of the Ancient Egyptian Gardens

In Egypt, examples exist of various approaches to the problem of designing a garden or landscape in that particular arid climate. The most obvious is that of the oasis that presents a contrasting form against the desert landscape (Fig 3.01.). Another approach is that of the garden tomb which tries to hide itself in the canyon walls of the Nile (Fig 3.02). A third approach may also be found there, that of a landscape architecture that attempts to adapt itself climatically within walls into the desert.

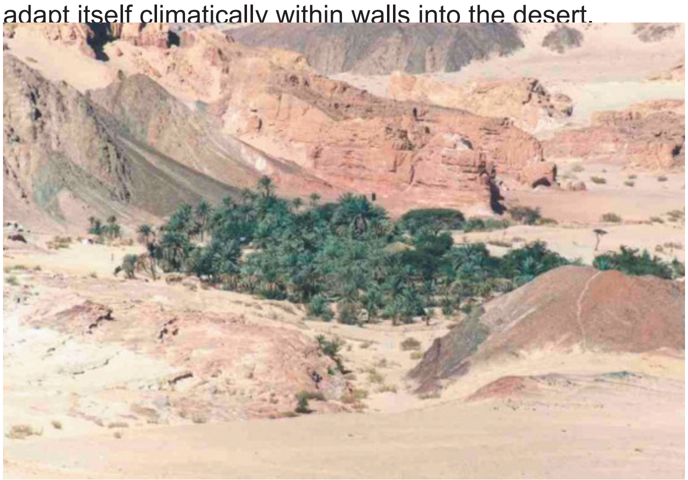

Fig. 3.01, Ain Khudra is approx. 8 km away from the main road (way from Nuweiba to St. Catherine).

Fig. 3.02, Queen Hatshepsut's Temple is the world oldest masterpiece of landscape architecture.

The Oasis Concept

Gardens in Egypt originated on the edge of the desert where the nature vegetation is sparse. There was no green landscape to copy except that of the oasis. Thus, the first garden can be thought of as an artificial, protected oasis and such gardens still exist (fig 3.03 and 3.04).

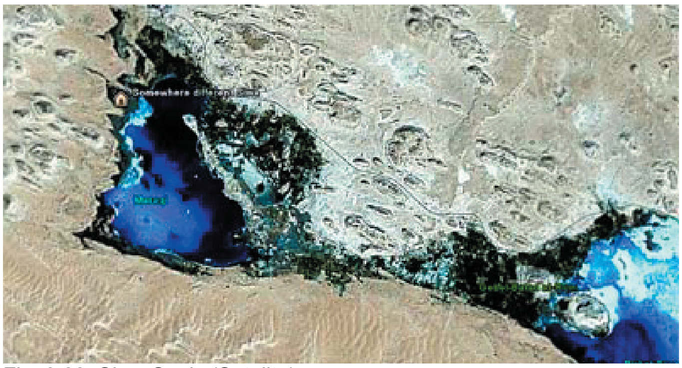

Fig. 3.03, Siwa Oasis (Satalite).

The garden oasis has roots in all religions even in Ancient Egypt. The oasis landscape is an earthly private garden, enclosed to shut out the desert with water as the main theme. The central theme is most often represented as a canal or pond, because without water there could be no fruit, flowers, trees or shade. The landscape of the Siwa Oasis is ranked among the finest creations of natural landscape in the Egyptian history.

Fig. 3.04, Siwa Oasis.

The Walled Garden Concept

Later gardens surrounded by walls were often terraced, containing enclosed pools to provide the "oasis" feeling and containing water plants (fig. 3.05). Gardens emphasised the contrast between two separate worlds: the outer one where nature remained impossible to control and an inner artificially created sanctuary, a refuge for man and plants from the burning desert, where shade trees and cool canals refreshed the spirit and ensured growth (fig. 3.06).

The gardens were full with statuary and ornamental columns (fig 3.07). Plantings became ordered and set in straight rows because of irrigation requirements and the flatness of the land (fig. 3.08). Irrigation canals were a common feature. Plants were treated architecturally; trained on lattice structures to artificial shapes referred to as arbors, bowers, or pergolas. Fruit trees, palms, and vines in symmetrical arrangements were common garden plants providing food and shade.

The Walled Garden in Tombs (Afterlife)

Many tomb paintings showed the walled garden, including a fish pond shaded by sycamore figs. The pillars of the tombs are moulded to resemble bunched papyrus canes. The tomb paintings do not depict real gardens but serve as symbols of the necessary refreshment of the soul on its long journey through the afterlife. The layout is simple; a high wall protects the garden from intruders and a formal rectangular pool, with flowering lotus, is edged with flower-beds and flanked symmetrically with tall shade trees.

The Walled Garden in Houses (Earthly)

The garden in Fig 3.09 is surrounded by a wall, probably tile-capped, and divided into unequal portions by low walls, about two feet high, of dry stone or baked mud, with painted wooden gates. The entrance from the tree-shaded canal-walk passes a grandiose porter's lodge; the house is reached by a path under the central vine trellis. On both sides of the house are pavilions overlooking flowers and pools planted with lotus and teeming with wild ducks. Inside the surrounding wall is a screen of date-palms, doum palms and smaller trees (Jellicoe and Jellicoe, 1995) (Janick, 2002).

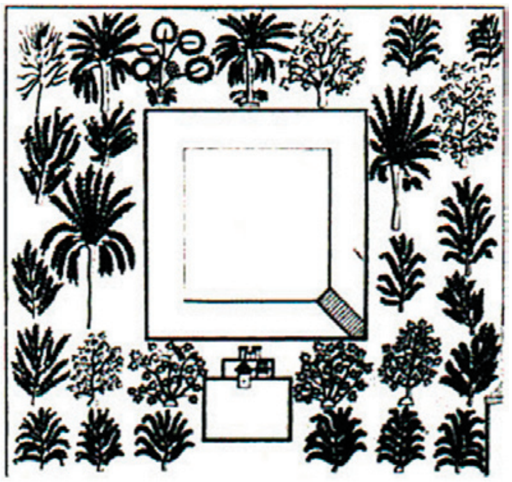

Fig. 3.05, Randomly-placed trees within a square enclosure surrounding square pool. Carving from the tomb of Akhnaton(18th dynasty).

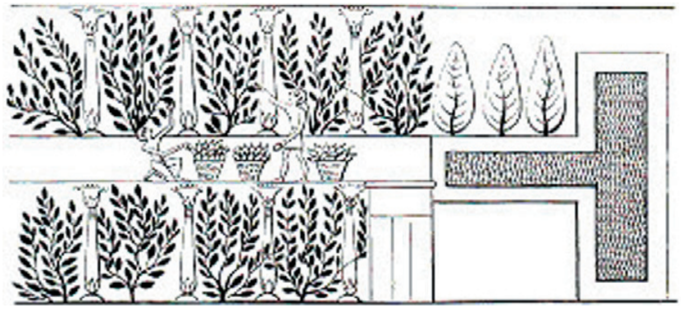

Fig. 3.06, Harvesting pomegranates in formal planting interspersed with ornamental columns next to a T-shaped pool.

Fig. 3.07, Garden planted with fig, olive trees and flowering plants containing a pavilion.

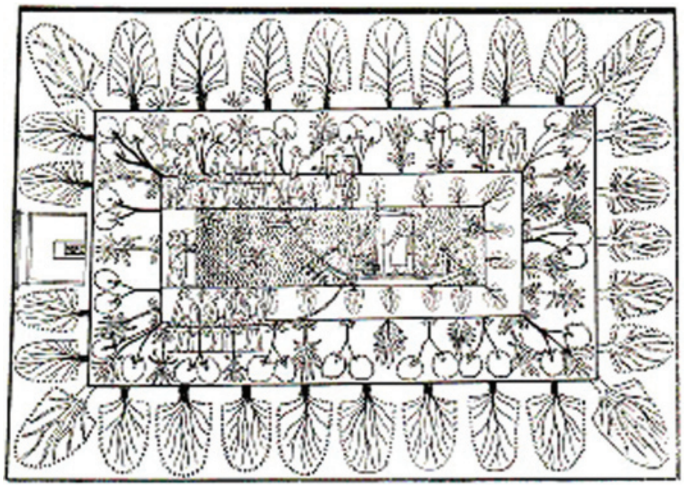

Fig. 3.08, The lotus pool, on which statue of the vizier Rekhmire is being towed by boat, faces a pavilion or summerhouse. Around the pool grow doum palms, date palms, acacias, and other trees and shrubs.

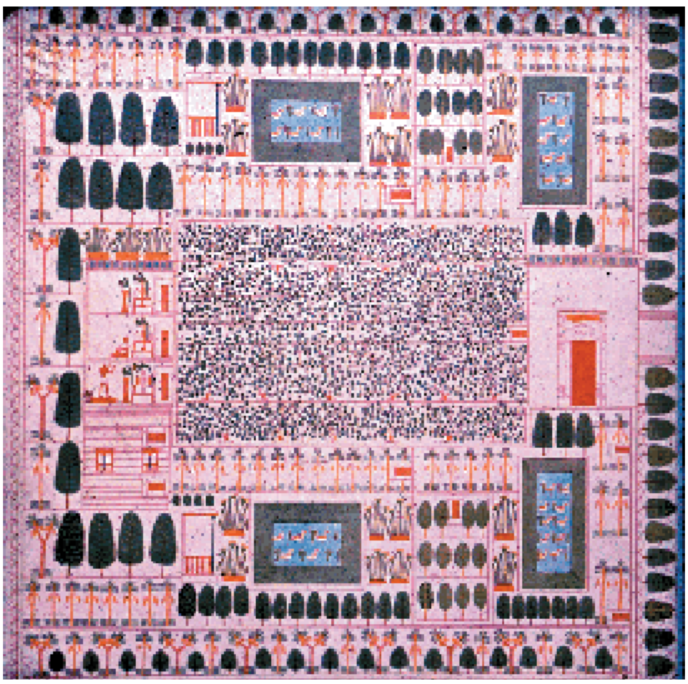

Fig. 3.09, Egyptian Offical's Garden

Landscape Vocabulary of Pharonic Gardens

1. Formal and symmetrical layout avenue:
The Pharonic gardens were had a bilateral symmetry and formal layout. It seems that trees and plants were laid out in rows and symmetry for ease of irrigation. But It is also claimed that the direct and straight lines were meant to facilitate the transport of the pharaos to the after life.

2. Site selection:
All buildings as well as gardens in Egypt had to be on high ground, because of the peculiar nature of the country. The floods, slowly rising, had from early days been encroaching upon the temples, and also upon the private dwellings.

3. Vegetation and shade:
The plants in Ancient Egypt fulfilled dual roles. The first was functional through fruit trees, herbs and medicinal plants and ornamental with a decorative character. The second role was spiritual and the symbolic significance of trees was related to Gods and their powers. It is obvious that with so much labour entailed, the only such trees and plants to be considered were those found useful enough to repay a man for his trouble. It was precisely from the profit-making care of plants that all horticulture arose. Edible fruits, timber, and shade –these the Egyptian demanded and obtained from his garden.
First, among these trees, which belonged to the earliest form of Egyptian garden, is the sycamore. It seems that, according to a very ancient belief, a sycamore stood under the canopy of heaven besides both the rising and the setting of the sun. The fruit and the wood of this tree are both of use; in its shade the living rejoice as well as the dead, and the pleasant honours it as especially sacred, and sacrifices to it the fruits of the earth. Shade was so important that houses and their garden courtyards were sometimes built around existing trees so that large date palms or sycamore figs dominated the garden from its inception (see appendix IV).

4. Water and cooling:
The lotus growing pool was also inhabited by fish and waterfowl, at its edge tall papyrus flourished in moist mud. The water created also humid and pleasurable outdoor environment compared to the surrounding barren desert. A canal often gave access to the garden through a grand water gateway, providing water for the pool or for irrigation. Water was moved upwards using the device called *shaduf.*

5. Walls:
The gardens were walled and protected by trees to give protection from sand storms and desert winds. The walls were essential design elements and they were even made during the early beginnings out of renewable materials like reed and bamboo.

Landscape Design Examples:

The Thebes valley landscape including the Karnak and Hatcshepsut temple in addition to the traditional courtyards gardens are examples of Pharonic landscape design. They clearly shared a common foundation of symbolic form and sensory delights. The five principal design elements of Pharonic gardens were described in light of the surviving example.

Temple Landscape
The oldest garden survivals are the temple compounds of ancient Egypt. They were used by priests and pharaohs, though members of the public might be admitted on festival days. The design of temples helped to explain the nature of the world and the social order, as we now do through science, religion, art, history and politics. Temple compounds are the oldest surviving manifestation of the quest to make outdoor space works of art. Sacred groves were associated with temple compounds. The temple of the various gods was provided with landscapes in decorative layouts, as a source for flowers, vegetables and woods for even wine and olive oil, thus providing necessary ingredients for various rituals.

Fig. 3.10, Luxor temple and the formal entrance.

Fig. 3.11, Karnak Temple and the sacred lake.

Axial lines were used but the overall geometry was non-symmetrical. Temples were built in rectangular compounds bounded by high walls. The internal space was in part ceremonial and in part laid to gardens. Temples were linked by avenues, lined with trees, sphinxes and statues ((fig. 3.10, 3.11, 3.12 and 3.13). The line of the avenue ran into the compound and led through a series of processional gates to a hypostyle hall and then an inner sanctum, the holy of holies. Some of the enclosed land was used to accommodate store houses. Compounds also held sacred lakes, pools, statues, shrines, flower and vegetable gardens. The basic construction materials were stone and mud brick.


Fig. 3.12, Karnak Temple and the avenues of sphinxes.


Fig. 3.13, Karnak Temple and the sacred lake.

The path of the soul from this world to the immortal realm of death is symbolised in the Egyptian sacred landscape, which is one of progression, of movement in a straight line from space to space and level to level. The vastest of these landscapes that of Thebes, reached its zenith under Ramesses II in XIXth Dynasty, comprising Karnak and Luxor on the East Bank of the Nile and the Tombs of the Kings among the mountains on the West. On the plains stand the 'colossi of Memnon', and the whole majestic complex is linked in idea by the avenues of sphinxes.(fig)

There were two directions from sacred progressions: north-south between Karnak and Luxor by an avenue of sphinxes or on a barge along the river; and that which followed the course of the sun to carry the dead Pharoh to his tomb and, regularly each year, the image of the god Amun to '

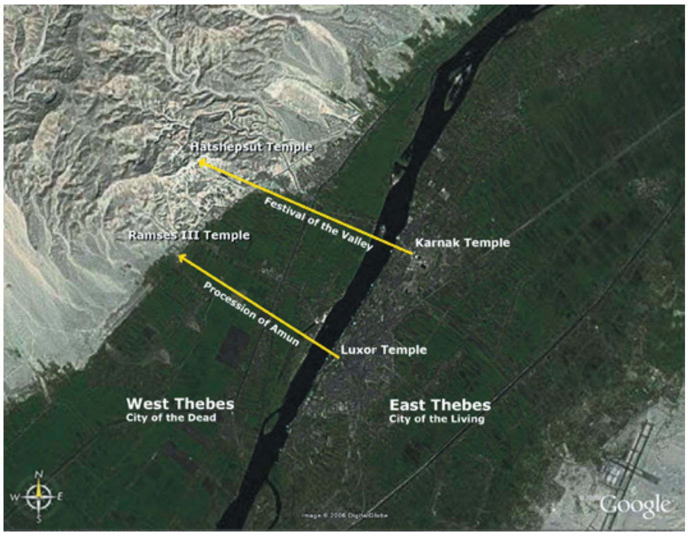

Fig. 3.14, Comprising Karnak and Luxor on the East Bank of the Nile and the Tombs of the Kings among the mountains on the West.

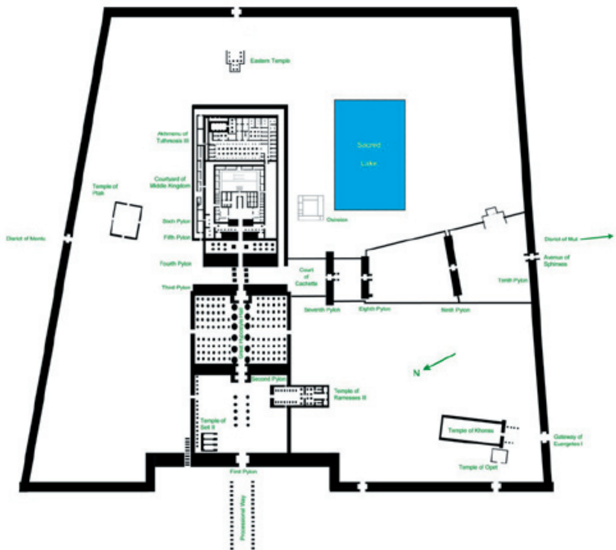
Fig. 3.15, Karnak temple layout.

pour water for the Kings of Upper and Lower Egypt'. The avenue of ram's head sphinxes at Karnak points directly to the mortuary temple of Queen Hatshepsut, XVIIth Dynasty (1503-1482 BC), whose terraces were originally planted with myrrh trees and whose unusual design had been inspired by the adjoining XIth-Dynasty templeof King Mentuhotep.

Ancient Egypt, Hatshepsut

The Temple of Hatshepsut (1470 BC) designed by Senemut has a spectacular composition of structures, vegetation, water, landform and climate. Senemut at Thebes, as depicted in his Sennufer tomb, that layout is symmetrical about an axis perpendicular to the river and running from the entrance along an alleyway flanked with two pergolas and leading to the temple shrine. In the temple of Hatshepsut at Deir el Bahari a garden with four ponds, papyrus, flowers and vegetables is represented schematically. There were exotic trees that were brought from the new countries subdued during the New Kingdom and planted in the gardens of Amun (fig. 3.16 and 3.17).

As a sacred landscape, gardens were laid on processional approaches to pylons, or in front of the temple quay along the river. Trees were planted in formal pattern framing the ramp leading to the entrance. The tree pits show that three rows of seven sycamore figs and tamarisk trees were planted to give an avenue effect. Statues of the king were placed in the shade of the figs and there were separate geometric flower-beds. Excavations have also uncovered the roots of perseas later planted in groves lining the approach to the queen’s terraced temple. Part of the plan for the temple was sketched in detail showing the pattern made by surviving root system. (Hobhouse, 1994)

The temple was carved from living rock. There are three great rectangular courts, connected by ramps and commanding extensive prospects of the valley. A serpent rail with a falcon's head followed the ramp. No trees or shrubs survive in the temple compound but archaeological investigations have revealed evidence of tree pits in the lower court. They formed a sacred grove which contained two T-shaped pools abutting the central path. Traces of papyrus were found when the pools were excavated and tree pits, dug into the rocky ground and filled with Nile mud, surrounded the pools. The pools may have been used for rituals connected with plants and animals. The Book of the Dead (Chapter 186) shows Hathor, as a cow, coming from a sacred mound into a clump of papyrus, representing the margin between life and death. The sycomore fig was her sacred tree. Hathor was the Goddess of the Western Mountain and a chapel was dedicated to her. The top terrace, which contained the inner sanctuary, had relieves of Amun's sacred lettuces in a grid of beds. Their milky sap symbolised the semen of the fertility god and were thought to be aphrodisiac. A relief shows an expedition to ‘the land of Punt’ [Somalila] to collect incense trees and thus provide Amun with resin. The trees arrived in baskets and were probably Myrrh trees. They may have been grown in pots on the terraces. A processional route, used for the Festival of the Valleys, led to the Nile and was lined with sphinxes, representing Hatshepsut. They were placed at 10m intervals and were 3m x 1m in size.

Fig. 3.16, Temple of Queen Hatshepsut.

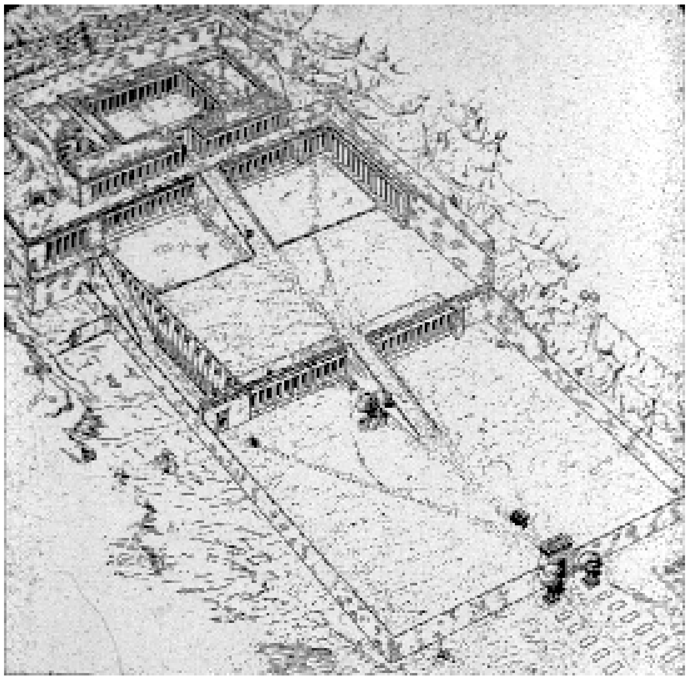

Fig. 3.17, Temple of Queen Hatshepsut.

Courtyard House Gardens:

Houses and palaces were set in a large garden surrounded by a wall. Typically, a symmetrical layout was used with a rectangular or T-shaped pond in front of the house on the main longitudal axis. This garden would then be surrounded by rows of trees of various species, possibly alternating in the same rows. It was not uncommon to find a pergola bordering the main alley along the axis or surrounding the pond. It should be noted that many time these ponds were stocked with fish and at that times included exotic examples. Fruit trees have their leaves or braches supported on the trelliswork of the pergolas. The shortest species of trees are planted nearest the pond, while the tallest, such as doum palms and date palms, are in the outside rows. This arrangement provided a graded perspective about the centre of the garden (fig 3.19).

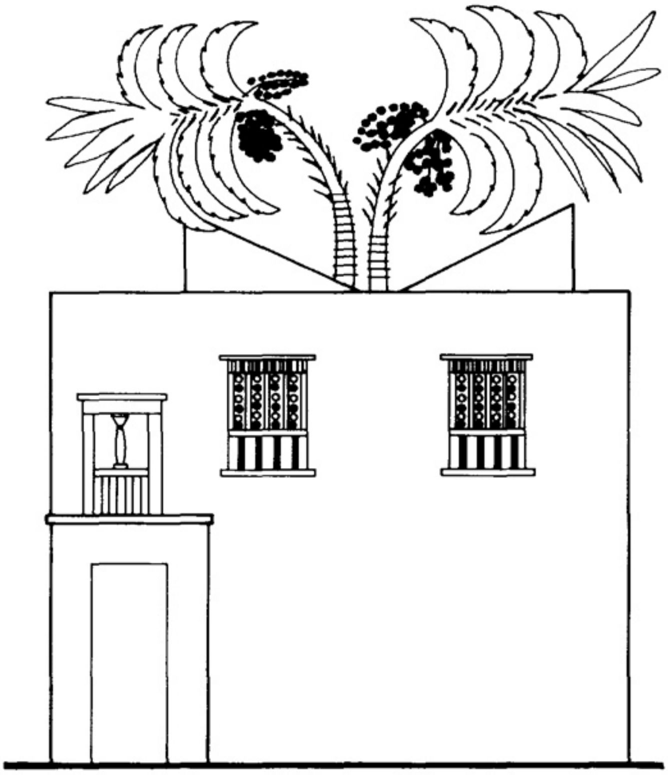

Fig. 3.18, Malqaf of the Pharaonic house of Neb-Amun, from a painting on his tomb' Nineteenth Dynasty (c. 1300 B.C.).

The courtyard gardens have been found in its simplest forms in the early Egyptian architecture during the period of the Old Kingdom in the peasant's houses. During the period of the Middle kingdom, the house took the form of a Maison, divided into four quarters: The Mastar's quarter is the focus of this plan, reflecting the prevailing social life. This type of courtyard house continued to exist in the New Kingdom; they were seen in Nab Amoun's house and the Nekht house. In general, the Egyptian houses were characterized by the use of air ducts (*malqaf)* to make use of the cold northern breeze (fig 3.18).

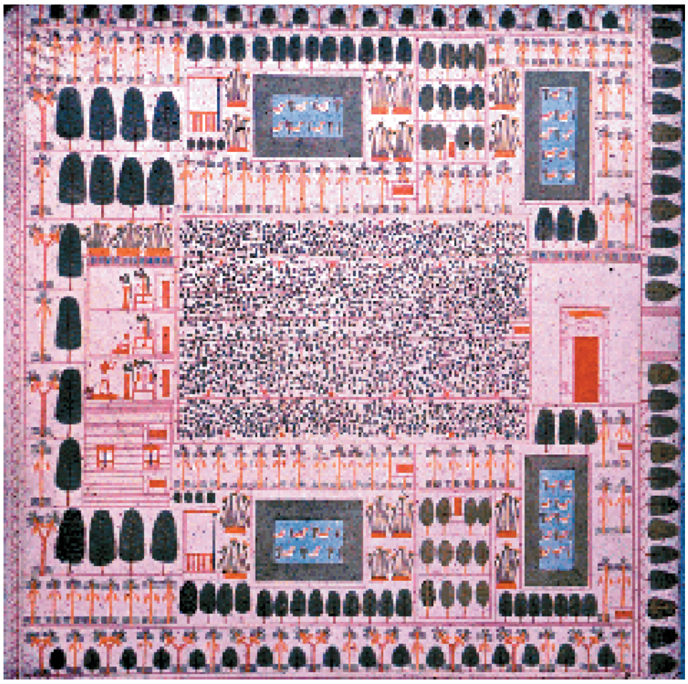

Fig. 3.19, Egyptian Offical's Garden.

3.2 Islamic Gardens

The Islamic Garden Concept

The Islamic buildings and gardens are often described as introverted and inward-oriented as presenting faceless walls to the outside world and a precious refuge to those who dwell within. The literature on Islamic gardens does not contain clear references to the landscape factors that influenced garden design. In landscape research there are two main theories that explain and provide the foundation for understanding of Islamic gardens.

The first theory is guided by the dictates of arid environment. The need to provide shade and to conserve water meant that urban open spaces and gardens were sheltered and enclosed. The aridity and heat stress explain the refreshing manipulation of water, vegetation, and shady garden pavilions. The landscape design principles were responsive to the climatic dictates and made efficient use of natural resources.(Wescoat, 1986) (Saad, 1986)

The second theory is guided by the dictates of Koran. Where Muslim designers conception of gardens as 'earthly paradises' (Lehrman, 1980)represents the mythological narratives in Koran.
This is the Paradise which the righteous have been promised; it is watered by running streams: eternal are its fruits, and eternal are its shades: Such is the reward of the righteous. But the reward if the unbelievers is the fire of Hell. The holy Koran, Sura 13:35

The clear separation between the believers and non-believers was reflected in the physical landscape through the 'paradise garden' which was detached from the 'surrounding landscape'. This meant that the Islamic garden is created within a cultural Islamic context. The visual experience of Islamic gardens is bounded by enclosing walls and buildings. The garden recognizes no scenery beyond its walls, except perhaps that offered by the sky. Islamic gardens frame views which are symbolically expansive and spatially contained. They present idealized landscapes representing the *jenna* (Arabic word of paradise). It is at once a physical place that is cool and shaded, with abundant fruit trees, scented flowers and flowing water and a conceptual peace and state of peace and contentment. The physical place is that of Koranic paradise and decidedly not the naturalistic imagery of forest or countryside.(Makhzoumi, 2002) (Saad, 1986)

The third theory is related to the long evolving tradition of ornamental and palatial water usage in the Mediterranean and in Persia, both in the pre-Islamic and Islamic periods.(Grabar, 1978)

The Development of the Islamic Gardens Concept and the Courtyard House:

By observing the existing urban and landscape structures of many Islamic cities today, for example Cairo, I might be convinced that Islamic cities have been always monotonous cities with no gardens or parks. The idea of the Islamic city as a puzzle of cramped houses around a maze of narrow streets and *cul-de-sacs*, surrounded by an indecent periphery oppresses by deafening traffic, is a misleading one. Before the transformation brought about by fairly recent immigration processes, which lead to an overcrowded urban sprawl, Islamic cities had always been portrayed as unique blend of nature and human settlement. Low building density was maintained in order to preserve a strong relationship with greenery. Vegetation prevailed. Even in the humblest house, the courtyard left room for a tree. Wide green spaces functioning as food reserves, orchards, and flower gardens formed a green belt between the city centre and the walls.(Petruccioli, 2001)

The *bustan*, which in modern terminology is equivalent of a park, is a type of open space that flourished in the medieval period. In fact, the city of *al-Qahira* (Cairo) was originally founded around a *bustan*, When the Fatimid army arrived on 969, its general Jawhar al-Siqilli was charged by his master, Caliph al-Muizz li-Din Allah to establish a new royal city around the Bussan al-Kafuri, which was a sizeable and pleasant garden (figure 3.20). The proximity of the Nile River allowed the powerful wealthy Fatimid, Ayyubid and Mamluk to exploit its eastern bank and the

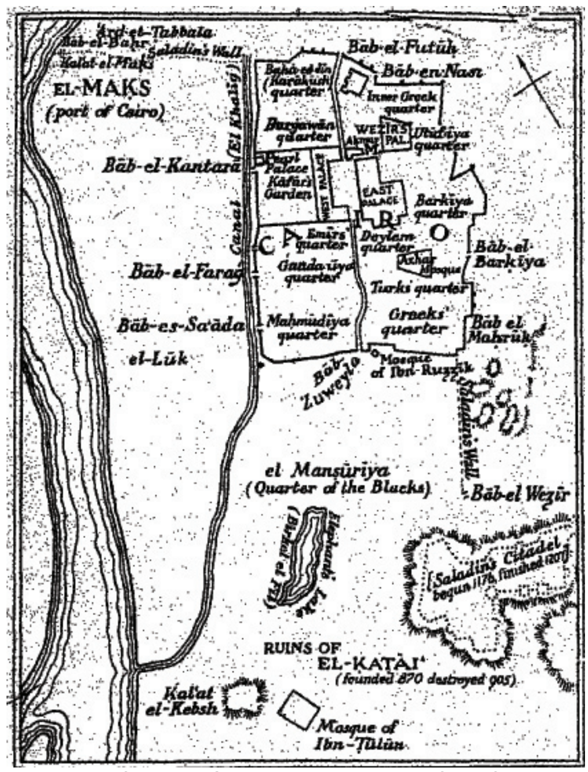

Fig. 3.20, Plan of Fatimid Cairo with Bustan al-Kafuri, after Paul Ravaisse.

borders of several seasonal ponds that formed after its annual flood in the low land west of the city, to establish huge *basatin* for their recreation (Rabbat, 2004).

Another type of open spaces of the Islamic city was the *maydan.* The *maydan* was a large open space covered with grass. The use was not meant for the use of the masses they were royal establishments for military parades polo games and equestrian exercises. Many rulers took great care to ensure its usability all the year around and to protect its grass from the heat of Cairo in the summer. The *maydan* had palms and fruit trees planted in it and a number of wells dug and equipped with waterwheels (saqiya) for its irrigation. The *maydan* had been filled with a special kind of rich black soil (called al-ibliz). See figure 3.21.


Fig. 3.21, An example for a Maydan in front of Sultan Hassan, Cairo.

However, as Nasser Rabbat stated “The *basatin* and *mayadin* were outside the city proper. They formed a sort of *cordon vert* in the space between the Nile and the boundaries of the city and around the Citadel.” (Rabbat, 2004) But these spaces were lost during the urban expansion between the thirteenth and the end of the nineteenth century and to some extent this was true for most cities of central Islamic region between the eight and nineteenth centuries. Consequentially no large open green space existed in the urban core of medieval Cairo. This was first of all, due to the arid climate which made the maintenance and irrigation of a green space a very difficult and costly procedure. The second reason may be in the distinction between private and public space in the traditional Islamic city, whereby entertainment and relaxation were kept strictly within the confines of the private domain and the public communal spaces and waqfs (endowments) were devoted to business interactions, charitable and religious activities.

Around the late fourteenth century, huge suburban *basatin* and *mayadin* were being slowly urbanised. The shrinking wealth leads to the interiorisation of the *bustan* to the residences. Like in many Islamic cities the *bustan* was reduced to be an urban residential garden and became an integral component of the Islamic courtyard house. The major architectural elements were arranged around and opened onto large planted courtyards. “Gardens began to be laid out in the otherwise functional courtyard that always existed in Cairene palaces and residences beginning with the ninth-century Fustat houses. They contained flowers and medicinal herbs, evergreen trees, and palm trees and vines. Their flowerbeds were sunk both for aesthetic and irrigation purposes. The palace was given an introverted composition centring on its green courtyards. This could hardly have been seen from the street, and the inevitable impression many pre-modern visitors had was that Cairo was an overbuilt city that lacked green, open spaces”

Landscape Vocabulary of Islamic Gardens and Courtyards:

However the concept of courtyards had evolved due to climatic conditions or socio-cultural values it was noted that the planted courtyard constituted the common elements in all Islamic civil and religious buildings. The court was meant to be the symbol of life and the focal point for all other elements that surround it and opened onto its space.

The Muslim architect was greatly influenced by the Heaven's description in the Holy Koran, its trees, rivers and springs, the sequential motion between day and night, light and shade, and the perfect integration of colours. The courtyard was then developed into a marvellous garden with fountains and running water in an attempt to create an earthly heaven.(Moustafa, 1984)

Five principal physical design elements are identified. While they complement each other in describing the Islamic courtyard, they present unique aspects of the overall design conception. As mentioned before, the Koran provides vivid description of physical design elements that has been incorporated in the Islamic courtyard garden as well as Islamic garden. In 164 verses, the Koran refers to design elements that include: quadripartite layout, use of water, vegetation and shade, pavilions, and walls and gates.(Nassar, 1986)

1- Quadripartite layout:

One of the well recognized characteristics of Islamic courtyard garden is that it follows a geometrical and often symmetrical layout. Typically, they are square or rectangular in shape enclosed within the walls of the building. The layout is a quadripartite with slightly raised walkways or canals leading to a focal fountain or a pool at the centre of the courtyard.

Reference to a quadripartite design occurred more than once in the Koran. *Surat* (Arabic word for a chapter-used for designating the chapters of the Holy Koran) Mohammed describes four rivers of paradise: "in it are rivers of water incorruptible, rivers of milk of which the taste never changes, rivers of wine, a joy to those who drink, and rivers of honey pure and clean." Surat ar-Rahman provides a longer and more detailed description of four gardens. Koran: ***They are the gardens of the Soul and the Garden of the Heart, and the higher two are the Garden of the Spirit and the Garden of the Essence, Surat ar-Rahman, 50.***

However, the four-channel pattern or the quadripartite layout was recognised as a central motif in Islamic gardens. The origin could be traced to the Persian Chahar Bagh, adopted by the Arabs after Islam and established as the trade mark of Islamic gardens.(Alemi, 1986) But this was an adoption of the form and function of a system marked by a perfect responsiveness to environmental constraints on garden's planning, micro-climate control and irrigation.

2- Use of water:

Most of the Muslim world lies in arid and semi-arid environments. The creation of cool and shaded courtyards was a logical response to alleviate the harshness of the physical environment. Thus the use of water in the courtyards was essential for creating localized micro-climate. In addition to its pragmatic quality, water contains within itself aesthetic properties that were highly appreciated and frequently used in Islamic courtyards. It trickles gently, cascades down small waterfalls, jets from fountains, runs along canals, or remains still in pools reflecting the sky (fig 3.22 & 3.23). Endless combinations of stillness and movement provided an interior environment that both delights and soothes.

Fig. 3.22, The sky reflection in the pond of Generalife palace, Granada.

Fig. 3.23, A courtyard building with a central water pond, hotel en Casa Morisca, Granada.

The Koran refers to both dynamic and calm qualities of water. ***"Gardens underneath where rivers flow"*** was repeated thirty times in different Suras. The righteous are promised to reside amidst gardens and flowing rivers: ***"As to the righteous, they will be in the midst of Gardens and Rivers"*** (al-Kamar: 54); ***and in them (both) will be two springs pouring forth water in continuous abundance"*** (ar-Rahman: 50). A calm central water tank corresponds to the basin *haud*, which was promised to the prophet Mohammed (PBUH) in Surat al-Kauther. The central planting bed is connected to a cistern by water channel. Running water thus not only irrigates the vegetation but also provides aesthetic and cooling effects.

3- Vegetation and shade:

Trees, shrubs, and foliage grow in the adjoining quadrants of the Islamic courtyard gardens. Plant materials were used both for their pragmatic and aesthetic qualities. The Islamic courtyard garden was densely planted for shade thus creating cool usable space. Fruit trees, which were planted in abundance, often drew on a palette of trees mentioned in the Koran. Pomegranates, vines, and palm are the most frequently mentioned. In addition to shade, they provided food, aroma, and colour. Tall cypresses were planted for protection against the wind, and diverse species of oaks and eillows to shade the gardens from the heat and brightness of the summer sun.

The Koranic descriptions are rather consistent in providing a vivid portrait of greenery, lushness, shades, delicious fruit, and unimaginative beauty: ***"Branches, unfalling fruit, grapes, and pomegranates"*** and ***"and fruit in abundance, whose season is not limited nor (supply) forbidden"*** (al-Waki'a 32-33); and ***"In them will be fruit, dates, pomegranates"*** (ar-Rahman: 68). ***"Spreading shade"*** is an expression posed in the Koran as part of the reward awaiting the righteous: ***"And the shades of the (Garden) will come low over them"*** (al-Ensan: 14); and ***"we shall admit them to shades; cool and ever deepening"*** (al-Nesaa: 57) (see appendix V).

4- Pavilions:

The perception of the Muslim of his surrounding environment, both open spaces and built ones, includes both the Earth and Seven heavens which are guarded and ruled by Allah. As a result, the flow of space in Islamic architecture perceived by Muslims and strongly rooted in the Islamic culture creates a sense of continuity and unity of space. Such sense of unity became a strong attribute of the Islamic courtyard garden enforced by the centrality of the quadripartite layout.

According to the Koran, the ultimate place of residing for righteous Muslims is the "pavilion". As implied in the Koran and Hadith, pavilions are cool structures, built in the gardens of paradise, over running water. Abu-Ummamah narrates **"He who has good dispositions shall have a house built for him in the highest apartment of paradise"**. (Abu-Ummamah is a Sahabi. The definition of Sahabi is someone who companioned the Prophet Mohamed PBUS and believed in him as well as died as Muslim). And the Koran describes: ***"For those who fear their Lord, that lofty mansions one above another, have been built: Beneath them flow rivers"*** (al-Zumar: 20)46. In gardens, the design of pavilions or structures where Muslims enjoy the shade, coolness, and the water, differed architecturally depending on the geographic location in the Muslim world.

5-Walls and gates:

The form of Islamic courtyard garden has such distinctive characteristic as privacy for contemplation and repose, protection from the hot, dusty, and noisy environment, reduction of glare, and abundant refreshing shade and cool air which are essential for human comfort. This was readily provided by surrounding walls and buildings. In the Koran, paradise is described as an enclosed garden, surrounded by "walls" and accessible through "gates": "and those who feared their Lord will be led to the Garden in crowds: ***"Until behold, they arrive there: Its gates will be opened……"*** (al-Zumar: 73), and ***"Gardens of Eternity, whose doors will (ever) be open to them"*** (Saad: 50). By analogy, the Islamic courtyard garden is the Muslim's paradise: if permitted, gates will be open.

6- Colours and fragrance:

Colours and fragrances are important elements in the Islamic landscape vocabulary. Colours and odours create biological reactions in our bodies. These reactions, in turn, can change out behaviour. Studies have shown that the colours green is calming. Green was a sacred colour ancient Egyptians, representing the hope and joy of spring. It is also a scared colour to Moslems. Many mosques and religious temples throughout the world use green (the colour of renewal and growth) and blue (the colour of heaven) to balance heavenly peace with spiritual growth. The variety of colours was mentioned several times in Koran. This variety is also related to the paradise and fruits and the description of the paradise landscapes. The same meaning is associated with fragrances. In Egypt perfumes and incenses are important till now and when it comes to plant selection the preference is for fragrant fruit plants.

In summary, six principal design elements of urban Islamic courtyard gardens were highlighted, which included: quadripartite layout, use of water, vegetation and shade, pavilions, walls and gates and Colours and Fragrance. The design elements were described in light of the surviving example of urban courtyard garden in Islamic Cairo.

Landscape Design Examples:

In most Islamic designs the role of landscape design was highly appreciated. In examining the traditional courtyard gardens, it becomes clear that the role of urban landscape design was not restricted to purely ornamental or theological function. It was used to control and improve the micro-climate around and inside the building. This paper attempts to present the role of landscape in the traditional Islamic garden courtyards by analysing the design characteristics of Al Suhaymi house courtyards in Cairo and the layout of three courtyard gardens in Alhambra and Generalife palaces in Granada. Some physical-parameters measurements regarding temperatures and humidity were made, in addition to a shade study. In fact, shades in courtyard-buildings where not sufficient to ameliorate the micro-climate during hot summers. Therefore vegetation and water were used to compensate the shade.

Al Suhaymi House

Bayt al Suhaymi is one of the most important examples of Cairene traditional courtyard houses representing the Islamic landscape design around the 16th and 17th century. The house stands in El Darb EL Asfar alley and is directly located off the famous Fatimid street called El Moez Street. The house witnessed several building phases before reaching the final layout, which covers 2000 square meters and includes 115 spaces distributed on five levels. The house is marked by perfect responsiveness to environment and contains architectural elements of the traditional Cairean house. The bent entrance that assures the privacy of the house leads to an inner courtyard surrounded by rooms and overlooked by the *maqaad* (a roofed balcony facing the cool northern breeze) and the *takhtaboosh* (a space annexed to the court for receiving male visitors during the summer). The *shukhshaikha* (a wooden lantern allowing for entrance of light and circulation of air); the *malqaf* (a slanted – roof wind catcher that allows the cool northern breeze to reach the southern hot rooms) (Fig. 3.24)(Nadim, 2002).

The House layout:

By analysing Al Suhaimy house layout, I find that Al Suhaimy house layout was based on creating a passive ventilation system, in order to ameliorate the micro-climate. This was done by locating two inner courtyards with two different pressures. The northern courtyard (Fig. 3.25), which was called the rear garden, was a large open space and was meant to have low surrounding walls in order to keep the space sunny and relatively hot. The rear garden was planned to occupy 28 percent of the total

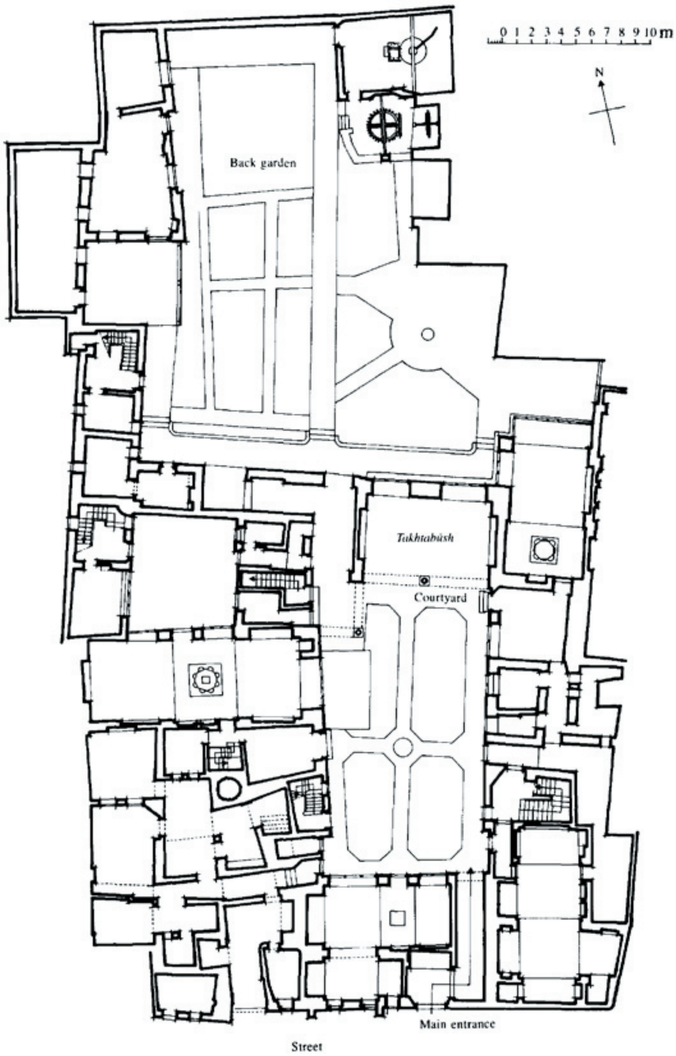

Fig. 3.24, Al Suhaymi house ground floor plan.

Fig. 3.25, Rear garden.

Fig. 3.26, Courtyard garden.

house area with a 2.6:1.3:0.5 ratio (l:w:h). While the south courtyard (Fig. 3.26), which was called the courtyard, was a rectangular courtyard covering only 200 square meters and was planned to occupy only 10 percent of the total house area with a 1.8:1:1.3 ratio (l:w:h).

This passive design solution is confirmed, by comparing the shade in the rear garden and the courtyard. During winter (21 December, 2:00 p.m.) I find that the amount of shade in the rear garden is more than 53% compared to 100% in the courtyard space. While during summer (21 June), the amount of shade in the rear garden is more than 12% compared to 40% in the courtyard space (Fig. 3.27). Moreover, measurements have proofed that when temperatures raises in the rear garden of Al Suhaymi house during most daily hours the air flows ,against the north prevailing wind directions. The wind flows from the south entrance passing the courtyard then into the takhtaboosh, with a wind speed 1.3 m/s, reaching finally the rear garden (Fig. 3.27b). On the other hand, during the stillness of the previous mentioned wind movement, the prevailing wind flows from the rear garden when the sun drops down after noon through the takhtaboosh to the courtyard reaching 0.7 m/s (Fig. 3.27a) (El Debrky, 1999).

Fig. 3.27, Shade study of Al Suhaymi House courtyards (left) 21 December, (right) 21 June.

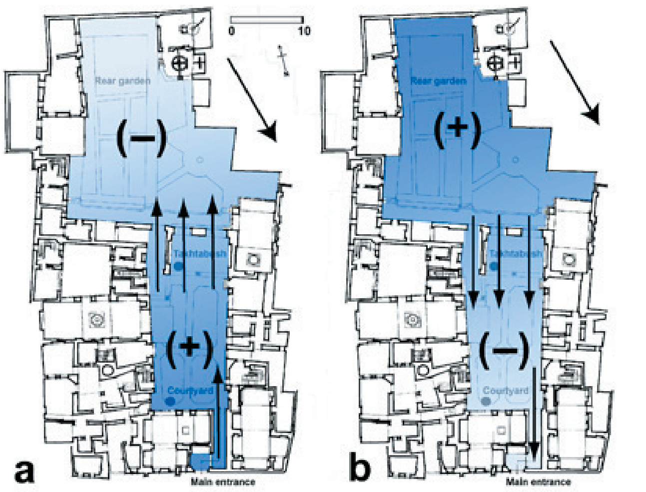

Fig. 3.28, (a) air movement during the noon, (b) air movement after noon.

2.2 Landscape design in Al Suhaymi house:
Based on the previous design theory I find that the role of landscape architecture in this design was essential. By analysing the plan, I find that the landscape design was aiming to emphasize the passive ventilation in Al Suhaymi house. The Islamic landscape design considerations for the composition of vegetation and water were including the following environmental-responsive design principals:

Quadripartite layout
References to the quadripartite design occurred more than once in the Koran therefore Islamic gardens adopted the geometrical and often symmetrical layout. Planning the layout was based on creating two axes perpendicularly crossing each other in the middle. But the quadripartite layout was also considered as an environmental landscape design principal. The axes were planned as narrow water canals or walkways while the left rectangles were planted or used as water ponds. In Al Suhaymi house, the courtyard had a quadripartite layout with slightly raised narrow walkways leading to the focal fountain at the centre of the courtyard. The walkways created four relatively large planted rectangular shapes (Fig 3.30). While the rear garden had two different planned layouts. The left part was following a quadripartite layout, while the right part of the garden had a circular planning with a well in the centre. The quadripartite design helped the designer to manipulate the site and created a variety for the water, vegetation and pavement composition.

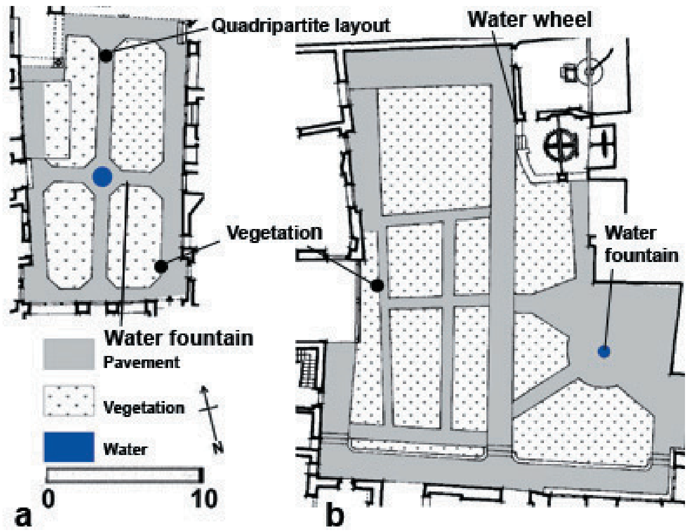

Fig. 3.29, Landscape design elements in Al Suhaymi courtyard gardens (a) courtyard, (b) rear garden.

Use of water
Al Suhaymi house had a focal fountain in the courtyard and some other fountains in the halls. The focal fountain was located at the centre of the courtyard. Next, a water wheel in the north-east corner of the house supported the fountains and house user with water. Using the fountain inside the courtyards had helped to create a cold air reservoir, in addition to humidify Cairo's dry air. Using also the fountains in the halls helped in soothing the internal climate of the halls reflecting the importance of having elements from the natural environment such as water inside the house.

Vegetation and shade

The courtyard and rear garden were both planted. But to serve the passive ventilation concept and create a relatively hot open area, the rear garden was mainly paved and planted with some flowers, medicinal herbs and palms. On the other hand, the courtyard was mainly planted with ground covers, evergreen trees and fruitful trees to provide maximum shade for the ground the inner courtyard walls (Nassar, 2003). Moreover, greenery inside the courtyard and rear garden absorbed dust and dirt hanging in the atmosphere besides reducing the glare. This study measured the differences between the planted courtyard and the house roof temperature and found a difference between 4oC to 7oC. Furthermore, by comparing the relative humidity in the house inner courtyard with El Darb EL Asfar alley, a difference ranging between 11 to 19 percent was recorded.

Walls and pavilions

In the Koran, paradise is described as an enclosed garden, surrounded by “walls” and accessible through “gates”. In Al Suhaymi House, the courtyard was surrounded with thick high walls to achieve protection from the hot, dusty, and noisy environment, and to provide a refreshing shade and cool air, which are essential for human comfort. Moreover, the rear garden was surrounded by low walls in order to minimize shades and create a hot open space. The surrounding walls of Al Suhaymi gardens are considered as environmental landscape design element of the Islamic garden.

Alhambra and Generalife Palatial Complex:

Alhambra is a prototypal Islamic garden and was the fortified palatial city of the Nasrid rulers of Granada. The complex's architectural and decorative programs have remained relatively intact since the fourteenth century, and as such are an important source of information about medieval Islamic palace architecture and its connections to classical and Mediterranean traditions.

Alhambra was constructed in the fourteenth century by the Nasrid sultans and the Generlaife on the hillside above, built in the middle of the thirteenth century and used as a summer residence. The complex underwent frequent additions and changes during the thirteenth and fourteenth centuries. Its walls enclosed a fortress, baths, mosques, industries, and a number of palaces and gardens. The complex is set on a steepened spur that falls dramatically into a ravine, projecting into a fertile valley. Richly planted terraces sparkling with water-courses and set about with jewel-like pavilions, were used to convert the fortress palace of the eleventh century into a 'paradise'. Breezes from the snow covered Sierra Nevada keep the gardens cool in summer. High walls protect and hide a series of open courtyards in which water rushes through marble channels or curves in graceful arching jets to cool the air and fill it with sparkling beauty. The water, without which the whole ambience and the luxuriant planting could have no existence, was channelled from the River Daro some distance above Granada.

Generally, the ruler dwelt in fortified palaces with a system of interlocking courtyards supplemented by garden space for climatic control and relaxation: a life-style less congested than that of the city but not substantially different. The Formal gardens functioned within palaces not only as courtyard space but intervening between palatial elements conceived as units within an overall scheme less architectonic than horticultural.

The Islamic garden as a concept was differently conceived according to the cultural content, so the Hispano-Islamic garden is a regional version of Islamic gardens. The main living units gravitate around courtyards, sometimes on two levels, and turn their backs to the outside, while getting their view, sun and light from the courtyard-garden. Basic components are a raised grid, irrigation under gravitonal pressure, central collecting pool or distributing point (*taqsim*) and formal walkways incorporating channels by which the irrigation is accomplished. The walks define the zone formally, leaving room for a less formal approach within the areas so defined. A quadripartite arrangement was standard but not strongly applied. Files of trees symmetrically arranged, an arrangement that is obviously horticultural, and goes on to mention a courtyard, a water course, serpentine in outline, and a central basin into which all waters fall, all in addition to a pavilion exquisitely executed in gold and azure.

Alhambra Palace Layout:

The Palace of Alhambra has always been praised for the balanced composition of architecture, vegetation and water. The hierarchical order and the symmetrical patterns that govern the organisation of the structure and the spaces in the Palace seem to have applied to the uses of fountains and channels, creating and integrated architectonic ensemble of water and built elements. Most courtyards are rectangular with rectangular pools in the middle. The courtyards are organised along quadripartite lines but the emphasis on perspective, by letting its length exceed its width so that the look may roam freely in its contemplation. That is rather than take it all in at a glance, as would be the case with a normal courtyard where space is constricted by the urban location (Dickie, 1986).

Most courtyards are rectangular with rectangular pools in the middle. The courtyards are organised along quadripartite lines but the emphasis on perspective by letting its length exceed its breadth so that the look may roam freely in its contemplation. That is rather than take it all in at a glance, as would be the case with a normal courtyard where space is constricted by the urban location (Dickie, 1986). Two main courtyards that have been analysed in Alhambra Palatial Complex are (Fig. 5):
Court of Myrtles or Patio de los Arrayanes.
Court of Lions or Patio de Los Leones.

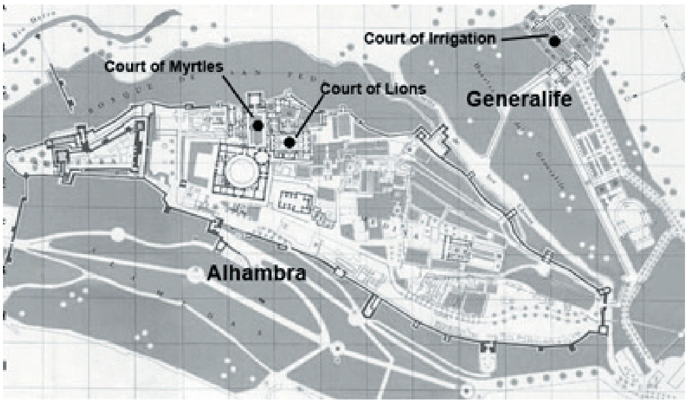

Fig. 3.30, Alhambra palatial complex and Generalife.

Landscape design in the Court of Myrtles:

The Court of Myrtles also called the Patio de la Alberca (Court of the Pond). This court is 36 meter long by 23.5 meter broad; and has a dimension ratio of 4.5:3:1 (l:w: h). In the centre, there is a large pond set in the marble pavement and with myrtles growing along its sides. The following landscape considerations were integrated in the courtyard's design:

Quadripartite layout

In the Court of Myrtles, the quadripartite arrangement is not present but still follows a geometrical symmetrical layout. The urban architecture take up most of the courtyard axial and ample, not just to reflect the two porticoed sides but to cool the surrounding apartments during summer.

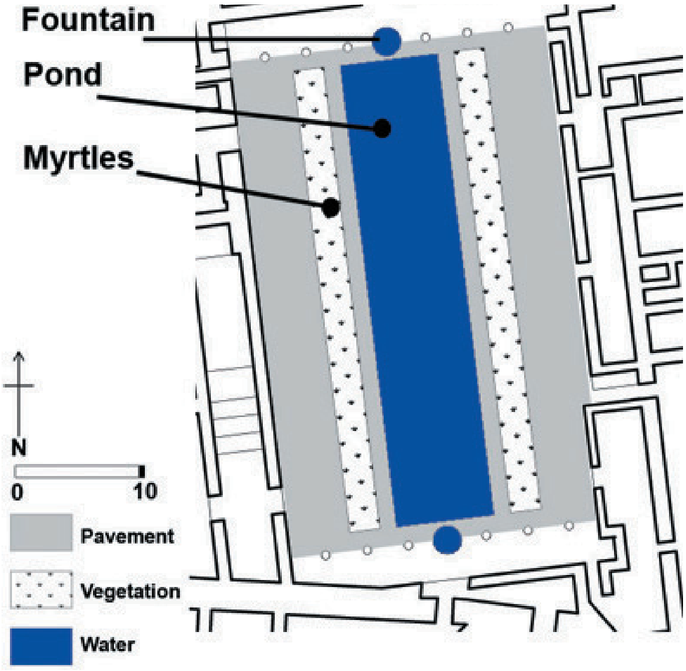

Fig. 3.31, Landscape design elements in the Court of Myrtles, Alhambra.

Use of Water

The Court of Myrtles is characterised by rectangular 40 by 7.5 meter central pond. The large central pond creates a spacious courtyard, which reflects the porticos of the Comares, Comares tower, landscape and sky. At the ends of the canal stand two fountains in small circular bowls. The water flows from the bowls in channels carved out in stone before spilling in the rectangular pond. This configuration creates a continuous sound in the courtyard. While the water creates continues movements to the pond surface, which was once a residence for golden fishes. (Fig. 6)

Vegetation and shade

The central canal of the Court of Myrtles is lined with two rows of the aromatic myrtus communis bushes located parallel to the walkways and planted with only four orange trees in the four corners. The myrtle was planted in the nineteenth-century restoration and is possibly authentic. I may also suppose that the myrtle was tall and the shrubs were rich in sweet-scented blossom. Next, two axial walkways paved by white marble are perpendicular on

Fig. 3.32, The court of Myrtles, Alhambra.

the north and south walkways, which are covered by the portico.

The shade study (Fig. 7) shows that during winter (21 December, 2:00 p.m.) the amount of shade in the Court of Myrtles is 77%. While during the summer (21 June, 2: 00 p.m.), the amount of shade reaches only 25% of the total area. This means that the courtyard reaches a critical condition of solar radiation. It seems that the designer compensated this condition by laying a large water pond in the courtyard. The recorded temperatures showed a difference between the temperature inside the court of Myrtles and outside the palatial complex. The temperature difference was ranging between 4°C to 8°C. A difference in the relative humidity was also found ranging between 10 to 22 percent was found.

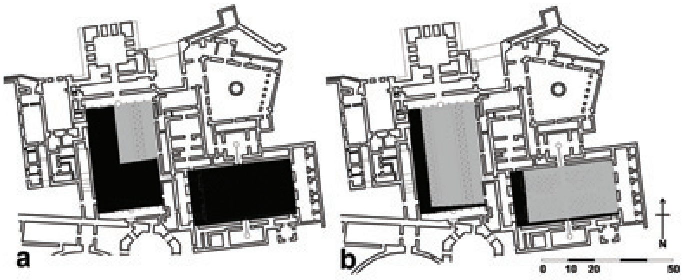

Fig. 3.33, (a) shade study of the Court of Myrtles and the Court Lions 21 of December and (b) 21 June.

Walls and pavilions

As a walled city fortress the courtyards of Alhambra are surrounded by massive walls. There are galleries on the north and south sides of the courtyard. The one on the south is 9 meter high, and supported by a densely decorated marble colonnade. Underneath it, to the right, was the principal entrance, and over it are three elegant windows with arches and miniature pillars. From this court the walls of the Torre de Comares, the caliph's official residence, are seen rising over the roof to the north and reflected in the pond. Moreover, by analysing the eastern and western façade we discover that they are simple, with very little openings in order to emphasise the axial setting of the courtyard.

3.2 Landscape Design in the Court of Lions:

The Court of Lions, with its fountain and its four axes channels, forms the nucleus of Alhambra Palace. The palatial courtyard is an oblong court, 35 meters in length by 20 meters in width, surrounded by a low gallery supported on 124 white marble columns. A pavilion projects into the court at each extremity, with filigree walls and light domed roof, elaborately ornamented. The courtyard dimension ratio is 4:2:1 (l:w:h). The following landscape considerations were integrated in the courtyard's design:

Quadripartite layout

The Court of Lions has typical quadripartite layout. The Court of Lions has a rectangular court bisected by both longitudal and transversal axes, the long axis is emphasized by having pavilions placed at either ends.

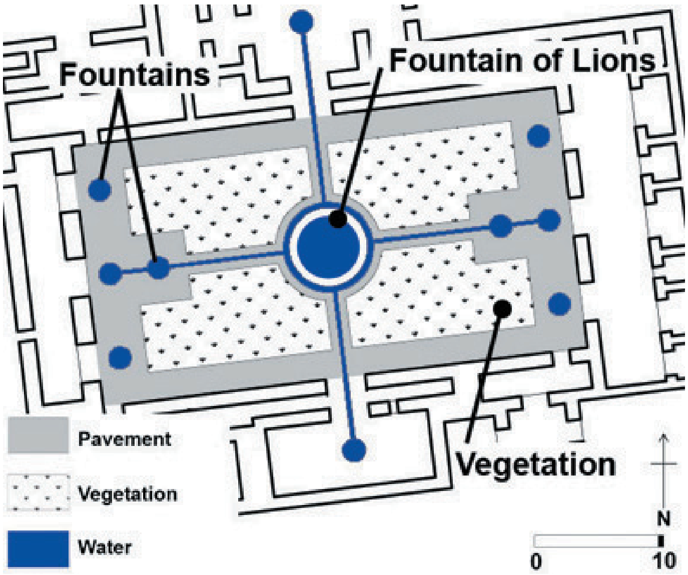

Fig. 3.34, Landscape design elements in the Court of Lions, Alhambra.

Use of Water

Fountains, at both ends of the pool provided animation to the courtyard. The centre of the water arrangements is the Fountain of the Lions. The Fountain of Lions is an alabaster basin supported by the figures of twelve lions in white marble. The water spurts out from fountains from the sides of small, sunken bowls, located either inside the two halls on the north-south axis, or under the portico's projecting pavilions on the perpendicular axis. Then it runs to the central fountain in channels carved out in the stone pavement, after streaming down the steps of the hall's entrances, and forms a miniature cascade, carved also in steps, to spill in the dodecagonal basin at the base of the twelve lions. The pattern provides the physical continuity of the axes in form of the unbroken channels. In addition, the inward orientation toward the centre is apparent, and is actually emphasized by the direction of the centripetal water flow (Rabbat, 1985).

Vegetation and shade

There are no plants in the Court of Lions, but as there are great shell-fountain in all four squares there will have been plants too, rather short in pots or in separate beds set at intervals between pavements. The bebble surrounding pools today are unlikely to be original; excavated examples are tiled in terracotta with ceramic inserts forming a pattern. The garden survives as minor beds for climbing plants, particularly jasmine, although myrtle hedges might border the pool, where space allowed. [5]

The shade study shows that during winter (21 December, 2:00 p.m.) the amount of shade in the Court of Lions is 100%. While during the summer (21 June, 2:00 p.m.), the amount of shade reaches only 23% of the total area. This means that the courtyard reaches a critical condition of solar radiation. It seems that the designer compensated this condition in the courtyard through vegetation and shade trees. Despite the pebble surrounding the pool, the recorded temperatures showed a difference between the temperature inside the court of Lions and outside the palatial complex. The temperature difference was ranging between 2oC to 4oC. A difference in the relative humidity was also found ranging between 8 to 15 percent.

Fig. 3.35, The court of Lions, Alhambra.

Walls and pavilions

The courtyards is paved with squared white marble tiles, and the colonnade with white marble; while the walls are covered 1.5 meter up from the ground with blue and yellow tiles, with a border above and below enamelled blue and gold. The columns supporting the roof and gallery are irregularly placed, with a view to artistic effect; and the general form of the piers, arches and pillars is most graceful. They are adorned by varieties of foliage. About each arch there is a large square of arabesques; and over the pillars is another square of exquisite filigree work.

Generalife Palace Layout:

The Generalife, built during the reign of Muhammad III (1302-1309), was used as a Nasrid summer retreat. Separated from the Alhambra by a ravine, and overlooking the Nasrid palatial city, the Generalife is composed of terraces arranged on the hillside, with pavilions overlooking the courtyard and lush gardens. The sequence of courtyards in Generalife is based on laying the main courtyard at right angles to their common axis so that the sultan commands a spectacular view from his principal apartment. As Selle stated "The gardens of Generalife may best convey the true spirit of Muslim garden; a true paradise, 'a place of delight' almost unequalled in any other garden in the west" (Semple, 1929).

Landscape Design in the Court of Irrigation:

The plan of the Patio de la Acequia is an oblong court, 49 meters in length by 12 meters in width. A channel that carries the water from the irrigation ditch of the Alhambra divides it lengthways. The channel is surrounded by several little jets and has a stone basin at each of its ends. The courtyard dimension ratio is 4:2:1 (l:w:h). The following landscape considerations were integrated in the courtyard's design:

Quadripartite layout

The plan of the Patio de la Acequia in the Generalife shows its medieval layout, with beds flanking the central water rill divided to make a quadripartite shape. The Acequía Court, is located on the lowest terrace, consists of a rectangular court divided into four quadrants by long water channels, with a basin at the centre. (Fig 10)

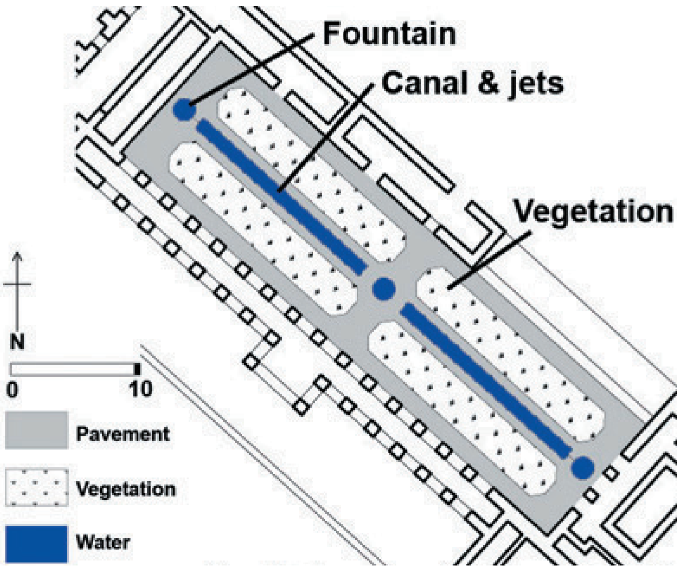

Fig. 3.36, Landscape design elements in the Court of Irrigation, Generalife.

Use of Water

The water supply to the Generalife, channelled in the top of the walls, runs diagonally across the steep hillside to fall to feed canals and jets in the patio gardens. But the new feature is the water stairway, which have not met with Islamic garden design before. The water stairway is between two towers and has streams above and in the middle, the upper one watered from the upper part, the middle one from the middle part, the lowest one from the lowest part, all in strictly regulated amount.

The highest terrace of the complex is linked to the lower levels by a stairway whose water-channel balustrade connects three circular landings, each with its own shallow basin and jet at its centre. Each landing provides dramatic views over the landscape, juxtaposed with the visual play of water and stone.

Vegetation and shade

In the painting of the Patio de la Acequia by Ludwig Hans Fischer, which was painted in 1885, stands tall cypresses and aromatic Mediterranean plants which no longer exists. (Fig. 11)

Today, the court is not retaining authentic planting but we

Fig. 3.37, Court of Irrigation now.

Fig. 3.38, Court of Irrigation in the past with a cypress tree.

find summer flowering annuals. Ibn Luyun's fourteenth-century poem gives clues to the planting organization of the gardens when first constructed. He advised that " next to the reservoir plant shrub whose leaves do not fall and which rejoice the sight; and somewhat farther off, arrange flowers of different kinds and farther of still evergreen trees and round the perimeter climbing vines . . . and under climbing vines let be paths which surround the garden to serve as a margin". The courtyard garden was so dense that the sun rays cannot make contact with the ground and any breeze blowing over it, day or night, is instantly impregnated with perfume (Al Tahiri, 2001).

The shade study shows that during winter (21 December, 2:00 p.m.) the amount of shade in the Court of Irrigation is 100%. While during the summer (21 June, 2:00 p.m.), the amount of shade reaches only 29% of the total area (Fig. 12).

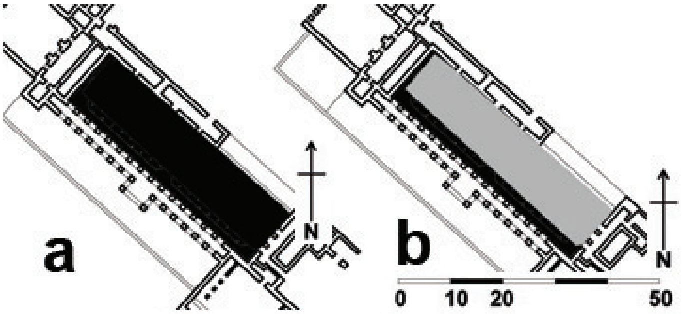

Fig. 3.39, (a) shade study of the court of Irrigation at 21 December and (b) 21 June.

This means that the courtyard reaches a critical condition of solar radiation in summer. It seems that the designer compensated this condition in the courtyard through vegetation specifically and shade trees. If a row of tall cypresses existed as shown in Fig 11.b the shade would cover at least 80% of the total area (21 June, 2:00 p.m.). However, the recorded temperatures showed a difference between the temperature inside the court of Irrigation and outside the palatial complex. The temperature difference was ranging between 3°C to 7°C. A difference in the relative humidity was also found; ranging from 12 to 22 percent.

Walls and pavilions

The Acequía Court has a gallery with a balcony, which runs along the west side of the court, providing dramatic views of the landscape and of the Alhambra. A pavilion on the north end also contains a balcony, and overlooks the Albaicin quarter of Granada. The three-storied pavilion on the southern end of the court was used as a residence. Both pavilions open onto the Acequía Court through arcades.

Conclusion

The result of a comparative analysis of the Islamic landscape design demonstrates that landscape design helped in improving the micro-climate in the courtyards of Al Suhaymi house, Alhambra and Generalife palace. The courtyards were used as cool air reservoirs to improve the micro-climate. The landscape design-elements such as the quadripartite layout, water, vegetation and walls were all integrated in the courtyards as a way of passive cooling. The shade studies proofed that in cases when shadow was insufficient in courtyards, shading trees, vegetation composition and water were used to compensate this lack. One may conclude that, the above results showed that the landscape design principles inherent in the traditional courtyards buildings can make a valuable contribution to contemporary design. One may conclude that, the above results showed that the landscape design principles inherent in the traditional courtyards buildings can make a valuable contribution to contemporary design (Attia, 2006).

Conclusion

This chapter explored the traditional landscape design solution to improve the micro-climate and provide passive cooling in and around buildings. Both the ancient Egyptian and Islamic civilisations adopted the oasis and walled garden concept to create thermally-pleasant environments. Moreover, the idea of creating earthly paradises was common between both cultures. It is also interesting to note that the garden components and design were similarly treated in both cultures. I mean that the following design elements were commonly used (fig. 3.40):

1. A geometrical setting or configuration to arrange water, plants and pavement.
2. Plants were used for shade and evapotranspiration.
3. Water was used for evaporative cooling.
4. Walls, hedges and fences for protection from warm wind and sand.

But, however, reasonable and logical these traditional design solutions may appear on paper, planners have not turned to the landscape-design elements recommended above in sufficient numbers. They have not learned the important lessons taught by ancient civilizations that thrived in the arid region. They, rather, noting the lack of substantial research fell back on forms used in humid regions and introduced them into the arid region where they are bound to fail. Based on the crucial lessons taught by past civilisations, I recommend a landscape design featuring the following:

1.Individual structures grouped in compact clusters in order to maximize shadow with cities consisting of many such clusters.

2.Orientation, so as to capture cool breezes, minimize glare, and reduce solar-heat reflection

3.If available, water to effect cooling and reduce the landscape's harshness.

4.Heavy use of open central courts to maximize both shadow and ventilation

5.A shadowed, protected pedestrian network and

6.Avoidance of large unshaded open spaces by planning the proximity of different land uses.

Landscape Design for Micro-Climate Improvement and Passive Cooling.

Pharonic Landscape Design - Islamic Landscape Design

Concepts

1- Oasis
2- Walled Garden
3- Earthly Paradise vs Heavenly Paradise

Concepts

Elements

Pharonic	Islamic
Formal Layout / Symmetric	**Quadripartite Layout**

Pattern for Plants, Water and Pavement

Plants	**Plants**

Evapotranspiration and Shade

Water	**Water**

Evaporative Cooling

Walls	**Walls**

Wind and Sand Barrier

Elements

Fig. 3.40, Comparison between the common landscape design concept and elements of the Pharonic and Islamic civilisation.

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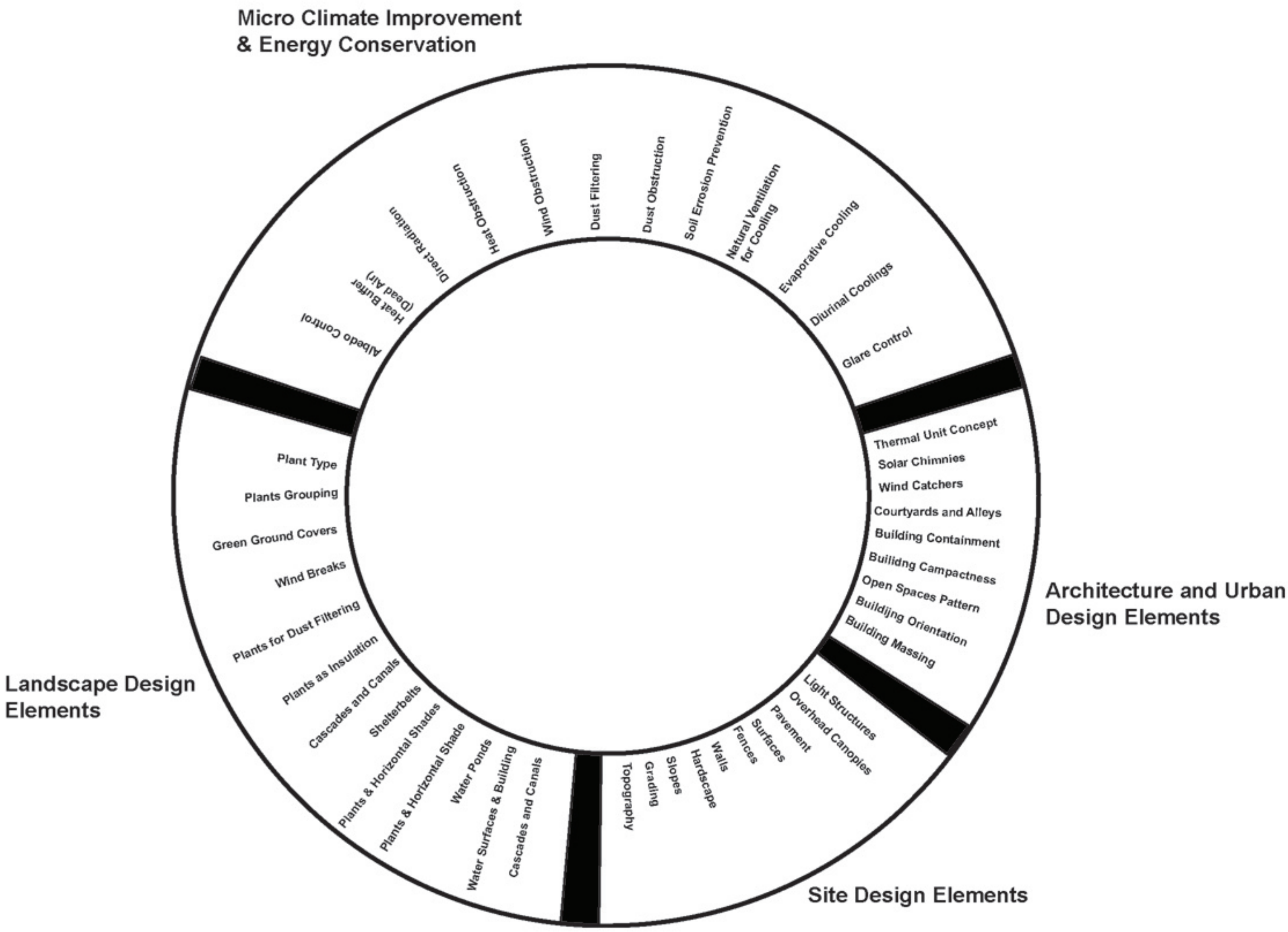
Chapter 4

Landscape Design Principles and Guidelines for Climatic Control and Energy Conservation.

Chapter 4

Landscape Architecture Circle



Chapter 4: Landscape Design Principles and Guidelines for Micro-Climate Improvement and Energy Conservation

Introduction:

The micro-climate of a building site can make or break a project. Shadows cast by nearby buildings, trees, or any design elements are important considerations in improving the outdoor environment passively.

Winds can affect how a solar system performs. It is important to analyze whether topography, trees, and buildings funnel winds into or away from a particular site. In summer, cool breezes can help disperse heat from a well-designed garden, making it more comfortable and reducing cooling requirements. In summer a good landscape design of a building site can decrease the cooling requirements of a building and consequently conserve energy. Also winds can be effectively controlled by interception and diversion, or by generally lessening their force with obstructions such as earth forms, vegetation, and architectural elements like walls, fences and buildings.

Using climate assessments in design involves more than creating a nice landscape within the context of a specific environment. The landscape design and building structures can enhance solar system performance. For instance, overhangs and eaves can shade windows when solar heating is not desired. Deciduous trees and shrubs can strategically place outside to help keep buildings cooler and more comfortable during the warmer months. Courtyards filled with trees, flowering vines, shrubs and a large fountain can create a cool oasis even in the hottest desert climate.

The landscape layout can improve the micro-climate around a building, taking advantage of existing topographical features, adjacent buildings and vegetation for solar protection. Good site layout can also take greater advantage of local breezes by the formation of air funnels and also aid natural ventilation by organizing the building layout. The presence of water and vegetation on the site can also be used for natural cooling. Good site layout can reduce cooling loads appreciably by optimising natural solar protection and local breezes.

This chapter will introduce the landscape design principals and guidelines for climate improvement and energy conservation. As described in chapter 1 (Figure 4.01) this classification of the design will be based on three aspects.
(1) Site Design.
(2) Architectural Form and Urban Fabric.
(3) Landscape.

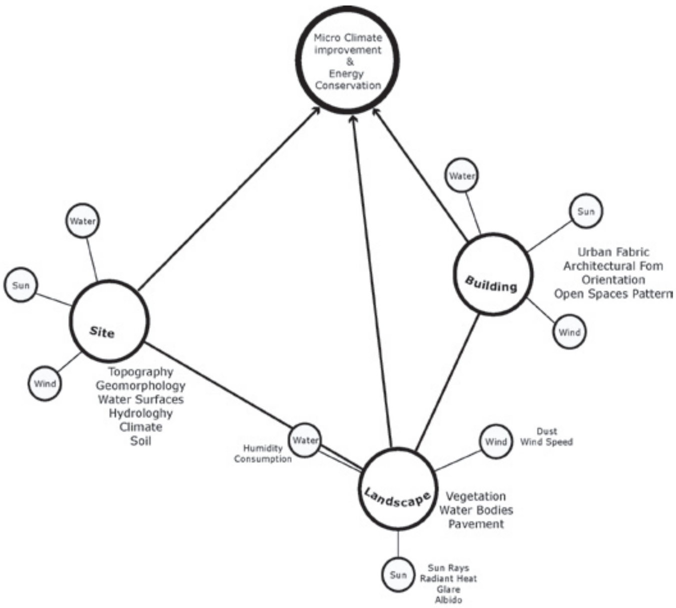


Fig. 4.01, Landscape Design Elements, by author.

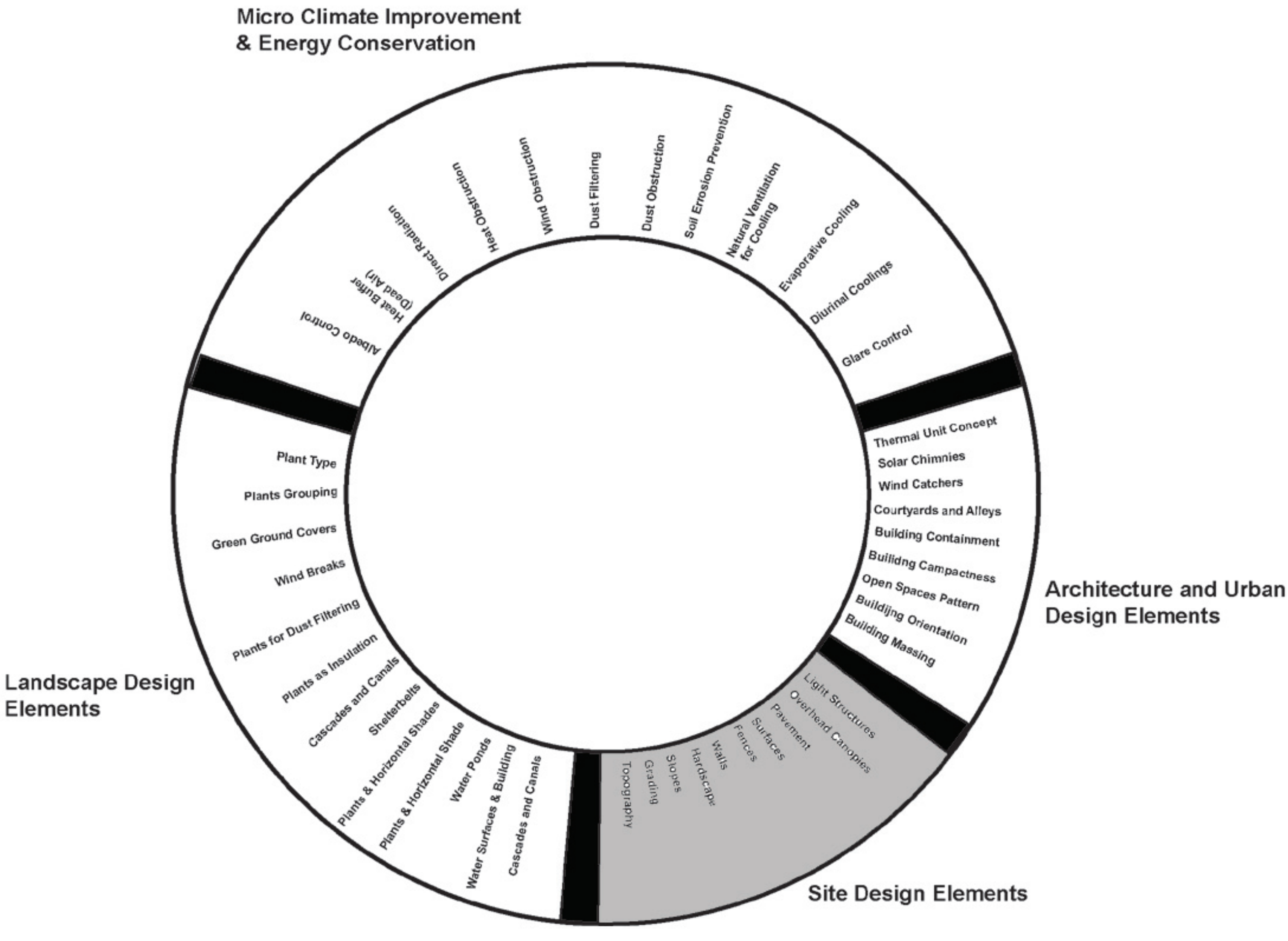
Chapter 4

Site Design Principles and Guidelines for Micro-Climate Improvment and Energy Conservation.

Section 1

Site Design for Micro-Climate Improvement and Energy Conservation.

Landscape Architecture Circle



4.1 Site Design for Climatic Control and Energy Conservation

The primary purpose of site design is to give areas comfort and maximum usage for its users. Site design is related to many factors such as elevation, topography, geomorphology, wind direction and velocity, exposure to solar radiation, relative humidity, aeolian movement and other soil characteristics, and the amount and nature of the precipitation. The designer should manipulate the site with emphasis on the previous mentioned factors to positively enhance the micro-climate and conserve energy.

4.1.1 Topography and the Climatic Impact

Topography or landforms are the natural rises or depressions with respect to the horizontal plane of earth. These concave rises and convex depressions are caused by geological forces of upheaval and meteorological forces of weathering. Generally, cold air is heavier than warm air and because of this cold air sinks and warm air rises. Temperature decreases with altitude 1C degree for each 100m in summer and 1C degree for each 130m in winter. The landforms effect the precipitation and cause large temperature changes. Consequently the types of vegetation on the earth surface get affected too.

The landforms effect the climate due to the thin layer of air flowing over these relieves. The air close to the ground is cooled by the earth at night. The earth is cooling at night through the loss into the night sky of heat stored during the day. Consequently, the down hill cold air flow is a nightly phenomenon on open slopes. It is a thin layer which flows into a stream in open valleys. Therefore, negative ground forms can be heat traps during summer days, receiving radiated heat and glare and allowing little opportunity for breezes to carry away the accumulated heat. Controversies during winter night, areas at the base of long slopes or lower hillside are usually cold and damp. Low *wadis* with no outlet could become during winter frost pockets. They form also cold air reservoirs where its downhill flow could be blocked by a topographical barrier.

The Landscape designer should use this cold air to improve the outdoor environment. Landforms are also responsible for the phenomena day/night onshore/offshore wind movement near the edges of water bodies. Large scale forms near the sea responsible for temperature inversion and smog situations (Robinette, 1983). See Figure (4.02).

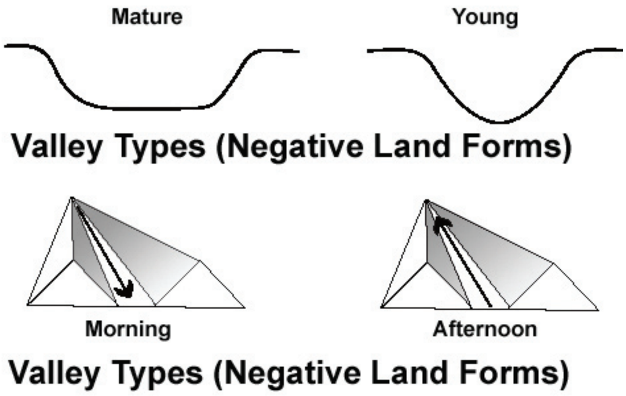


Fig. 4.02, Valley types and wind patterns (Robinette, 1983).

Unfortunately, landforms flow together and they are continuous and unified. The landforms are finely controllable and may be able to direct wind patterns. Landforms can directly control wind through air deflection, interception or reduction. They can also be used for solar radiation blockage or catchments. Landforms become very important site features that work in combination with architecture and vegetation to control the micro-climate and conserve the energy consumption. See Figure (4.03).

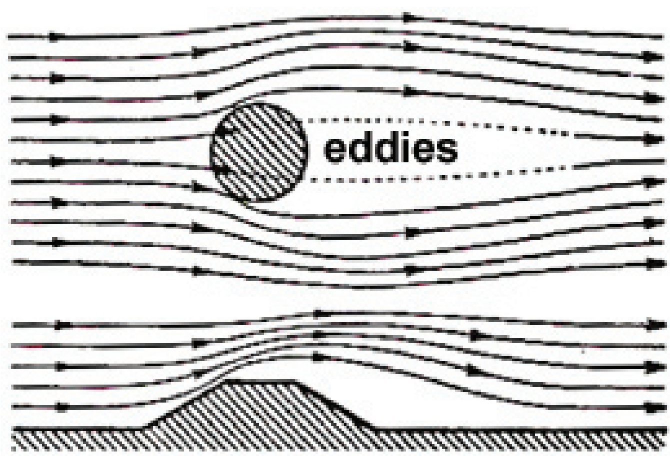


Fig. 4.03, Wind pattern around a hill (Robinette, 1983).

Slopes and solar radiation

Slopes have significant effect on the micro-climate. By analysing the slopes in relation to the sun path and wind flows we find three influential factors, the angles of slope, the orientation of slope and the form of the slope. The angles of slopes of the ground affect the micro-climate due to the amount of solar radiation striking the slope plane. In the summer the high sun angle is maximal on perpendicular sloped surfaces compared to flat ground. On the other hand, the orientation of the sloped landforms, on the horizontal plane, has the same importance in catching or blocking the sun rays. It is necessary to mention that the underlying geology and soil classification help also in magnifying or reducing the solar gain of the landforms.

According to Kevin Lynch in his book, Site Planning (Lynch, 1984): “On a cloudless day 40° N. latitude, the total direct and diffuses radiation on a 10 degree slope attains the following approximate percentages of the possible maximum, depending on season and the orientation of the slope”. See table 4.01.

Table 4.01 The direct and diffuse radiation depending on season and slope orientation (Robinette, 1983).

Slope direction (10 degree slope)	Mid-summer	Equinox	Mid-winter
North	95%	55%	15%
East or West	100%	60%	25%
South	100%	70%	35%
Slope direction (90 degree slope)	**Mid-summer**	**Equinox**	**Mid-winter**
North	40%	15%	5%
East or West	90%	70%	25%
South	50%	95%	100%

The micro-climate of areas with different slope orientations differs depending upon the effects of solar radiation and wind direction. Northern slopes provide better habitats for people and plants since they receive cooler breezes in the summer. Northern and western slopes also receive less solar heat and more cold wind in the winter. Development plans prepared on the basis of the variations in micro-climate of different slopes could result in significant reductions in heating and cooling costs, as well as conserving energy. Therefore, it is suggested that a higher intensity of development take place on the northern slopes and less intensive development on northern slopes (Fig. 4.04).

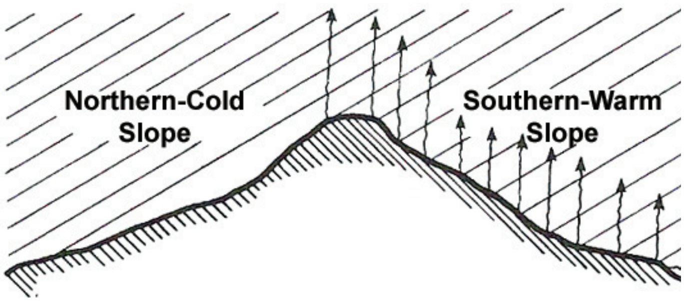


Fig. 4.04, Slopes and the effect of different orientation (Robinette, 1983).

Landforms and wind

Landforms have also an important influence on winds, breezes and air flows. In general, the wind speeds is higher on hill top compared to base-level land. The speed is also slower on lee side than the weather side. Airflow is generally faster through an opening in a land form. Landforms can channel or deflect air movement. Winds passing through canyons and narrow valleys have a tendency to increase in velocity due to the venture effect created by the valley walls. Sites located within these areas will need added protection against strong air currents (Fig. 4.05).

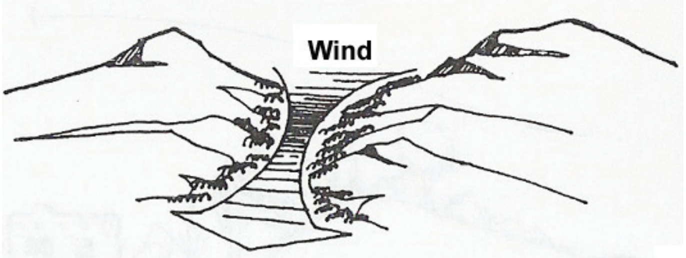


Fig. 4.05, The venture effect of canyon walls speeds up air flow (Miller, 1980).

Positive landforms, such as hills and ridges, also affect airflow. A steep windward slope cause compression of the air, resulting in wind speeds as much as 20 percent greater over the crest of a hill with turbulence beyond. A gradual windward slope will life and deflect air masses more efficiently with a greater zone of protection on the leeward side (Fig. 4.06).

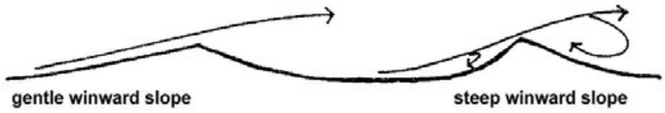


Fig. 4.06, Wind and slopes (Miller, 1980).

Artificial berms can be used to provide wind protection in much the same way as hills and ridges, only on a smaller scale. By construction an earthen barrier on the windward side of developments, or even a single building, airflow will be diverted up and over the site. The berm must be large enough to allow structures to be located within its effective zone of protection at the leeward side.

Large-scale landforms should be an integral part of the site design when used and not treated as an isolated or independent element. Berms can be organically sculptured to blend into the existing landscape as much as possible and will require planting to stabilize the soil and add visual coherence to the site. A concentrate of trees and shrubs at the crest of the berm will also increase the barrier's ability to deflect wind, as well as filter noise and dust (Fig. 4.07). Well designed and landscaped berms can provide valuable open space, recreational areas, and natural buffer zones for wildlife (Miller, 1980).

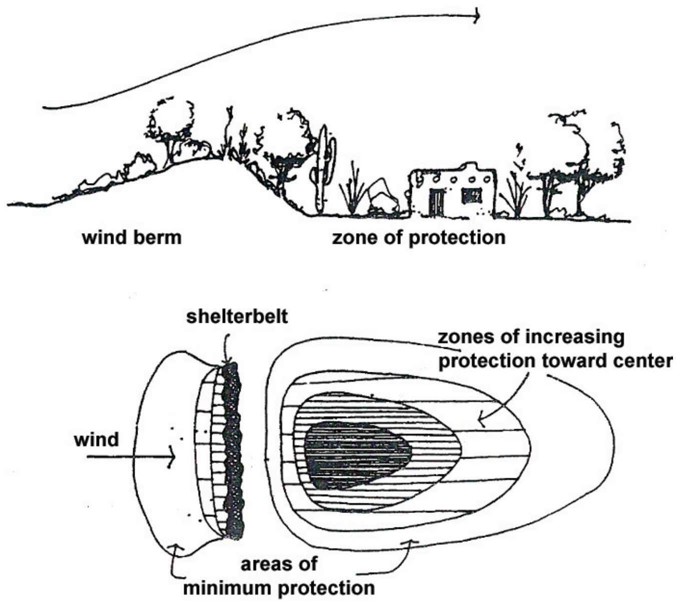


Fig. 4.07, Wind control and shelterbelt (Miller, 1980).

The importance of landforms lies in its ability to block or direct the air flows in co ordinance with the urban pattern and vegetation. The landform can also raise the vegetation to a higher elevation. Both plants and landforms have the ability to change climatic conditions. They can make the environment cooler or warmer, depending on their manipulations. The following illustrations show some basic

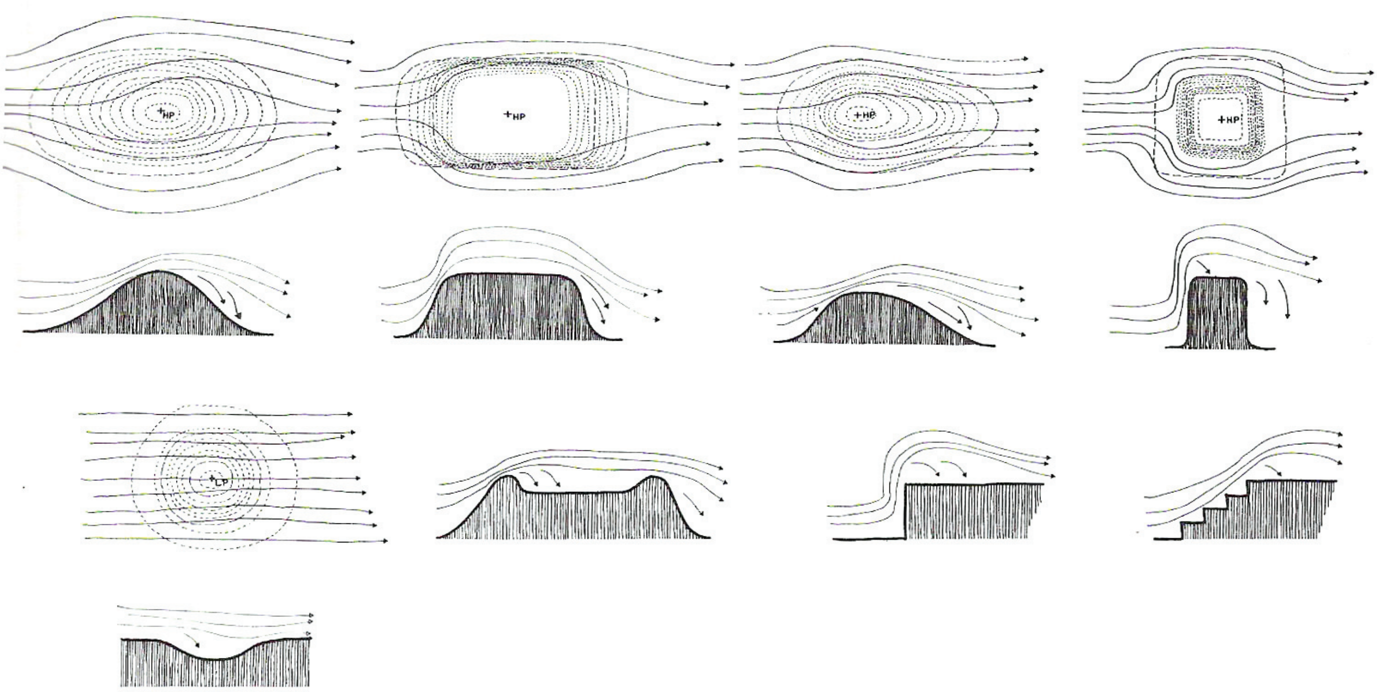


Fig. 4.08, Landforms and wind flows (Robinette, 1983).

concept (Fig. 4.08 & 4.09).

Landforms and underlying soil

The major worry in grading is the type of soil which will be adjusted and used. The soil classification is important whether it is gravel, stone or sand to decide how it will be adjusted to the basic angle of repose and if there will be necessity for surfacing or stabilization. The soil limitations in specific areas should be also considered before the configuration the land for solar radiation or energy conservation. It is necessary also to insure the soil stabilization and erosion control on steep slopes. This may require excessive costs for irrigation and maintenance and will not help in energy saving. Also, in regarding to the existing underlying geology, it is important to integrate drainage systems in the whole site.(Robinette, 1983)

4.1.2 Grading

In respect to the aspects mentioned previously, grading becomes a very important design step to control the micro-climate and reduce the energy consumption of building. Grading is a major component of landscape design which is the basis for any design. It can improve the orientation and location of the architectural elements and landscape elements while reducing the energy consumption.

Site building should take advantage of landforms to control specific micro-climate. Earth forms may be moved and adjusted in order to provide protection from wind and solar radiation, to control air flows and create cool air reservoirs, to provide visual screening as well as traffic and access control.

The evaluation of the grading plan is necessary in order to stand on the precise earth form that will be realized in the location and the angle to which it is desired. Either to maximize the benefit of the available solar radiation or to conserve the energy that will be used in buildings. Landforms can be successfully manipulated to increase the height of the location and enhance the effectiveness of either hardscape such as fences or walls or softscape. A precise grading plan should be developed by the landscape architect including the ways for soil stabilization and erosion control(Robinette, 1983). The following illustrations show some details of land form uses (4.10):

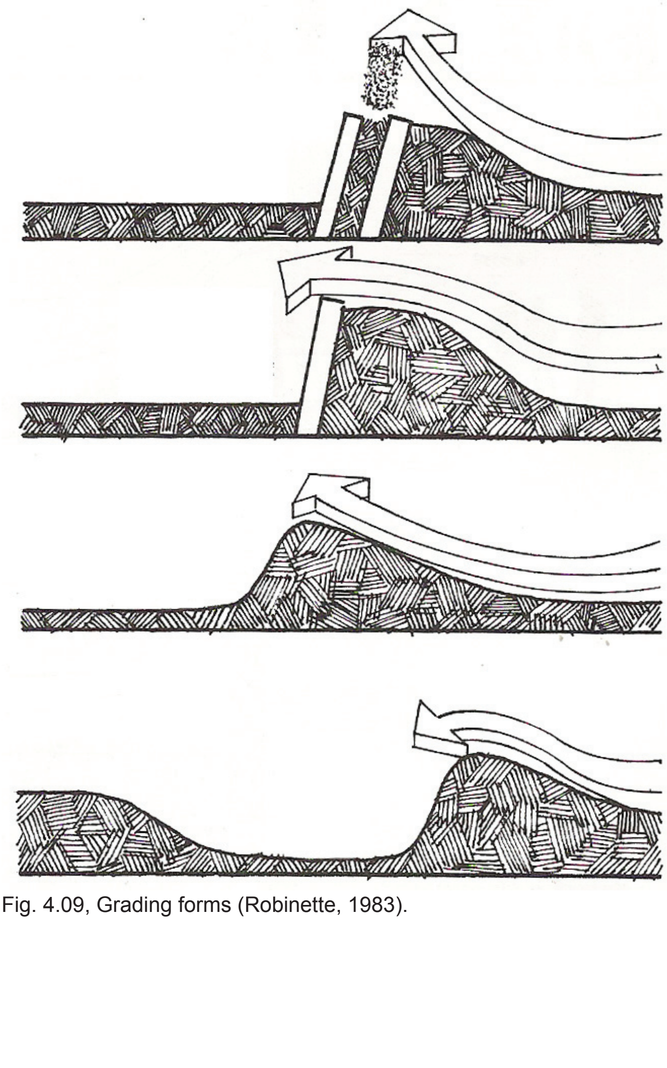


Fig. 4.09, Grading forms (Robinette, 1983).

4.1.3 Hardscape

Many definitions agreed that hardscape, consists of the inorganic elements of landscape, especially any masonry work or woodwork. For instance, stone walls, concrete or brick patios, tile paths, wooden decks and wooden arbors would all be considered part of the hardscape. But by extension, anything used in landscape that is not part of the softscape can be considered a hardscape element. The book *Landscape Planning for energy conservation* classifies the hardscape elements as followed (fig. 4.10 and 4.11):

Walls

Landscape designer must consider fenestration and screening in his design. The height, material and the exact location for walls, fences and screens is necessary design decisions. Such walls, depending on the function and dimensions may be able to block solar radiation and wind. The common used materials are obviously brick, stone, and concrete blocks. The walls could be free standing or retaining walls and could be utilized to increase the height or provide a more optimum location for vegetation or architectural materials. The following diagrams indicate some possible settings for walls for solar radiation utilization, wind control and for energy conservation.

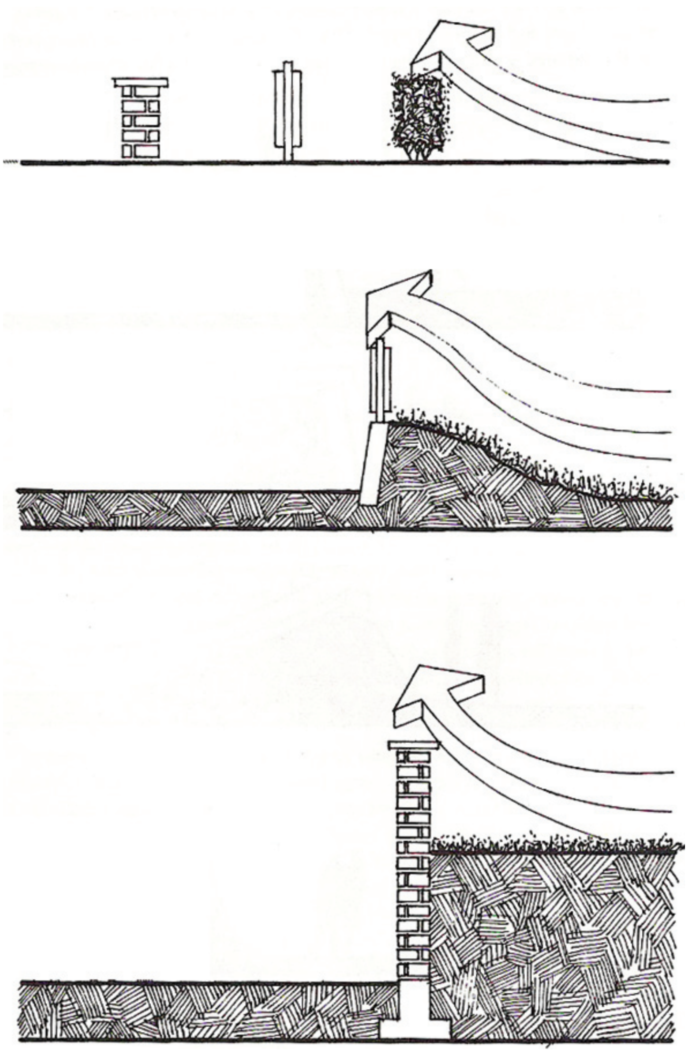


Fig. 4.10, Different wall types (Robinette, 1983).

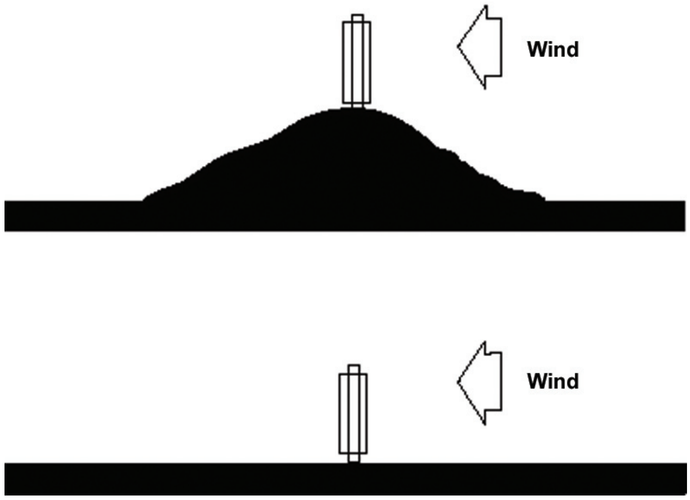


Fig. 4.11, Preventing wind through walls (Robinette, 1983).

Fences

Fences are free-standing architectural elements, usually made out of wood, metal, glass or plastic. Once again, certain necessary design decisions need to be taken concerning the height, width and materials in relation to the surrounding architectural used materials. In addition to the availability of possible fencing materials, and the effect desired from the fence, either in solar radiation control, wind control or in energy conservation. Fences may be closed all the way to the ground or may have openings at the lower levels to allow for the passage of air under or through the fence. Fences have certain height and length limitations. Fences below one meter are mainly for used for traffic control. Over this height, they have the ability to control the micro-climate of the outdoor environment (Robinette, 1983). The following illustrations demonstrate some examples (fig. 4.12).

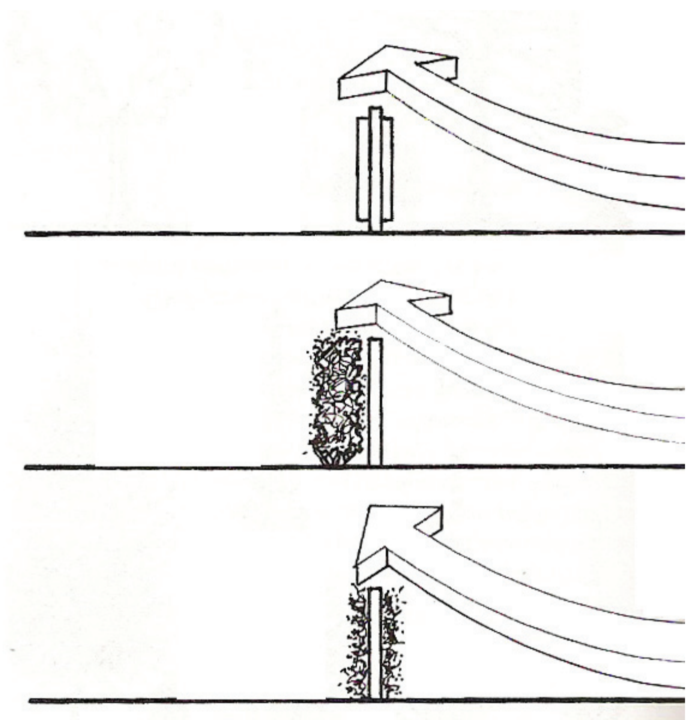


Fig. 4.12, Fences types (Robinette, 1983).

Fences can be combined with landforms, light forms architecture and overhead canopies. Fences can control the solar radiation. Heat and glare can be controlled by fences made of wood or bamboo or anti glare materials. Louvers can brake the sunlight intensity as well basket-weaves fences or trellis. Vertical screens in front of buildings or terraces can stop the late afternoon sun, which leans under roof overhangs or trees. This type could be also combined with climbers or vegetation in order to cool the western walls of a building by blocking or filtering the sunrays *(Robinette, 1983)*.
On the other hand, it is not easy to control the wind because its behaviour is unpredictable and even the most advanced computational fluid dynamics (CFD) simulations can hardly predict the wind behaviour in the site or specific location. The prevailing wind in a specific area is not necessarily the direction of the real air flows in the site. Buildings and other objects such as fences, walls planting can act as obstructions for the wind. Therefore, it is important to prepare a basic study about the air flows and wind currents before starting to locate wind screens or fences.

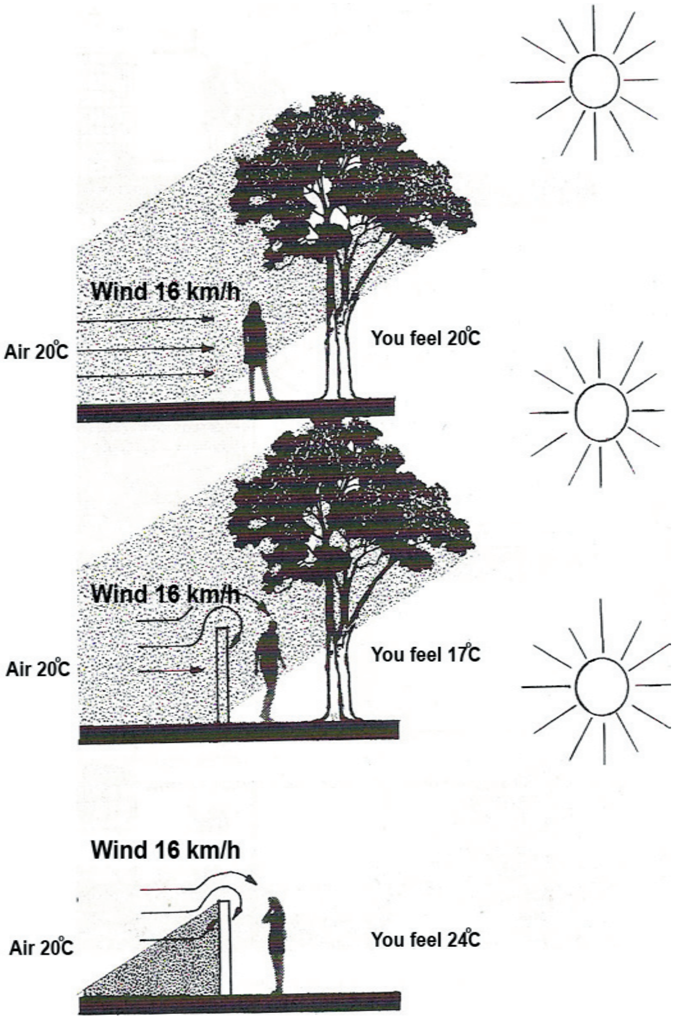


Fig. 4.13, Solid fences and their effects (Robinette, 1983).

There are many choices to select the fences materials. A wind screen made of closely woven slats will break up a strong wind more efficiently than a solid glass fence. A fence for wind control and a tree for solar radiation control could be used in conjunction to alter or adjust the comfort levels significantly and reduce the need for extra energy usage.

According to Robinette in his book *Landscape planning for energy conservation* a study was made on solid fence, which reaches all the way down to the ground level. A wind speed of 16 kilometres per hour an air temperature of 20°C and a shaded situation gives a feeling of 17°C. Whereas an air temperature of 20oC with full sun and wind blocked gives a feeling of 24oC.This means that a solid fence may not be the most effective means of controlling or reducing wind flow, because a total blockage of wind may not be essential to raise the temperature to comfort level.

The designer should decide the degree of wind control and comfort level based on the function and activities that will take place. Sometimes it is wise to design fences with movable louvers in order to direct wind and breezes. The fences should be also movable to adapt to the seasons of the year and times of the day to achieve the desired comfort level (Vandervort, 1975). Placing solid fences in areas of consistently heavy prevailing wind areas is not a good idea because the wind screes can reverse flow and create strong air turbulences or eddy formed leeward of it.

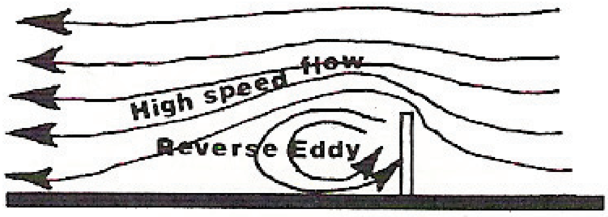


Fig. 4.14, The reversed eddy (Robinette, 1983).

Vandervort states" *A 15 cm space left at the bottom of a solid fence relieves some of the pressure and reduces the leeward eddy. By adding a 45° baffle to the top of a 180 cm fence the amount of wind protection behind the fence is increased considerably depending upon the direction which the baffling device faces".* Various types of louvered fence configurations have differing effects upon wind flow pattern by both lowering the wind velocity and the temperature leeward of the perforated fences.

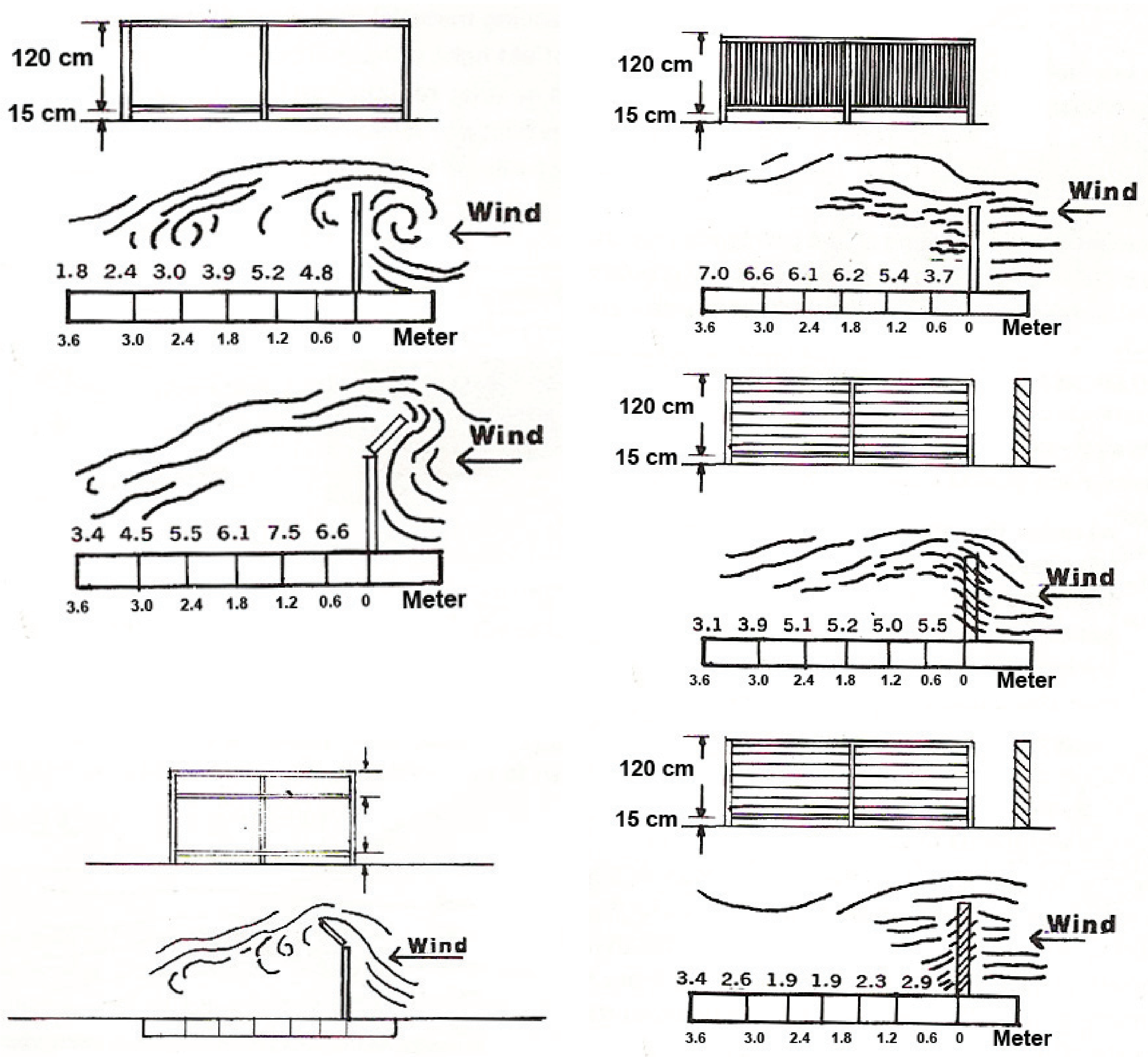


Fig. 4.15, Fences and leeward (Robinette, 1983).

Furthermore, the colour or lightness or darkness of fences may contribute to the reflectivity or ability to absorb or deflect light or heat. This has direct impact on energy conservation and solar radiation use of site elements. Because fences can reflect or radiate heat or light into relatively colder places and to retain day time daytime heat for release during the cooler evening hours (fig. 4.16).

A lighter colour fence will reflect a greater amount of heat.

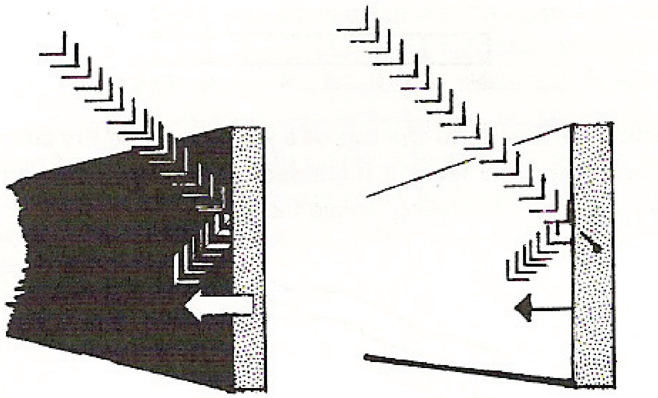


Fig. 4.16, Light and dark coloured walls (Robinette, 1983).

It is advisable to use light coloured fences in southern walls and fences as well as dark coloured fence in the North. It is also important to take account of glare. Another example could be present in fig 4.17 where a vine covered wall has a less temperature compared to bare wall with direct sun exposure.

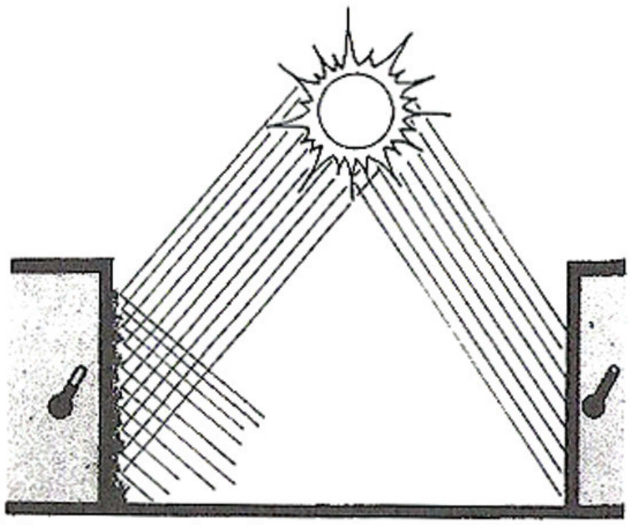


Fig. 4.17, The effect of vine covered walls (Robinette, 1983).

Surfaces

The surfaces of both building and ground provide a tactile framework for all spaces. Choices for surfaces can play a role in the conditioning of the environment.

The principles for surfaces should accomplish the following objectives:

• Integrate landscape, urban furniture, and the grain of the architecture.

• Qualify the edges and limits of the space.

• Efficiently address building conditions such as orientation, and maximize the performance of the enclosures affected by those conditions.

Principles for Ground Plane Surfaces

The exterior ground plane surfaces, through change in elevation, surface texture and pattern, define the “floor” condition of all public spaces. A basic distinction in the materialization of the ground plane presents hardscape (paved) and softscape (landscaped) areas. Hardscape areas include primary and secondary circulation paths and most civic gathering places.

The area ratio of softscape to hardscape is a function of the civic nature of the space, its potential for congregation, and circulation routes. In major public spaces, soft areas should not exceed 30% of the overall space area.

1. Planned elevations in the ground plane (berms, mounds, overlooks) and ground depressions (sunken spaces, gardens and platforms) should not disrupt the vision of the spaces in which they occur. Any manipulation of topography within major public spaces, connective elements and courtyards should not surpass 20% of the total floor area of each space.

• Shape the earth to form barriers to undesired sun or winds. Effects are most useful within 5 times the height of the berm away from wind break. Use the moderating effects of earth either as berms or on roofs.

• Use deep ground areas for habitation and to form reservoirs of cool temperatures.

2. Adjacent water features, softscape and shaded zones are recommended for the creation of humid/cool micro-climates.

3. Additional environmental criteria:

• Use reflective materials for the ground plane and surrounding walls to reduce the absorption of solar radiation and energy use in interior spaces. Shade the ground plane, above the level of the building, at the hottest times of year.

• The color of the surface affects the degree to which solar radiation is absorbed. Light colors are more reflective and will be cooler than dark surfaces. If shaded, surface color makes less difference, and temperatures will be determined primarily through convection with adjacent areas.

• Balance the visual field. Use light-colored materials to reduce heat gain impacts, and keep them shaded. Darker materials (which absorb heat) often are more visually comfortable. Groundcover plantings are a good option to provide visual and thermal comfort.

• Reduce the amount of dark, hard, impervious surfaces on the site. Aggregate building massing to minimize the footprint.

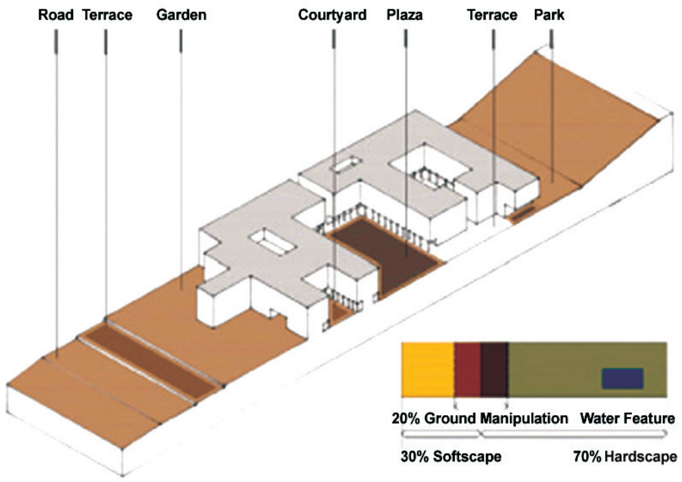


Fig. 4.18, Pavement types (Abdel Halim CDC and Sasaki Associates, 2000b).

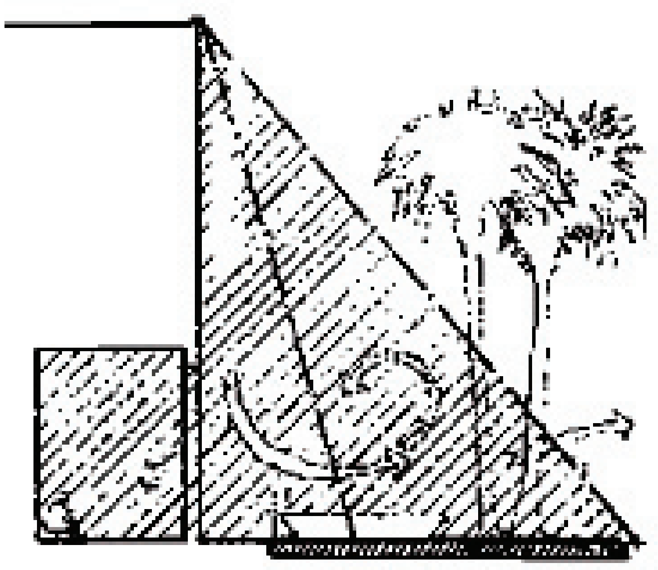


Fig. 4.19, Evaporative convective cooling (Abdel Halim CDC and Sasaki Associates, 2000b).

• Where hard surfaces are used (paving, etc.), use porous materials that allow for storm water management, groundwater recharge, and biotic growth.
• Design impervious surfaces to accommodate plant material. This will engage the scope of biotic ecosystem services, such as thermal tempering of the surfaces, production of biomass, carbon sequestration, storm water management, and nutrient cycling. It will also help in managing scarce resources and increasing biodiversity.
• In courtyards, use unit paver systems, promoting some water Infiltration, and allowing subsurface repairs without wholesale replacement of the surface. Root systems typically breathe better under unit paver systems, provided compaction is not too great. Porous pavements should be considered, especially in interior courtyards and other tight places. Integrate surface water runoff with paving and grading design.(Abdel Halim CDC and Sasaki Associates, 2000)

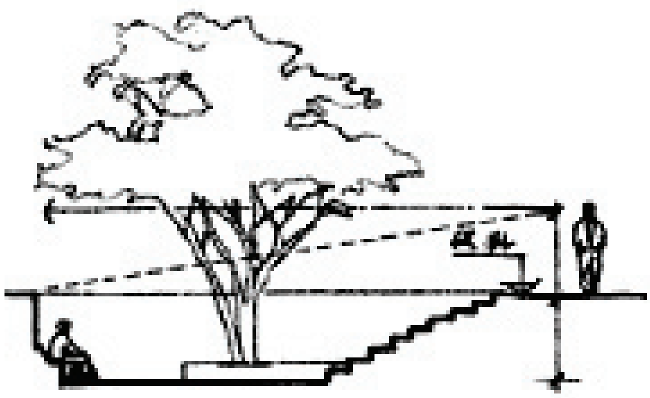


Fig. 4.20, Ground plane depression (Abdel Halim CDC and Sasaki Associates, 2000b).

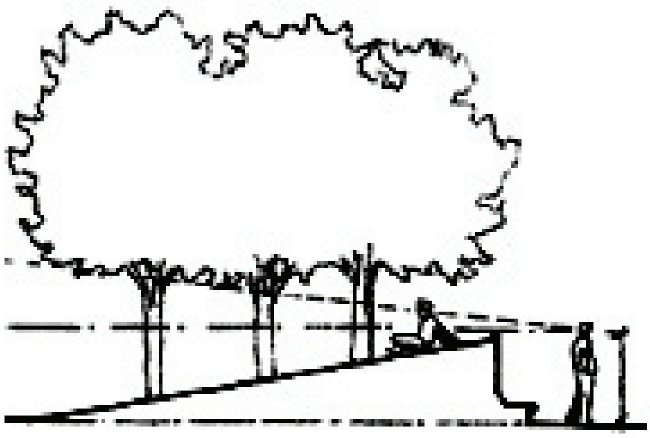


Fig. 4.21, ground plane elevation (Abdel Halim CDC and Sasaki Associates, 2000b).

Pavement

Surface material used in the outdoor environment will play an important role in micro-climate control. Unprotected wall surfaces and excessive paving can be a source of unwanted glare and re-radiate heat. The capacity of materials to absorb or reflect solar radiation is principally a function of their density, colour, and surface texture. Dense materials, such, as stone, will have a greater absorptive capacity than wood, which has a higher percentage of pore space and a greater isolative value. Surfaces tend to re-radiate stored energy at night in the form of heat, contributing to the heat load of the immediate area. Likewise, dark-coloured surfaces will absorb more radiation than highly reflective light-coloured surfaces, and a high rough uneven texture will reduce reflection by scattering light strikes it.

Albedo, a measurement of the percentage of solar radiation, both direct and diffuse, is a useful indicator of its glare potential, with the higher the albedo the more a surface will produce glare from reflection, as shown in table 4.02. (Miller, 1980).

Table 4.02 including the Albedo temperatures.

Material	%
Light sand dunes, surf	30-60%
Sandy soil	15-40%
Meadows and fields	12-30%
Densely built-up areas	15-25%
Dark cultivated soil	7-10%
Water surface	3-10%
Concrete	30-5-%
Brick various colours	23-48

To control re-radiated heat and glare from paved areas and wall surfaces, the following suggestions will be helpful in coordinating site design and building layout with the placement of vegetation and other solar control devices:

The following suggestions are important for site design together in coordination of building layout, vegetation and solar control devices placement. The landscape designer should study precisely the specification and detailing of the paving material used in various areas of the site. Using the same material throughout the whole site is not possible because every material will have its own climatic effects. The basic pavement materials are concrete, asphalt, brick, stone, wood and cast stone materials considering the reflectivity, the ability to absorb and the ability to retain heat. Most paved surfaces elevate temperatures. Large paved areas near a building store and radiate heat for many hours after sundown and many cause undesirable climatic conditions. A solidly paved walk or drive way absorbs as well as reflects heat and causes also glare.

Ground temp can be altered also by using materials of different absorptive properties. Mulches can also modify the ground conditions. Marble, chips, rocks or bricks used as decorative mulches around the bases of plants and carry more heat to the soil. Loose mulches such as grass clipping, leaves, or straw act as insulation, reducing the solar radiation and the evaporation of water from the soil (fig 4.22).

Large surface areas of different substances radiate and reflect solar energy in varying degrees, producing changes in the temperature of the air. Rocky areas, pavements and masonry can create extremely hot mesoclimates in the surrounding environment. As light surfaces reflect more than dark ones, the colour value of a material is another micro-climatic control. A wall painted in a high key can send light into an otherwise dark or cool area especially one on the north side of a building or on a shaded situation.

Bajwa (1995) refers to observations, where asphalt surfaces reached 51°C in 36°C air temperature and concrete surfaces reached 55°C and metal up to 70°C. Paved driveway and pathways can absorb and re-radiate great quantities of heat. Therefore pavement should be broken up with intervening patterns of grass cover and shaded with architectural or landscape elements. The colour of the paved surfaces has also a great deal with heat absorption and re-radiation. Lighter colours with rough surface finishes should be used to reduce glare. Excessive glare and radiation may be reduced by plant-material and by east west orientation of narrow roadways(Bajwa, 1995).

Fig. 4.22, Mulches in Al Tahrir Nursery, 100 km northern Cairo.

Cooling the Pavement

Even if an outdoor dry surface is shaded effectively, its temperature would be somewhat elevated above the ambient air level. Cooling the pavement of a relatively wide shaded area can be lower the radiant temperature to which the people in the area are exposed, although the effect of the air temperature, at the level of the occupied zone, would be negligible. In a private paved courtyard the pavement can be cooled simply by wetting it from time to time during the daytime, using sprinklers or mist spray devices or even garden hose(Givoni, 1996).

4.1.4 Overhead Canopies and Light Structures

Overhead Canopies

Solar exposure is desired certain times of the year, while protection from excessive heat gain is needed other times. The efficiency of any shade device is depending on its ability to shade a given surface during the overheated period of the year without intercepting the sun's warmth during the under heated times. In order to determine when to shade, the overheated and under heated periods for any location must be defines.

Overhead canopies are devices that limit the impact of solar radiation. Overhead canopies are architectural extensions and are very effective for energy conservation. When it is not possible to curtail excessive solar radiation and heat either with land forms or plants, the overhead canopies can extend from the architecture. This solution is considered as a landscape architectural solution. For energy conservation and optimum solar energy utilisation there are many options for overhead canopy design, location and covering. The usage, design, placement of overhangs is based in some principals.
The south side of any structure in Egypt receives the majority of solar radiation all during the day at all seasons of the year. The east side receives strong early morning sun which is usually not as warm as the afternoon sun. The afternoon sun strikes the west side of a building. The area directly on the north side of any building does not receive any mid-day sun. The early morning and some of the late afternoon sun may strike the north side but only for a short period. Therefore, the north facades are in creating shade most of the day.

The degree and amount of solar radiation, the season of the year and the time of the day are amount of solar radiation, the season of the year and the time of the day are basic data the designer should know. Also the amount of shade, places of paved surfaces, or turf or earth are dictate to the form covering and location of the canopy. To conserve energy in outdoor areas it may be necessary to design a canopy to shade a paved area but not the structure.
It is desirable to use canopies or horizontal trellis with a vine covering or a sort of mist-spray device on order to make the area usable. In general, any site development facing south requires a sort of a roof that can be left up all over the year to provide sun protection. Due to its direct sun exposure, the roof can be safely covered with perishable material such as canvas, reed or bamboo because they will be dried out quickly after a heavy dew or rain. Louvers and east-west running lath can provide effective protection. Likewise do covering.

A west-oriented outdoor area will be extremely warm in the late afternoon when it receives full force of the sun ray's. As Robinette states, the sun radiate against the west wall of a building with six times as much heat in the summer as it does in winter. However, the low hot rays of the afternoon sun can be caught by vertical sunscreens.

In a hot arid region like Egypt, the design of overhead roof structures should be made carefully. Landscape architects should provide air circulation and avoid light coloured building materials on order to avoid building up a heat trap or heat islands.

When an outdoor area faces the east, it benefits from the morning sun and begins to cool off in the afternoon. The east side is a desirable orientation for a hot climate. Louvers or lath set to block the hot morning sun make good sense in hot arid locations (fig. 4.23 and 4.24).

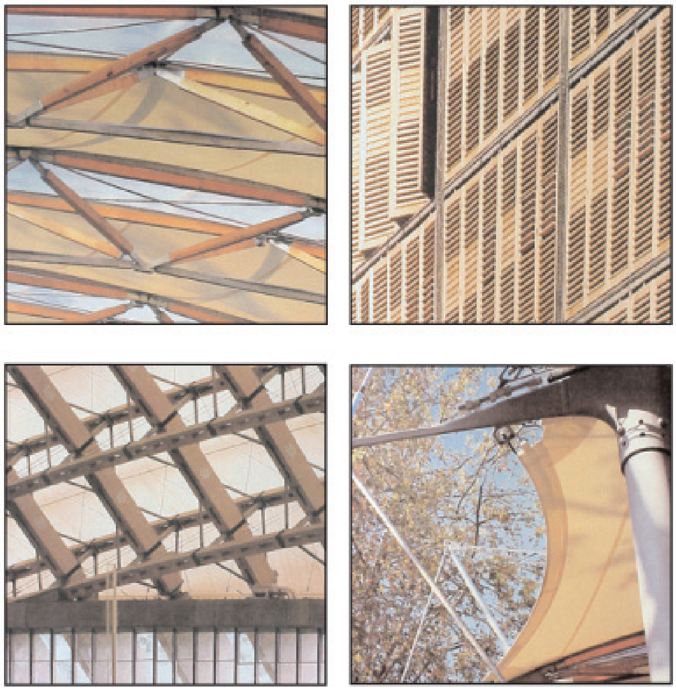


Fig. 4.23, Variant overhead canopies.

Fig. 4.24, Trellis as canopy.

Light Structures and Pergolas

Screens should be made of wood, metal or other light material. If stone, concrete or other masonry material is used as a screen, it should be expressed as a veneer. Plant material, sod roots to be incorporated into the inhabitable roof areas. On the other hand, light Structure do not only provide shade for seats or spaces in the outdoor environment they can also integrate solar panels, which minimizes the electric demand of the surrounding buildings. The following images are some showcases for light structures such as pergolas and carports in which the solar panels are integrated in the sheds (Hermannsdörfer and Rüb, 2005). Such examples do promote the idea of using photovoltaic in general besides saving on the energy costs. See Figure 4.25, 2.26, 4.27, 4.28, 2.29 and 4.30.

Fig. 4.25, Ornamental tent, Al Tuwaiq Palace, KSA.

Fig. 4.28, Sunbrellas in Hamburg, (Hermannsdörfer 2005).

Fig. 4.26, Car parking trellis , Al Tuwaiq Palace, KSA.

Fig. 4.29, Carport in Basilicata, Italy, (Hermannsdörfer 2005).

Fig. 4.27, Teflon Tent t, Al Tuwaiq Palace, KSA.

Fig. 4.30, Solar Pergola, Bocca di Magra, Itlay, (Hermannsdörfer 2005).

Design Principles and Guidelines for Hot Arid Regions:

- Use earth forms to shade or screen the exposed walls of buildings.
- Use earth forms as windbreaks.
- Use earth forms to channel winds or breezes.
- Hard surfaced materials should be used for terraces and other outdoor sitting areas, since solar heat on hard surfaced terraced, patios and courtyards will increase the length of the evenings.
- Employ medium colours on sun exposed surfaces, use dark colours only in recessed places protected from summer sun. Light colours will generally be too reflective in the hot arid region. Dark colours, except in special places, absorb more radiation than desired.
- The total non-permeable paving areas, such as parking lots, side walks, and street should be kept to a minimum. Those paved areas which must be used should be shaded through the use of vegetation, landforms, walls, screens, canopies and overhangs. Grass ground cover, gravel or other permeable surfacing material should be used in place of non-permeable paving around all walls of a building since the lower light reflectivity may be employed as an element of cooling. Place trees so that they overhang and shade roof areas.
- Lighter coloured materials should be used on the north side of structural elements, with darker colours on the south side.
- Orient buildings to minimize the impact of excessive solar exposure on east and west walls. Glazing should be kept to a minimum and shaded where possible. Shaded glass transmits to interior spaces approximately one-third as much heat as an unshaded window surface, depending on location and orientation. Screens prevent direct radiation from heating interiors and help reduce glare both inside and outside.
- Keep paving to a minimum. Paving should be reserved for streets and heavily travelled pedestrian ways. Where paving must be used for outdoor social or recreational activities use strategically placed pergolas, vegetation, or other shading devices, to protect key areas. Consider breaking up paved areas with grass or other groundcovers that grass or other groundcovers that are less reflective and radiate less heat. Locate areas with excessive paving away from or leeward of buildings to allow prevailing breezes to carry away unwanted heat.
- For high density developments structures can be situated so as to shade one another as well as outdoor living areas and circulation ways, especially if buildings are close, walkways are narrow, and open spaces are small. To realize the fullest benefits from shade produced by the clustering of structures, streets should kept narrow and generous rights of ways avoided. Opt for small parking bays and interior courtyards that are easily shaded. Buildings with cantilevered overhangs and deep-set walls provide natural shade.(Miller, 1980)

Summer

- Avoid valley or bowl-like settings which tend to overheat during day without the benefit of cooling day breezes. High, exposed hillside settings are subject to high winds, dust pollution, and increased solar radiation.
- East and west exposures are subject to heat buildup; west-facing slopes experience the highest annual temperatures of any slope orientation.
- Location on site to east of a high land feature will decrease hours of solar exposure and protect from wind and dust.
- Need to cool hot desert breezes.

Winter

- Valley or bowl-like settings become cold air pools at night and prolong under heated period. High exposed hillside settings are good for solar heat gain.
- Best winter exposures for solar heat gain range from SE to SW.
- Location of site leeward side of prominent land feature to block winter winds.
- Bodies of water tend to modify temperature extremes of adjacent land mass.

Balance between Summer and Winter

- Lower hillside locations are preferred to take advantage of modifying air movements in both summer and winter. Thermal belts make good sites for desert dwellings; these belts are located on sloping terrain between colder elevations above and temperature extremes in valley below.
- A south-east facing slope is the optimal, allowing good winter exposures and blocking summer afternoon sun.
- Locate site adjacent to high land form in order to thereby decrease sun and wind exposure and provide a psychological ‘place’ in desert vastness.
- Sites located leeward of large bodies of water or irrigated fields will benefit from evapotranspiration cooling and temperature modification.

(Clark, 1980; Cook, 1980; Fredrickson, 1980; Givoni, 1980; Golany, 1980; Legorreta, 1980)

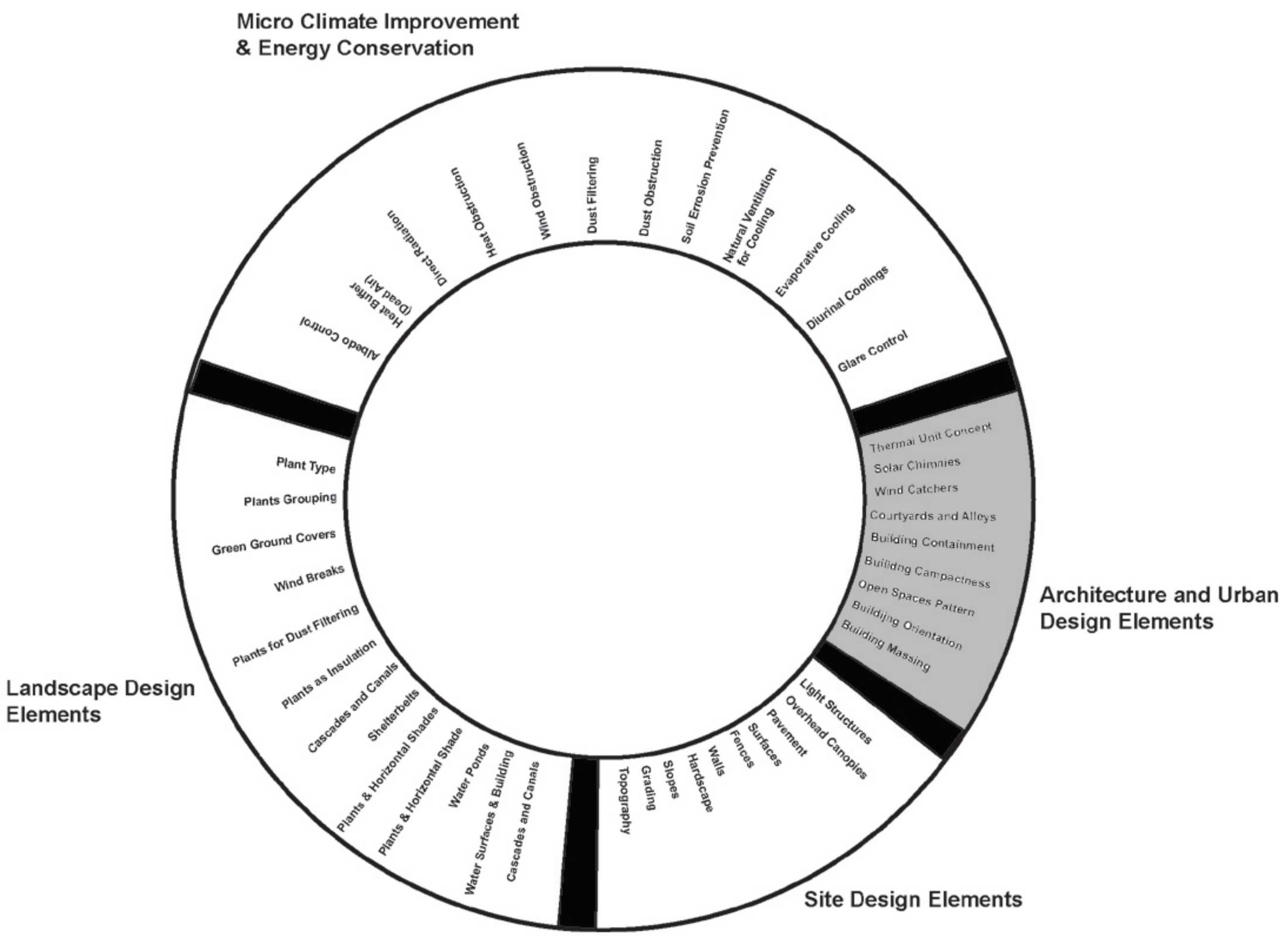
Chapter 4

Architecture and Urban Form Principles and Guidelines for Micro-Climate Improvement and Energy Conservation.

Section 2

Architecture and Urban forms for Micro-Climate Improvement and Energy Conservation.

Landscape Architecture Circle



4.2 Architectural Form and Urban Fabric for Micro-Climate Improvement and Energy Conservation.

Climate, in particular, produces certain easily observed effects on architectural forms. For example, the proportion of window area to wall area becomes less as one move toward the equator. In warm areas, people shun the glare and heat of the sun, as demonstrated by the decreasing size of the windows. In the subtropical and tropical zones, more distinctive changes in architectural form occur to meet the problems caused by excessive heat. In Egypt, Iraq, India, and Pakistan, deep loggias, projecting balconies, and overhangs casting long shadows on the walls of buildings are found. Wooden or marble lattices fill large openings to subdue the glare of the sun while permitting the breeze to pass through. Such arrangements characterize the architecture of hot zones, and evoke comfort as well as aesthetic satisfaction with the visible endeavors of man to protect himself against the excessive heat. Today a great variety of devices such as sun-breakers or brise-soleil have been added to the vocabulary of architectural features in these zones.

Notice, too, how the gabled roof decreases in pitch as the rate of precipitation decreases. In Northern Europe and most districts subjected to heavy snow, gables are steep, while in the sunnier lands of the south, the pitch steadily decreases. In the hot countries of the North African coast the roofs become quite flat, in some areas providing a comfortable place to sleep. Still further south, in the tropical rainfall zone, the roofs are again steep to provide protection from the torrential downpours typical of the region.

It is worth noting that so long as the people of the humid tropical regions built their huts with reeds and grass, which allowed air to pass through the walls, the steeply pitched roof was a useful device. However, once they began to use more sophisticated materials like cement block and the common gabled roof topped with corrugated iron sheets, the houses became unbearably hot and stuffy. This kind of roof prevents the catching of draughts at the very level where they prevail, and the solid walls prevent the passage of air.

The traditional flat roof and the brise-soleil of recent tropical architecture, with its modern feel, have attracted the imagination of architects in colder regions who are continuously searching for something different and exotic. The result is that in some northern cities thoroughly inappropriate examples of architecture, with shapes suitable to an alien climate, have succeeded in making the neighbouring buildings look old-fashioned without responding to the needs of the people in their climate. The temptation to create up-to-date designs which assails a modern architect prevents him from achieving the chief aim of architecture: to be functional. He forgets the environment into which he will implant his buildings because he is attracted by new and modern innovations and gadgetry. He fails to realize that form has meaning only within the context of its environment.

The choice of an appropriate urban form is important.

Habitable

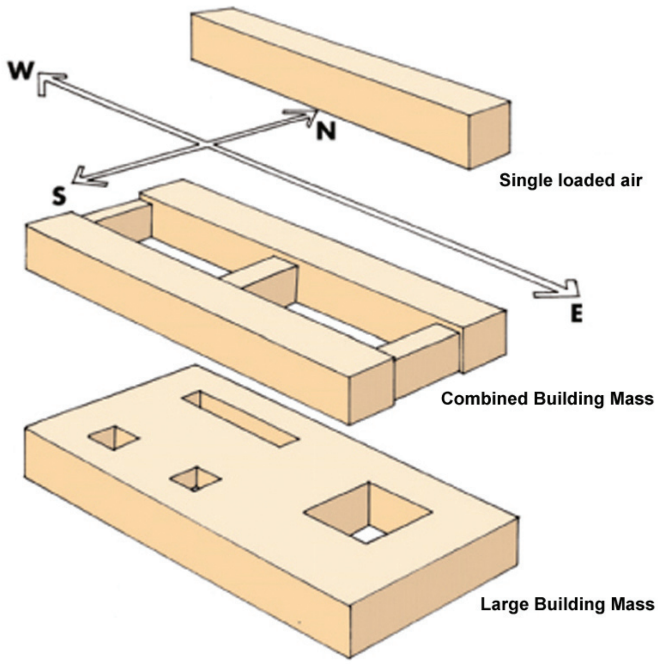
- Structures grouped in compact clusters in order to maximize shadow.
- Orientation so as to capture cool breezes, minimize glare and reduce solar heat reflection.
- Heavy use of open central courts to maximize both shadow and ventilation, Avoidance of large unshaded open spaces
- A shadowed, protected network. (Golany, 1980)

4.2.1 Building Massing and Orientation

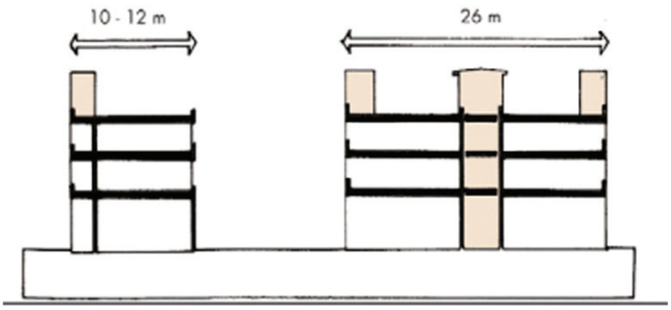
The orientation and organization of buildings on the site have great impact on comfort and thermal performance. The greater the scale of environmental optimization, the greater the load reduction and positive environmental impact. Each orientation experiences different solar impacts, thus defining building form.

- Extend building massing along the east and west axes, to maximize along the north and south building façade exposure.
- Try to keep the building mass within 15 degrees of north/south orientation.
- Minimize east- and west-facing building facades.
- Apertures should be oriented north/south wherever possible.
- Keep building forms narrow in section. Single-loaded corridors are ideal, allowing bilateral access to light and ventilation.
- Single-loaded corridor buildings should be approximately 10 to 12 meters wide or less.
- Double-loaded corridor buildings should be approximately 26 meters wide or less.
- Keep floor to floor heights as high as feasible: 4-meter and 5-meter heights will be acceptable.
- Maximize floor to ceiling heights within the envelope by coordinating structural systems and articulating ceilings; 3.5- to 3.6 meter floor to ceiling heights should be the minimum.
- Consider placing some building spaces below grade for thermal tempering.
- Minimize building footprints by consolidating masses.
- Perforate larger masses with small courtyards and light wells. All buildings must be organized around courtyards
- Locate buildings to allow sunlight to reach the entire façade during the winter solstice. This implies a 40-degree envelope. Separate north- and south-oriented buildings by a distance equal to their height (1:1 or 45-degree cut-off).
- East and west facades should be closer together (1:2) to provide self-shading.

See Figure 4.29 (Abdel Halim CDC, Sasaki Associates. 2000).



Typical Building Massing and Orientation



Typical Building Section

Fig. 4.31, Typical building massing and orientation (Abdel Halim CDC and Sasaki Associates, 2000b).

4.1.2 Pattern of Major Open Spaces

With proper arranged system of green areas cutting through the entire built-up area, vegetation can be located to direct and channel cool summer breezes through structures and outdoor spaces and deflect cold winter winds. This could be realized through arranging the pattern of major open spaces in generally the same direction of the favourable prevailing winds. On the other hand, cold air drainage can be blocked with shelter belts, but care should be taken to deflect, not trap, cold air (fig. 4.32).

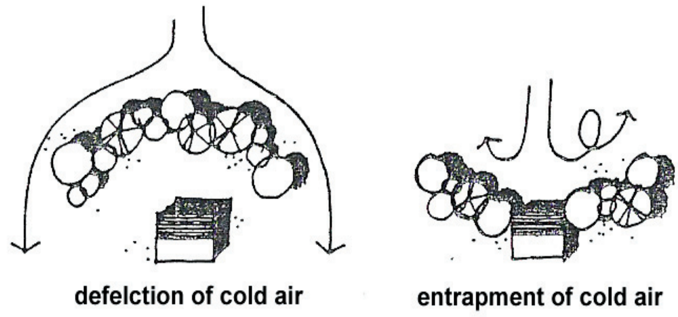


Fig. 4.32, Air deflection and entrapment (Miller, 1980).

Orientation of pedestrian and vehicular traffic corridors can direct and channel airflow. Secondary air currents develop along straight open walkways and streets. Buildings should be clustered together or connected with hedges and walls to provide some degree of wind protection. The use of interior courtyards and patios should be encouraged in desert communities because they receive natural wind protection from several different directions throughout the year. Green open spaces can also decrease the undesirable heat island effect (Farahat, 1984).

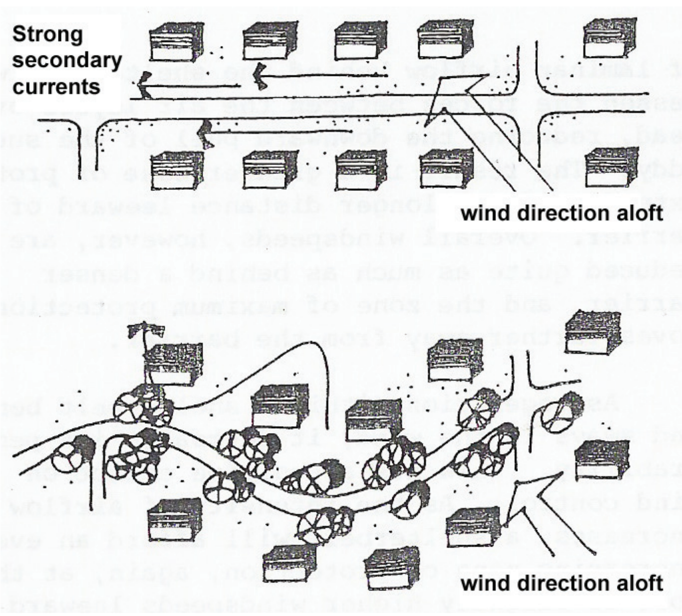


Fig. 4.33, Wind and traffic corridor orientation (Miller, 1980).

No single solution is apt to be the best for all situations and architectural elements, vegetation, and landforms are best used in combination with one another to realize their full potential to control wind (Miller, 1980) (fig. 4.33).

4.1.3 Massing and Compactness

A strategy key to optimizing comfort and reducing energy load is building massing. Tradition and land use efficiency dictate compact buildings. Proper sizes and proportions of interior and exterior spaces improve the effectiveness of passive solar heating and day lighting and greatly reduce energy consumption and negative environmental impacts.

Containment

Adequate sizing and proportioning of exterior spaces and their relationship to their surrounding built mass could be defined initially by a measure of containment. Containment is both a perceptual and environmental mechanism used for proportioning spaces and their limits. According to the scale of the space to be designed (plazas, courtyards or connective elements), an optimum coefficient of wall height to floor width is recommended. This ratio ensures that a perception of enclosure will be experienced in the space and that the spaces will be environmentally efficient. Some of the basic wall-to-floor ratios are:

- 1W/1F to 1W/3F in courtyards
- 1W/6F to 1W/8F in plazas
- 3W/1F in connective elements

Degree of Containment

The central plaza could be divided into zones according to containment principles. These zones could be achieved through vertical and horizontal "partitions." Vertical partitions are architectural and landscape screens that act as partial dividers and do not interrupt visual continuity at eye level. Horizontal partitions are temporary or seasonal architectural or landscape canopies and must respond to criteria for solar gain (Abdel Halim CDC, Sasaki Associates. 2000).

4.2.4 Courtyards and Alleys

"Perhaps the most satisfying architectural response to the continuously dry topics is the Mediterranean residence centered on a courtyard. With a meager but well-developed water supply, the courtyards feature fountains, ponds, and growing plants for both evaporative cooling and for aesthetic enhancement. But it is the fine-tuning of the courtyard environment - its optimization of wall heat resistance, ventilation rate, and evaporation rate - that is most satisfying." - William Lowry and Porter Lowry, Fundamentals of Biometerorology.

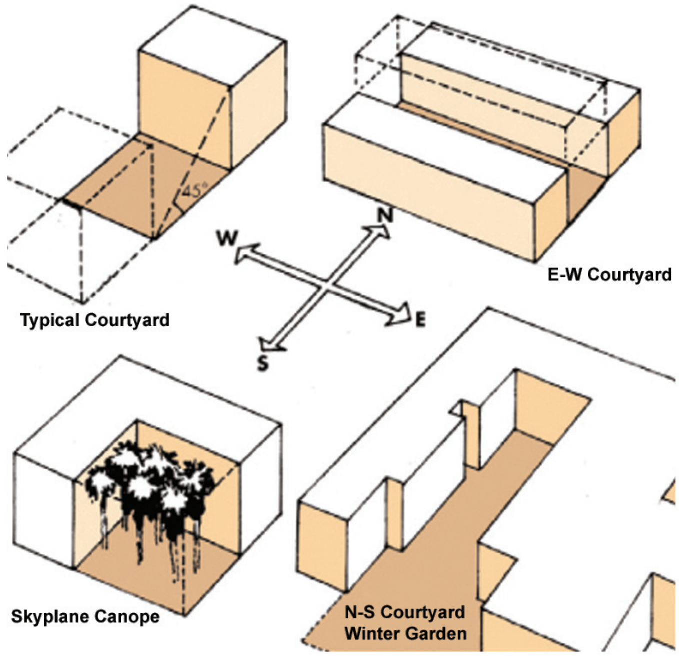
This is the most significant component of architecture and the environmental measure in such a climate. This assumes the centrality in the design not only in the physical aspect, but the functional and environmental aspect as well. Courtyards represent an attempt to bring the forces of nature under partial control.

Design Principles for Courtyards

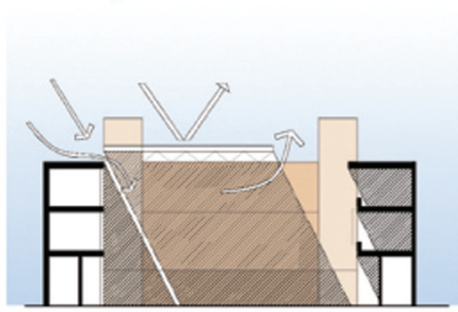
Massing and Orientation

1. All buildings are to be developed around internal courtyards. Shape courtyards to provide the building orientation described previously.
2. Sun angles and sky view should be used to determine courtyard proportions, to provide both adequate light and shade. A spatial envelope could be defined by sun path and desired exposure time. The massing which results from such guidelines will be somewhat asymmetrical, and change according to orientation and solar requirements.
3. Consider program uses in relationship to courtyard orientation. Courtyards elongated on a north/south axis will experience a sunlight and shading pattern that changes daily as the sun moves from east to west across the sky. Courtyards elongated along an east/west axis will have a lighting pattern that changes seasonally, with more shade in winter than summer.
4. Although courtyards elongated along an east-west axis are preferred, square courtyards oriented relative to north have proved to be seasonally efficient. If square courtyards are to be used, use dimensions close to 24 by 24 meters by 13 meters high.
5. The typical courtyard should be sized to allow for winter access to sunlight at the building facade. Separate north- and south-oriented buildings by a distance equal to their height (45-degree cutoff).
6. East/west courtyards may be optimized for shading building facades by close adjacency (1:2 ratio). Additional shading at the courtyard "sky plane" may be necessary.
7. Large courtyards will be minimally affected by orientation. Solar access and shading should be influenced through the introduction of supplemental structures and landscaping rather than by adjacent buildings.
8. Small courtyards (less than 1:1) should be employed within building mass. These may be light wells, ventilation courts, water features or other elements that provide relief from building mass and allow for environmental engagement. They will not replace the need for typical courtyards, which provide significant ambient light and thermal benefit.

See figure 4.34.



Courtyard Massing and Orientation



Courtyard Shading

Fig. 4.34, Courtyard massing and orientation (Abdel Halim CDC and Sasaki Associates, 2000b).

Design Principles for Connective Elements

Spatial Boundaries

1. Edge configurations or connective spaces not surrounded by buildings may not create visual barriers along vistas into parks, gardens, or any significant distant architectural landmarks (i.e., towers).
2. Edges of connective elements facing west should include screening.

4.2.5 Wind Towers and Building Materials

4.5.1 Wind catchers

Malqaf - an equivalent of Badhahanj (wind catcher) has been around as early as the pre-dynastic period, where a vent of some nature that faces north to catch the cool prevailing winds. This traditional Arabic element has been used very successfully in low standard housing for centuries. However, the care has to be taken while integrating them into the design (fig. 4.35).

4.5.2 Shukhshikha- an equivalent for solar chimney

A traditional element, typically a 'clerestory' that allows the rising hot air to escape from the top. The Shukhshikha, historically, has always been handled as part of the design itself rather than an add-on. (See figure 4.36, 4.37) The principle is very similar to that of the Solar Chimney. Solar Chimneys are devices where sunlight, at the outer surface of the high levels heats outgoing air above the occupied volume, drawing air out of the building by thermal force called stack effect. Thousands of buildings in the region over have these two elements as integral part of the design, which is a testimony of how well it has helped cope with the inhospitable summer months over centuries (Fathy, 1973).

Fig. 4.35, Wind Catcher El Sennari House, Cairo (1798).

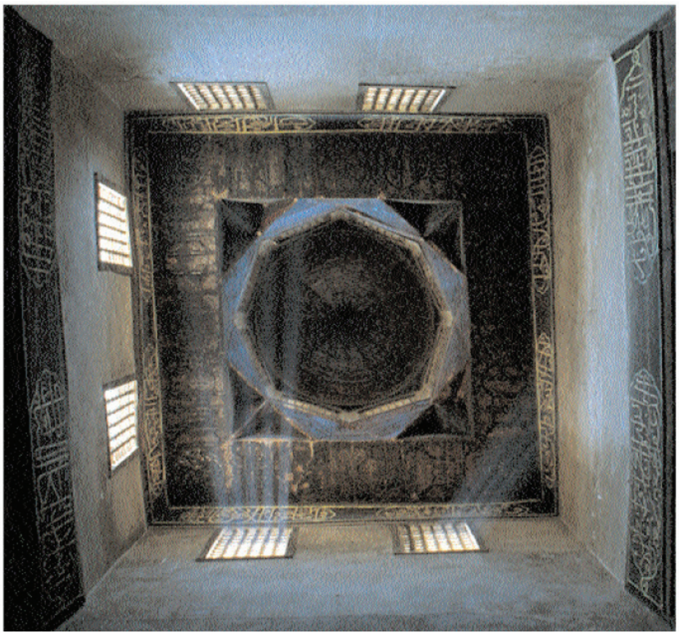


Fig. 4.36,The Shukhsheikha at Zahabi House, Cairo (1634).

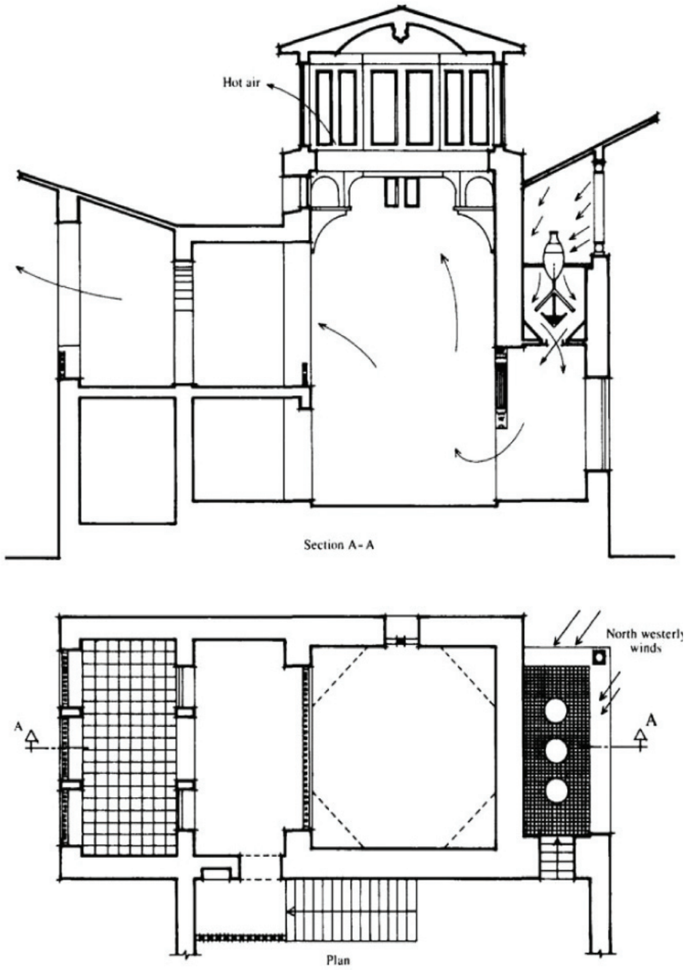


Fig. 4.37, Plan and Section of one of Hassan Fathy's designs showing a well integrated wind catcher and the Shucksheikha.

4.1.6 Passive Principles and Strategies

Diurnal Strategies

Because the diurnal temperature swing averages 15 degrees C, heat absorbed by buildings during the day can be discharged at night directly through the roof or indirectly through water or another fluid (Figure 4.38). Perforated building masses are more effective at dissipating heat to the night sky than solid ones (Figures 4.39). Figure 4.40 shows the heat loss of a building at night. About 75% of the building cooling load is offset by this direct night ventilation. The vernacular combination of courtyards and tiled roofs creates cool, tempered spaces. At night, roofs with high insulative value and emissivity adiatively and conductively cool air, this flows into the courtyard (Figure 4.41). If the courtyard is shaded, it may even remain cool during the day. Nighttime ventilation used to reduce the temperature of thermal mass should not be fan driven.

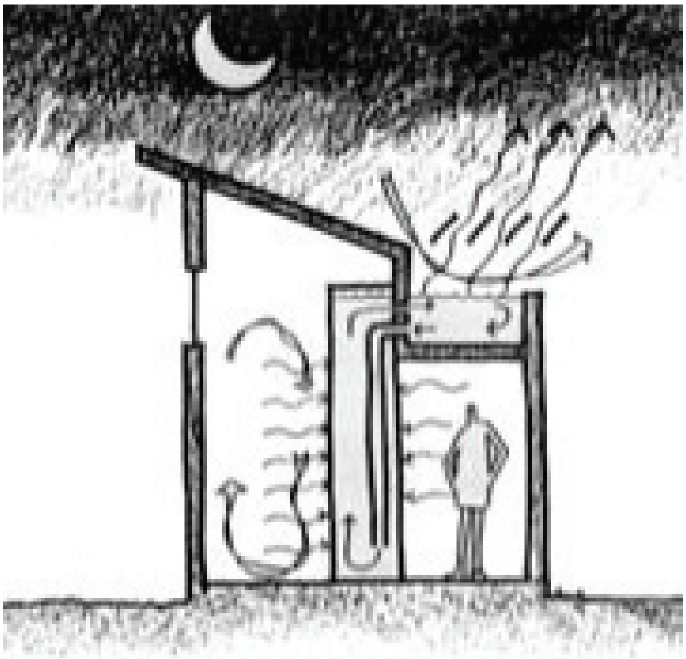


Fig. 4.38, Hydronic Radiative Cooling System (Abdel Halim CDC and Sasaki Associates, 2000).

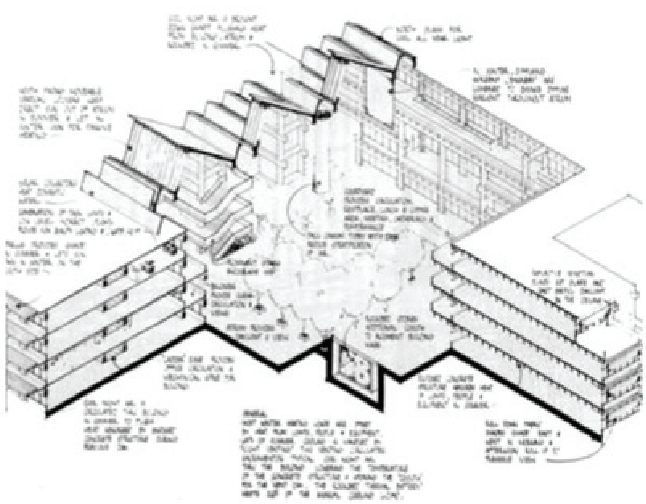


Fig. 4.39, A perforated building mass allows cooling by night time ventilation. (Gregory Bateson building, Sacramento, CA: Van der Ryn, Cathorp and Partners Architects)

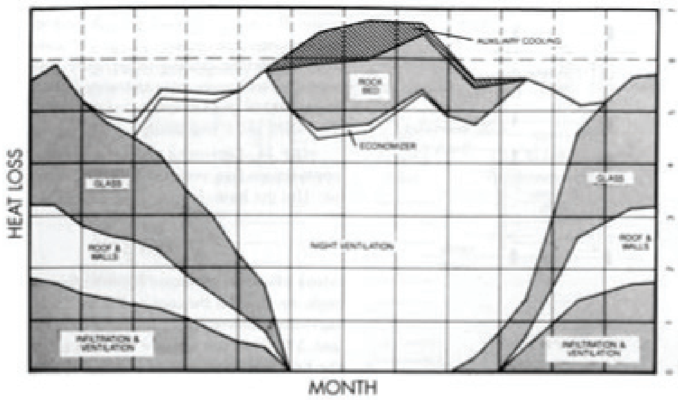


Fig. 4.40, Heat loss in a Building (Abdel Halim CDC and Sasaki Associates, 2000).

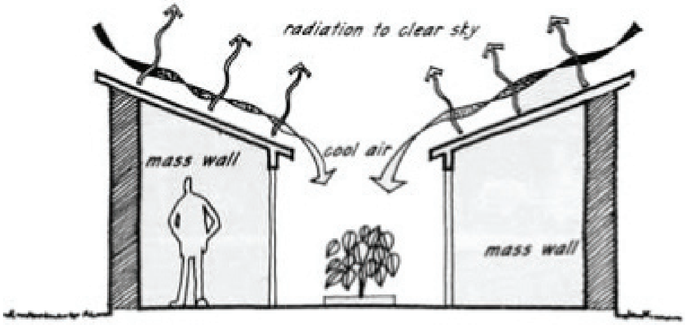


Fig. 4.41, Air is radiantly cooled by roofs and convectively drains into courtyard.

Natural Ventilation

By creating passages between building masses, the master plan has set a framework on which to build an effective naturally-ventilated environment. Further, building design should continue to facilitate natural ventilation through opposite or adjacent apertures in rooms. Natural ventilation designs should incorporate pressure-driven (wind) and buoyancy-driven (stack or temperature) effects (Figures 4.42 and 4.43). Wind towers catch prevailing breezes, induce ventilation through negative pressure and exhaust buoyant hot air. The designs should be able to work in either mode and wind-driven effects should complement stack effects (Figure 4.44). Thermal towers or chimneys not only reduce cooling loads but also form distinctive architectural emblems (Figure 4.45). Natural ventilation systems may, however, conflict with some of the other strategies noted. When combined with strategies that attempt to retain the cool night air during the daytime, daytime ventilation is counterproductive. Some guidelines for designing buildings to optimize natural ventilation include:

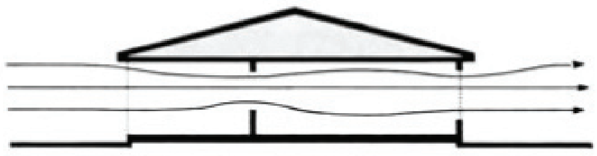


Fig. 4.42, Wind-driven ventilation(Abdel Halim CDC and Sasaki Associates, 2000b).

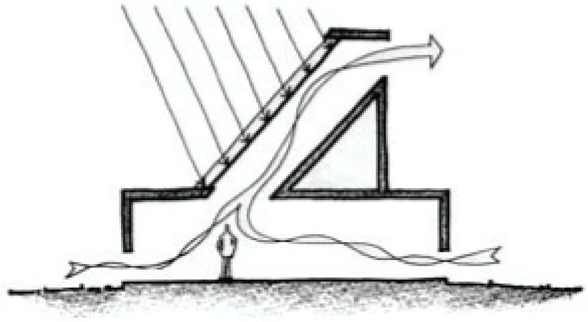


Fig. 4.43, Buoyancy-driven ventilation with solar chimney(Abdel Halim CDC and Sasaki Associates, 2000b).

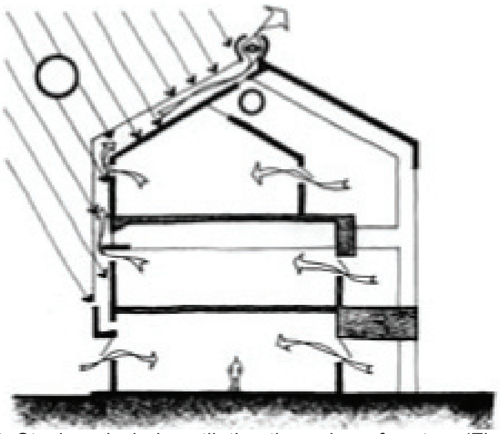


Fig. 4.44, Stack and wind ventilation through roof system (Florida A&M School of architecture).

Fig. 4.45, Natural ventilation as Icons (De Montfort University, UK: Short Ford & Associates, Architects).

- Locate windows on opposite or adjacent walls to allow for cross-ventilation.
- Use wind towers to promote ventilation.
- Use thermal assistance, such as solar chimneys to further improve ventilation
- Use ceiling fans to cool space convectively.
- Integrate evaporative cooling into the natural ventilation system.
- Use the thermal unit concept to provide sources of cool air to buildings and courtyards, and to move air from low pressure to high-pressure areas.
- Locate air inlets in areas of cool air, and outlets in hotter areas.

Evaporative Cooling

Evaporative cooling is especially effective in Cairo's dry, hot climate. Because it is an adiabatic process (constant energy content), the cost per cooling each unit of electricity produced must be determined. Compared to generating electricity for air-cooling systems, evaporative cooling is very cost effective. Evaporative cooling can take many forms, such as fountains, large, porous, unglazed ceramic pots of water, reflecting pools, irrigation channels, or moistened fabric. Humidity levels should be designed not to exceed ASHRAE standards, limiting the extent of this strategy for interior spaces. Evaporative mechanisms may be combined with wind stacks and solar chimneys to cool incoming air (Figures 4.46, 4.47 and 4.48).

When designing to cool a courtyard to use evaporative cooling, the following factors must be considered: the quantity of air to be cooled, the degree to which it must be cooled, and the amount of water to be used. As an example, consider the design of a fountain, misting spray, pool, or other water feature in a typical courtyard (11 by 11 by 13 meters). In open courtyards, an air-exchange rate is used rather than an amount of air. Assume an air-exchange rate is 1 air change per hour, a water flow of 1.1 kilograms per hour, and an outdoor temperature of 28 degrees C. To reduce the temperature to 25 degrees C using evaporative cooling, approximately 1 kilogram of water per hour must be evaporated. At lower air-exchange rates, less water is needed to achieve the same cooling effect. Critical to this strategy is the ability to control the amount of water used. To a lesser extent, control over the water flow and airflow is also needed (El Wakeel and Seraj, 1989).

Principles for Cooling:

1. Provide means for cooling south, west and east elevations during the summer months. The following strategies may be employed; however, all devices must allow winter sun to penetrate.

• Shading elements
• De-coupling façade walls
• Planting screens
2. All zones are to be conditioned by either planting and/or architectural means. A minimum of 30% of the shading areas should be conditioned by the use of planting.
3. Solar collectors must have proximity to use of generated energy. The preferred location for units is over roof surfaces.
Moreover:
• Alternative energy-collection units may be integrated with or applied to vertical and/or horizontal building surfaces and urban furniture.
• Solar collectors, if visually exposed, must be integrated with the overall building elements and/or materials which support them.
See figure 4.49. (Abdel Halim CDC and Sasaki Associates, 2000)

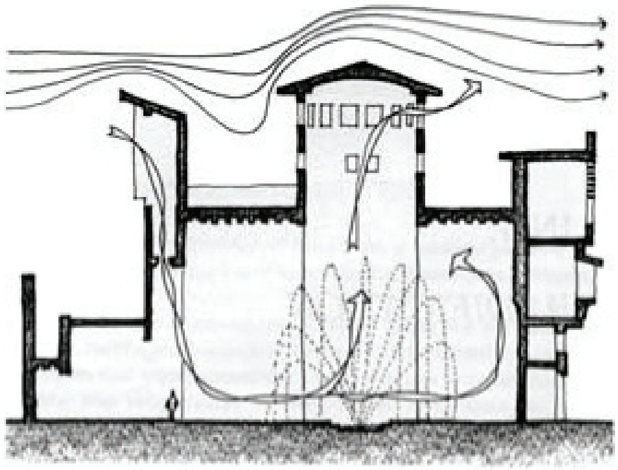


Fig. 4.48, Evaporative cooling and ventilation system (wetted air in this primary school in New Gorna, Egypt has been measures at 10 degrees C below ambient air temperature. Hassan Fathy, Architect.

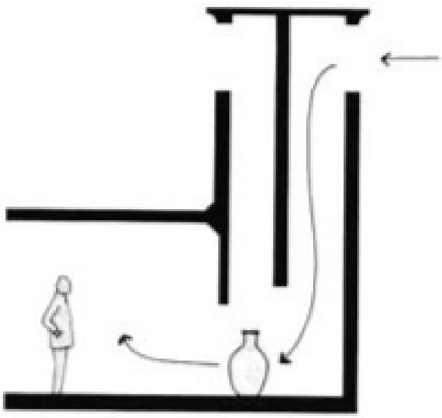
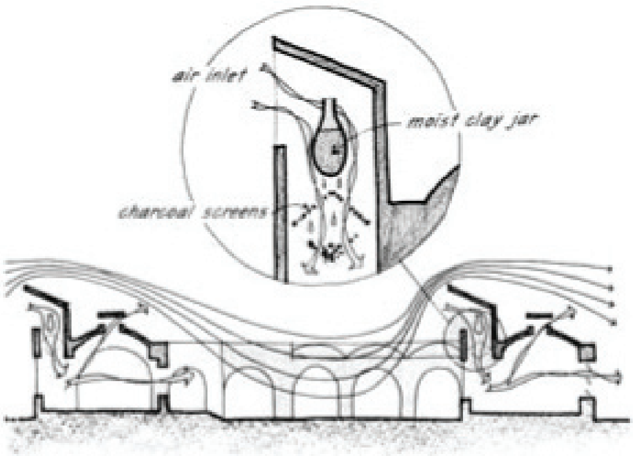


Fig. 4.46, Evaporative cooling through wind tower.



Fig, 4.47, Evaporative cooling fountain with wind catcher and stack ventilator (traditional Malkaf wind catcher in Cairene, Egypt.

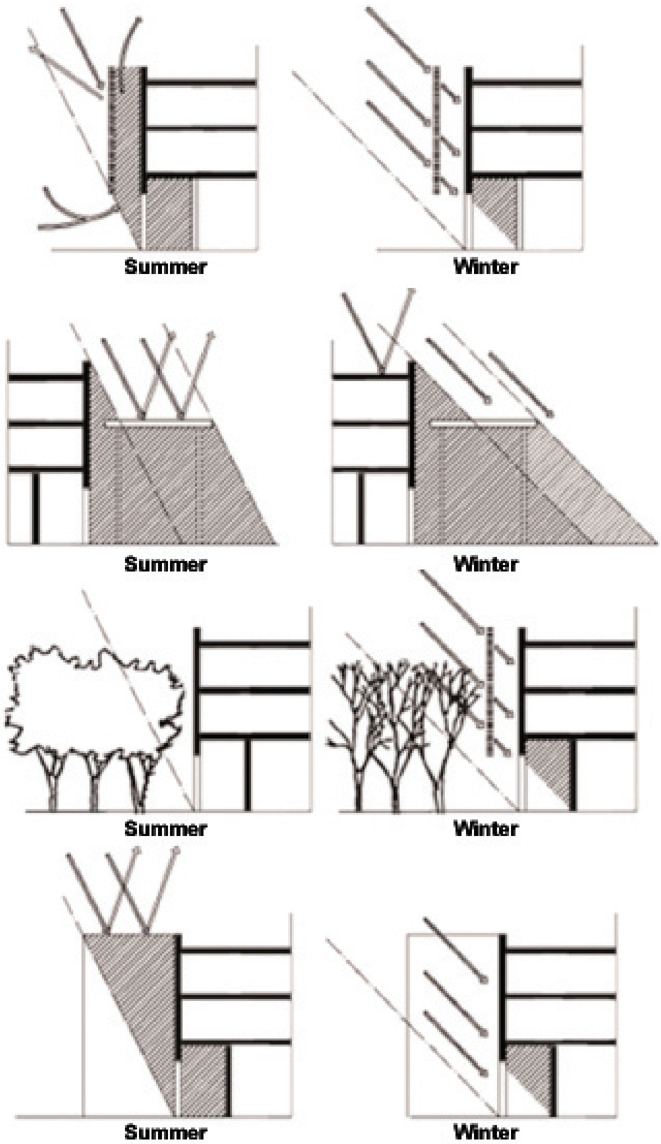


Fig. 4.49, Façade screening strategies (Abdel Halim CDC and Sasaki Associates, 2000b).

Building and Thermal Systems

Purpose:
The design principles for building and thermal systems provide a set of architectural parameters aimed at achieving environmental sustainability, resource optimization and human comfort in the exterior spaces. Careful design will amplify the positive environmental effects necessary for human habitation and constructively engage and restore existing environmental systems. The environmental infrastructure to be utilized in tempering building spaces is defined by elements such as spaces, solar orientation and radiation values, prevailing wind patterns, and temperature and humidity.

Management of this infrastructure is achieved through the creation of environmentally sustainable thermal units as temporal organizations of spatial elements to create thermal comfort. The term “thermal unit” is variously used to describe the elements composing a pattern as well as the assembly of elements. The definition of “unit” does not correspond to notions of size or scale.
The constituent elements of a thermal unit assembly are the container (the high-pressure element), the field (the low-pressure element), and the tunnel (the connective element). These are drawn from empirical observation, and refer to architectural scale elements. Basins are cool spaces during the summer, which function as warm fields during the winter. Tunnels provide convectively-cooled breezes during the warm season without relying on an unending supply of cool air. Each of these elements can be optimized to utilize appropriate energy levels at the time required to provide thermal comfort.

This model, based on a modular structure, treats the outdoor spaces as a "body" where each space contributes to the well-tempered sustainability of the whole (fig. 4.50) (Abdel Halim CDC, Sasaki Associates. 2000).

Elements:

Container
As a high-pressure element, the container is thought of as a enclosed volume which generates or holds cool air. The air may be generated elsewhere and stored in the container. However, the container must "contain" the air. For example, a container may be considered with the approximate dimensions of 24 meters by 24 meters by 13 meters high. The container may be able to generate cool air through shading, night sky radiation, or evaporative cooling. In the Cairo climate, it is assumed that human comfort is optimal in the cool container during the hot season (March through November), and is less comfortable during the cool season (December through February).

Field
Considered the low-pressure element in the system, the field does not require the same degree of enclosure that the container has. The field is assumed to have enough solar exposure to generate warm surfaces which heat adjacent air and create low-pressure areas through the decreased air density and increased buoyancy of the air. The hot air rises. The field may have shaded areas in it as well as sunny areas. In the context of the master plan, the university square may be considered a field with the approximate dimensions of 140 meters by 46 meters by 13 meters high. Because the purpose of the field is to generate a warm, low-pressure area, it is assumed that the field will be more comfortable during the three winter months and less optimal for human comfort during the nine months of warmer weather (fig. 4.51).

Tunnel
The tunnel connects the container and the field, and as such, does not necessarily generate either warm or cool air. It is assumed that cool air moves through it, and its environmental optimization is more similar to the container than the field, i.e., as an inhabited space it would be more comfortable during the summer than the winter. Within the master plan, tunnels are represented by corridors and arcades, with wind towers at tunnel ends to assist with airflow.
The assembly of these three elements constitutes a thermal unit at its largest scale. The described assembly container/courtyard, tunnel/connective element, and field/major public space) is expected to work seasonally

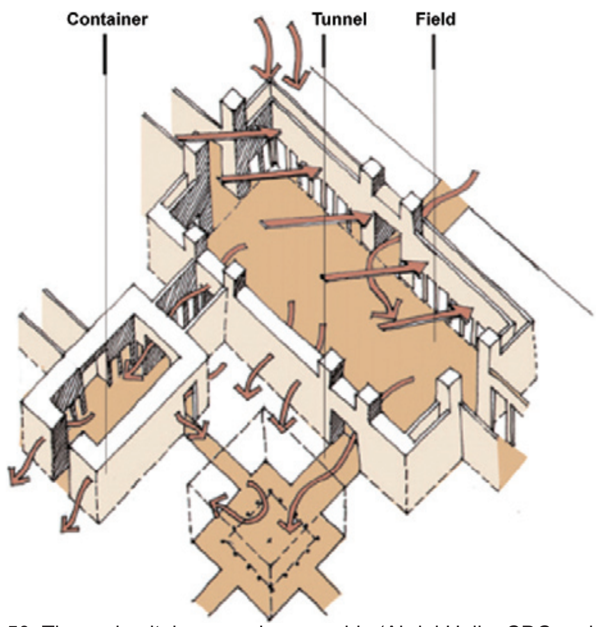


Fig. 4.50, Thermal unit, large scale assembly (Abdel Halim CDC and Sasaki Associates, 2000b).

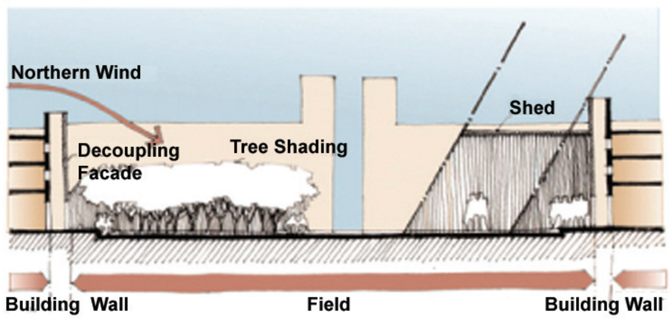


Fig. 4.51, Field (Abdel Halim CDC and Sasaki Associates, 2000b).

(especially in hotter seasons). For year-round conditioning, each element is expected to work by itself. In such a case, aside from air temperature, other "comfort determinants" will come into play (fig. 4.53).

Design Principles Applicable to Thermal Units
A zoning system based on seasonal comfort areas will overlap with the zones defined by the principle of containment. For example, the following illustrates the fluctuation of comfort zones in spaces like the Field during specific times of the year.

Containers
1. In order for courtyards to work as reservoirs of cool air during the hottest months, they must keep their floor area and building walls (up to 2 meters high) shaded for most of the day. This will determine a basic volume of cool air to be stored in the space (fig. 4.52, 4.54 and 4.55).

Fields
All design principles for containers will apply to fields. Major public spaces should be zoned to accommodate particular areas of thermal comfort. If building form and courtyard orientation are insufficient for self-shading purposes, additional screening must be provided. Summer gathering locations on the southern side of the plazas, against building structures, which, combined with depressions, will create cool shaded zones. As well, the northern side of the fields is identified as winter gathering locations with open solar exposure for warmth.
Wall surface conditions for courtyards will vary according to orientation. Some facades will absorb heat and light; others will reflect heat and light or reduce the effects of glare. A zoning system based on seasonal comfort areas will overlap with the zones defined by the principle of containment.

The following illustrates the fluctuation of comfort zones in spaces like the Field for specific times of the year:
• 3 pm and beyond during the months of March through September along the southwest/northwest should be able to accommodate larger numbers of people utilizing shading provided by building structures.
• Core of the day during atypical months of March and September primarily along the southeast and secondarily along the southwest will accommodate smaller numbers of people utilizing shading provided by building structures.
• 9 am to 1 pm during the months of October through February (with the exception of December beyond 12 noon) along the northwest corner, groups of various sizes will have the ability to take advantage of solar exposure.
To accommodate congregations beyond the identified times and locations would require the consideration of alternate orientation, or additional means of shading.
2. Provide permanent shading where necessary. All permanent shading other than planted areas and urban furniture located within the winter sun area of shade must allow the penetration of winter sun.
3. Provide temporary shading where necessary at potential gathering zones and areas of program expansion in major public spaces.

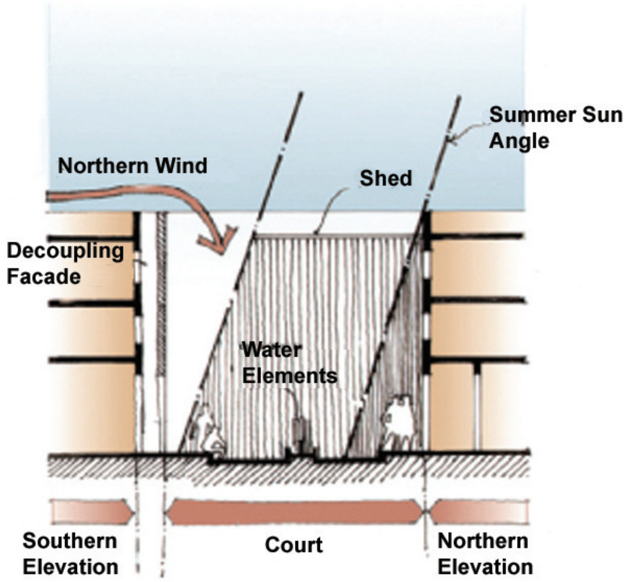


Fig. 4.52, Container (Abdel Halim CDC and Sasaki Associates, 2000b).

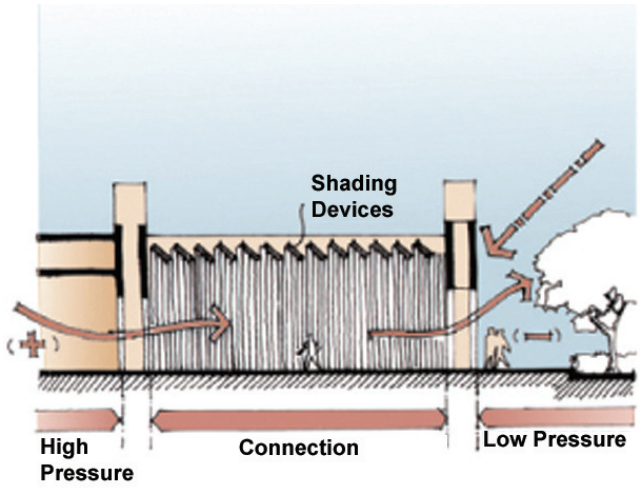


Fig. 4.53, Tunnel (Abdel Halim CDC and Sasaki Associates, 2000b).

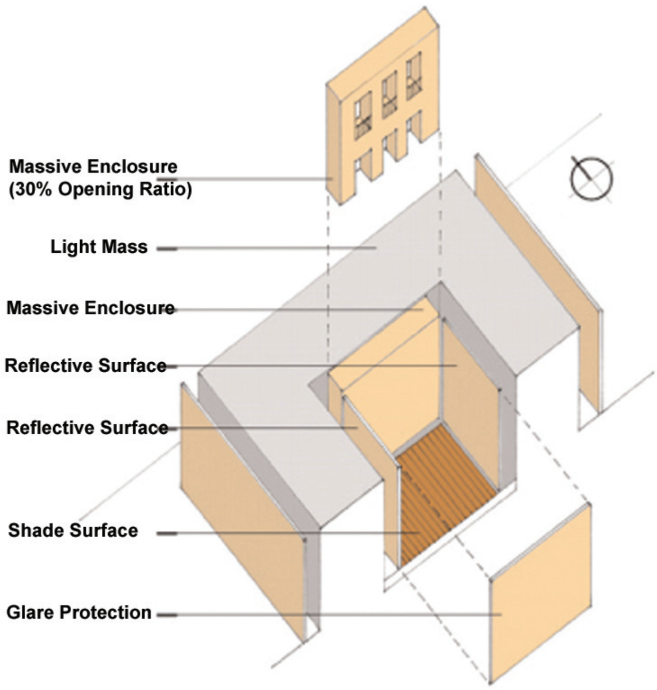


Fig. 4.54, Container Surface Structure (Abdel Halim CDC and Sasaki Associates, 2000b).

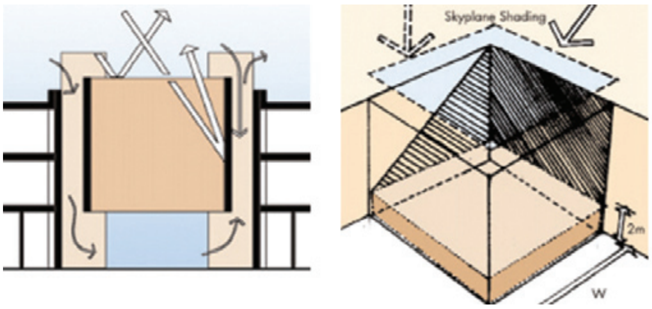


Fig. 4.55, Left, Container Decoupling of Wall - Right, Cool air reservoir(Abdel Halim CDC and Sasaki Associates, 2000b).

4. Passageways leading into and from fields must be oriented to allow the intake of prevailing winds or supplement their air intake capacity through the use of wind towers. Passageways must remain unobstructed.

Tunnels

1. Connecting elements will function as tunnels for venting and exhaust of major public spaces. Air circulation patterns must be optimized and preserved. Air currents will include:
• Filtered winds from the shelter belt through the gardens.
• Cooled northern currents from gardens and courtyards.
2. Shading must be limited in main circulation areas and localized gathering spaces.
3. Spaces between building zones may be temporarily shaded.
4. Appropriate thermal articulation of passageways is to be achieved by the use of:
• wind catchers
• solar chimneys
• solar walls
• double walls
And their connection to spaces such as:
• Solar yard (plazas)
• Garden
• Containers (courtyards)
5. Provide appropriate enclosure for containment of passageways. See recommended containment levels per space types in Spatial Organization.
6. Wind towers must be oriented with air intake away from leading roof edge, to prevent the entry of heated air.
7. Provide temporary and/or permeable shading at roof of tunnels.
8. Provide south-facing solar chimneys to function in tandem with wind-catchers to maintain optimal convective air currents.
See figure 4.56 and 4.57 (Abdel Halim CDC, Sasaki Associates. 2000).

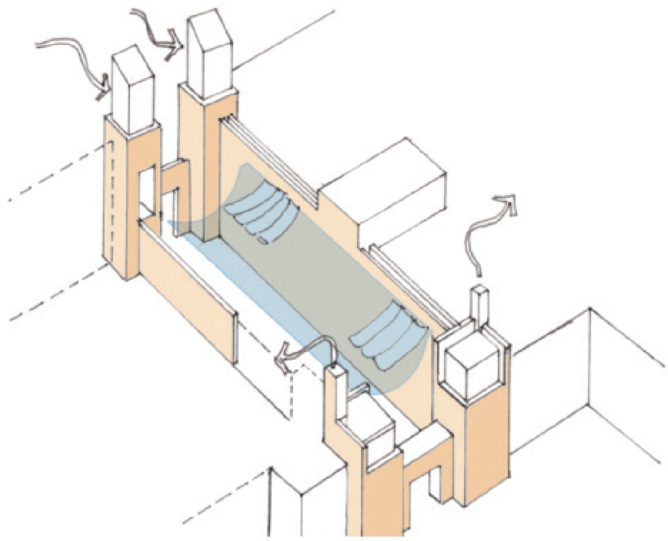


Fig. 4.56, Tunnel Structure(Abdel Halim CDC and Sasaki Associates, 2000b).

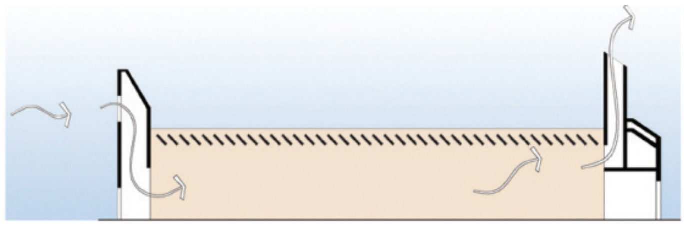


Fig. 4.57, Tunnel air-flow diagram(Abdel Halim CDC and Sasaki Associates, 2000b).

Design Principals and Guidelines for Building Structure and Arrangement:

Summer

- A dense building configuration with small shaded open spaces is desirable. Unit buildings benefit from being grouped for mutual protection from the sun and heat while shading exterior spaces between them. Groups or clusters of buildings increase volume effect, providing mutual shading and minimizing sun exposure.
- Arrange grouped building clusters so that east and west exposures are minimized.
- Tall, massive buildings benefit from reduced solar exposure to roof while providing shade for micro-climate around structure. Walls of buildings and gardens should be tall to create shade for exterior living and circulation spaces. Western exposures need to be sheltered from afternoon sun.
- Need to channel hot summer winds around building, while allowing night-time cool air to penetrate structure.

Winter

- A dense configuration is desirable, but with unshaded exposure of south facing walls; multi-story or grouped units benefit from reduced heat loss per unit.
- Buildings should be grouped so as to increase southern exposures.
- Tall buildings can be placed so as to serve as thermal heat storage for both interior and exterior spaces with the potential of increased southern exposure on 2 floor units. Walls of buildings and gardens should open to SE,S and SW to allow maximum penetration of winter sun. High walls that shade exterior living areas are undesirable.
- Winter winds need to be deflected around building and exterior living spaces.

Balance between summer and winter

- The single free-standing building is the most difficult to heat and cool, because all walls and roof must repel heat in winter. Multi-storey buildings can reduce total BTU gain and loss. Optimal from the desert individual houses would be row buildings, carefully arranged to provide mutual summer and winter protection.
- Design connected building groups along their east-west axis, with openings to E, SE, S, SW for optimal solar protection (summer) and solar exposure (winter). Avoid facing groups of buildings due west (undesirable exposure in summer).
- Tall, massive structures should be closely grouped so that shade is cast on public spaces in summer while allowing exposure to winter sun for heat build up in walls and exterior areas. The taller the house walls, the larger the courtyard. Two-story or stacked continuous units can benefit in both summer and winter. Orient building and garden walls generally north-south, with higher walls to west in order to block summer afternoon sun. Design overhangs and place structures to shade walls and walkways only during summer season.
- A staggered arrangement of buildings units with carefully arranged planting can discourage unwanted winds and encourage desired breezes.

Design for Public Spaces:

Summer

- Heat build up in man-made areas tend to elevate temperatures in down town areas, creating undesirable micro-climatic effects. Downtown temperatures can average 12^{o}C degrees higher than suburban temperatures for same day. Large concentrations of parking provide a heat sink during the day and radiate heat throughout the night. Parking should be covered or at least shaded. Large parking areas become a source of runoff during rainy season.
- Walking is considered a hardship except in early morning or at night.
- Fountains and pools of water in public areas have a great cooling effect and can reduce the harshness of the desert landscape.

Winter

- Heat build up in downtown areas during underheated period can have a positive effect by elevating night time temperatures. Large areas of parking increase glare from cars and collect water during rainy season.
- Walking during day is considered healthful and a pleasant experiences.
- Cooling from evaporating water during underheated days and nights is to be avoided.

Balance between summer and winter

- Design for summer critical condition, by restricting impermeable paving to traffic areas and heavily used pedestrian walkways. Break up large paved areas with shaded areas or with zones of vegetation and ground cover. Locate excessively large areas of paving on leeward side of structure so that any heat build up will be blown away from buildings by summer breezes. Break up parking into many small bays and parking into many small bays and parking pockets and shade with deciduous trees or shading constructions.
- Minimize distance between public and residential areas, and create half or full shade for walkways during summer.
- Operate fountain or spray on seasonal basis so that public spaces do not become uncomfortably cool in winter. A summer fountain can become uncomfortably cool in winter. A summer fountain can become a winter reflecting pool or heat sink.

(Clark, 1980; Cook, 1980; Fredrickson, 1980; Givoni, 1980; Golany, 1980; Legorreta, 1980)

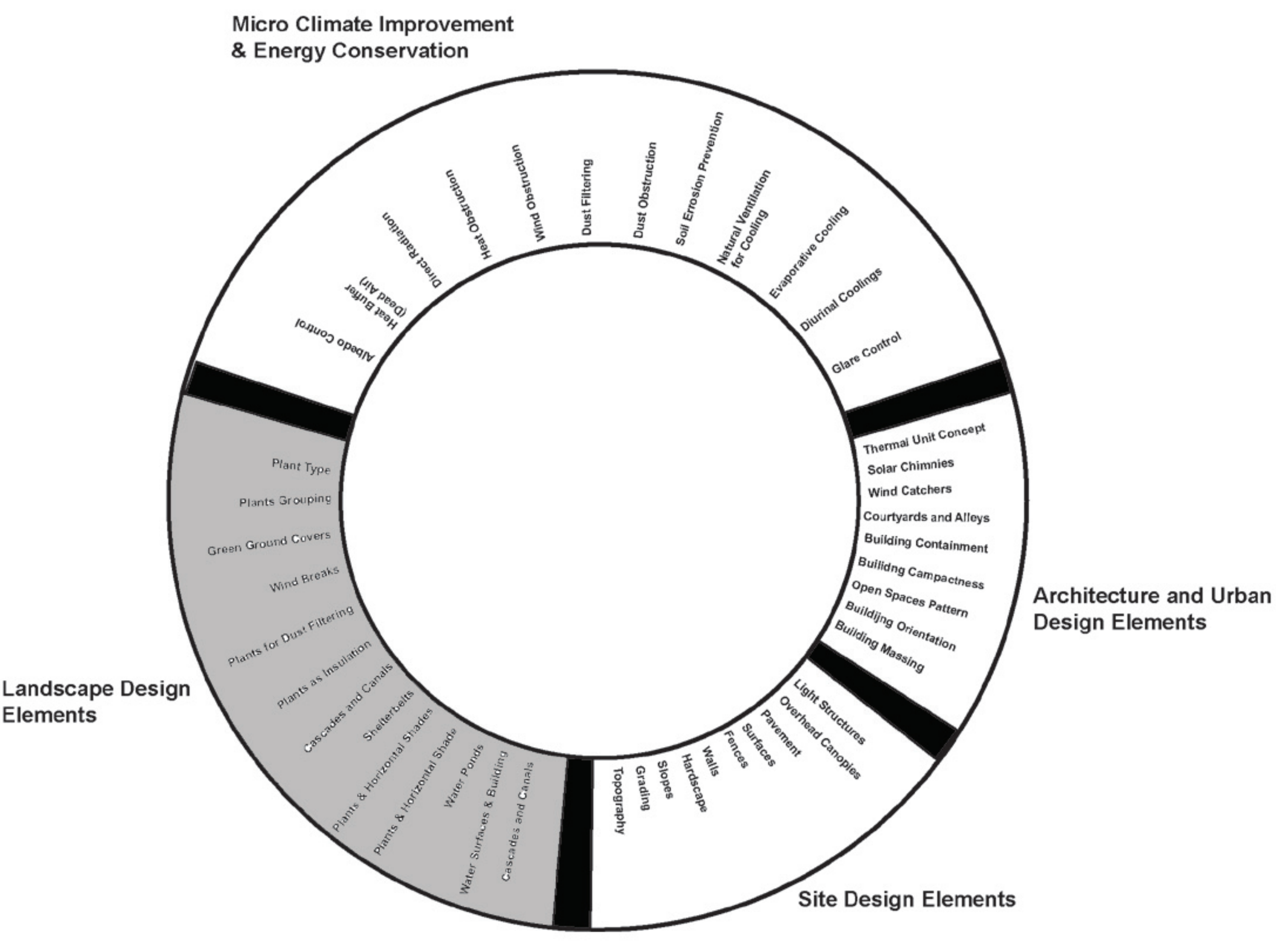
Chapter 4

Landscape Design Principles and Guidelines for Micro-Climate Improvement and Energy Conservation.

Section 3

Landscape Design for Micro-Climate Improvement and Energy Conservation.

Landscape Architecture Circle



4.3 Landscape for Micro-Climate Improvement and Energy Conservation

Landscaping can vastly improve the micro-climate in the summer. Vegetation absorbs large amounts of solar radiation in summer helping to keep the air and ground beneath cool while evapotranspiration can further reduce temperatures.

Use of natural shade trees, shrubs and vines can provide protection from solar radiation in summer. Careful planting of trees for wind channelling can provide efficient ventilation and circulation of summer breezes in addition to creating attractive spaces for outdoor activity.

Grass and other ground cover planting can also influence the micro-climate, keeping the ground temperature lower than most hard surfaces as a result of evapotranspiration and their ability to reduce the effect of solar radiation. This happens due to the shading provided by the grass, which prevents radiation from reaching the ground Windbreaks can enhance air pressure difference around buildings and improve cross ventilation. Hedging, for example, can allow a gentle breeze to filter through the foliage, while masonry windbreak can create a calm, sheltered zone behind it. Gaps (cracks) in windbreaks, openings between buildings or openings between the ground and canopy of trees can create wind channels, increasing wind speeds by about 20%.

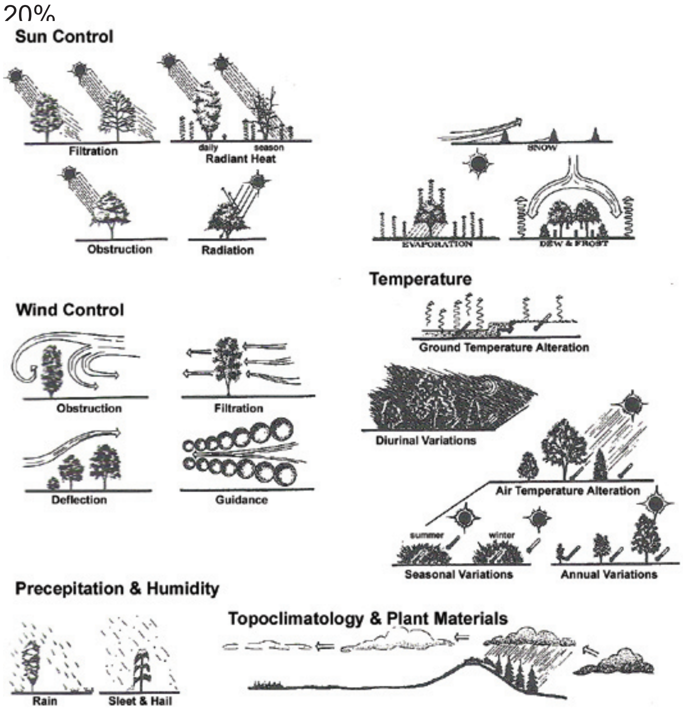


Fig. 4.58, Plants and the Micro-Climate elements (Robinette, 1983).

Water can also be used effectively for cooling of internal as well as surrounding environment - Ponds, streams, fountains, sprays and cascades are some effective ways to achieve the comfort level. Landscaping is an integral part in helping energy-efficient buildings to perform better in the winter and stay cooler in the summer. Using the lay of the land to shelter the building to keep harsh winter winds away and allows summer breezes have been considered. Carefully selecting and strategically planting deciduous trees can provide maximum winter solar gain, as well as effective summer shade (fig. 4.58).

This section will discuss the landscape design elements that can improve the micro-climate and conserve energy. The section will explore the types of vegetation and water elements that can be applied in Egypt’s hot arid climate.

4.3.1 Plantings and Vegetation in Arid Climates

Outdoor greenbelts can help to improve the micro-climate in the outdoor space close to the building by means of dust and sand-binding effects and cooling effects through evaporation. Small and large surface planted areas improve air quality in terms of pleasant odors, dust reduction and mild adiabatic cooling effects through the evaporation effects provided by plants and soil. Planting trees, bushes and lawns around the building and inside the building, is an important aspect in improving the micro-climate in the immediate vicinity of the building and in sections of its interior.
Trees and moist green areas and areas of water have the advantage that adiabatic cooling effects occur in the outdoor areas close to the building through the evaporation effects and thus reduce the external air temperatures near ground level. In addition, dust-binding effects occur which improve the quality of the air-flows which are drawn in from outside.

Plants are a major design element for landscape designers. Landscape architect should understand the nature of plants in order to contribute to the micro-climate improvement and energy conservation. Plants form a very small ratio in the cost of the total building construction. Despite this fact, plants are the only maintained day to day item of any building. Plants have a high running cost in some areas of Egypt. Therefore plants should be picked with care to match environmental conditions and to reduce the water budget. To compensate the scarcity of water, plants in hot arid climates reduce the transpiration surface area and to reduce water extent loss. This is achieved by shedding leaves and branches in exceptional drought conditions, by providing a wax coating on the leaves and by reducing the leaf blade size often to the extent that petioles and stems are carrying out leaf functions. Another problem associated with planting, particularly in arid areas, is that of salt. “Some plants (tamarix sp.) have the ability to secrete salt through their glands. Many plants are provided with a layer of fine hair on the stems which insulate against the heat. Others have a resinous or vanish like coating on the stem” (Vandderweit, 1982).However, in hot arid climates the natural order tends towards barren desert and objective for landscape architects to establish and keep vegetation going.

Plant Classification

It must keep in mind that vegetation of all types is a growing, changing natural element and, as such, it is not possible to predict a precise or exact form for every single plant used on a particular project. In the use of any vegetation, the following aspects must be taken into consideration in regard to the ability of plant to assist in solar radiation control and energy conservation:

- The height and the spread if the single plant
- The spacing of multiple plants
- The shape or form of the plant
- The density of the plant
- Whether the plant is a conifer, deciduous or an ericaceous plant
- The ultimate size and shape of the plant

Basically, plant forms may be divided into the following categories:
Tree: major and minor, these may also be categorized as canopy trees or under story trees. The division is generally made between those trees under 6 meter high and trees which are over 6 meter high.

- Shrubs: may be arbitrarily divided into low shrubs, which mean those below 1.20 meter, medium shrubs, those from 1.2 to 2.5 meter; and tall shrubs, those eight and over.
- Ground cover: may be categorized as to their height, through most of them are 45 centimetres and under, their colour, their density and whether they are coniferous or deciduous plants.
- Vines: have a wider variety, whether they are clinging, twining, or rambling vines. Quite often vines may be used to shade the wall of a building or may be used as part of an architectural canopy to provide additional climate control.

The following are series of diagrams illustrating some of the considerations concerning the precise selection of various forms of vegetation for solar energy utilization and for energy conservation (fig. 4.59) (Robinette, 1983).

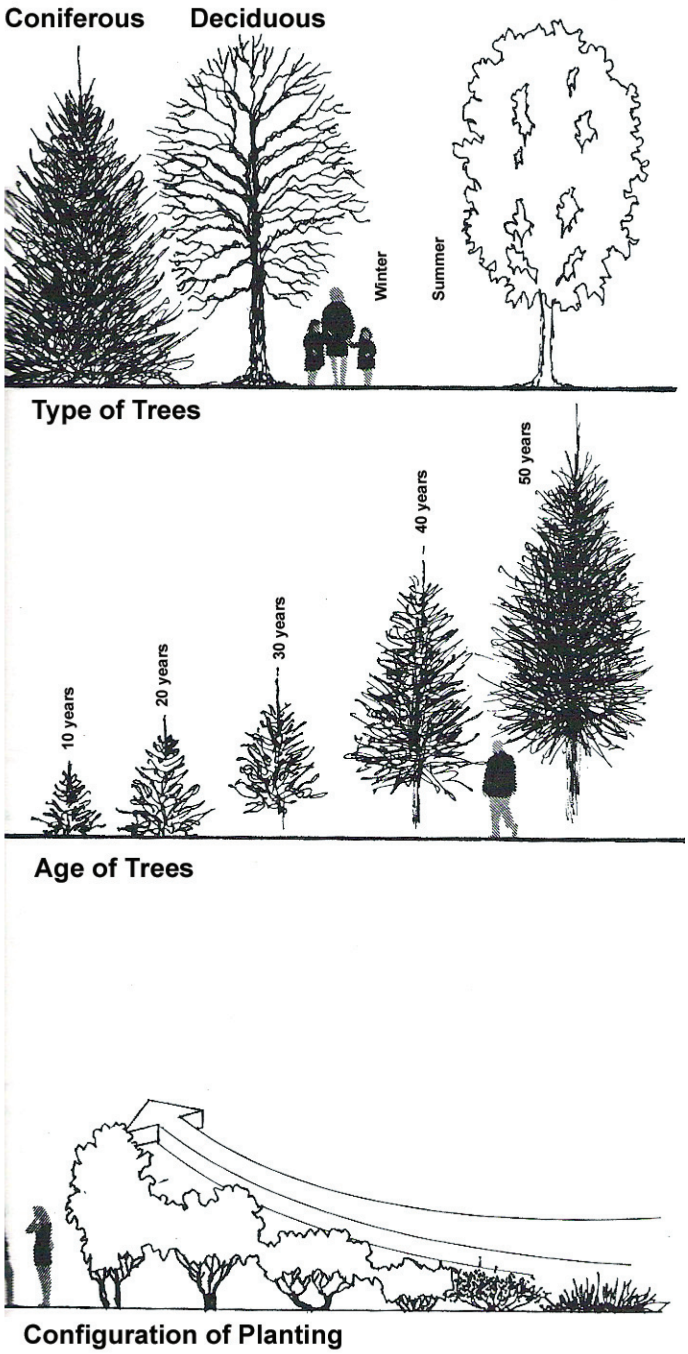


Fig. 4.59, Tree types and Configurations (Robinette, 1983).

The following components form the core of the landscape design principles and guidelines:

Plant Selection

The selection of the plant material in hot arid climate should be mainly based on:

1- Tolerance to micro-climate, drought, soils, salinity, and transplanting.
2- Performance with relation to the function. This refers to the height, geometry, crown size and density of branching.
3- Low water consumption.
4- Availability of nursery stock or potential to support large scale projects.

But the previous mentioned aspects are also related to morphological and physiological characteristics of the plants. The following table lists some of these principal characteristics (see appendix VII).

Table 4.2 morphological and physiological characteristics of plants (Lesiuk, 1980).

Leaf surface characteristics	
Leaf shape	
Optical properties of the leaves	
Leaf area	
Leaf density	
Foliage distribution	regular, random, clumped, & variable.
Foliage angle distribution	erectophile, planophile, plagiophile & extremophile
Canopy characteristics	Monolayer or multilayer
Aerodynamic characteristics	
Evergreen or deciduous	Winter or summer deciduous
Transpiration	

Plants types
Palms and cycads
Trees
Shrubs
Ground covers and lawns
Vines
Ornamental grass
Cactus
Aquatic plants

Trees
The importance of the contribution of trees towards a better urban environment is referred to by an increasing number of authors (Givoni, 1980; Olgyay, 1963). The use of trees improves the desirable characteristics of meso and micro-climates.

Tree Geometry
Geometry and orientation play a major role in determining an outdoor climatic feature. When using trees to shade buildings or ground surfaces one of the problems is to find out where their shadows will be at different times of the day throughout the year. The solution of the problem must take into account three elements: the tree's geometry, the position of the sun in the sky and the characteristics of the surfaces to be shaded. Trees can be classified as having a spherical, conical or cylindrical shape, or as being a result of some these trees. Figure () illustrates the idea, showing that trees can be geometrically defined(Sattler et al., 1987).

Lesiuk (1980) list a relationship between the geometry configuration of the tree canopy and the solar radiation interception. At low solar elevations, cylindrical shaped trees with a low radius to height ratio are most suitable. "At mid elevations spherical shaped trees is most efficient, while at high solar elevations conical trees with a high radius to height ration are most appropriate (fig. 4.60).

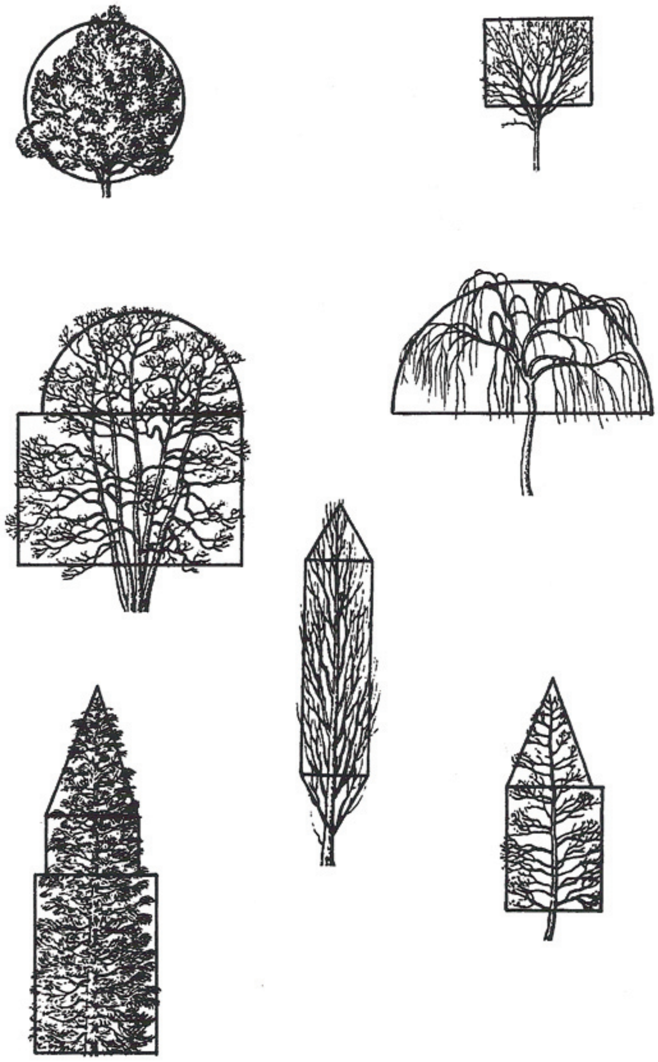


Fig. 4.60, Plants (Sattler et al., 1987).

Crown density
The density of a tree's leaves or needles is important to consider. Dense evergreens make great wind breaks. To impede summer undesirable winds a tree or shrub should be with more open branches and leaves. Such trees are also good for filtering dust, while denser trees are better for blocking harsh afternoon summer sun.

Tree type
Deciduous trees are commonly preferred over evergreen for shade on east and west walls because they permit greater winter heating. Deciduous trees with high, spreading crown can be planted to the south to provide maximum summer time roof shading. Trees with crowns lower to the ground are more appropriate to the west, where shade is needed from lower afternoon angles.

Plants and Wind Control

Desert winds are extremely desiccating to plants as well as well as people, and unprotected vegetation will require more water, which is a scarce commodity in arid regions, to perform as well as plants that receive some protection. This is especially true for imported exotic plants that have no physiological adaptations to arid conditions. Wind control, then, is an essential ingredient for effective design in a desert environment.

Airflow affects the temperature of our environment by encouraging body heat loss through increased evaporation and convection. Where there is free air movement there is little difference in the ambient air temperatures in the sun or in the shade. When wind is deflected, there is a decrease in the rate of thermodynamic heat exchange between air layers within the protected area. Shaded locations in the protected zone will be cooler, and exposed locations warmer than prevailing open field air temperatures (Robinette, 1983).

Wind and vegetation

Vegetation is one of the most commonly used devices for controlling wind. Plants offer varying heights, widths, and densities, and can be planted individually or in groups, and in conjunction with landforms and structures to deal with a variety of wind problems. Plants control wind by obstruction and filtration, and by deflection and guidance. See figure 4.61. The figures 4.62, 4.63, 4.64 and 4.65 were obtained as an aid to the designer to help him direct wind through or around his project.

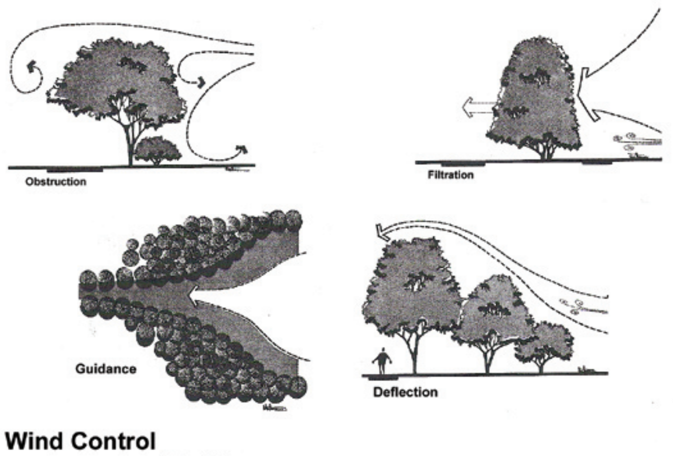


Fig. 4.61, Wind control and vegetation (Robinette, 1983).

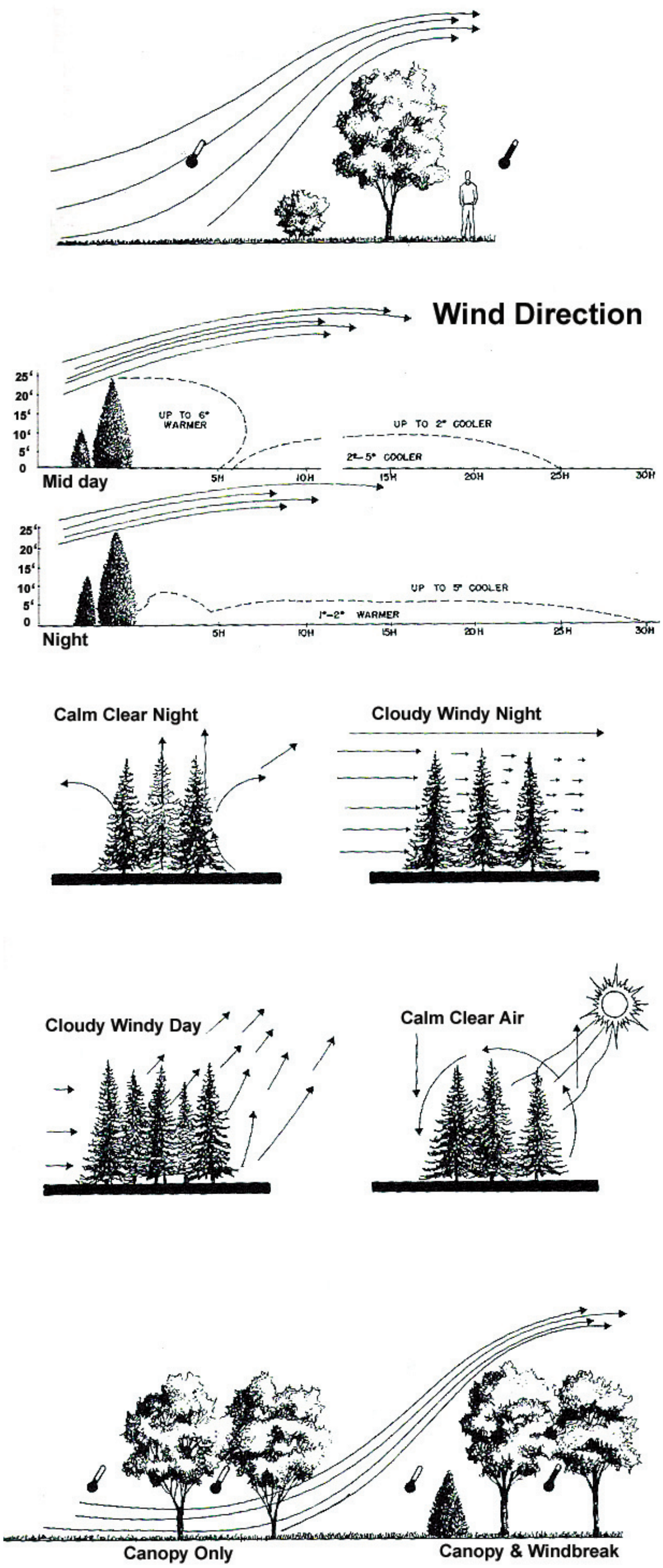


Fig. 4.62, Wind Control and Plants (Robinette, 1983).

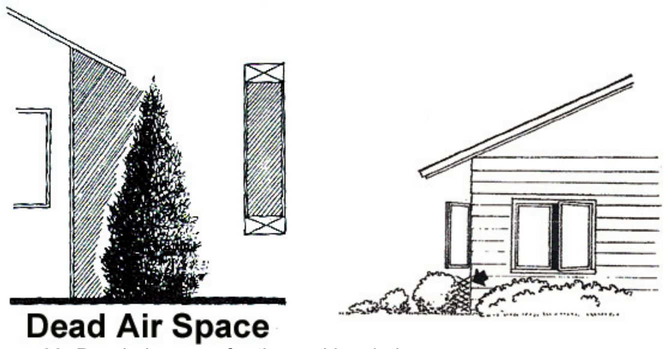


Fig. 4.63, Dead air space for thermal insulation.

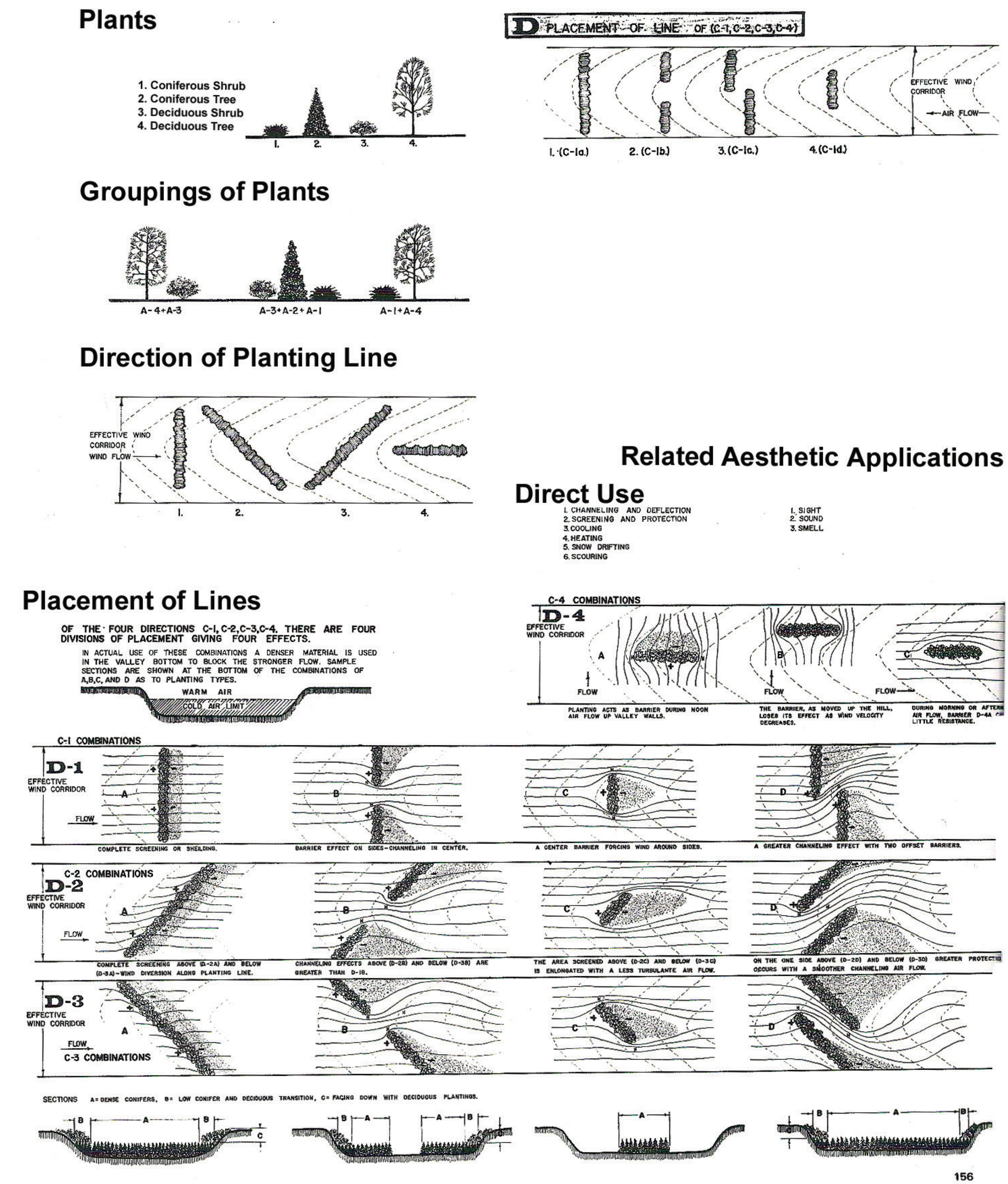


Fig. 4.64, Plants placement and grouping (Robinette, 1983).

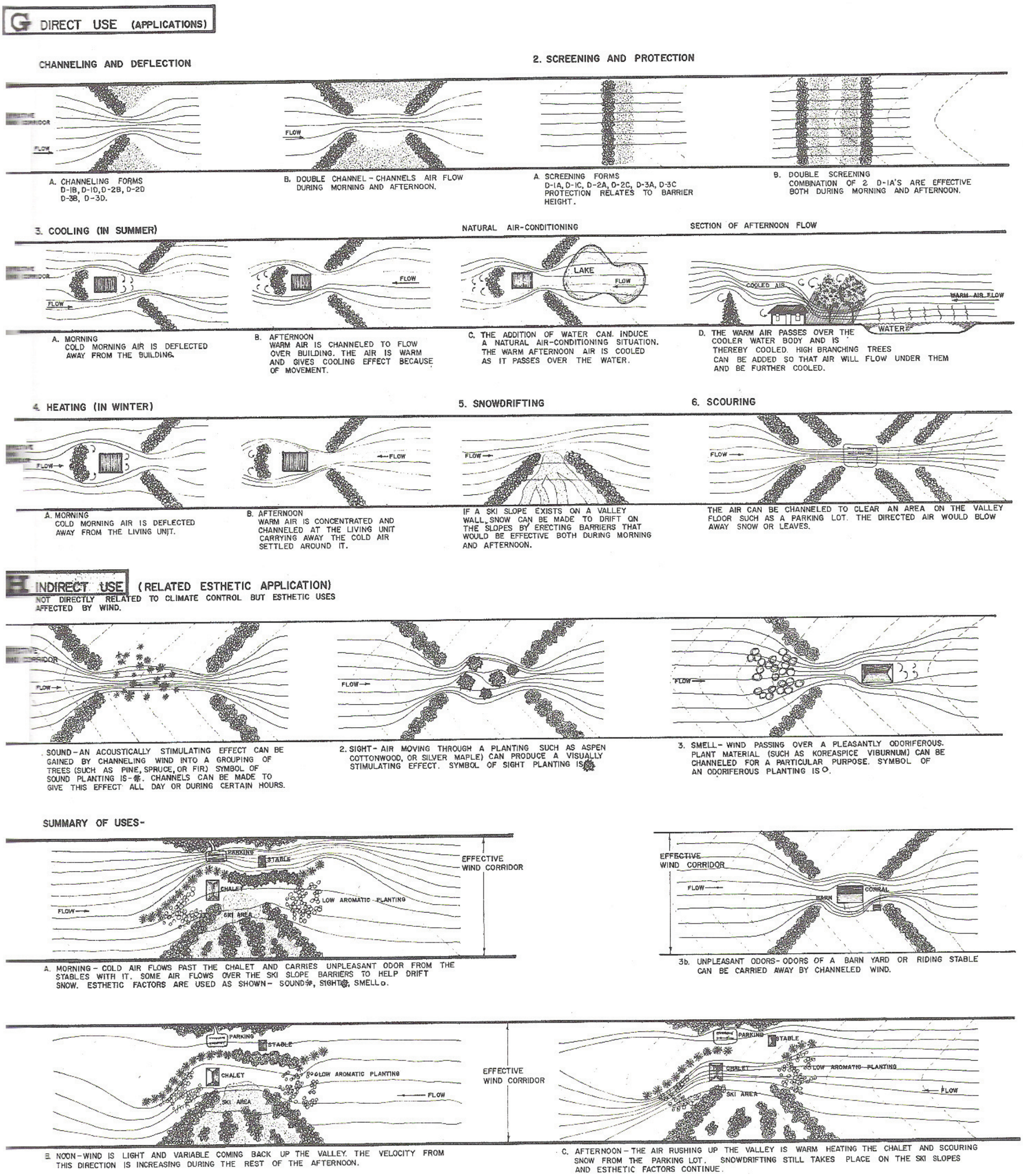


Fig. 4.65, Plants placement and grouping in relation to wind (Robinette, 1983).

Shelterbelts

Wind breaks can be used to protect both buildings and open spaces from hot or cold winds. A windbreak of vegetation creates areas of lower wind velocity in its lee by (1) deflecting some of the wind over the windbreak and the zone immediately to the leeward of the barrier, (2) absorbing some of air's momentum and (3) dissipating some of the air's directed momentum into random turbulent eddies. (Arens and Watanabe, 1986)

Shelterbelts are most effective when placed perpendicular to the wind. Wind velocities on the leeward side of shelterbelts may be reduced by as much as 50 percent for a distance of 10-20 times the height of the barrier. The total influence of the shelterbelt may extend as far as 25-35 times its height, depending on penetrability, width, and height. Only limited protection is afforded on the windward side of the barrier. Figure 4.66 shows isotacks representing the influence a typical shelterbelt will have on airflow. Note that the leeward sheltered zone is wider than the barrier itself. At the edges of the shelterbelts wind speeds may actually be increased by ten percent or more at the open field wind velocities (Miller, 1980).

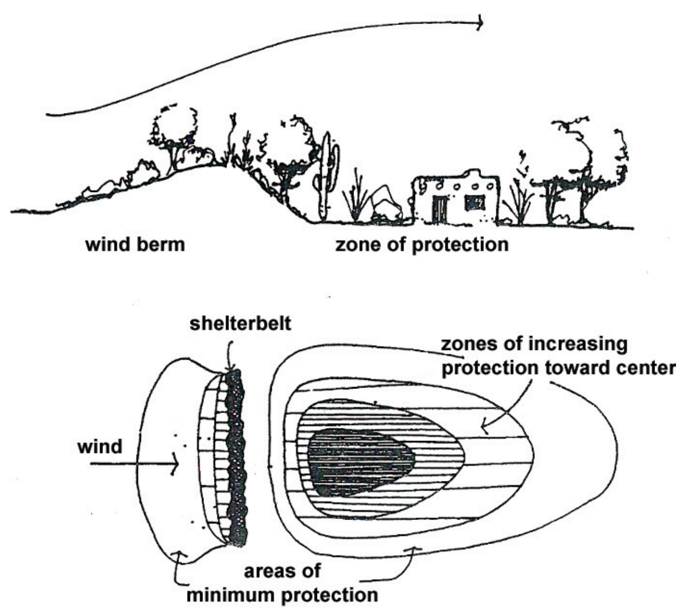


Fig. 4.66, Wind berm and zones protection (Miller, 1980).

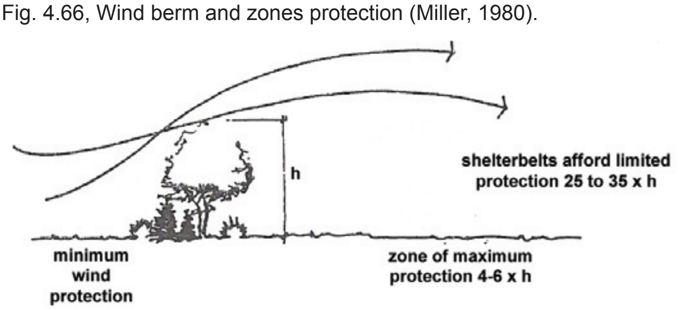


Fig. 4.67, Wind and shelter belts (Miller, 1980).

The zone of maximum protection, where the wind speed is reduced the greatest, is at a distance approximately 4-6 times the height of a moderately penetrable barrier to its lee side. The less penetrable planting, the more air is forced up over the barrier. This will create a more powerful suction eddy, or low pressure zone, behind the barrier, and will pull overhead air flow back down to its original path soon than if some of the air is allowed to pass through the barrier. See figure 4.66 and 4.67.

The air that passes through a partially penetrable barrier will retain some of its laminar flow characteristics. The presence of laminar airflow behind the shelterbelt will lessen the forces between the air layers overhead, reducing the downward pull of the suction eddy. The result is a greater zone of protection extending for longer distance leeward of the barrier. Overall, wind speeds, however, are not reduced quite as much as behind a denser barrier, and the zone of maximum protection moves farther away from the barrier.

As vegetation within a shelterbelt bends and sways in the wind, it decreases its penetrability .This has a positive effect on wind control. As the intensity of airflow increases, a shelterbelt will afford an ever increasing zone of protection, at the cost of slightly higher wind speeds leeward of the barrier. Since irregular surface is more efficient at breaking up airflow than a smooth uniform surface, the most effective shelterbelts are composed of a variety of species, tree heights, and densities. The optimum density, including leaves, branches, and trunks combined are estimated to be between 50 and 60 percent. At this density, narrow belts are just as effective as wider belts with the same overall penetrability.

The foliage mass of plants serves as a direct block to the passage of air. Wind will be diverted under, as well as over, a barrier. Studies have revealed that the air passing under trees, provided penetration is possible, is generally at higher velocities than open field wind speeds. Because most trees chosen for use in shelterbelts can have several feet or relatively open understory, shrubs must be planted at the base of the barrier for optimum wind control. The denser the overstory vegetation, the greater the need for understory plantings. In most situations medium density overstory planting of mixed species and densities, and an understory planting of dense shrubs is very effective for deflecting wind.

The greatest possible protection near the centre of a shelterbelt is obtained with a height to length ratio 1: 11.5 (Robinette, 1983). A series of shelterbelts parallel to one another have been found to have no significant accumulative effect, therefore, as several in a row.

Wind breaks

Vegetation may reduce the wind at ground levels significantly. Tall vegetation like trees are extremely effective at absorbing wind energy rather than deflecting it as do solid obstructions such as terrain and buildings. Two types can be categorized:

1- The surrounding forest and the isolated windbreak. Within a forest, the velocity is minimal near the centre of mass of the foliage in the crown (approximately 0.75 times the height); in the absence of underbrush there is a velocity increase among the tree stems. The shape of the wind profile in the forest is contingent on the type of the trees in the forest, their spacing and openings in the crown and the distance from the edge of the stand from which grand level wind can penetrate. Figure 4.68a compares wind velocity profiles in a ponderosa pine stand to those in the open and 4.68b shows the influence of foliage from seasonal wind measurements in a deciduous oak-beech forest. The extent of the sheltered area produced by a windbreak varies not only with the physical dimensions of the windbreak, but also with the porosity of the barrier. Porous barriers cause less turbulence and can create a greater area of total shelter than solid barrier. The more solid the barrier, the shorter the distance to the point of minimum wind velocity and the greater the reduction in velocity at that point. The velocity however, increases more rapidly downwind of the minimum point than behind a more porous barrier. Figure 4.69 shows a cross section of the airflow near a screen of 50 percent porosity. Figure 4.69 also shows the effect of varying porosity in shelter at ground level down wind.

A porosity of 40 to 50 percent has been found to provide maximum distance of sheltered area. This reduction in leeward velocity occurs without appreciable disturbance of the airflow. Wind breaks with higher porosities (greater than 50 percent) do not form a turbulent wake and the airflow pattern is dependent on the velocity of the flow. These windbreaks provide more protection from 5H to 20H with velocities reduced to 30 percent of the free stream velocity, but less protection up to 5H. Windbreaks with lower porosities (less than 35 percent) exhibit a turbulent wake that provides more protection up to 5H with velocities reduced to 10 percent of the free stream, but provides less protection from 5H to 20H with velocities up to 60 percent of the free stream. The large-scale eddies within the wake are sensed as gusts and may to disruptive to outdoor uses in the wake area.

Additional belts downwind of each other have been found to have slightly decreasing effect, presumably due to the increased turbulence in the lee of the first belts. Similarly, the sheltered zone leeward of a wide shelterbelt or forest is less extensive than that behind a single permeable windbreak.

If a sheltered area is desired for a zoned or seasonally adjustable building, it is recommended that the landscaping be designed to allow for reduced velocities without large scale turbulence. To achieve this windbreak should be at least 35 percent porous. The windbreak is most effective when the building it is to protect is located within 1-1/2 to 5 heights of the windbreak.

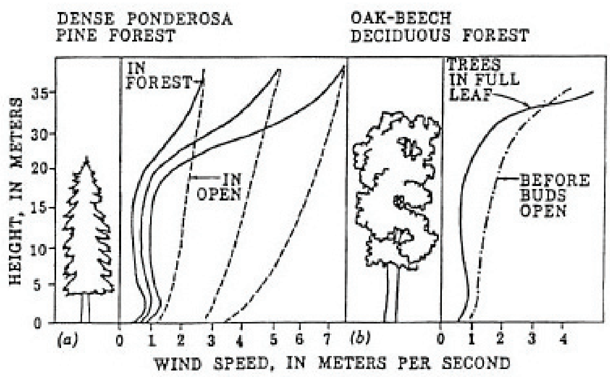


Fig. 4.68, Wind velocity profiles and trees (Arens and Watanabe, 1986).

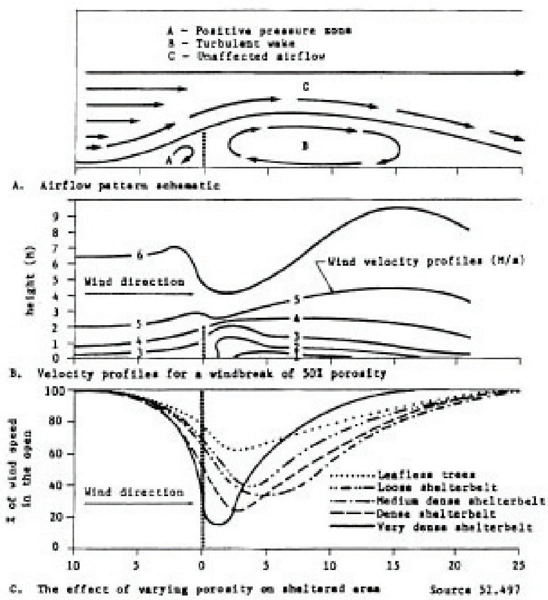


Fig. 4.69, Shelter around windbreaks (Arens and Watanabe, 1986).

Effect of the physical dimension of the windbreak on the sheltered area:

The leeward sheltered area varies with the length, height, depth and density of the windbreak. As the height and length of the windbreak increase, so does the depth of the sheltered area. The sheltered area also increases with windbreak depth, up to a depth of 2H (two windbreaks heights). If the windbreak depth is increased beyond 2H, then the flow reattaches to the top of the windbreak and the length of the sheltered area decreases. See fig (4.70)(Arens and Watanabe, 1986).

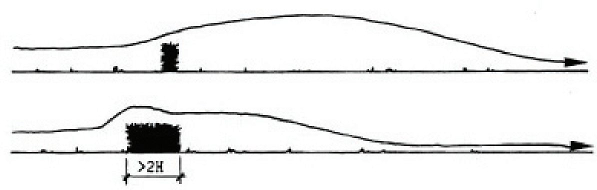


Fig. 4.70, Effect of the along wind depth of windbreaks on the sheltered area (Arens and Watanabe, 1986).

Effect of porosity of the wind break on sheltered area:
The incidence angle of the wind also affects the length of the sheltered area. Tree and hedge windbreaks are most effective when the wind is normal to the windbreak. If the wind approaches a windbreak at an oblique, the sheltered are is reduced (fig. 4.71).

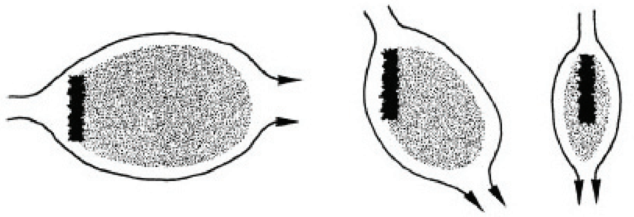


Fig. 4.71, Effect of wind angle on sheltered area (Arens and Watanabe, 1986).

Type of vegetation
Hedges provide a more pronounced sheltering effect than trees because they have foliage extending to the ground level. In fact, the flow beneath the branches (around the trunk) of trees can actually be accelerated above the free wind speed upwind of the tree.

Change in the direction and velocity of airflow:
Avoiding sheltered areas:
If shelter is not desired, plant trees far apart. Shade trees can be used around buildings without too much ventilation interference if the trees are tall, the trunks are kept bare and the trees are kept close to the building. See figure 4.72. Dense hedges should not be placed so that they affect the airflow through building openings.

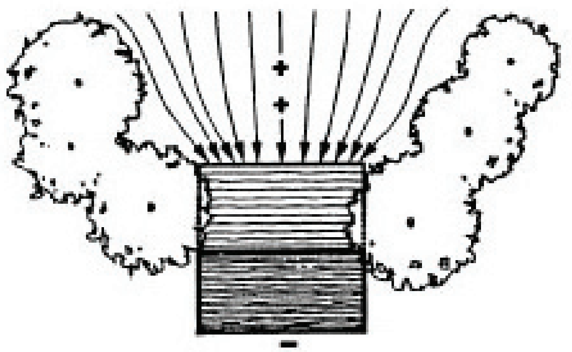


Fig. 4.72, Funnelling of air by landscape (Arens and Watanabe, 1986).

Deflecting airflow
Rows of trees and hedges can direct air towards or away from a building. See figure 4.72. For ventilation, it is generally best to orient rows perpendicular to the wind walls to channel airflow towards openings, provided that solar control is maintained. Dense hedges can be used in a manner similar to solid building windwalls to deflect air into the building openings. Vegetation may be used to create positive and negative pressure zones for ventilation or to increase the windward area of the building. Per unit area, vegetation will be as efficient as solid windwalls in producing these effects, but it can be more cost effective than windwalls because it can be much larger at lower

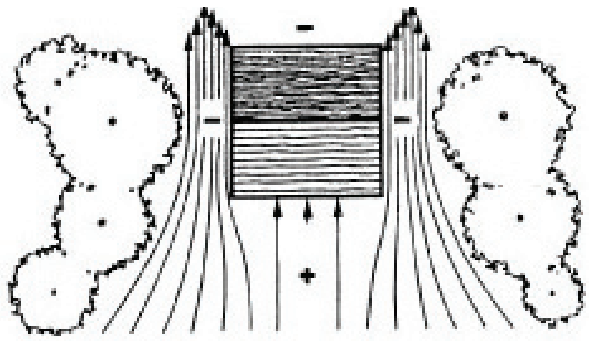


Fig. 4.73, Areas of accelerated velocities due to landscape (Arens and Watanabe, 1986).

cost.

Increasing wind velocities
Vegetation can create areas of higher wind velocities by deflecting winds or by funnelling air through a narrow opening (see fig 4.73). Narrowing the spacing of the trees used to funnel air can increase the airflow 25 percent above that of the upwind velocity. A similar effect occurs at the side edge of a wind break.

Soil erosion and Wind

In arid regions, wind causes erosion to the soil surface textures and vegetative covers. The Aeolian particles or wind-blown dust can also be harmful to humans, vegetation, and water bodies. The entrained sediments can harm traffic flow and reduce the visibility to near zero. Studies has proofed that as long as there is some type of soil crust, gravel, or vegetative ground cover, the surface of the soil has some type of erosive control. (Hupy, 2004)

Sand and Dust and Wind

Vegetation filters the air and minimizes lifting of dust from the ground. It is most useful on the windward side of buildings, especially when highways, open lots or parking lots are located nearby. To illustrate the effect of vegetation on sand movement by wind the following two diagrams are given (fig. 4.74).

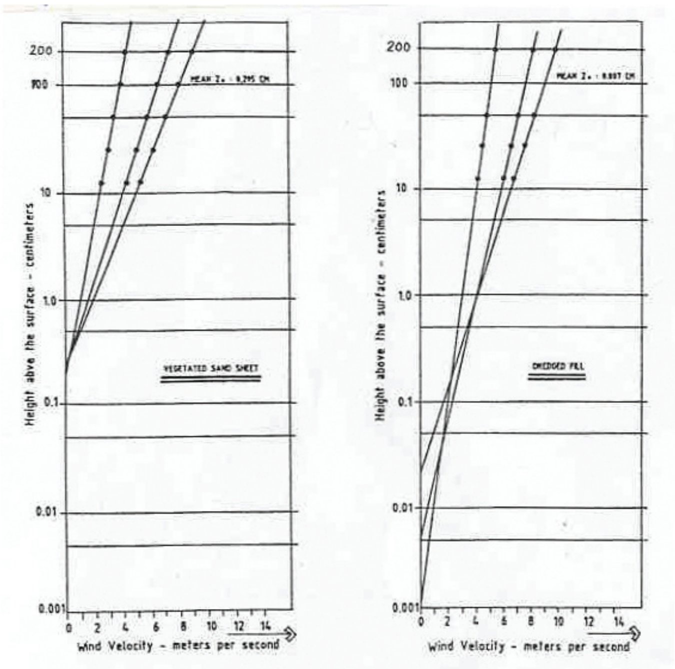


Fig. 4.74, The effect of vegetation on sand movement (Germeraad, 1986).

The diagrams compare the wind velocity at different height above a dredged fill sand area and a natural vegetated sand sheet in the Jubail region in Saudi Arabia. The diagrams shows that the wind speed equals zero above a vegetated sand sheet area at a height of 0.295 cm above a dredged fill area and a height of 0.007 cm by a wind speed of 8 m/s. (Germeraad, 1986) One hectare of dense forest can catch approximately 55 tons of dust.(Alsayyad, 1984)

Plants for Temperatures and Humidity Control

Plants decrease the ambient air temperatures. Plants offer the possibility of reducing the air temperature by reducing the undesirable effect of high solar radiation and thus reduce peak power consumption in buildings.
(Okke, 1989) in his article " The Micrometeorology of the Urban Forest" notes that the heat gain by a tree beside a building is particularly large: the tree receives, apart from the direct solar radiation, large amounts of reflected short wave energy from the irradiated building walls and floor, and it may also receive boosted inputs of long wave energy from the built surfaces. The dissipation of this heat load is through evapotranspiration and convective sensible heat exchange with the outdoor air. (Shashua-Bar and Hoffman, 2003) tried to proof this by the measurements of the air leaf temperatures of Ficus trees, taken on calm days in August 1996 in Ramat-Gan as shown in table (4.3).

Table. 4.3, Air leaf temperature above and below tree canopy (Shashua-Bar and Hoffman, 2003).

Table 3
Air and leaf temperatures in Hayeled Avenue (°C)

Temperatures	9:00 h	15:00 h	18:00 h
Air temperature above canopy	27.4	31.8	29.6
Leaf temperature	25.5	30.7	29.6
Air temperature below canopy	26.6	29.3	28.5

The applied plants should be deciduous, which mean that in summer their foliage shade the buildings, while in winter the leaves have fallen, plants let solar radiation to be freely absorbed by the building. Direct temperature measurements of tree leaves in an experimental study showed that tree leaves during daytime had a lower temperature than that of the air, while the relative humidity around trees kept constantly higher than the open air. The plants have an evaporative cooling effect which leads to lower air temperatures around the trees and shaded buildings.(Papadakis et al., 2001). See Figure 4.75 and 4.76.

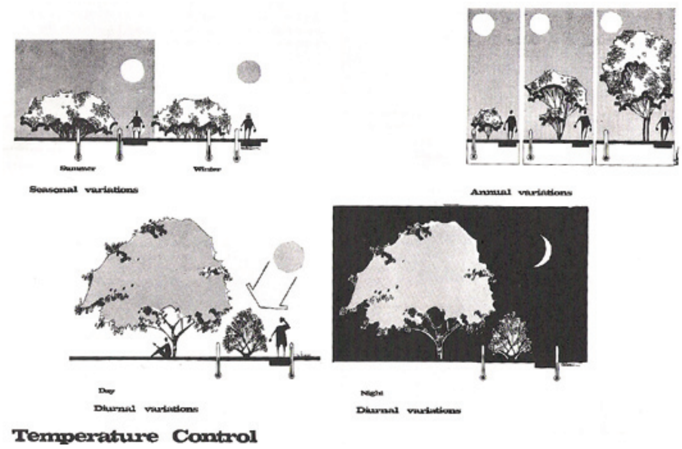


Fig. 4.75, Temperature Control (Robinette, 1983).

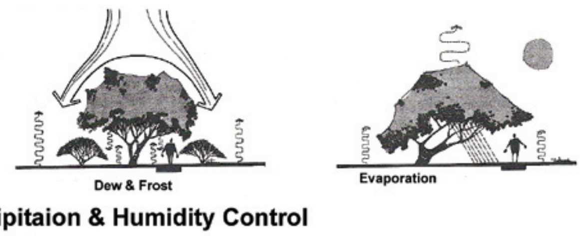


Fig. 4.76, Humidity Control (Robinette, 1983).

Plants and Solar Radiation Control

Vegetation can be used very effectively as an intercepting device to control the sun's rays. The large variety of forms, textures, and colours of plant materials provides an endless palette to choose from, adding beauty as well as utility to the landscape. Climbing and clinging vines function as solar control devices on overhead trellises or provide protection for a hot wall. Groundcovers can reduce unwanted glare and prevent excessive heat gain near structures and outdoor areas. The right tree in the right location can shade the house or courtyard during the hottest period of the year while letting the winter sun warm these same areas during the under heated period of the year (Miller, 1980). Trees, shrubs, groundcovers, vines and turf provide solar control by:

- Effectively reducing direct and reflected radiation.
- Absorbing heat
- Providing the cooling effect of evapotranspiration
- Creating dead air spaces that act as insulation in cold weather.
- Acting as a buffering agent to abrupt temperature changes.

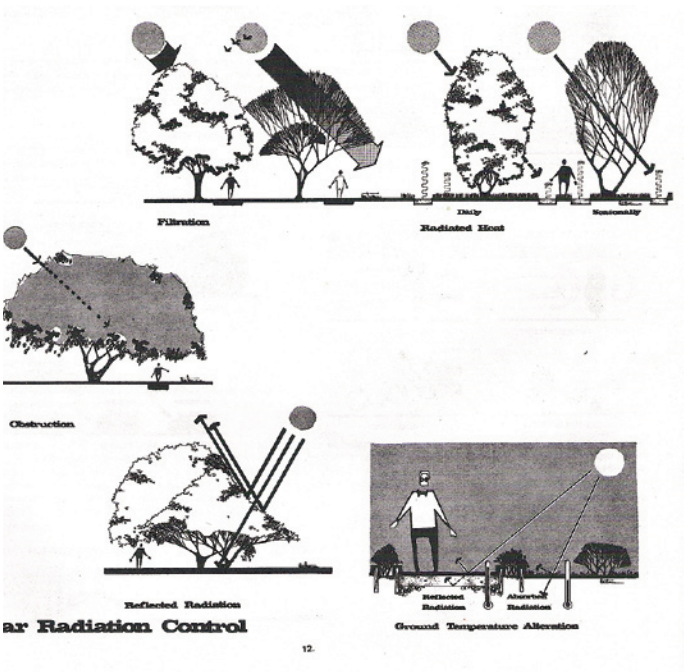


Fig. 4.77, Radiation Control (Robinette, 1983).

The foliage and braches of plants will selectively reflect, absorb, and transmit solar radiation. Vegetation with a loos open foliage and branch structure will filter radiation, allowing a portion to pass through the canopy. Dense foliage and multiple layers of canopy can almost totally obstruct incoming radiation. Very little, however, actually penetrates the canopy, resulting in cooler temperatures at the shaded side of leaf surfaces. In addition, plants have rough textures compared to most manmade objects, and the leaf canopy presents a multi-faceted surface which is more efficient at diffusing incoming radiation. Needles and small-leafed plants commonly found in desert landscapes are very effective at reducing glare from reflective surfaces.

The ability of plants to buffer rapid temperature changes is an important attribute for solar control. The cool soil under shaded areas will absorb heat from the air faster than heat can be transmitted to it by conduction or convection, and the greater humidity associated with vegetation means more heat is required to raise ambient air temperatures significantly. Temperatures within planted areas, therefore, remain cooler through more of the day than that of surrounding areas. Plant cover will also reduce diurnal temperature fluctuations by trapping and reflecting outgoing thermal radiation at night. The capacity for vegetation to retain warm air at night is directly related to foliage density. See figure 4.77 and 4.78.

During the night the tree canopy blocks direct radiant heat loss from the ground to the sky, because radiation is emitted only from the upper layer of the leaves. However, whenever the air blow the canopy is warmer the air aboce, it rises, and the air that has been cooled by contact with the upper leaves can sink down to replace it, creating natural convective cooling (Givoni, 1996).

Deciduous vegetation should be considered not only where shade is required to avoid excessive heat gain during the overheated times of the year but also when solar exposure is desired during the under heated periods. Because the leaf drop and refoliation of most native plant material corresponds very closely to the times of year when solar exposure and shade, respectively, are needed, it is wise to take advantage of the natural rhythms of these plants .

The degree to which plants function as effective climate control devices depends on their size, shape, density, and location. The proper location for plant material is best determined using the sun path diagrams in conjunction with overheated period data. Plant material is multifunctional, however, providing more utility than just solar control, and care should be taken to consider all aspects of site design requirements before final placement of vegetation is decided.(Miller, 1980)

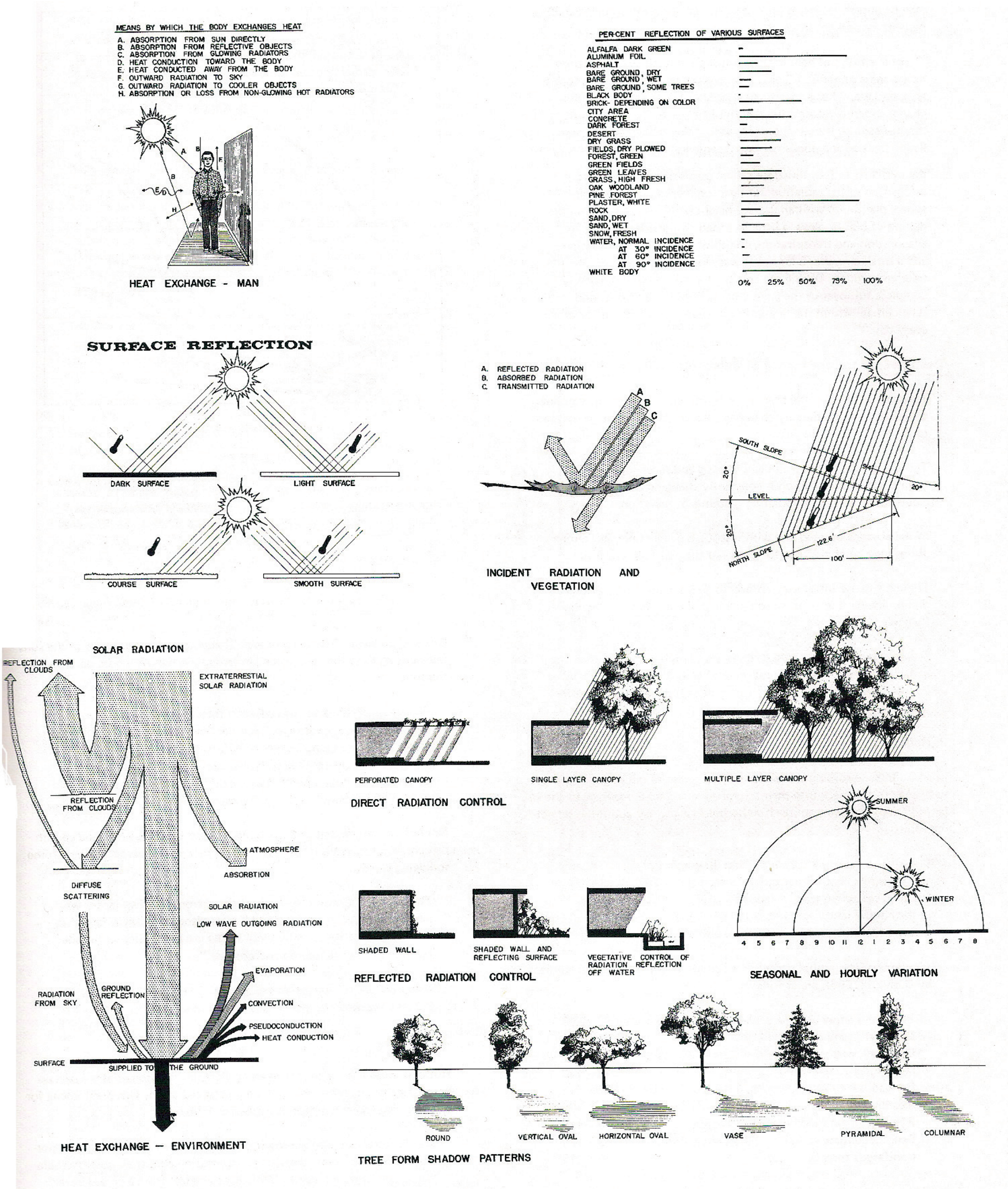


Fig. 4.78, Plants and Solar Radiation (Robinette, 1983).

4.3.2 Vegetation the Impact on Cooling and Heating of Buildings

The desirability of unimpeded wind flow through developments in hot regions can conflict with the equally important needs for shade, privacy, and dust suppression. A compromise solution may be to locate plants near the building for shade. To promote both shade and breezes one might specify high branching shade trees and low ground covers, but few shrubs.(McPherson et al., 1988a)

Trees are most effective when located to shade air conditioners, windows, or walls and when located on the side of the building receiving the most exposure. By locating dense trees (like conifers) to shade directly south and east facing walls and windows, and the air conditioner condenser unit, the cooling energy savings could reach more than 30%, corresponding to an average daily saving of 3.6 and 4.8 kWh/d. By aligning a row of tall trees (6 m) with combination of short trees (~2.4 m) the temperature and the in speed in the exterior surfaces reduces dramatically (Akbari et al., 1987; Akbari et al., 1997). Cooling loads are most sensitive to shade on the roof and the west wall, while heating leads are most sensitive to shade on the south and east walls. Landscape designers can balance solar access and control by locating vegetation to shade roof and west wall while minimizing winter shade on the south and east walls. Preliminary results from computer models showed that an additional 25% increase in the urban tree cover saved 40% of annual cooling energy use for an average home in Sacramento, USA(Simpson and McPherson, 1998b). Effects of shading trees on cooling load are illustrated here in table 4.(Simpson, 2002).

Fig 4.79 shows the effects of irradiance reductions on annual space cooling and heating costs for prototypes residences in Tucson. Abbreviations for shaded surfaces: R=roof; N- north wall; E= east wall; S=south wall; W= west wall; RW= roof, west wall; RWS= roof, west, and south walls; RWSE= roof, west, south and east walls; All- all surfaces shaded.

Furthermore, Lesiuk showed in his study the influence of three plant canopies, located in the south, on the energy load of buildings. Fig 4.80 shows a dramatic drop in solar heat load (Lesiuk, 1980).

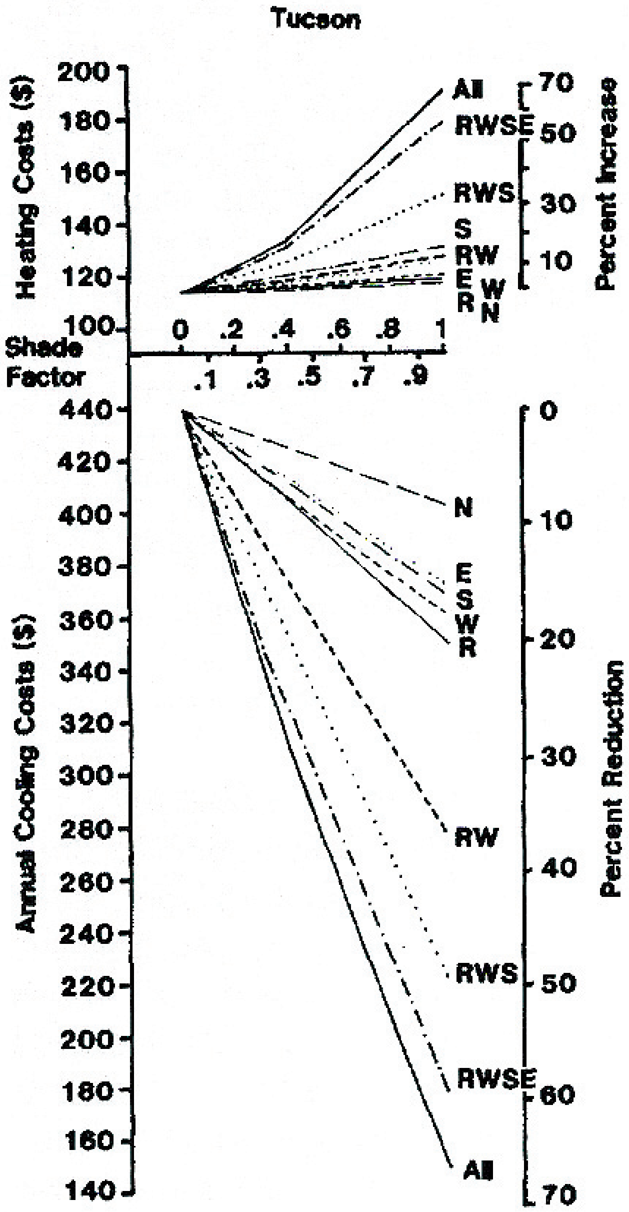


Fig. 4.79, Irradiance reduction on annual space cooling (Lesiuk,1980)

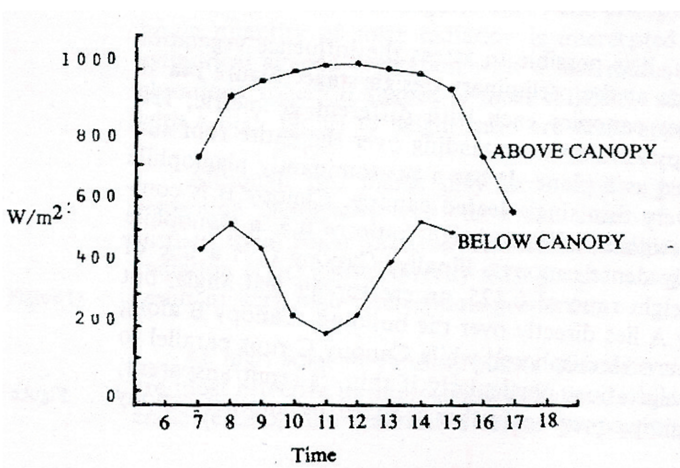


Fig. 4.80, Tree canopies and solar heat on buildings. (Lesiuk,1980)

Ground covers

The natural cover of the terrain tends to moderate extreme temperatures and stabilize conditions through the reflective qualities of various surfaces. Plant and grassy covers reduce temperature by absorption of insulation, and cool by evaporation. This reduction can amount to 1,500 Btu/sq ft/season. It is generally found that temperatures over grass surfaces on sunny summer days are about 4 to 8 cooler than those of exposed soil. Other verdure may further reduce high temperature; temperature under a tree at midday was observed to be 3^{o} lower than in the unshaded environment.

The treatment of the ground can affect the ground surface temperatures and outgoing fluxes and radiations. Natural covers can reduce the outgoing radiation from a ground up to 26%. The surface temperature of the rock reaches $45^{o}C$ and could be as $14^{o}C$ warmer than the turf. The previous mentioned facts were proofed in a study on the effect of three different landscape treatment on buildings energy and water use in Tucson, Arizona. The three treatments where (1) turf, (2) rock mulch with foundation planting of shrubs, (3) and rock mulch with no plants. The study also concluded that granitescape near building should be avoided, and instead the trees and shrubs and vines should be used. The use of turf in the desert landscapes was less appreciated due to the large consumption of water. Although many people find that lawns provide needed areas for play, cooling air, and are aesthetically appealing See figure 4.81 (McPherson et al., 1988b).

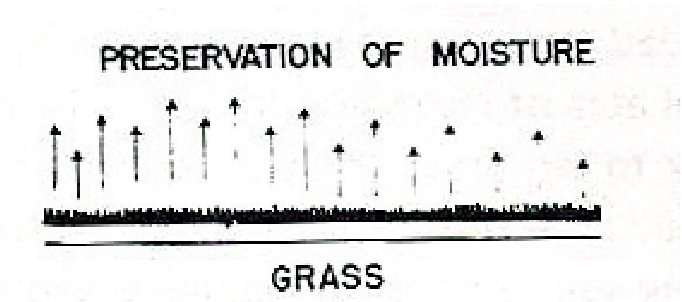


Fig. 4.81, Grass and the moisture preservation (Robinette, 1983).

Shade and Energy Consumption Reduction

Trees are primary in an energy conserving landscape because shade reduces the amount of radiant energy absorbed and stored by built surfaces. Evapotranspiration, which converts liquid water in plants to vapour, cools consequently the air. Trees can have a canopy large enough to shade roofs, reducing cooling costs and increasing comfort. The best locations for deciduous trees are on the south west sides of a building. When these trees drop their leaves in the winter, sunlight can reach the building and help in heating the spaces. Even without leaves, trees can block as much as 60% of the sun, making placement of trees critical to effectiveness.

Trees should be strategically located on a site. With appropriate shading, there is greatly reduced need for fans and air conditioning. Landscape architect should have a good understanding of the sun's movement in the sky, both throughout the day and at different times of the year. In the northern hemisphere trees are most effective when used on the eastern, southern, and western exposure.

Of course, a tree's optimal distance from a building will vary with the tree's height and the angle of the sun. In early evening, the sun is hitting the western exposure at a relatively low angle. A tree positioned farther away from the building on the west side will cast long shadows on the building. Generally, the taller the canopy the farther away from the house the tree should be placed to effectively cast shade. A tree that is too short, or is too distant from the house, can be ineffective for shading when placed on the southern exposure, because the high midday sun causes it to shade its own trunk rather the adjoining building surface (Council) (Shaviv and Yezioro, 1997). See table 4.4.

Changing tree size, determined by species and age, or location, defined by tree-building distance and tree azimuth with respect to a building, results in dramatic variation in amount and timing of building shade(Simpson and McPherson, 1998a).Tree azimuth and location are two major important factors to reduce the energy loads of a building. The location of tree-building distance of 2-5 m is most common. Jones and Stokes Associates Inc. proposed savings inversely proportional to the square of the distance to the building, and proportional to the square of canopy diameter. In terms of real-world applications, there is little available information about tree location with respect to buildings of different types as a function of species and age (Stokes, 1998)

Table. 4.4, Lookup table for change in cooling energy use for mature trees and the post. (Stokes, 1998)

Tree type	Tree–building distance (m)	Tree azimuth							
		N	NE	E	SE	S	SW	W	NW
Change in site cooling energy use (kWh)									
Large/rapid	0–7.6	14	100	276	180	258	183	391	126
	7.6–12.2	2	6	238	73	176	116	411	25
	12.2–18.3	0	2	136	31	51	66	338	20
Large/moderate-slow	0–7.6	13	79	245	149	246	146	347	95
	7.6–12.2	0	4	195	56	134	95	375	21
	12.2–18.3	0	1	96	21	29	50	274	15
Medium/spreading	0–7.6	13	62	229	131	225	139	364	96
	7.6–12.2	0	4	155	40	87	70	345	21
	12.2–18.3	0	1	49	10	4	26	207	16
Medium/upright	0–7.6	5	5	124	36	111	67	214	22
	7.6–12.2	0	2	65	15	24	41	185	13
	12.2–18.3	0	0	24	5	2	16	121	8
Small	0–7.6	10	5	149	65	146	99	261	28
	7.6–12.2	0	1	59	15	20	41	213	15
	12.2–18.3	0	0	15	3	0	13	113	8

[a] Tables for pre-1978 and 1978–1983 vintages, and heating table for the post-1983 vintage, are not shown.

4.3.3. Water Surfaces and Fountains

Water surfaces may improve the micro-climate of the built environment and reduce the energy need for cooling the buildings. Climatologists proposed to planners more strategies to improve he micro-climate: more vegetation, higher albedo or water ponds favouring the cooling by evaporation. These strategies enables us to modify the climatic impact like the local heat, mass, and momentum balances influencing air quality, thermal comfort and energy consumption of buildings.

Water surfaces:

The presence of water ponds improves the outdoor micro-climate by evaporative cooling. The surface temperature of the water pond is affected by the heat transfer caused by radiation, conduction, convection and the latent heat transfer due to water evaporation. Water is normally warmer in winter and cooler in summer, and usually cooler during the day and warmer at night, than the ground. Accordingly, the proximity of bodies of water moderates extreme temperature variations, and in winter raises the minimums, in summer lowers the heat peaks (fig. 4.82).

The characteristic of the solar radiation reaching the water surface vary strongly according to sun position, site location, possible presence of shadings and parameters depending directly on the atmospheric conditions. The rest crosses water where it is absorbed, changing its temperatures. There are many factors which affect the attenuation of the solar radiation in the water ponds, among which spectral distribution of water properties, the incidence angle, the thickness of water layer and the reflectivity of the pond bottom.

A modeling study proofed that the air temperatures at the surface water, of a 0.5 m deep and 4m by 4m pond, was 38.4°C less than the temperature of the asphalt surface air at 13 hour. The presence of water pond reduced the air temperature by water evaporation (Robitu et al., 2003). See figure 4.83.

If wind driven air streaming towards a building passes over a water surface, adding moisture to the air, mild adiabatic cooling effects can be achieved. In the example on figure 4.84, the temperature decreases depending on the length of water surface and air speed.

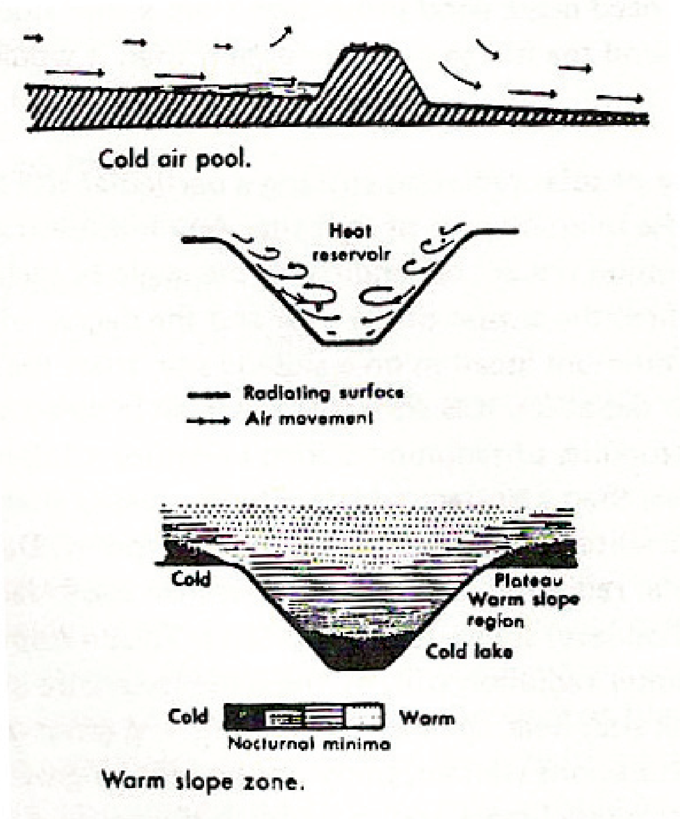


Fig. 4.82, Water surfaces and air (Robinette, 1983).

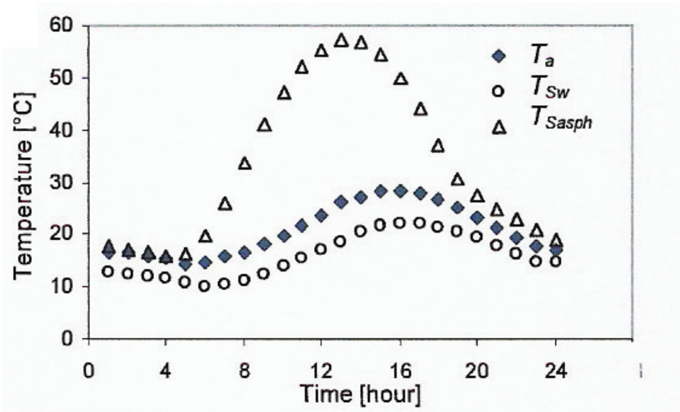


Fig. 4.83, Solar radiation and water surfaces (Robitu et al., 2003)

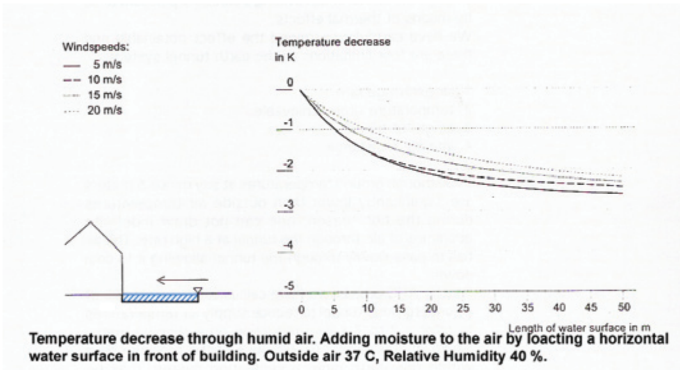


Fig. 4.84, Temperature decrease through humid air (HL-Technick, 2001)

Water Ponds
In private courtyards adjacent to a house it is possible to design the entire landscape, including a pond that is surrounded by trees and effectively shaded. A shaded pond would be cooler than an unshaded one and can maintain the water average temperature slightly above but close to the diurnal average of the wet bulb temperature. Deciduous trees will allow sunshine into the courtyard during winter.
A cool pond by itself will have a very small effect on the air temperature in the courtyard, because there is just a limited heat exchange between the pond's cool water and the warmer air above it. This heat exchange can be greatly increase if the water in the pond can be circulated through fine drops fountains. The semiconifined air in the courtyard can then be cooled, mainly by convection, by the large surface area of the fine drops.
If a pond with still water is not shaded, its temperature of such a pond by circulating the water through a fountain that generates a fine drops spray. This cooling effect will be accomplished at the cost of an increased rate of evaporation and water use as compared with the case of the shaded pond.

The Single Fountain Feature
The effect of fountains in courtyards has in terms of adiabatic cooling effects only a very limited impact on reducing air temperatures, due to the relatively small water surface they can provide. Nevertheless the psychological effect can not be neglected. It is pleasant for the eye and to the ears to experience a play of water. Such fountains are very valuable means to enhance the subjective perceived level of comfort.
Water is scarce in desert lands, and people in the hot arid zones have always cherished water and tried to remain in contact with it as long as possible. Apart from its refreshing effect physically, it has always had a pleasing psychological effect. Furthermore, water is very important in increasing the humidity and thereby promoting thermal comfort in hot arid lands. In the Arab house, the fountain plays a role equivalent to the fireplace in the temperate zones, although one is used for cooling and the other for heating. Thus, the fountain is an architectural feature occupying a privileged place in the house plan.

Artificial Fog
Artificial fog can be generated by injecting water at high pressure through very minute orifices. If the water droplets are small enough, and the wet bulb temperature depression below that air temperature is large enough, the droplets evaporate almost instantly. The evaporation of the droplets cools the air without forming liquid water over people staying nearby, although the fog is visible.
Fog generators consume a large quantity of a pump's energy relative to their cooling effect, and they need water with low mineral content or water that has been treated chemically.
Even with a very light wind the fog is carried away downwind. When the winds in a given region are light and the direction is more or less constant, fog generators or mist devices set out in a line, located upwind of the area to be cooled, can provide a measurable cooling effect. Artificial fog is an especially attractive cooling technique for local "spot" cooling of small areas where people gather, such as in front of kiosks along walkways (Givoni, 1996).

Water Conservation

The available water supply for any region is dependent on five factors:

- The amount of water stored underground.
- The amount of rainfall received annually.
- Water resources around the region.
- The legal amount of water available for the user.
- The amount of money the user can spend on money.

In Egypt, the water is limited on all five counts. Annual rainfall in arid regions is minimal. Available water from outside sources, i.e. perennial flowing water courses, typically do not supply enough water courses, typically do not supply enough water to areas of concentrated population.

A large percentage of municipal water supplies are used for the irrigation of outdoor landscapes. The remaining water is essentially lost through the process of evapotraspiration. The remaining water is used inside the home, and because it is used inside the home, and because it is used inside the home, and because it is potentially available for reuse. The conservation of water outside the home, therefore, can have a significant effect on overall municipal water consumption.

One way to conserve water is insure the most efficient use of existing supplies. In the case of landscape irrigation, this may take several forms:

- Use as many drought-tolerant species as possible, and locate plants according to their water requirements.
- Minimize waste by using efficient irrigation techniques.
- Supplement city water with rainwater whenever possible.
- Discourage evaporation of soil moisture from around the root zone of plants.

Water Conservation and plant-water relations

While there are varieties of irrigation systems capable of delivering water to thirsty plants, their purpose remains the same. The function of irrigation is to supply the root zone of a plant with sufficient moisture at an appropriate rate to insure healthy root growth and plant development.

The rate and frequency of water distribution is very important. Extreme fluctuations in soil moisture from near saturated conditions to very dry arid conditions do not represent a stable growing medium for plants. A saturated soil holds little or no air within the open pores between soil particles, thus starving plant roots of oxygen. As a soil dries by drainage and by evapotranspiration, a point is reaches at which the remaining water is held so tightly by the soil particles (hygroscopic water) that plants are unable to absorb it. This is termed the wilting point of the soil. When this condition is reached, the plant will show visible signs of wilting from lack of cell turgor.

The excess water is a saturated soil that soil pores are unable to hold will drain away by gravity. At this point the soil is said to be at field capacity – the maximum amount of water that a thoroughly moistened, well-drained soil will hold against the force of gravity. At field capacity, the soil-moisture tension for most soils is from zero to 3 atmospheres, and plants can absorb water the soil with minimum stress. At the wilting point, the soil-moisture tension is approximately 15 atmospheres.

The remaining soil moisture (total soil moisture minus gravitational water minus hygroscopic water) is the water actually available for plant use. A medium textured loam soil containing roughly equal parts of sand, silt and clay will consist of approximately 50 percent solid material and 50 percent pore space.

A theoretical optimum moisture level for plant growth is when one half of the pore spaces are filled with water and the other half filled with air. Fine-textured clay soils will have a much higher water holding capacity, and coarse sandy soils will have a much lower water holding capacity. Figure 4.85 shows the approximate plant-available water for various textures soils in terms of inches of water per foot of soil.

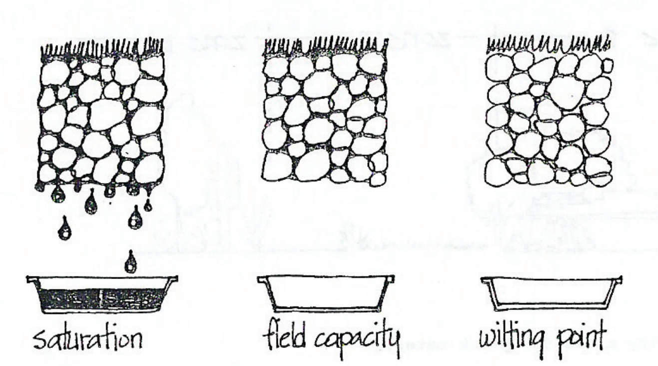


Fig. 4.85, Water holding in soils (Miller, 1980).

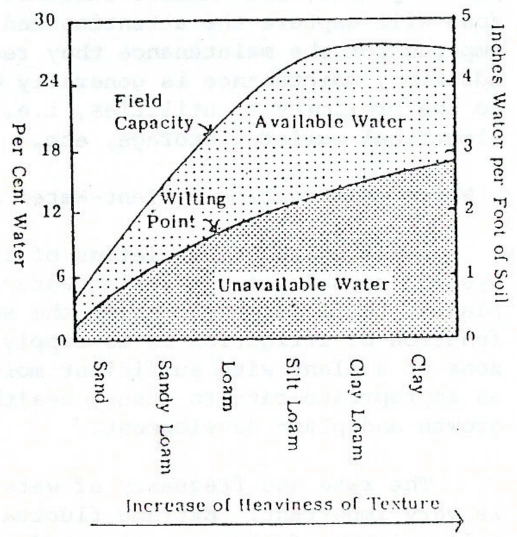


Fig. 4.86, Diagram for water holding in soils (Miller, 1980).

An efficient irrigation system will deliver water to the root zone of a plant of a plant at the appropriate rate and frequency to maintain the soil moisture within the upper and lower limits of the plant-available water. See figure 4.86.

Drip irrigation

One of the most recent developments in irrigation techniques to satisfy this requirement is drip or trickle irrigation. The technique involves small diameter plastic tubing which delivers water directly to the root zone of a plant through special emitters at a slow but frequent rate. This is in contrast to more conventional flood or sprinkler irrigation which supplies large quantities of water at considerably less frequent intervals. Plants typically use only 30-60 percent of the water supplied by flood irrigation. Sprinkler irrigation is more efficient, with plants utilizing as much as 70-80 percent of the water supplied, but major losses of water occur through evaporation and losses of water occur through evaporation and excessive drainage of gravitational water with both systems. Drip irrigation, on the other hand, has an efficiency of 80-95 percent.

Small diameter polyethylene tubing (approx. 15 mm) is used to carry water from Polyvinylchloride (PVC) laterals, or headers, to the drip emitters. Headers will vary in size, depending on the flow of water required and the length of run.

Depending on the type, emitters may be positioned above or below ground, but always directly within the root zone of the plant. For large shrubs or trees, several emitters are typically looped around the base of the plant for effective coverage.

A low pressure micro porous tubing that sweats water along its entire length is also available. Micro porous tubing is used in place of emitters for lawn areas or bedding plants. Because of the number of rows and the close spacing required for uniform distribution of water from micro porous tubing, large areas may be irrigated more economically by other systems. Because the soil has ample time to absorb the slow trickle of water from emitters, drip systems perform well on sloped land.

Drip irrigation and saline water

An added advantage of drip irrigation is that it works well even with e saline water. When irrigation with conventional systems, the concentration of salt in the soil increases as the soil dries out between applications of water. Eventually, the soil moisture tension rises sufficiently to make it difficult for the plant to absorb the remaining irrigation water. This will occur even through the soil appears moist. Leaf burn (the margins of the leaf turning brown and crisp) or the accumulation of a white salty crust on the soil surface is a visible clue to this condition. To control salt accumulations, soils must be flooded at regular intervals to leach the salts down and away from the root zone.

With drip irrigation, the builup of salts is minimal. Because of the slow continual application of water, the salts are carried out to the edges of the root zone by a continuous advancement of water. The salt concentration within the centre of the root zone remains fairly constant, at the same level as the irrigation water. This is particularly important in arid regions, where much of the available irrigation water is saline (fig. 4.87).

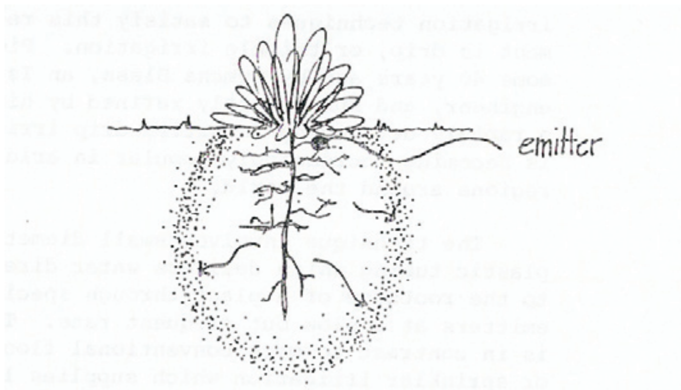


Fig. 4.87, With drip irrigation, salts are leached away from root zone (Miller, 1980).

Drip irrigation also allows the most efficient application of fertilizers since water-soluble fertilizers can be injected directly into the system. Nutrients are accurately distributed into the root zone, eliminating the waste that occurs when fertilizers are distributed to areas between plants or lost through deep percolation. Consequently, this technique of irrigation minimizes the chance of chemical contamination of groundwater and surface water. Also, fertilizers burn is virtually nonexistent because the chemicals are heavily diluted in the irrigation water before application.

The efficiency of a drip system, like any irrigation system, is dependent on how well the system is managed, as well as the cost of labour, materials, water, the condition of the soil and the choice of plant material, but the benefits that can be realized with a drip system, as outlined below, clearly indicate that it is an effective way to irrigate desert regions. Some benefits of drip irrigation:

- Water is distributed only to the root zone of the plant, and not to areas between plants.
- Evaporation is minimal
- Water can be delivered at a rate roughly equal to the rate of evapotranspiration, eliminating excessive loss through deep percolation
- Drip systems work well with saline water
- An efficient application of fertilizer can be achieved
- Drip systems can effectively irrigate sloped land
- Installation and labour costs are less than with other systems

Harvesting rainwater to supplement irrigation

In arid lands the greatest portion of annual precipitation is classified as runoff. A small percentage of this runoff is used to recharge underground water tables. The remainder, as much as 75 percent or more depending on the area, is lost to the atmosphere through evaporation from the soil surface and as transpiration from vegetation. This can amount to a sizeable quantity of water.

The harvesting of rainwater, by means of a catchment area to collect the water and concentrate it into a controlled area, or into a storage facility for later use, is a viable alternative water source for arid regions.

Water harvesting can be viewed at two different scales. First is the large-scale system designed for the irrigation of field crops or for supplying water to livestock. The catchment areas can be treated artificially in some fashion to make

them less impervious and therefore increase runoff. Treatments are typically classified as either land surface alterations (cleaning and soothing, shaping, compaction), chemical treatments (silicone water repellents, sodium clay dispersants), or groundcover modification (various asphalts, concrete, sheet metal, plastic). Storage facilities range from large steel, above-ground tanks, to plastic or rock lines earthen reservoirs.
The size of the catchment, area and the storage facility are a function of local precipitation, the site, the quantity of water desired, and the efficiency of the system's components used to collect and store the water.
Secondly, at a smaller scale, is the use of rainwater collected from roof tops, driveways, and courtyards for the irrigation of residential scale, as with the larger systems, the collected water may be diverted directly to planted areas or stored for future use.
If we return to our zones of suitability discussed earlier, it is easy to see that one direct use of site runoff would be to irrigate the drought-tolerant plants in Zone 1. For the average site minimal grading could direct rainwater to the edges of the property where shallow depressions would serve as watering basins. Both Zone 3, with its high percentage of impermeable surfaces, and Zone 2, having relatively large open spaces of lawn and inert groundcovers, will function well as collector areas.

By using this same technique, water could be diverted to any area on the site, depending on topography and the location of the planted areas. The size of the collection area and the size and depth of the watering basin around the plants can be designed to deliver quantities of water proportional to the requirements of the species used, with high water-demanding plants receiving proportionally more water than low water-demanding plants.
Sharp changes in grade, such as from collector areas to detention basins, are critical erosion points. An attractive and economical way top treat these problem areas is with rock rip-rap.

Mulches help conserve soil moisture
Used as mulch, rock is also an effective way to prevent excessive evaporation of soil moisture. When using mulches for this purpose, rock or otherwise, the soil out to the drip line of the plant should always be covered to insure that most of the root zone is protected. Rock mulches also act as thermal insulators. On cold winter nights they protect tender roots from frost damage, and during the heat of the day they help prevent excessively high soil temperatures.
Rock is certainly not the only effective mulch for desert landscapes, but its availability (economy), its relation to the desert landscape (aesthetics), and its ability to prevent erosion (functional durability), make it a top contender.

4.3.4 Zones of Plant Suitability

Both the type and location of plant material can have a substantial effect on water consumption. The use of arid plants has been emphasized for its ability to withstand extended periods of drought. The location of plant material in relation to structures and other site elements can have an equally important influence on plant-water relations. Plants in an exposed, windy location will require many times more water than plants located in protected areas, such as under overhangs or behind walls. It is important therefore, to identify the micro-climates or 'zones of suitability' for various plant types that might be chosen for any site (fig. 4.88).

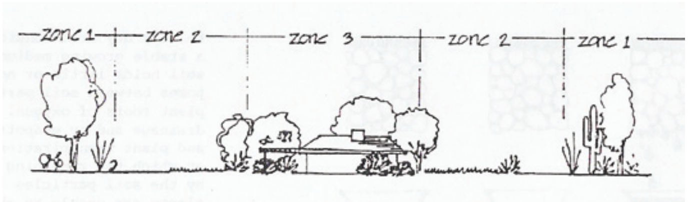


Fig. 4.88, Suitability zones for plant materials (Miller, 1980).

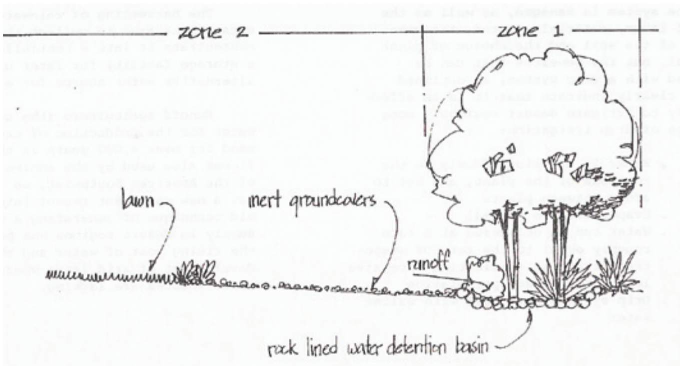


Fig. 4.89, Zone 1 and zone 2 (Miller, 1980).

Zone 1
The edges of the property, often the most exposed, typically represent the most arid zone on the site. Because this zone is usually a low use area, it should be planned accordingly as a low maintenance area. Visually, Zone 1 lends itself well to large-scale trees and shrubs that serve either as a buffer to activities on adjacent sites or to frame key views. One of the primary functions of Zone 1 is to create privacy. This zone should be planted with the lowest water-demanding plants.
Zone 2
The level of use of Zone 2, a transitional zone, is moderate. Here we may find small areas of functional lawn used for recreation and open areas of inert groundcovers. Because of the buffering effects of Zone 1, the exposure of Zone 2 is moderate. Again, very drought-tolerant species are best here, although some plants requiring more water may be located in protected areas (fig. 4.89).
Zone 3
Zone 3 affords the most protection from wind and sun. Structural overhangs, walls, shade trees, fences, pergolas, and atriums provide an environment more suitable for high water-consuming vegetation than either Zone 1 or 2. If tender exotics are planted, this is the zone where they are

most likely to survive.

The level of use and the visual interest of Zone 3 are high. Accordingly, the exotics, potted plants, and annuals suitable for this zone will capture the attention and provide impetus for the maintenance they require. In addition, maintenance is generally easier due to the proximity to utilities, i.e. hose bibs, electrical outlets, storage, etc.

4.3.5 Design Recommendations

To make it cooler

- Make extensive use of shade trees as an overhead canopy
- Use vines, either on an overhead trellis or canopy or on south and west facing walls
- Use overhangs, trellises, arbors or canopies where possible (this makes an area cooler in the daytime and yet warmer at night since it limits the release of colder air into the colder night air)
- Use ground covers or turf on earth surfaces rather than paving
- Prune lower braches of tall trees and remove or thin lower trees and shrubs to improve and increase air circulation.
- Provide for evaporative cooling from sprinklers and pools
- Use areas on the north and east sides of structures for outdoor activities
- Remove windbreaks, ether natural or man which would limit or hinder airflow especially during the warmer months.

- Locate activities on the leeward side of water bodies.
- Orient all activities to the north and east of structures.
- Use extensive coarse textured deciduous, shade trees and vines.
- Provide shade on the south side of all activities and areas.
- Do not block or curtail down-hill airflow.
- Use overhangs, awnings and canopies during the day which may be moved aside at night to allow for release of the trapped warm air.
- Use extensive turf and ground covers throughout the site.
- Use a minimum of hard, paved surfaces. Shade all paved surfaces with structural or vegetational canopies.
- Use raised decks for paving where possible.
- Use vines, shade trees or canopies over all exposed wall surfaces.
- Prune lower growth on all trees to allow for increased air circulation.
- Plant to divert winds or breezes throughout the site.
- Provide pools, fountains, spray devices and irrigation as extensively as possible throughout the site.

To make it breezier

- Remove all restrictions to natural air flow patterns on a site
- Prune all lower branches of taller trees
- Curtail and limit all low plant growth between 30 cm and 3 meters high which would inhibit or limit wind flow.
- Locate outdoor activities in areas which have the maximum access to wind on a particular site
- Build decks or platforms on the windiest areas on the site in order to take advantage of natural breezes.
- Create natural wind tunnels or breezeways using either plant materials. Earth forms, architecture, fences or walls.
- Locate activities or areas on the sides of a valley wall to take advantage of the day and night wind flow patterns.
- Orient activities to the north and west quadrants of the site.
- Minimize or remove all windbreak elements or devices which block wind, breezes or airflow.
- Use structural, vegetational or geological elements to direct and focus desirable winds or breezes to areas desired.
- Prune lower branches of all trees in order to allow for easier air circulation
- Remove under story or low plant growth which blocks wind
- Locate activities ether on a hilltop, or a narrow valley floor or on a sloping hillside.
- Orient openings in mature vegetation to accommodate roadways and walkways so as to channel or direct wind flow.

Landscape and vegetation:

Summer

- Rapid evapotranspiration of plants in hot sun and winds makes standard irrigation practices ineffective.
- Create cool air pools around house and in patio areas.
- Shading walls and windows is the most effective method of impeding solar heat gain on a structure.
- Vegetation can satisfy the need for visual privacy, glare reduction, reduced thermal gain on structure, night time radiation of heated walls.
- Shield house from sand storms and high winds.
- Larg run-off from summer rainfall has to be channelled.

Winter

- Need for flooding or irrigation of non-native plants is less critical.
- Protect non-native plants from cold winter night time temperatures.
- Walls and openings on E, SE, S, and SW do not want to be shaded.
- In winter, house needs visual privacy, increased thermal gain of structure, decreased night time radiation.
- Deflect winter winds away from building openings and outdoor living areas.
- Run-off from water rainfall has to be channelled.

Balance between summer and winter

- Use native or drought-resistant imported plants and trees to conserve water and to harmonize with desert character. Use drip irrigation instead of flooding or sprinkling; flood periodically to rid soil of salt build up. Use mulch to retard evaporation around root zones of plants. Establish vegetation zones around structures according to water use.
- Concentrate planted areas in oasis fashion, adjacent to openings in house wall. Grouping vegetation provides efficient watering as well as protection from

summer winds and winter frost.

- Deciduous planted should be used for shade in summer and transparency in winter. Foliage density determines the capacity to retain warm or cool air, and to create micro-climate effects.
- The use of trees and vegetation requires proper and studied location. Simulate shadow seasonal shadow patterns before locating trees to insure desired shading. Misplaced vegetation can impede desirable heat loss by radiation during summer nights.
- Block unwanted winds by use of well placed earth forms, vegetation, and or architectural elements (fences, walls, buildings). Vegetated earth berms filter out noise and dust while deflecting wind. Use of shelter belts can block unwanted desert winds on flat sites horizontal protection will be 5 times the height of barrier.
- Rainwater catchment from drives, roof, and other paved areas should be channelled to vegetated areas or stored underground for later use.

(Clark, 1980; Cook, 1980; Fredrickson, 1980; Givoni, 1980; Golany, 1980; Legorreta, 1980)

4.4 Conclusion

The preceding sections have illustrated that site, form of building; urban fabric and landscape have a strong influence on micro-climate improvement and energy consumption. Careful considerations of the climate, landscape and building fabric can reduce the worst effects of climate on buildings energy consumption.

In order to provide the landscape architect with the design principals and design guidelines that can help him to improve the micro-climate and conserve the energy there are some aspects that should be considered during the design of the outdoor environment. These aspects are listed below and are associated with 3 diagrams representing the solutions that could be adopted considering the site, the architecture and urban fabric and the landscape. See figure figure 4.90, fig. 4.91 and figure. 4.92.

1. Solar Radiation (Radiation Control, Heat Control, Albedo Control and Glare Control).
2. Wind (Dust Control, Soil Erosion Control and Natural Ventilation).
3. Evaporation (Evaporative Cooling and Diurnal Cooling).

By overlapping the three figures on one diagram (fig, 4.93) we can find that in arid climate shade is a perquisite for improving the outdoor spaces and there are two reasons for that:

1- Protection form solar radiation has a larger physiological effect in reducing heat stress than the effects that can be expected from lowering the air temperature without providing shade in outdoor spaces.

2- Shading does not involve any expenditure of energy or water for irrigation, as do almost all systems that can lower the temperature in an outside area.

I would also like to point at another important remark. In dealing with the issue of comfort in outdoor spaces a conflict may exist between two approaches:

a. Providing comfort through the cooling effect of the wind.

b. Lowering the air temperature in the outdoor space by evapotraspiration.

Because the lowering of the air temperature in outdoor space requires that the warmer wind penetration is minimized. The conflict between the two approaches exists because minimizing the wind penetration in an open space usually is accomplished by fixed devices. The wind blockage can not be turned on and off, as is possible in a building. Therefore, once the space is semi enclosed by such devices as surrounding walls, shrubs, or earth berms, the wind cooling effect is minimized even during periods when wind would be desirable (Givoni, 1996).

In arid regions, the choice between the two options depends on the local typical maximum air temperature. In places where the maximum temperature is below about 30 degrees centigrade, wind can be very effective as a comfort element. In such regions shading the space, while leaving it open to the wind, might be the best approach to minimize heat stress. In places where the daytime temperature are higher, the humidity is lower than 50%

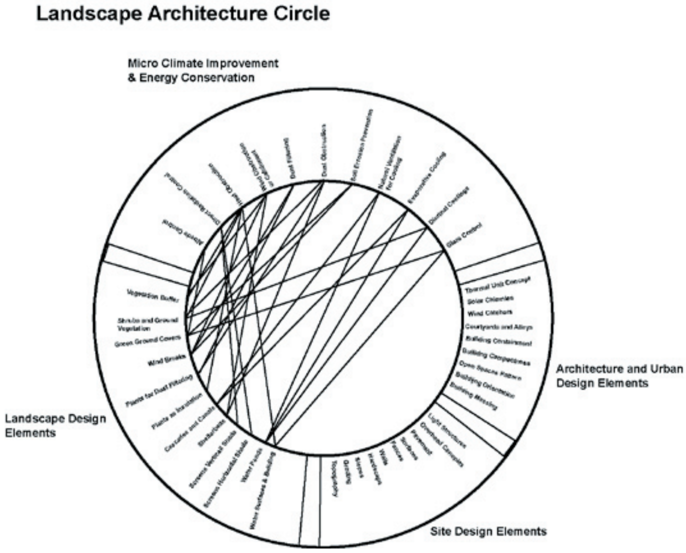


Fig. 4.90, Site Design for Micro-climate Improvement and Energy Conservation, by author.

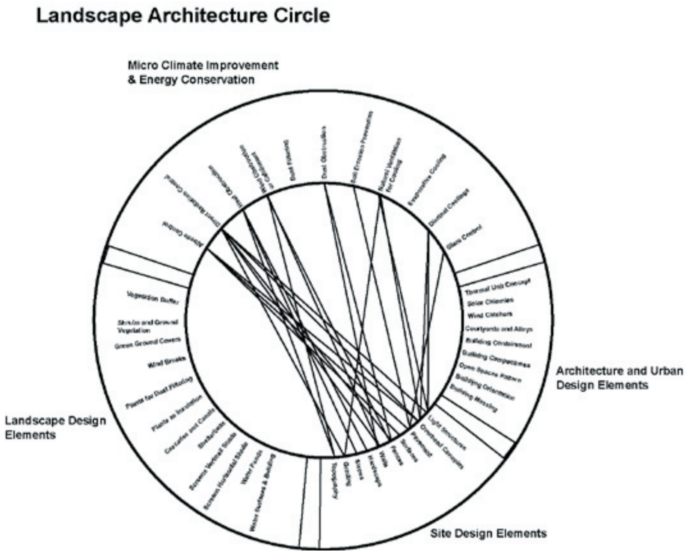


Fig. 4.91, Architecture Design and Urban Fabric for Micro-climate Improvement and Energy Conservation, by author.

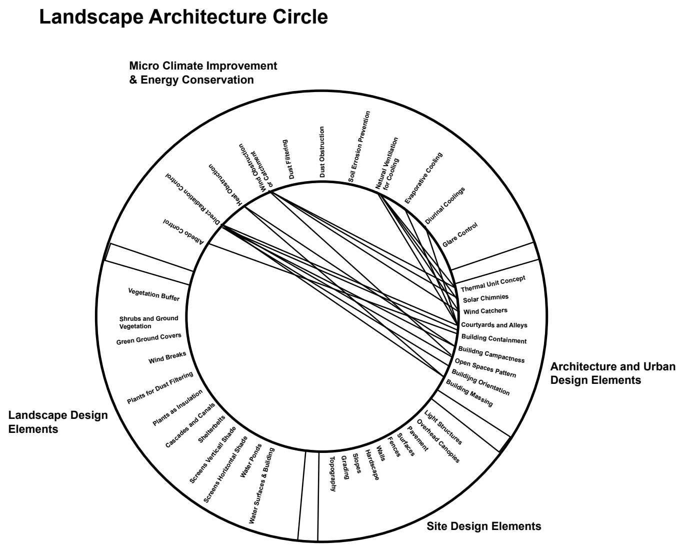


Fig. 4.92, Landscape Design for Micro-climate Improvement and Energy Conservation, by author.

Landscape Architecture Circle

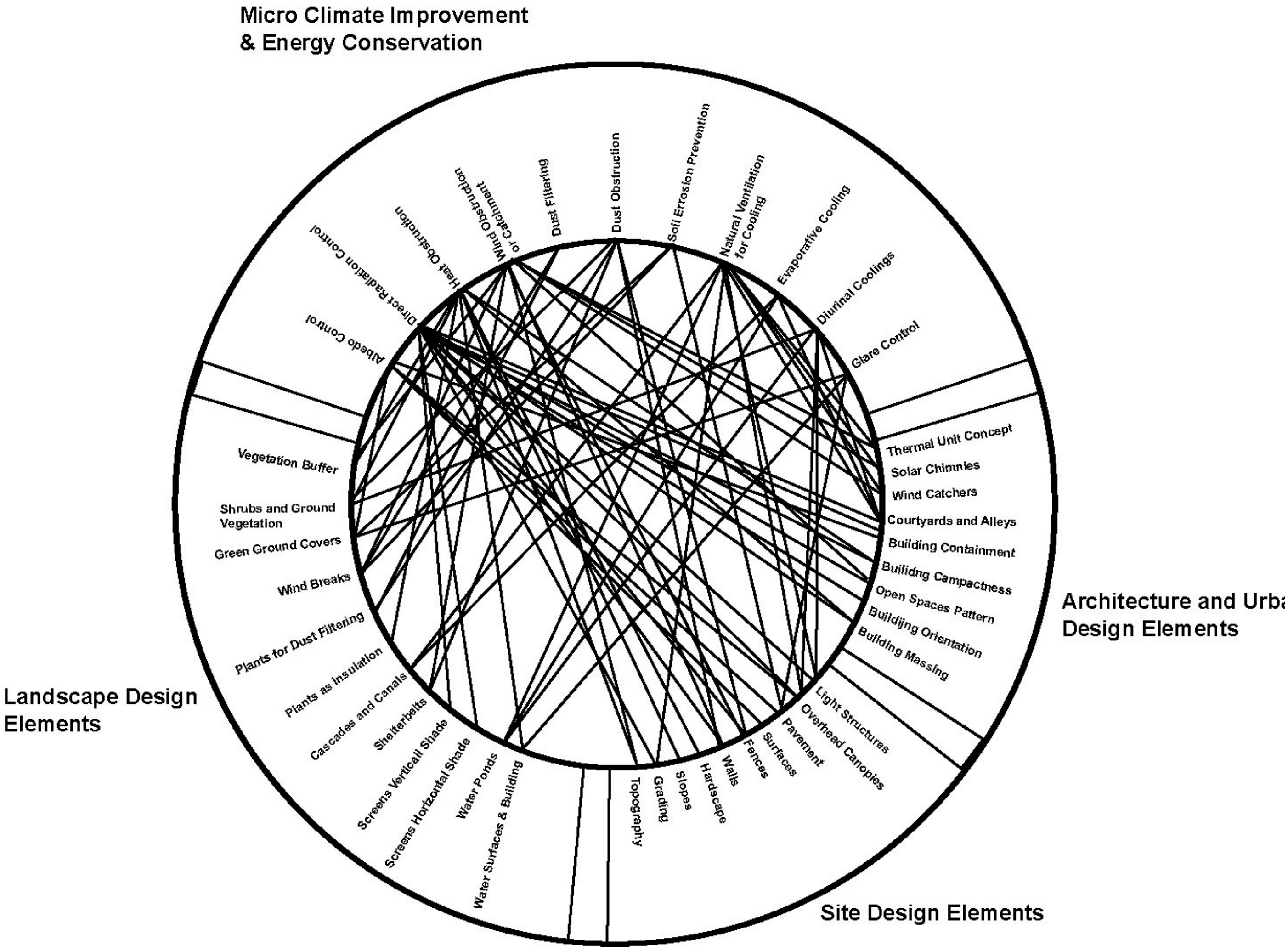


Fig. 4.92, Landscape Architecture Micro-climate Improvement and Energy Conservation, by author.

and water is available, lowering the temperature and blocking the wind may be the preferable approach. This could be accomplished by the various mean discussed in this chapter. But in all cases, quantitative comparisons and measurements of the comfort conditions should be always done after the implementation by the use of the comfort indices.

One final note is that the climate as described will be subject to change due to global warming. The climatic effects of global warming are still being debated. Any change in Egypt's climate will require a change in the ways that buildings respond to it. But one of the most interesting predictions, that we will have hotter summers in Egypt. Mechanical cooling or conditioning will be more and more essential. However, prolonged periods of high temperatures especially when temperatures do not fall significantly at night, can disrupt passive cooling strategies on exposed mass and night time ventilation.

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Chapter 5

Case Study and Design

Chapter 5

Chapter 5: The Case Study and Design

The aim of this chapter is to explore the design process for a selected design case study. This chapter seems to be number five in the chapter orders but in reality it could also be called chapter 1. As mentioned in chapter 1, the design process started parallel with the research. Because the research started by a design assignment and a problem statement that as steering and guiding the research to generate, (1) mainly knowledge and (2) secondly, to present a design show case that follows and adopt the research outcomes and findings.

This chapter will include three sections. The first section presents a design inventory and analysis for **Function and Circulation Aspects** in the American University Campus (AUC) in order to introduce the project. The second section will include the **Human Aspects** (historical and socio-cultural context), in addition to the **Biotic Aspects** and **Abiotic Aspects**. Then section 2 will address the **Spatial and Aestetical Aspects** before drawing and setting some design potentials and recommendations strategies that might be applied for the last section, which is the design concept. The importance of the design as a research method lies in its ability to process the generated data, including the design guidelines, in a form of an analysis that can lead eventually to a coherent design concept. I may also add that, the connection between the analysis and the end design is very important. In this chapter, I will go from a divergent brainstorm phase to a convergent phase. Several scientific research loops will take place in order to reach a developed design that includes visual and spatial translations.

In order to achieve this idea, a case-study will be conducted on a large scale educational building, recently designed in Egypt (implementation in 2008). The selection of this building is based on the designer's will or trial to integrate landscape architecture and green measures to achieve the environmental optimization in his design. The project is located in the hot arid desert area surrounding Cairo. The project is considered to be contemporary local pilot projects. As mentioned before in Chapter 1, the landscape design of the new AUC Campus will be based on an existing Master plan. The existing buildings of the Master plan will be kept as a fixed determinant. This means, that I will not be allowed to change the building's layout.

Chapter 5

Case Study and Design

Section 1

Introduction

Introduction: The new American University Campus in Cairo.

In 1997, the American University in Cairo (AUC) purchased a 260-acre plot of land in New Cairo, approximately 35 kilometers east of its current campus, as the site for its new campus. AUC will build a new comprehensive and cohesive campus on this new site to replace the existing one in Tahrir Square in downtown Cairo. Firms from Egypt, Europe, and the United States submitted pre-qualifications to be considered for the planning-design of the new campus competition. On September 16, 1999, AUC announced that the architectural firm of Boston Design Collaborative (BDC) in partnership with the landscape firm of Carol R. Johnson Associates (CRJA) had been selected to develop the master plan for the New Campus Project (see appendix III 2).

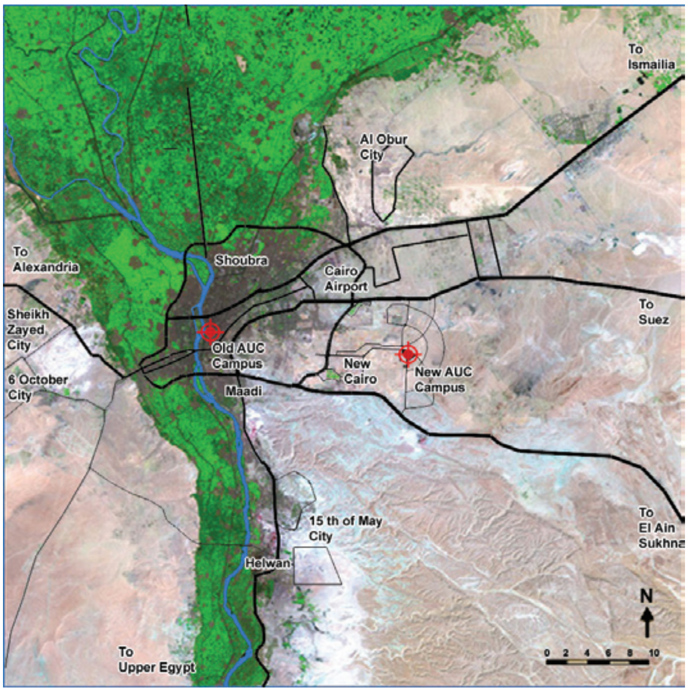

Fig. 5.01, The location of new AUC in Cairo.

Fig. 5.02, The AUC site layout.

The new AUC campus is in the emerging settlement of New Cairo, approximately 35 kilometers east of AUC's present location. Within New Cairo, the new campus complex is located in the center of the second phase of New Cairo. The site area is about 260 acres, with a mild slope from south to north. This natural topography is part of the larger system of land forms and wadis that fan out in an almost radial pattern at this location, constituting a "natural" terminus to the urban development of New Cairo. As part of this larger system, two shallow wadis, or ravines, traverse the site towards its northwestern tip.

The site is almost triangular in shape, and is surrounded by three circulation arteries of varying significance for New Cairo in terms of urban configuration and projected traffic load. To the north is a major artery that may develop into a highway or a principal boulevard, directing the largest vehicular traffic load towards the west, back to the city of Cairo. The road to the west of the site will accommodate a higher traffic volume while the narrower secondary road to the south will serve slower forms of circulation. Presently, urban developments in the immediate vicinity of the site are almost non-existent. While land allocation for different uses were assigned within the framework of an overall master plan for New Cairo as a whole, such uses are obviously tentative and partly dependent on the particular manner and schedule by which the AUC will evolve over the coming years. Owners of different plots are awaiting the development initiatives of the new university. As for New Cairo as a whole, several developments are already in place. Most are isolated and exclusive residential communities, some of which are organized around golf courses. The moving of the institution generates a series of profound shifts associated with historical and community contexts.

The AUC Mission

The AUC Mission Statement summarizes the values and aspirations of the university:

1. *The Population Served:* The aim is to provide "high quality educational opportunities to students from all sections of Egyptian society as well as from other countries and to contribute to Egypt's cultural and intellectual life."
2. *Educational Approach and Values:* "The university advances the ideals of American liberal arts and professional learning, freedom of academic expression, and promotes open and ongoing interaction with scholarly institutions throughout Egypt and the world."
3. *The Quality and Scope of Education:* "The pursuit of excellence is central to AUC's mission; it also provides a broad range of disciplines and learning opportunities."
4. *Intellectual and Professional Skills:* "The university environment is designed to advance the student's analytical capability, language and personal skills," as well as offering through continuing education programs "educational opportunities to enhance the professional and job skills of non-degree students."
5. *Identity and Culture of the Institution:* "AUC considers it essential to foster students' appreciation of their own culture" and promote international understanding through "scholarship, learned discourse and a multicultural campus environment."
6. *The Quality of Faculty, Staff and Facilities:* In emphasizing the pursuit of high quality in an AUC education, the statement enumerates the importance of quality in teaching faculty and administrative staff as well as instructional technology and physical resources.

Goals and Objectives

Institutional Objectives

Over the last few years, the AUC has been refining its mission as one of the leading institutions of higher education in Egypt and the Middle East. Egypt's economic development has put an increasing demand on the country's universities to produce capable and thoughtful graduates with the skills and outlook necessary to participate fully in the political economy and culture of the country. In addition, the increasingly globalized economy has broadened the opportunities for these graduates to work overseas and to compete internationally. As a US-accredited institution based in Egypt, the AUC has a uniquely powerful role to play in preparing young men and women for these new leadership roles.

Several themes have emerged in the quest to provide the best and most appropriate solution for a new generation of leaders in science and technology, business and public life. The ability to attract and educate the best students, to attract and retain the best faculty, and to give students a grounding in liberal arts rests substantially with the quality of curriculum and faculty, but also with buildings and facilities which must of necessity be comparable to similar facilities elsewhere in the developed world.

In addition to the "push" factor of congested facilities located in downtown Cairo having limited potential for expansion and improvement, there was also the consideration that the potential quality of environment on a new campus with new buildings could also provide a greatly improved context conducive to learning in its broadest sense. A principal challenge in moving from downtown Cairo to the eastern desert lies in the creation of a social, cultural and physical context within which to place the new campus, developing connections with the community. While these relationships are taken for granted in an existing urban situation, it will be a major task for the AUC to create, or re-create, such vital links in the entirely new social economy that promises to develop in the new city.

Design Objectives

The overall design objectives for the new campus, the guidelines for planning, and the criteria by which the campus may be evaluated several years hence are summarized below. While each of the parameters is distinct, the overall design is generated by the active interaction of each with the other, as with the foregoing, broader institutional objectives.

Functional and Programmatic Goals

The site and buildings should successfully reflect and translate the required spaces, their allocation and relationships to support a convenient and efficient learning environment. The formal program incorporates international standards for classrooms, lecture halls, laboratories and all support spaces, appropriately related to each other, reflecting the opportunities and constraints offered by the site.

Environmental Goals

The competition brief expressed a desire for a "campus design that belongs to its environment" and that is "appropriate to culture and climate." In pursuing these objectives, there is an additional objective of making this approach and the technical solutions a model for the region. To the extent that environmentally responsible solutions are integrated into the planning and design, there is a desire to make these "transparent" or "legible" to students, faculty and visitors so that the design serves a didactic purpose in addition to its programmatic and environmental function.

The desert location and the extremity of the hot, arid climate (with some mitigation from natural condensation) impose their own discipline on design. A "sustainable" approach to design can best be described as managing an economy of scarce resources in which the intention is to maintain and sustain the natural "capital" of geological and biological resources, clean air, fresh water, biological diversity and integrity of site. In energy terms, the aim is to achieve a "balance of payments" equilibrium, or at least to reduce the deficit, by achieving an acceptable level of load reduction, minimizing the importation of energy and natural resources from external, depletable sources. A critical issue in this equation is in the continuing dependence on the automobile as the primary source of transportation to and from the campus.

Experiential Goals

Quite apart from the attainment of a degree or other qualification, many reflect on university life as a series of formative experiences—social, psychological and educational in the broadest sense. There is undoubtedly a physical matrix that provides the form within which such experience takes place. In addition to the formally programmed spaces, the atmosphere of the civic realm—principally the outdoor spaces—within the campus should be conducive to that variety and experience. The new campus aims to be both matrix and stimulus for the wide variety of activities that constitute university life—from the intense interaction of the street to the quiet and contemplative sanctuary of gardens. The creation of areas within the campus for contemplation and relaxation is favored as this is missing, to some extent, in the AUC downtown campus. Location, connection, views and treatment of surfaces (walls, paving, ceilings, and landscape), when integrated into the design of a campus setting, generate atmosphere.

Social Goals

Closely connected with the experiential goals is the goal of creating a community within the campus. While much of this depends on programs and extra-curricular activities (e.g., sports, culture and residential life), the physical form of the site and buildings can also be more or less conducive to a sense of community. In its role as the "soul" of the downtown campus, the Greek campus is a model to emulate. In this new location, there is a special responsibility for the university to help establish, and make connections to, the community of New Cairo that, as yet, does not exist. The concepts of extending the educational aspects of AUC out into the community, of inviting the community into the campus, and of physically linking campus open spaces with the neighborhood, are elaborated upon under the themes network of learning and network of open space in later sections.

The introduction to the master plan presented the mission and vision of the AUC as it relates to the improvement of the campus and its facilities. After careful consideration, the decision to relocate was the only conclusion remaining to ensure that the campus will play a significant role in achieving the mission and vision. (Abdel Halim CDC and Sasaki Associates, 2000a).

The Program for the Master Plan

The master plan has been developed from the *New Campus Facility Program* which remains the source document for program information. The master plan accommodates 5,500 students and 1,500 faculty and staff—the base population of the campus (see appendix IV).

The AUC Master Plan

The master plan for the AUC campus is characterized by intimate and compact groupings of buildings constructed around a pedestrian spine linking the entrance portal through the campus and continuing to the community outside. Plazas of various sizes that relate to the schools are located along the procession, with the largest of the spaces opening to the main library. Secondary and tertiary spines running parallel to the main spine serve as entrances into each building group. Through the scale and location of spaces along the spine, a clear hierarchy of spaces is established, providing a coherent organization. The central spine serves the spaces organized along it, providing a variety of venues for social interaction. From the smaller courtyards within each discipline building to the largest courtyard fronting the library, the design provides a variety of meeting places. Arcades and balconies provide a permeable layer between inside and outside spaces.

Like Jefferson's University of Virginia, the campus has been designed as an "academical village." The overall form of the core buildings, however, is compact, continuous and urban. As in the *Beaux-Arts* model, individual schools and departments defer to the identity of the institution, and interior spaces are subsumed to the exterior continuum of spaces punctuated by courtyards, portals and connecting passages. The master plan is an organic and street-based composition providing a progressive relation as one proceeds from entrance to portal to passage to courtyard in a continuum of exterior space. As in the organic city, each turn of the path is punctuated by framed views and by the articulation of a new landmark, each one in a series, never a final destination in the classical sense (fig. 5.03).

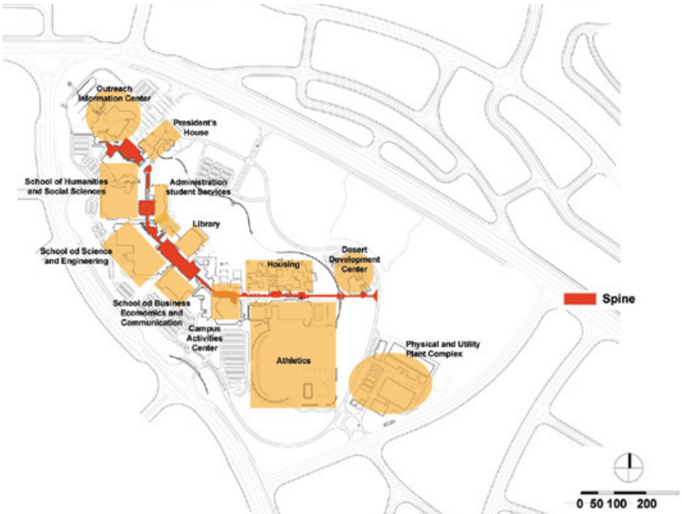

Fig. 5.03, The AUC Spine and activities, adapted from (Abdel Halim CDC and Sasaki Associates 2000) by author.

Fig. 5.04, The AUC master plan, adapted from (Abdel Halim CDC and Sasaki Associates 2000a) by author.

Open Space Structure

Because of the scarcity of water in New Cairo's desert environment, the AUC open-space structure is built on concepts responsive to that scarcity and at the same time supportive of a comfortable human environment: conservation, sustainability, and functionality.

Within the open-space structure, plant materials are carefully used to be fully effective in the environment in which they are placed. Their use is based on their function, and species are selected to conserve water, optimize solar benefits, and control wind. Each plant is highly valued and is part of an overall irrigation and thermal strategy developed to create a comfortable environment in exacting conditions.

Land Use

The land use organization for the site was created to respond to the requirements presented by the mission and vision of the university; the community and environmental context; the program; the physical condition of the site; and the master plan concept. The land use pattern, the organization of buildings and open spaces, meets these requirements by:

- Maximizing the functional relationships, compatibility and affinities between the main program components, internally (within the campus) and externally (between campus and community). These program components total approximately 200,000 gross square meters.
- Organizing the core academic buildings and spaces to maximize interaction between faculty and students and between disciplines, creating a community around a continuum and variety of external spaces.
- Relating the buildings and the landscape to the surrounding districts to encourage communication and interchange between campus and community.
- Creating a hierarchy of spaces to relate the buildings to each other within the landscape to provide a passive tempering of the environment, reducing energy dependence and minimizing impact on the environment.
- Providing a safe, comfortable and lively pedestrian environment.
- Accommodating growth of the university in the short, medium and long term.
- Encouraging university-related development to enhance the relationship between research and application.
- Complying with the planning guidelines stipulated in the agreement between the AUC and the New Cairo City Authority.

Land Use Components

The campus is made up of a series of similar land uses grouped together, forming components. These components are arranged to create the most efficient and interesting campus.

- *Community Outreach and Information:* Several facilities to be developed on the campus require a strong relationship with the community, and their placement in the plan has enforced this requirement. These components are for daily or special event visitor interaction.
- *Athletics:* Sports facilities, both formal and informal, should have a close relationship with student housing and the campus spine. The sports facilities and fields are located at the southern edge of the site, accessible to the residential community.
- *Physical Plant/Service:* The facilities management operations should be removed from the main campus core and center of activity and deliveries for this component should not interfere with other circulation patterns. The Physical Plant is located at the edge of the campus, easily accessible from the tertiary road on the eastern boundary. To service the compact pattern of land uses, the plan proposes the construction of a service tunnel under the pedestrian spine. This tunnel will allow continuous service of the campus without disrupting the other campus functions. The AUC print shop is located in the physical plant compound. This function is nearly industrial in nature and should be located to receive large shipments of paper and ship printed materials.
- *Student Housing:* Student housing is located at one end of the spine, overlooking the sports fields.
- *Desert Development Center:* The Desert Development Center is placed along the pedestrian spine where it may be accessible to students and visitors.
- *President's House:* The President's House and Guest Quarters are located prominently, near the front of campus.
- *Academic Core:* The academic core accommodates the administration, the School of Humanities and Social Sciences, the School of Sciences and Engineering, and the School of Business, Economics and Communications. The organizing principle of the main campus building complex is the central spine connecting the land use components. The schools are located on the south edge of the campus, providing the opportunity for each to expand incrementally over time. Classrooms are distributed throughout the central campus core buildings as a resource shared among the schools. Administration and student services are located near the President's House.
- *The Library:* The library is located in the center of the campus, symbolizing its role as the academic heart of the campus. This location makes it a key building both on the spine.
- *Campus Center:* Located directly at the primary student entrance, the Campus Center is located to serve students on a day-to-day basis. The Campus Center includes the convenience store. This location will be highly traveled by the majority of students on a daily basis (fig. 5.03).

Circulation

The primary means of access to the site is by road. The AUC campus site, triangular in plan, is circumscribed on all three sides by roads. On the north side, it is bounded by a primary road, a divided highway with three travel lanes in each direction and a two-lane frontage road on each side, a total 90-meter right-of-way. On the west side, the site is bounded by a secondary road, a divided highway with two travel lanes in each direction and a two-lane frontage road on each side, a total 82-meter right-of-way. The west boundary road forms the edge between the campus and the residential area as well as acting as a collector road for traffic from all directions leading to the campus. Finally, on the east side, the site is bounded by a tertiary road or

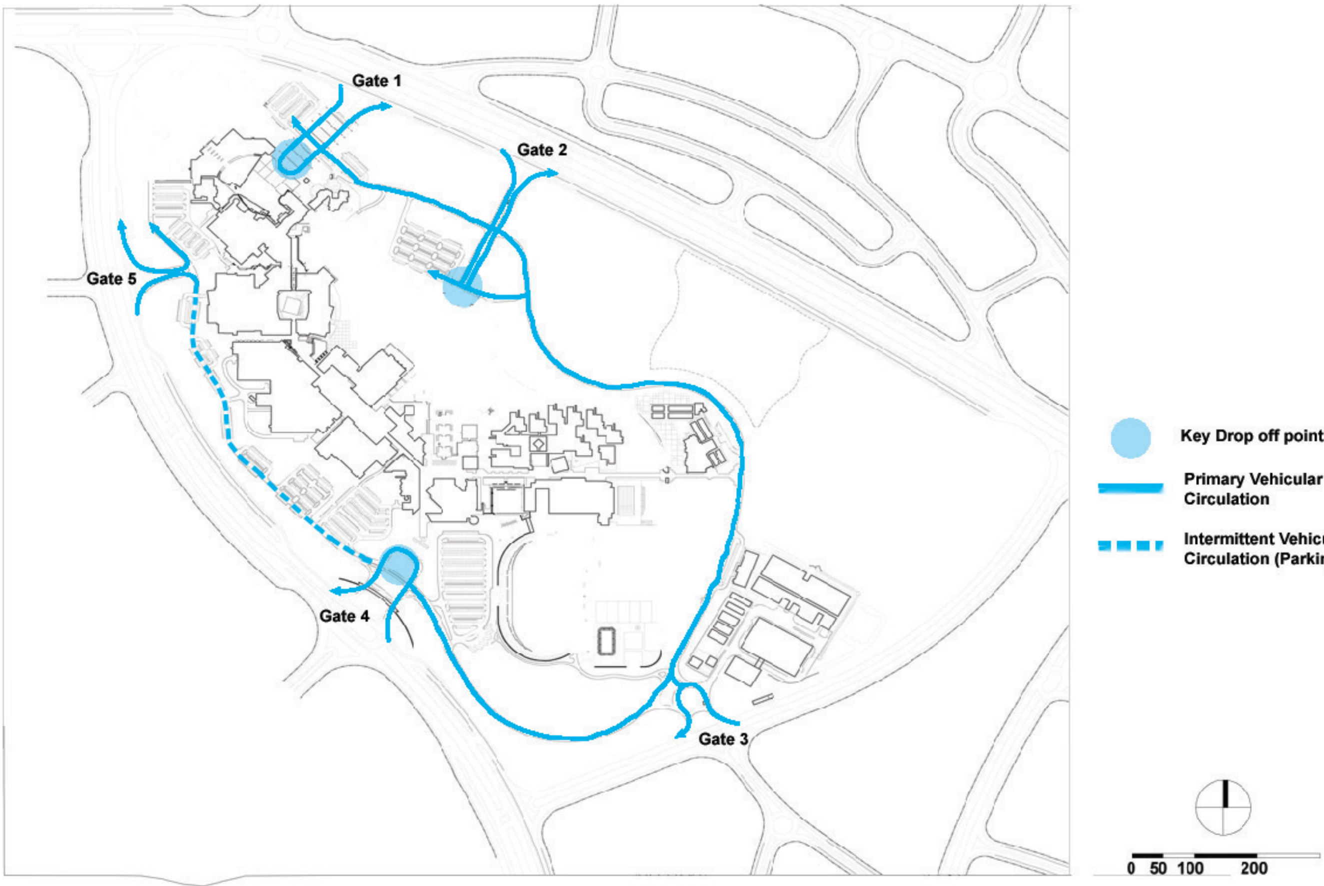

Fig. 5.05, Gateways and entrances, adapted from (Abdel Halim CDC and Sasaki Associates 2000a) by author.

local street, divided in the median with two travel lanes in each direction and parallel parking, a total 45-meter right-of-way.

In the initial stages of the campus development, the primary means of access to the site will be by automobile and private buses. Public transportation in the form of minibus, urban bus and light rail will be an alternative mode for gaining access to the campus. The university will also run a car pool with a fleet of 60 cars, primarily for faculty and administration. This section addresses transportation access to the site and circulation within the site in all modes.

Five primary access points are defined for the campus (see figure 5.04). These have been located to service the campus in an efficient yet functional manner, minimizing the number of control points where most logical with regard to the surrounding roadway network.

Campus Gates

For the master plan, the major considerations taken into account in locating the campus gates are as follows:

• The first view of the university will be of the northern corner, serving as foreground to the main campus buildings in the background.

• Most of the morning traffic flow will come from the west, approaching the campus on the primary road on the northeastern boundary.

• The destination for most regular student and faculty drivers on a daily basis will be the core campus buildings.

• The special destination points, mainly for occasional visitors, include the PVA Theater; the President's compound on the north end of the campus; the main Auditorium; the indoor and outdoor sports facilities; the physical plant and loading dock at the south end of the campus.

• The distribution of access and egress points throughout the campus to maximize flow in and out and, conversely, to minimize the likelihood of congestion at any one point.

• The accommodation of future development will be evenly distributed across the site to support the planned roads and access points.

• To provide flexibility in the light of changing developments in the growth of New Cairo.

Vehicular

The master plan creates a safe and comfortable environment for pedestrians and vehicles. To balance the needs of the pedestrian with the requirements for vehicular access the traffic flow should be efficient with minimum stoppages and disruptions and wherever pedestrians and vehicles intersect, priority should be given to the pedestrian. The primary vehicular circulation on the campus is provided by a two-way partial loop road around the core development. To provide flexibility in the changing environment of New Cairo, the plan suggests five campus gates. Each gate will serve a specific function in the near term while providing the ultimate flexibility in the long term. Gate 1 will be the ceremonial entrance to the campus, serving primarily visitors. Gate 2 will be the entrance for student parking in the north lots and for the bus system. Gate 3 is primarily for service deliveries to the physical plant. Gate 4 at the south portal will be the primary daily entrance for students, faculty and staff. Gate 5 will be a service and visitors entrance for facilities and

Fig. 5.06, Pedestrian Circulation, adapted from (Abdel Halim CDC and Sasaki Associates 2000a) by author.

will be an exit for faculty, staff and visitors. This location and configuration of the primary vehicular road separates traffic circulation from the pedestrian circulation while providing emergency access to parking and service access to the campus.

To reduce potential conflicts with pedestrians, the main two-way, two-lane vehicular circulation route is located on the periphery of parking areas, minimizing the intrusion of large volumes of circulating traffic into the main campus area. As the main vehicular circulation route continues to the east of the student housing and to the south of the sports facilities, it remains at the periphery of site development. It is only when the main vehicular circulation route runs south of the core campus that it comes close to the edges of buildings.

The vehicular circulation and pedestrian circulation interface at drop-off points to serve those who are driven to the university either in private cars or taxis. The proposed dropoff points are evenly distributed and should be constructed so that the drop-off vehicles should minimize interruption to those coming in and out of the parking areas. These drop-off points correspond to security points.

Pedestrians

Once outside of their cars and inside the campus gates, faculty and students will generally remain on campus for most of the day. This implies walking to and from classes as well as time in classrooms, offices, labs, etc., as well as the more informal spaces such as courtyards, or gardens. Ample circulation that is direct, comfortable, warm or shaded—depending on the season—as well as interesting, is important in encouraging and maintaining this pedestrian population.

Connecting the parking areas to the campus gates, to buildings and other destinations is the basis for successful pedestrian circulation. Pedestrian paths link the spine to the loop road with a series of “ribs,” i.e., routes perpendicular to the main pedestrian spine, joining the loop road and stretching beyond to the edge of the campus in some cases. Most of these walkways occur within the campus gates and are straight vectors as they direct people through the campus from origin to destination. The walkways follow a sizing hierarchy for anticipated volumes. For example, major north-south and east-west routes carry more foot-traffic than diagonal paths, thus they will be need to be wider. Some routes associated with the campus gardens are for recreational purposes and should assume a different character.

These walks, as well as other recreational routes outside the campus gates that encourage pedestrians to explore the full extent of the site, may be more sinuous or circuitous in form to engender a sense of relaxation away from the pace of the campus core.

In the near future the roadway to the north will accommodate the highest traffic load of any of the highways in the area with three travel lanes in each direction and a design speed of 90 km/hr. On the other side of the road is the proposed core area of New Cairo. It is clearly important to establish a link between the AUC campus and the New Cairo cultural center, as well as to the projected light rail station (probably in the highway right of way). However, the highway presents a serious deterrent to safe and comfortable pedestrian crossing. It is proposed, therefore, that under- or overpass crossings be considered to make these links on the northern edge of the campus connecting to the center of the city. The master plan circulation plan proposes pedestrian and bicycle connections across this roadway in the form of an underpass, to be built at the low point of the site on the northwest area of the site. This may eventually connect to a light rail station in the median by stairs, ramps and/or elevators for universal accessibility.

Recreational

A recreation pathway around the campus will allow and encourage the use of the site for recreational walking, jogging and bicycling. For security reasons, the path should be kept within the campus boundary, stopping short of AUC Square. The overall circumference of the perimeter pathway is approximately 4.0 kilometers, which translates into a ten- to twelve-minute run, a twenty-minute jog and a leisurely walk of half an hour to forty-five minutes. The landscaping of the path should provide some visual security, intervals of shade, refreshment in the form of water fountains and a repertoire of aromas from herbs or flowering plants (figure 3.05).

Parking

The location access and supply of parking spaces at the AUC campus is planned to keep parking within a 5-minute walk to the buildings. Initially, approximately 1,500 spaces are planned with expansion to 2,250 spaces planned. Reserved space for an additional 750 cars is located mostly on the south side of campus.

Faculty and Staff Parking

Faculty and staff parking is located close to the campus core or to the central plant area, respectively. Five parking areas have been assigned to faculty and staff as indicated in the accompanying plan. One visitor parking lot will accommodate the fluxuations in faculty and staff parking during the day.

Student Parking

Two parking areas have been planned to accommodate students' cars, with another two after opening day. This user group includes commuting students, non-commuting students who own cars, and students who carpool. It is assumed that those students living on campus who need access to their vehicles only once or twice a week have less need for parking spaces close to the campus core. Those students who commute on a daily basis in a ride-sharing program could be encouraged by being allocated the closest student spaces. The single-rider students who commute daily from New Cairo and its hinterland can be allocated the remaining student parking spaces.

Visitor Parking

Visitor parking areas should be accessible to visitors at all times. Special event parking areas, on the other hand, may be open to visitors but only by special invitation. The special event parking areas are those that, in the normal course of the day, are designated for another user group. The special event parking areas are close to buildings and complexes that hold such events. The Auditorium parking and Athletic Complex parking areas can double as special event parking zones, for public athletic events, theatrical performances, etc. During such events, these parking areas will be open to the public and access permitted.

VIP Fleet Cars

VIP-fleet cars need to be parked in a shaded area that will ensure protection from dust and sun. Since these vehicles will have drivers, the storage areas can be removed from busy campus areas. From a maintenance perspective, parking for VIP-fleet cars should be located near the facilities management area. The designated parking area for these 60 campus vehicles is within the facilities management complex which includes 19 additional spaces for facilities management staff.
(Abdel Halim CDC and Sasaki Associates, 2000a)

Chapter 5

Case Study and Design

Section 2

Design Inventory and Analysis

5.2 Design Inventory and Analysis

In the preceding section, the Functional and Circulation aspects of the new AUC Campus were addressed. This section will involve inventorying and analyzing data concerning the social, biological, and physical elements of the site. The major aim of this step is to obtain insight about the natural process and human plans and activities that will take place on the AUC campus. Later on in section 5.3, the Spatial and Aesthetical aspects of the new Campus will addressed. Finally, this section will sum up the inventory and analysis results in the form of maps that summarizes the potentials and constraints of the site.

5.2.1 Inventory and Analysis:

The Inventory and Analysis phased was based on the site visits, field measurements and literature review. As a first step in the design process I started to collect data related to the site and the project. Next, I started to classify the data in order to analyze it. It is important to mention that in this phase I was faced with many information and data that made it difficult sometimes to classify and sort and finally analyze. The most important thing about this phase is that the landscape architect should not get lost and try to summarize and select the useful data in order to move to the design phase. Finally, the landscape architect should be aware about the importance of linking the analysis phase including his findings and conclusion to the design.

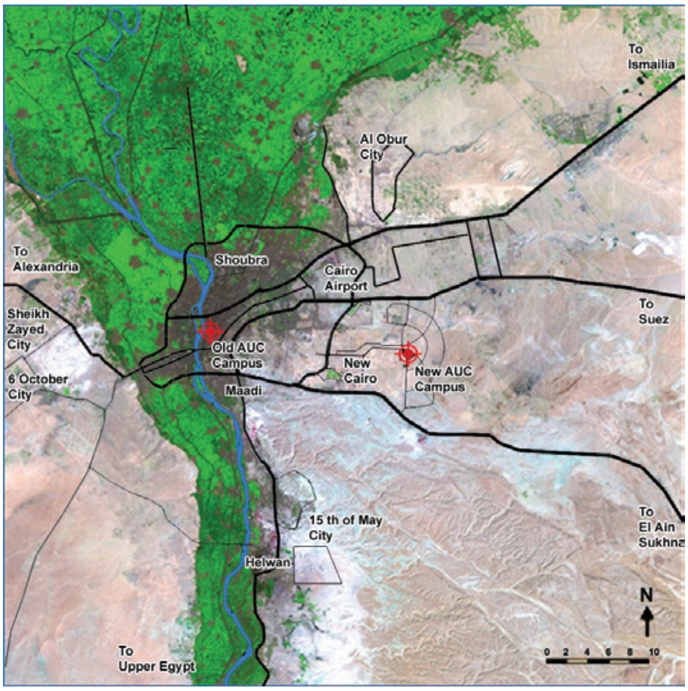

Fig. 5.07, The location of new AUC in Cairo.

5.2.1.1 Human Analysis

The relocation of the AUC campus is a unique undertaking. The AUC move is from the heart of downtown modern Cairo, where it has been located since its founding in 1919, to the suburb of New Cairo, where urbanization is but a concept. The intricate relationship that the AUC has maintained with the vibrant community of downtown Cairo has complemented and informed the AUC's liberal arts philosophy as much as it was shaped by it. The richness of the AUC's educational program is based partly on the campus' accessibility from all parts of Cairo, on the varied and layered interfaces with Egyptian scholars, and on the daily interaction with the immediate community gathered around cafes, restaurants and shops. Despite the fragmentation of the present AUC campus, the university and its community have developed a stable, rich and multidimensional relationship.

The university faces a unique situation in which its expansion and relocation are synchronized with the city's shift from one urbanization mode to another; and where the AUC's liberal arts philosophy coincides with the post-industrial planning philosophy as a framework for partnership and negotiation. The AUC finds itself in a new role in which it can initiate a community-based process of urbanization, exerting a vital influence on the future of New Cairo and its own internal community.

Following the former trend toward suburbanization, new suburbs continue to spring up around the city of Cairo. Far too many of these developments emerge from the construction dust as isolated developments with little promise of a “sense of community.” The demographics of the region indicate a complex structure—a society rooted in an historical sequence of settlements and series of communities. Clearly the definition of the New Cairo community is not merely an exercise in predicting the future.

To date, three identifiable communities of different socioeconomic characteristics have moved to New Cairo. The first group has a high income and may potentially be related to the AUC through students, alumni and professional associations; members of this group

Fig. 5.08, Students at the old AUC campus.

Fig. 5.09, The AUC in the Context of New Cairo (www.nuca.com.eg).

currently reside in a series of housing enclaves and gated communities around the Kattameya Golf Club. The second group is comprised of middle- to lower-middle-income households of young professionals and small nuclear families who now live in projects developed by both the government and non-governmental organizations. The third community includes lower- and moderate-income groups who settled in New Cairo prior to its transformation (as part of the Great Cairo Master Plan) from a low- and middle-income housing settlement, to a mixed-use suburban development for middle- and higher-income groups (see figure 5.09).

Liberal Arts as a Paradigm for Urban Transformation

In liberal arts education, different fields of knowledge are not constrained by fixed boundaries. The system of education is organized to encourage and induce frequent cross-disciplinary interaction, not as a complementary activity in that system, but rather as a structural one. This interaction is sustained by the exchange of knowledge by scholars from various fields of study, and between them and the world outside academia. In this system, knowledge is constructed in both scholarly and communal cycles.

Two historical and contextually different examples of the intimate relationships between the academic and communal settings are those of the Al-Azhar University in Cairo and Harvard University in Cambridge, Massachusetts. The University of Al-Azhar is situated in the fabric of the historic city; no boundary separates the space of learning from that of daily life. In addition, the university complex consists of a core (the courtyard of Al-Azhar) and a network of smaller spaces of learning (such as scholar houses) spread out within walking distance of the nearby community. Similarly, at Harvard University, schools, student housing, support facilities and research centers are intermingled with the city fabric so that Cambridge itself—its streets and squares—constitutes the connecting medium. This type of overlap, made possible through the evolution of cities and universities, enriches both the academic and the urban experience.

The AUC, being an American institution in Egypt, draws from the ideals and models of both Eastern and Western cultures. The new AUC campus should not imitate or draw blindly from either experience, but should instead benefit from established and successful precedents. The AUC needs to assist in the generation of the New Cairo Community. Both the institution and community will benefit from such process.

Influence On and Exchange with Surrounding Community

The following section outlines a series of concepts and strategies for application intended to structure different forms of relationships between AUC and its surrounding communities.

These concepts and strategies recognize the demographic complexities of the pre-existent developments in New Cairo and acknowledge the present situation of the new AUC campus. They range from physical, (architectural, urban and landscape or site strategies) to non-physical recommendations (at the level of school policy, schedule, curriculum and management).

The current condition of the AUC site is described as follows:

• Geographically, the AUC is located next to the center of the New Cairo Development, surrounded and separated by main infrastructure and transportation lines (highways, local boulevards, metro and bus lines) and in close proximity to the yet-to-be developed mixed-use parcels at the core of the new town plan.

• Only a third of the site will be devoted to housing the architecture, infrastructure and landscape of the new campus. The remaining areas of the site will be occupied by the institution's long-term expansion, a series of development parcels, public open spaces and a desert development center. The time for the total build-out of these areas is not yet determined.

• Both programmatically and physically, the new campus will be an urban enclave in town. Most of the site’s periphery will be devoted to future residential uses. The distance between the campus and the surrounding city fabric, and the low density of development around it, will be among its main features.

A Framework for Community Partnership

In shaping the vision for the New Cairo community, it will be necessary to develop a form of organization under which the aspirations and efforts of all parties involved in the development process may be represented and coordinated. The organization will need to mediate between the works of real estate development agencies, the central planning authority and other governmental organizations.

Parties represented in this organization could range from members of New Cairo institutions (such as AUC), homeowners and retail associations, New Cairo authorities, the Ministry of Transportation and other infrastructure-related departments, environmental agencies and Non-Government Organizations (NGOs) (figure 5.10).

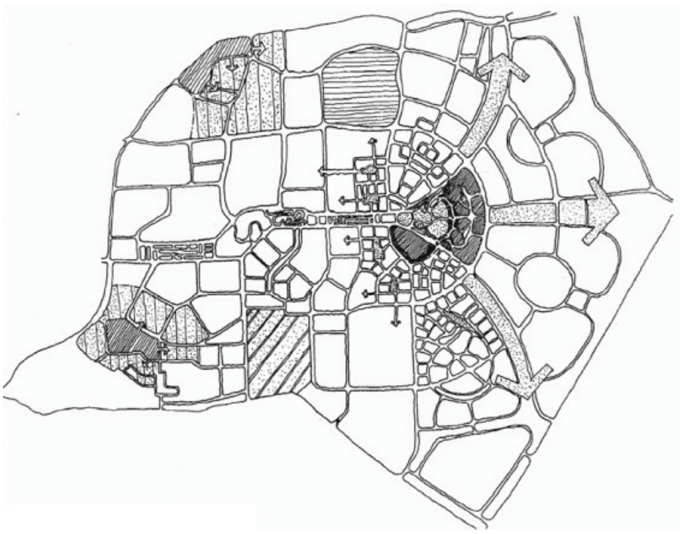

Fig. 5.10, Open space framework of new Cairo (Abdel Halim CDC and Sasaki Associates, 2000b).

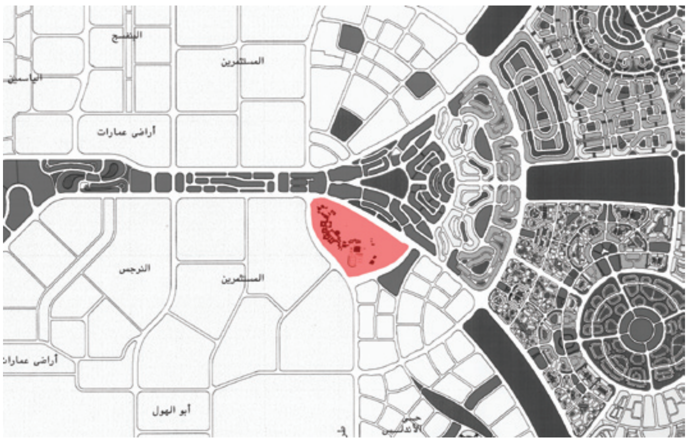

Fig. 5.11, AUC and surrounding context (Abdel Halim CDC and Sasaki Associates, 2000b).

Environmentally Sensitive Urban Approach

The environmental approach adopted by the AUC is intended to establish a model of sustainable development. A series of environmental measures, such as the "crescent of green" or planting belt, and the designation of green open areas, could be emulated throughout the surrounding fabric, consolidating environmental conditioning barriers as well as public open spaces for community gathering.

Interface with the Community on the Open Campus Site

The physical setting of AUC could be arranged in a way that accommodates a series of public spaces that would become part of a large constellation of public spaces around the new city. These spaces, ceded to the public, could constitute the first scale of connection with the immediate residential and business communities.

The AUC Network for Interactive Learning

A network of sites or locations throughout the city could act as points of exchange and interaction. A system of information centers, such as bookstores and cultural centers, together with other facilities, could be negotiated with future developers in the vicinity.

The extension of intellectual learning-related activities of the university into the city could help illustrate the university’s didactic depth in the community.(Abdel Halim CDC and Sasaki Associates, 2000)

Fig. 5.12, New Cairo context and location (Abdel Halim CDC and Sasaki Associates, 2000b).

Site Access and Transportation

Roads

Primary access to the site is by road. The main connection to central Cairo is a primary road accommodating three lanes of traffic each way, also serving as the central spine for New Cairo city (1500 meters). This primary road delimits the AUC campus on the northern boundary.

The western edge of the campus, 1400 meters long, is bounded by a secondary road, designed to make a direct north-south connection crossing the primary spine road and linking up with distributor roads to the north and south in New Cairo and adjacent municipalities in the region. For the AUC, this road provides a major connection between the campus and communities in the southern sector of Greater Cairo. The third, east side of the campus is bounded by a tertiary, local road 1000 meter linking the secondary road to the west and the primary road to the north, serving as local distributor to the university and to future development on the east side.

Pedestrian connections between the campus and adjacent communities have been considered with regard to the perimeter roads described above. The primary road consists of three travel lanes on the main highway and two travel lanes on the frontage roads each way, with median and edge-strip landscaping, resulting in a 90-meter right-of-way. This is a major obstacle to pedestrian flow between the two sides of the road which can only be addressed with the introduction of one or more pedestrian over- or underpasses at that length of highway. The most critical is the crossing on the northwest corner between AUC pedestrian entrance and the commercial and cultural center of the city, which would also be the most likely site for a light-rail station.

The secondary road to the west between the campus and the predominantly residential area was designed as a major north-south link as noted above. That design has now been modified, diverting regional traffic elsewhere, lightening the traffic load on that section, and thereby creating more amenable pedestrian links between the two sides of the road. The tertiary road to the east is a divided road with two travel lanes in each direction and parallel parking on both sides of each carriageway. As a typical commercial street, pedestrian crosswalks can be accommodated as needed.

Public Transportation

In addition to connections by car to the surrounding metropolitan area, there will be an extensive public bus service connecting the campus with Cairo center and with satellite cities and communities in the Greater Cairo region. A regional bus center is projected for a site at the eastern end of the spine road on the city limits of New Cairo. Bus stops for the municipal and regional services will be located on the frontage roads surrounding the campus. A bus service serving the university will have drop-off and pick-up points within the campus.

A light-rail service is projected to connect New Cairo and other satellite cities with downtown Cairo at some time in the future, as yet unspecified. A possible site for a station or terminus is near the cultural and commercial center of New Cairo, which is next to AUC pedestrian access. A pedestrian underpass, as mentioned above, may become the primary link from the campus to the station and commercial center. Projected access to the site for students, faculty, staff and visitors is discussed at greater length in the master plan section of this report.

Infrastructure: Services to the Site

Services to the site are in varying degrees of development. While the completed AUC campus will be a major utilities consumer in New Cairo, even during construction there will be considerable demand, particularly for electricity and water. The situation for the development and availability of each of the utilities based on information gathered in early 2000 is as follows:

Potable Water

A 60-cm potable water line is planned to run down the main connector road at the city center and from there down the west side of the site to the approximate location of the lower site entrance. A 50-cm line planned to run through the future residential area will connect with the 60-cm line on the west side of the site. Completion of construction is expected in September 2000. Water pressures may be as high as 8 or 9 bars (116 to 130 psi) but are expected to generally be at a level of 6 bars (87 psi). At the higher levels, pressure- reducing stations will be required at each building. A minimum of 5 bars (70 psi) is required for proper operation of fire protection systems and 3 bars (40 psi) for operation of domestic plumbing systems. At the available pressures, booster stations will not be required.

Raw Water

Detailed information on raw water from the Nile, normally used for irrigation, is not available at the time of writing. The closest source of this water is approximately 8 kilometers away from the site and there are no immediate plans to extend this water service to a point closer to the site.

Sewer

The municipal sanitary sewer is to be located in the road on the southwest edge of the site. It continues along the entire edge and is accessible at any point. (see Figure 5.13)

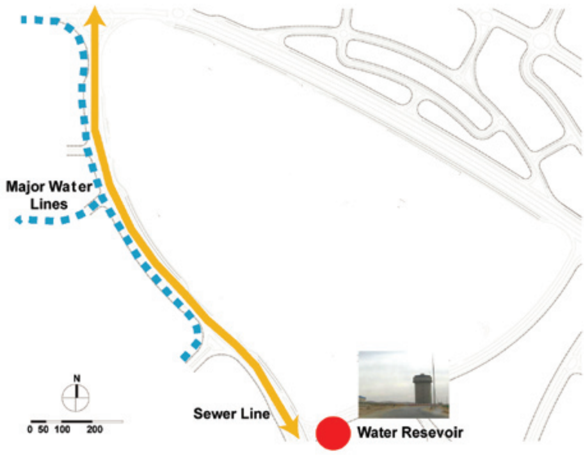

Fig. 5.13, Water and Sewer Service, adapted from (Abdel Halim CDC and Sasaki Associates 2000a) by author.

5.2.1.2 Biotic Analysis:

Vegetation

The AUC site is located in the Egyptian Eastern Desert. In general, the Eastern Desert receives sparse rainfall; it supports a varied vegetation that includes tamarisk, acacia, and markh (a leafless, thorn less tree with bare branches and slender twigs), as well as a great variety of thorny shrubs, small succulents, and aromatic herbs. The AUC campus is totally devoid of plant life of any kind, but where some form of water exists the usual desert growth of perennials and grasses is found. This growth is even more striking in the wadis during my site visit in February 2006. In figure 3.14 the brownish sign illustrates the existing thorny shrubs while the green sign shows the grown perennial after a rainy day.

Wildlife

In the extreme environmental conditions of arid lands there is no such variability of ecosystem structure. But during a short conversation with the AUC security team in new Cairo they informed me that they saw around the site some desert foxes or Egyptian jackals and a kind of jerboa (a mouse like rodent with long hind legs for jumping). There were too, several varieties of lizard and small poisonous snakes. Scorpions were also common in this desert region.

I would like also to state that Egypt is rich in bird life which could be a potential that can be emphasized in landscape design.

Fig. 5.15, Jerboa.

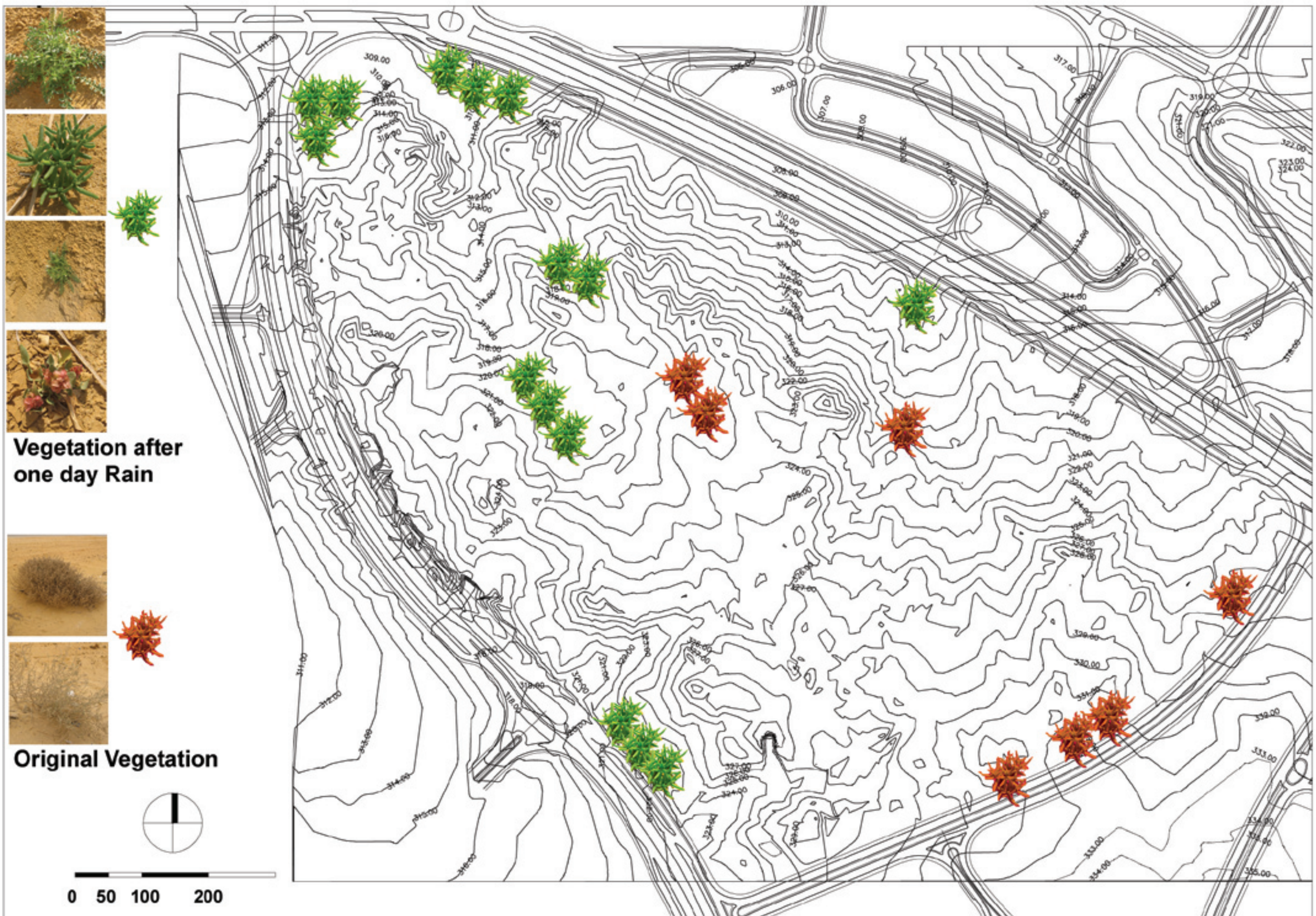

Fig. 5.14, Existing vegetation in the site.

5.2.1.3 Abiotic Analysis:

Site Conditions

The new AUC campus site is located in the desert region east of the River Nile and west of the Suez Canal at an altitude ranging between 307 to 332 meters above mean sea level. The 260-acre site is located in the geographical center of the planned city of New Cairo, approximately 35 kilometers from the center of downtown Cairo. The site is located on the primary arterial road of the New Cairo Extension, midway between the road from Cairo to Suez (to the north) and the road from Cairo to Ain-el-Soukhna (to the south).

Site Boundaries

The master plan for the New Cairo City Extension indicates the following proposed developments on the boundaries of the AUC site. To the north, the primary road forms one-half of a central development spine for the new city. Commercial and cultural development serving the new city has been proposed between both halves of the primary road. In the event of a light-rail connection being made between New Cairo and downtown Cairo, it would be logical to run the tracks within this primary road right-of-way. The northwestern corner of the site would be a probable location for a station. The primary road, as it runs along the north edge of the site, is likely to be developed with commercial or cultural buildings, connecting to extensive open space to the north.

Site Conditions

The new AUC campus site is located in the desert region east of the River Nile and west desirable to make connections in this direction, particularly for pedestrians, the road remains a formidable obstacle. The western edge of the site is proposed as predominantly residential. The AUC has already purchased plots of land to develop faculty housing in this zone. The secondary road has been modified since it was first planned and there is strong potential for pedestrian connections to be established between the campus and the neighborhood.

On the eastern edge of the site, a small commercial and retail area is proposed, with the added possibility of "intelligent villages" being developed. The road is designed as a tertiary connector and will be easily crossed by pedestrians. There is a desire for the university to establish strong links with the surrounding community. Pedestrian access to and from the campus with the residential, commercial, retail and cultural activities adjacent, will constitute a critical part of campus/community unity.

Fig. 5.16, Arial view from the west at the site.
(Abdel Halim CDC and Sasaki Associates, 2000b).

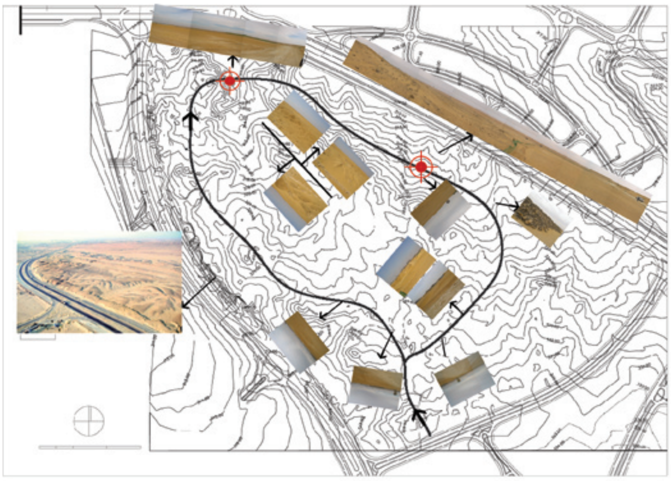

Fig. 5.17, Images and panoramas of the site.

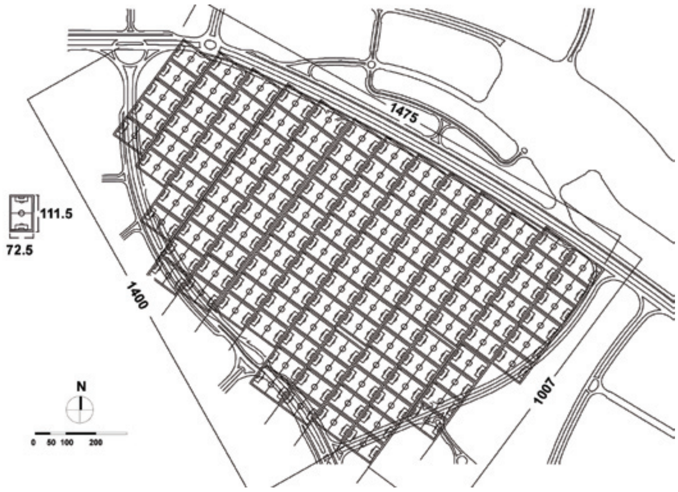

Fig. 5.18, Area and dimensions of the site.

Geomorphology & Topography

In general, the existing topography slopes from a high point of 332 meters above mean sea level along the eastern boundary road to a low point of 309 meters at the northwest corner of the site. Although featured with ridges and valleys, the elevation difference between these two points is only 23 meters over a horizontal distance of 1,300 meters, an overall average slope of less than 2%.

While most of the site is relatively flat (less than 5% slope) with some relatively modest ridges and valleys, the major changes in grade occur at the sharply graded edges along the built boundary roadways. Except at the edge escarpments abutting the roadways, almost the entire site is buildable without major excavation.

A topographical aspect analysis of the site reveals two east-west ridges dividing the site between the slightly larger north-sloping area and the southern aspect running parallel with the southwest boundary. As an indication of which parts of the site might be built upon and which left as open space, the north-facing slopes may be discernibly cooler and therefore preferable as open space.

The existing ridges and valleys network indicates the path of natural drainage during occasional storm events. As with the site aspect, preliminary inferences can be made as to which parts of the site would best accommodate built space and which might remain open. Siting the campus buildings along the prominent southern ridge will give the main body of the campus prominence and visibility from the road. While these vistas

Fig. 3.19, Topographical Analysis, adapted from (Abdel Halim CDC and Sasaki Associates 2000a) by author.

Geotechnical Data

A preliminary subsurface investigation of the site was undertaken in June and July 1998, the findings of which were presented in the *Subsurface Investigation and Foundation Report*, one of the background information documents for the design competition. The report contains descriptions of the field and laboratory phases of the investigation, a description of site conditions, groundwater and foundation-related subsurface conditions. The engineering design properties derived from the investigation are tabulated. The final section of the report presents the foundation recommendations based on the results of the field explorations and laboratory testing programs, the engineering analyses and observations by the geotechnical personnel on site at the time of drilling.

Field tests included 25 borings taken to a 20-meter depth, and 25 open pits taken to a maximum of 5 meters, distributed throughout the site at spacing of approximately 250 meters. The results of the field investigation indicate that the soil profile is practically uniform throughout the site, consisting primarily of dense to very dense, medium to fine sand. Varying depths of expansive clay were encountered in three of the borings and one of the open pits.

The site elevation varies from 308.972 meters to 331.516 meters above mean sea level. There are no existing structures or underground utilities on the site and no groundwater was encountered in any of the boreholes or test pits.

The shear strength of the sand, indicated by the recommended friction angle and the earth pressure coefficients, is adequate to support loads that have been assumed in the preliminary design phase. As a more detailed knowledge of the final configuration and bearing pressure of the structures becomes established, the structural designer may need to re-evaluate the results of the subsurface investigation to obtain a more accurate set of earth pressure coefficients. While the report indicates "moderate problems" of collapsibility upon inundation, the observation is that flooding the bottom of excavation and compaction using heavy equipment should overcome the problem of settlement following inundation.

The recommended allowable bearing capacity of the soil of 15 tons/square meter at a depth of 1.5 meters appears to be low even when considering the friction angle of 30º and a safety factor of 3. This allowable bearing capacity is more suitable for foundations on structural fill overlying the expansive clay, as pointed out in the report. For detailed structural design, the structural engineer will require data on allowable bearing pressures for two general cases: for foundations on natural compacted dense sand; and for compacted structural fill overlying the clay.

While the report provides information regarding the swelling potential of the expansive clay layer, no other engineering properties for design are given. Foundation sub grade preparation over this soil type has been adequately addressed in the report, stating that clay should be excavated down to 1.5 meters below the desired level of the footings, backfilled with structural fill, and placed and compacted in lifts no more than 25 centimeters thick. Earthwork issues, including acceptable fill material and compaction, have also been addressed.

Morphology and Soil

A chemical analysis of the surface soils materials indicates a low sulfate and chloride content according to the Egyptian Code for Design and Construction of Reinforced Concrete Foundations. pH values range from 7.5 to 9.6, with most readings in the mid-8 range. This is considered a normal pH range for the native soils of the area and does not pose a substantial constraint on the selection of native plant materials, or on the introduction of desirable ornamental plants. The only limitation on planting expected from the soils on site is the amount of available moisture in the root zone. All other adverse chemistry can be mitigated or remedied by economical means during initial plant installation.

Figure 5.21 shows four parallel cross sections in the site showing the different height variations and the potentials for vegetation and cooling. This illustration was made as a combination between the vegetation map and field measurements.

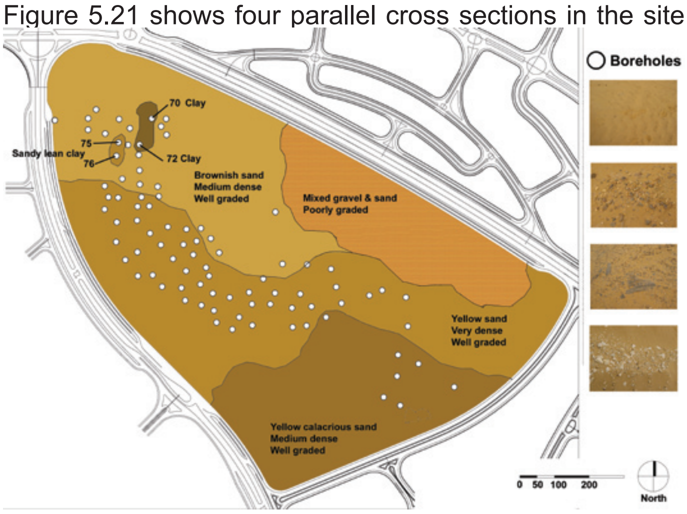

Fig. 5.20, Soil map including boreholes.

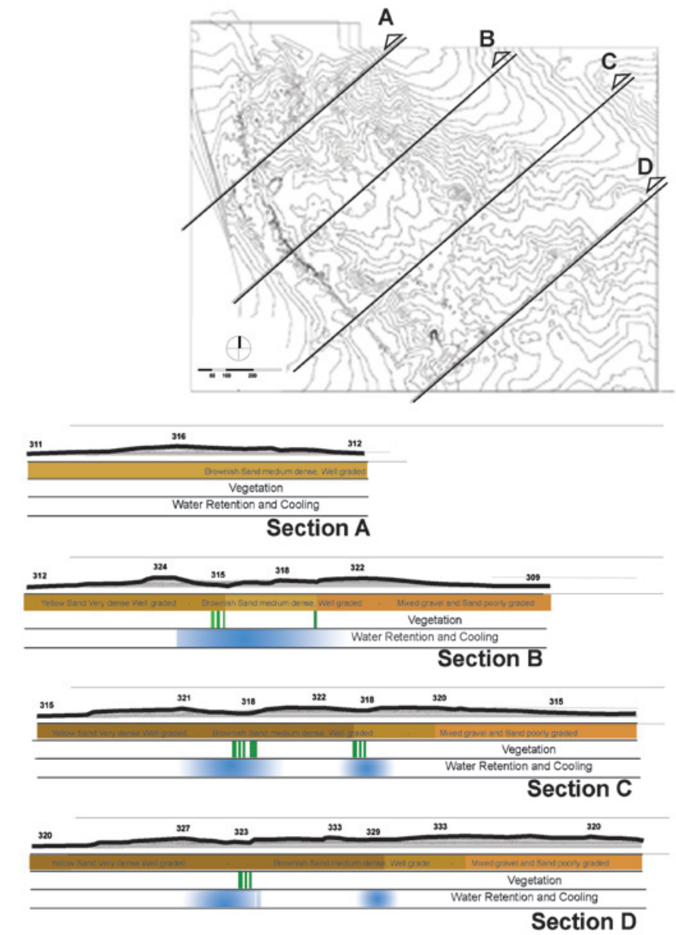

Fig. 5.21, See 5.28. Cross section with potentials for cooling and vegetation.

Ground Water

Boring data included in the *Subsurface Investigation and Foundation Report* (prepared by the United Consulting Group, 1998) indicated that no ground water was encountered within 20 meters of the surface at the AUC site. Additional ground water information for the New Cairo area is based on four test wells, two each at the Mirage Golf Course and the Police Academy. These test wells and additional well tests performed by Dasco Petroleum Services indicate that ground water is typically found at a depth of approximately 185 meters below ground. Ground water salinity was found to be 9,000 to 10,000 parts per million.

Renewability of groundwater in the Nile Valley is addressed in the paper "Water Resources in Egypt: Strategies for the Next Century"(Elarabawy et al., 1998). The paper notes that ground water in the Nile aquifer is renewable by seepage losses from the Nile, irrigation canals and drains, and by percolation losses from irrigated lands. The Nile aquifer has approximately 7.5 billion cubic meters per year rechargeable live storage. The groundwater potential of other aquifers adjacent to the Nile Valley also depends on the subsurface drainage. The paper tabulates groundwater potential for development in the floodplain and fringes, indicating that up to 1.2 billion cubic meters per year of ground water is available for tube well (deep well) extraction. It should be noted that the traditionally available Nile water can still be used, but due to the anticipated increase in water demand in the Nile area, alternative sources of water, such as groundwater from tube wells and treated wastewater, should be actively explored.

In order to install tube wells at the AUC site, a preliminary investigation, including a number of geo-profiles, is required. When the presence of ground water is confirmed, the tube well(s) can be drilled, tested and evaluated. When the well is capable of producing water, tests will be required to determine the quality of the water and the daily rate at which the water can be withdrawn. A desalination plant will be required to reduce the salinity of the water for irrigation use. The flow of a single tube well is estimated to be approximately 40 to 50 cubic meters per hour.

Cairo Climate

The seasonal environmental offering of sun, light, wind, rain, temperatures and humidifies should be used as directly as possible. But in order to harvest natural resources for the project and in order to be able to accurately state under which weather conditions the proposed micro-climate improvement come to play, we had to analyze the weather data of Cairo in full detail.

I have used data from the Egyptian Organisation of Meteorology. The data comprises average readings for a ten year period at Cairo Airport. The Cairo airport station is the closest station in the location of the future AUC campus. (10 km), accordingly the data can be considered applicable to the site of the new campus. In the following you will see an excerpt of the numerous graphs produced explaining the approach towards the enhancement of the climatic conditions.

Temperatures and Humidity

The weather data is plotted on the psychometric chart, which shows the thermodynamic properties of moist air. Fig 5.24 represents the weather conditions for each hour during the year with a spot. Darker areas in the chart indicate more common climate conditions. Figure 5.24 is showing the percentage of time for which weather conditions occur in each division. In both charts, the comfort zone is shaded in blue.

In the winter months (December through March), daytime temperatures typically rang between 13 degrees C and 23 C. On summer days that require cooling, 32% of the hours are below 60% relative humidity when the outside temperature is above 23 C. For comfort reasons, it is ideal to keep the relative humidity below 60%. This suggests that evaporative cooling may be used to cool the air enough to meet thermal comfort. Shading is also an important factor in maintaining people's comfort. The psychometric chart shows that 55% of the time, the temperature exceeds 21 degrees C, the dry bulb temperature above which shading is suggested.

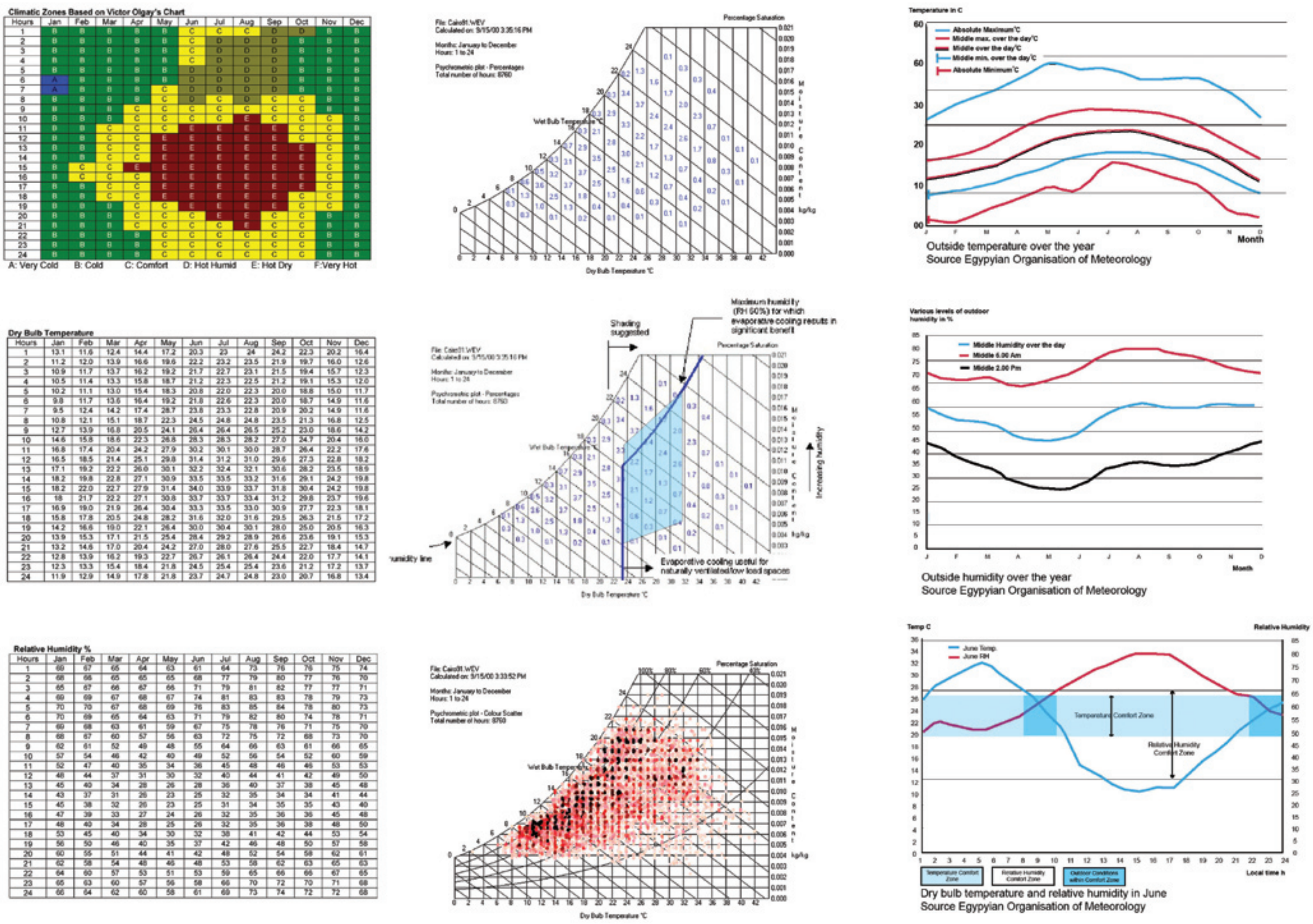

Fig. 5.22, Cairo's weather data I, Egyptian Organisation of Meteorology.

Wind

Chart 5.24 shows the prevailing wind direction in Cairo. The wind direction is mainly North and to a limited extent South. The compass card shows the average annual wind direction in percent. The blue are in the chart can be read as the frequency. Therefore the largest amount of harvestable wind blows from Northern directions. Furthermore, there is a strong seasonal difference with winds in summer blowing almost exclusively from the north and only two months in winter the wind direction is reversed and blows almost exclusively from the south. Undesirable south west winter winds should be blocked and desirable north winds welcomed. Unfortunately, during July and August, when the temperature peaks, wind speeds are at their lowest. Even at dry bulb temperature of 35 degree C, winds can effectively cool. However, the average wind speeds of approximately 4.0 m/s as shown in the chart on the left are moderate. Figure 5.23 is an analysis for the wind directions over the site. The two wadis of the site are relatively cool while the south-west (spring and summer) winds need to be obstructed.

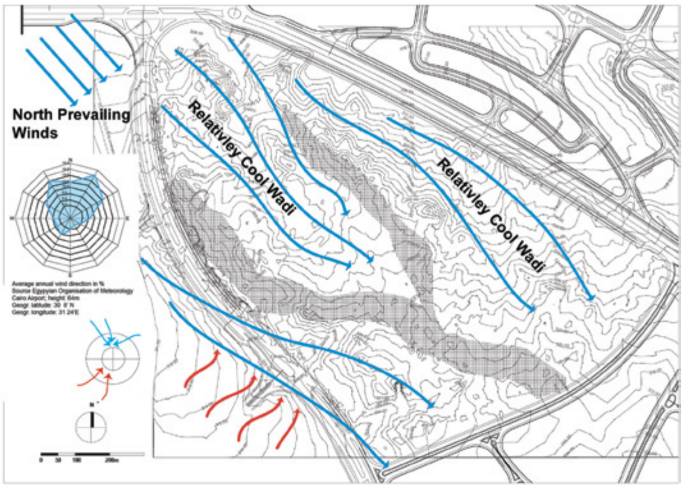

Fig. 5.23, Wind and air flow analysis.

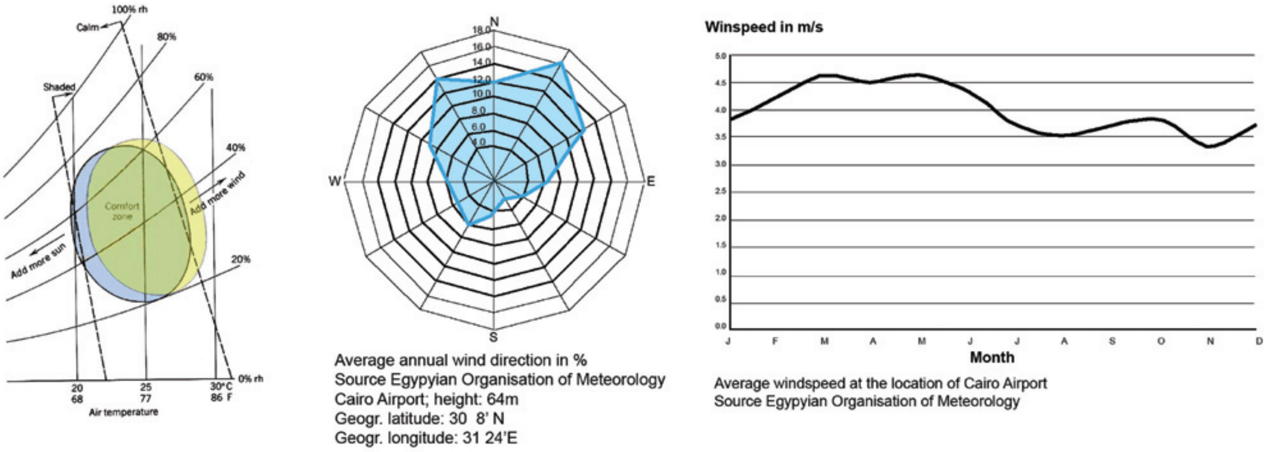

Fig. 5.24, Psychometric chart, wind rose and average wind speed chart, Egyptian Organisation of Meteorology.

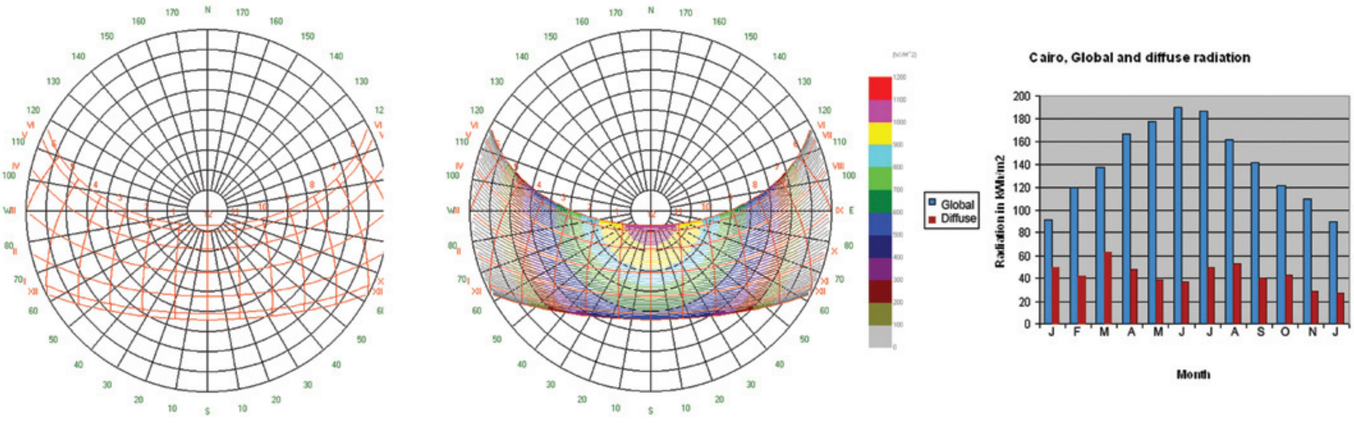

Fig. 5.25, Solar attitude, Egyptian Organisation of Meteorology.

Solar Radiation

Located at 30 degrees north latitude in a hot, dry climate, Cairo has a long lasting hot season. The AUC experiences a seasonal variation in solar altitude of approximately 47.5 degrees from winter solstice (36.5 degrees) to summer solstice (83) at noon (Figure 5.25). Solar attitude is represented in Figure 6 by the concentric circles, with 90 degrees (directly overhead) at the center of the diagram and 0 degrees (at the horizon) at the outermost ring. The radial lines indicate azimuth angles, with north at the top of the figure. The red lines indicate the sun's path for each of the seven representative days of the year. The summer sun path lies closest to the center, and the winter sun path lies at the bottom. The lines perpendicularly to the sun path lines indicate the time of the day, labeled from 6 AM to 6PM.

During much of the year, sun angles are high, resulting in significant radiation more than 700 watts per square meter-on horizontal surfaces (Figure 5.25). The most intense solar impacts are at noon in the summer (dark red) and the lowest at dawn and dusk. Diagram (Behling) shows also the global and diffuse radiation values, which is used to determine the external heat loads acting onto all outdoor spaces of the AUC Campus. Figure 5.26 represents the site topography with the most excessive heat gain.

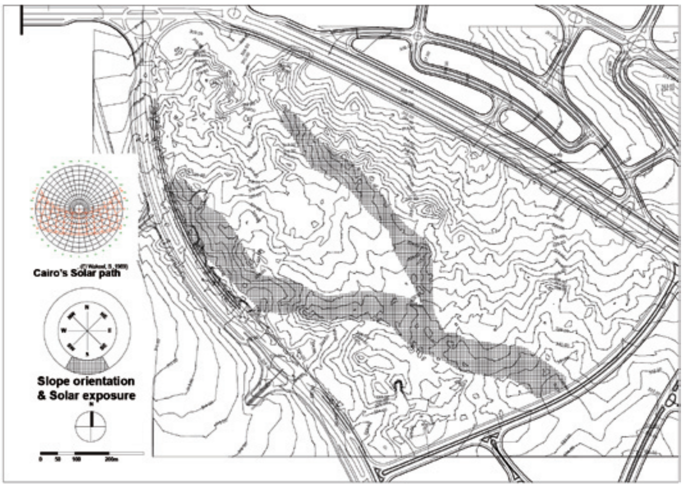

Fig. 5.26, Excessive heat gain analysis.

Field Measurements

During my site visit I used an in-out Thermometer with indoor humidity gauge to measure the relative humidity and temperatures of several spots in the site. Figure shows the locations where the measurements where made. It is quite interesting the temperature in the main *wadi* was higher than other locations. I relate this phenomenon mainly to the higher wind speed that was clearly sensed in this area (see appendix VIII). See figure 5.27.

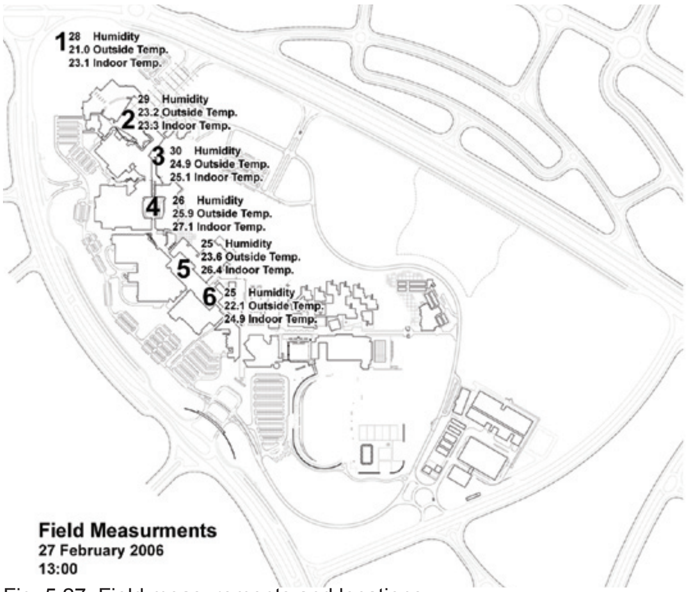

Fig. 5.27, Field measurements and locations.

5.2.2 Analysis and Inventory Results

The result of section 5.1 and 5.3 is presented on the following three maps 5.28, 5.29 and 5.30. Figure 5.29 illustrates sums the Biotic and Abiotic aspects in one map, while we can see that the wadis are potentially the coldest and wet spots on the site. The highest solar exposure could is on the southern ridge slopes. Moreover, the prevailing wind on the northern tip of the site is relatively cooler than at the south. Figure 5.28 shows four cross sections located perpendicularly to the prevailing wind direction. The sections are layering the soil, vegetation and cool locations in addition to the altitude changes. Next, figure 5.30 summarized the data related to the Functional and Circulation Aspects. The infrastructural network is illustrated showing the sewage and potable water lines. The pedestrian routes and vehicular circulation including the parking and entrance gates are also present. The red spine is representing the urban core of connecting the campus buildings. It is important to mention that there is infrastructure tunnel under the spine connecting and providing each building with its necessary demands while the tunnel begins in the Physical and Utility Plant context in the south.

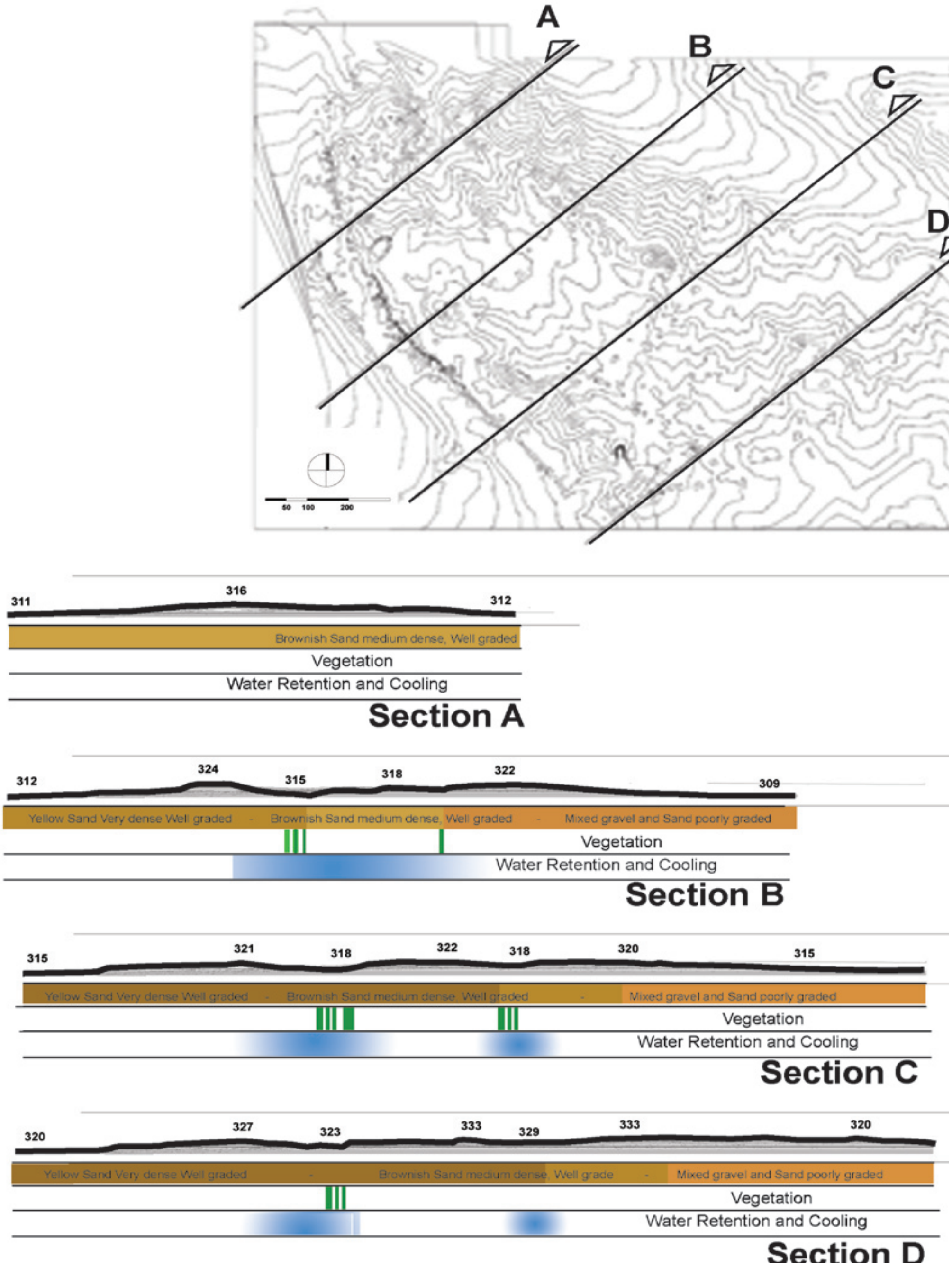

Fig. 5.28, Cross section with potentials for cooling and vegetation.

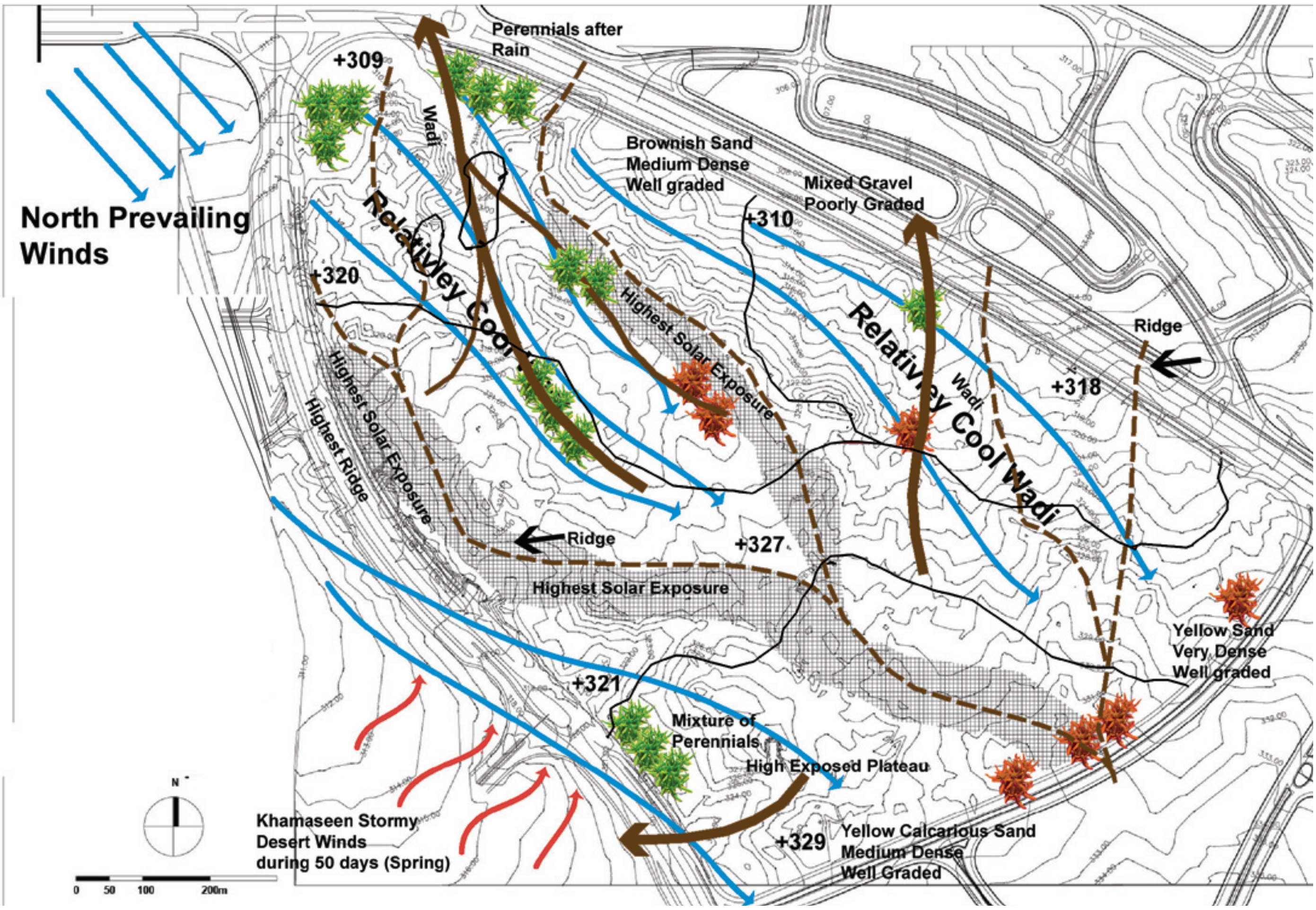

Fig. 5.29, Abiotic and biotic analysis result.

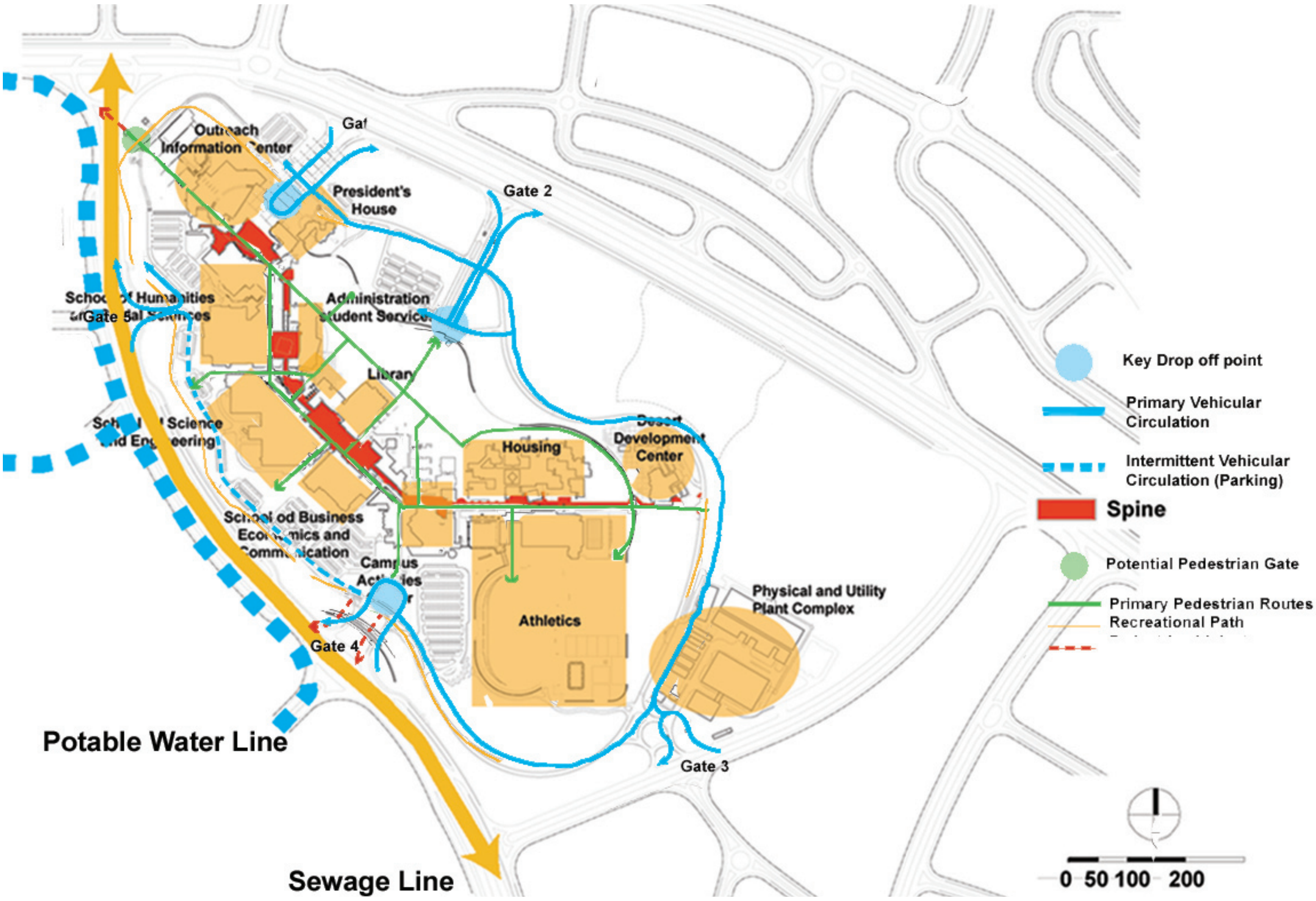

Fig. 5.30, Functional, Circulation and Infrastructure Aspects.

5.2.3 Landscape Potentials and Constraints

After analyzing the AUC human, biotic and abiotic aspects, a very important step should before the design. This step is about going from the divergent Inventory to a more convergent analysis phase. The following pages will explore the site potentials and constraints that could be used or modified in order to achieve an improvement of the outdoor environment of the AUC Campus and reduce the energy consumption. The potentials and constraints will be divided into four main aspects:

5.2.3.1 Landscape Design and Micro-climate Improvement

Shelterbelts

By analyzing Cairo's weather and the micro-climate of the site I can assume that the site needs a shelterbelt along the south west side in order to prevent the south west Khamassin dusty winds. Next, a wind filter is needed in the northern tip of the Campus. This wind filter is essential to filtrate and clean the northern prevailing wind before reaching the core of the site. The Analysis showed also that the best location to create gardens and livable landscapes could be mainly at the three wadis. While it seems that the best location to locate the buildings could be on the western ridge which extends from the north top the south. Finally, the whole eastern side of the Campus could be suitable for a diverse desert landscape. See Figure 5.31.

These basic design recommendations are primary design decisions that can improve the micro-climate. But further design decision will be taken upon the further studies.

Filtering

Figure 5.31 shows also the importance of filtering the wind on the north tip before the wind enters the site. It is also recommended that the air penetrates the project and the filters should not be dense in order to achieve the optimal natural ventilation in the north-south direction.

Screening

The shade analysis proved the importance of locating vertical and horizontal plant screens on the south and western facades. Screening could be made by long large growing trees while the roof could be treated by some vines and trellis. The idea of screening the walls with climbers could be also tested.

Evaporative Cooling

Locating water ponds, fountains, canals and mist spray along the spine and courtyards will be essential to decrease the temperatures and humidity. The correlation between the temperatures and humidity has an impact on human comfort. Moreover, the main wadi can be used as a garden for contemplation and nice outdoor environment. The use of water elements even in the wadi can in creating a relatively cooler garden.

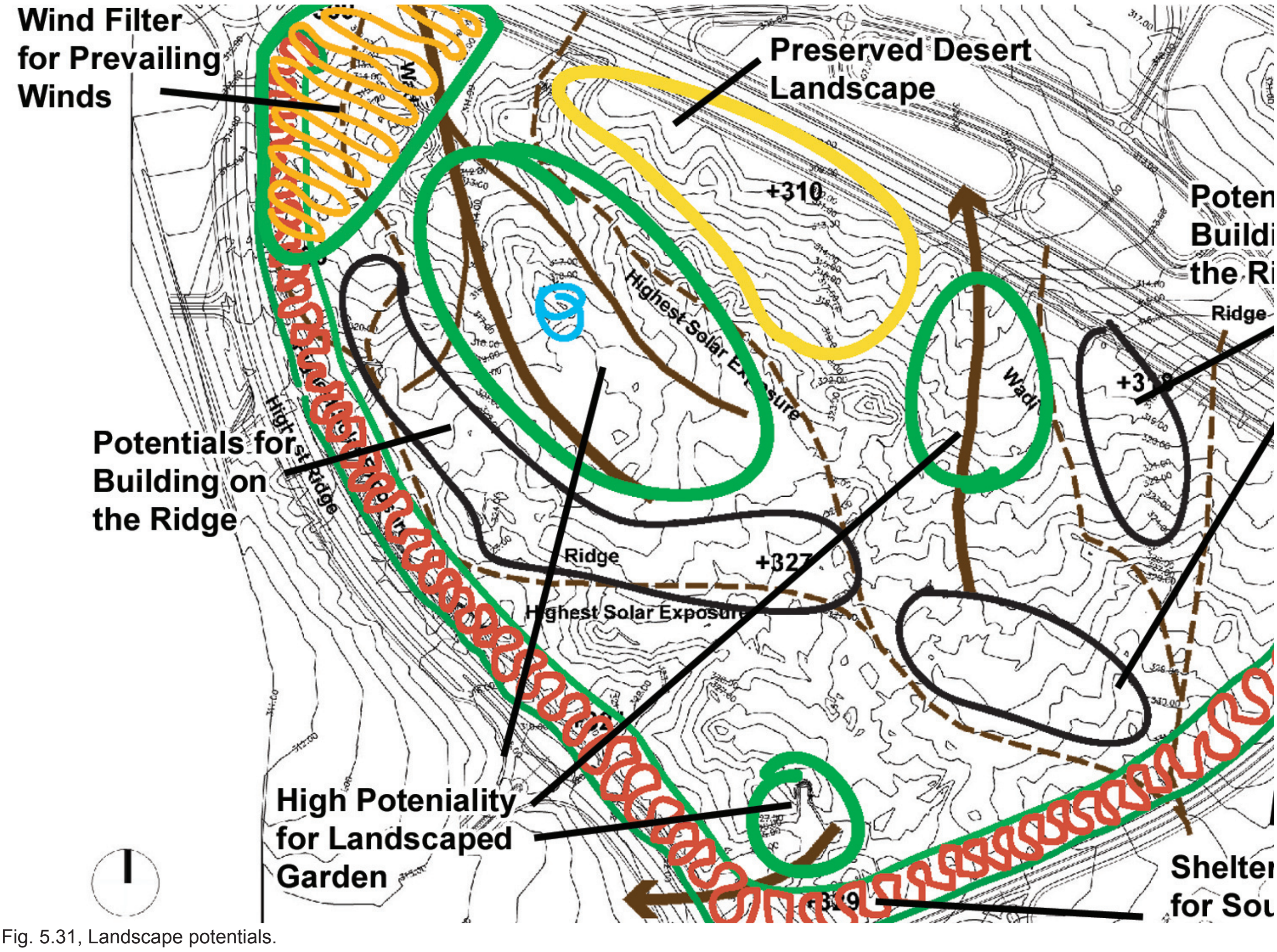

Fig. 5.31, Landscape potentials.

5.2.3.2 Landscape Design and Energy Conservation

Load and Consumption Reduction by the Thermal Unit Concept

The assembly of the field, container and tunnel, as shown in figure 5.33 and 5.32, needs to be tested in reality through field measurements. Theoretically the air movement between container and field should improve the comfort levels in tunnels. The thermal unit concept applied in the AUC Campus could be used as a tool for landscape architects to use appropriate environmental energies at the appropriate time to provide thermal comfort in public spaces. This concept works in public spaces around massed and compacted buildings. But it is not sure whether this technique would work or not. The landscape architect should be aware that shading, evaporative cooling and ventilation can improve the micro-climate while the thermal mass concept could be considered. See

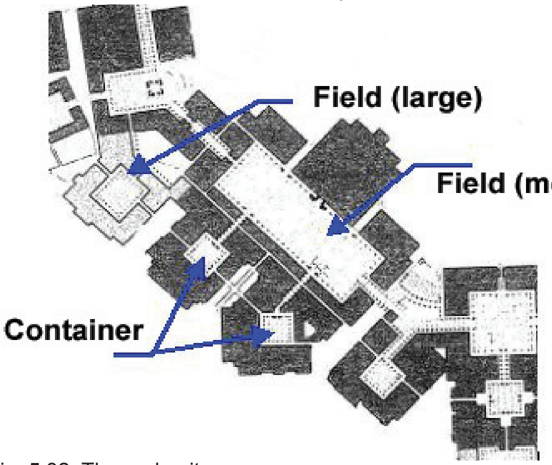

Fig. 5.32, Thermal units.

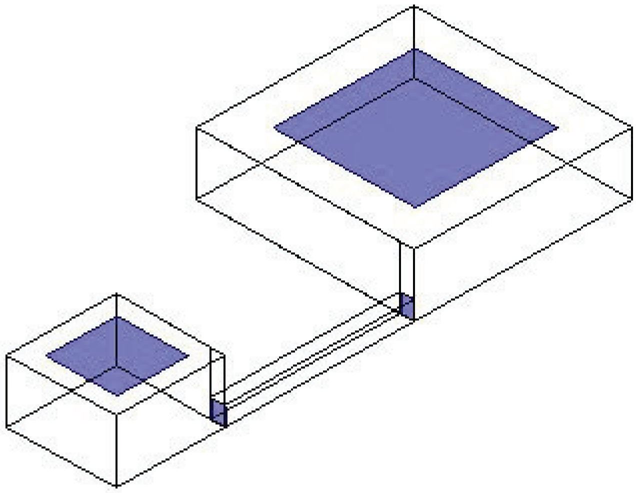

Fig. 5.33, Container Tunner Field Model (Abdel Halim CDC and Sasaki Associates, 2000b).

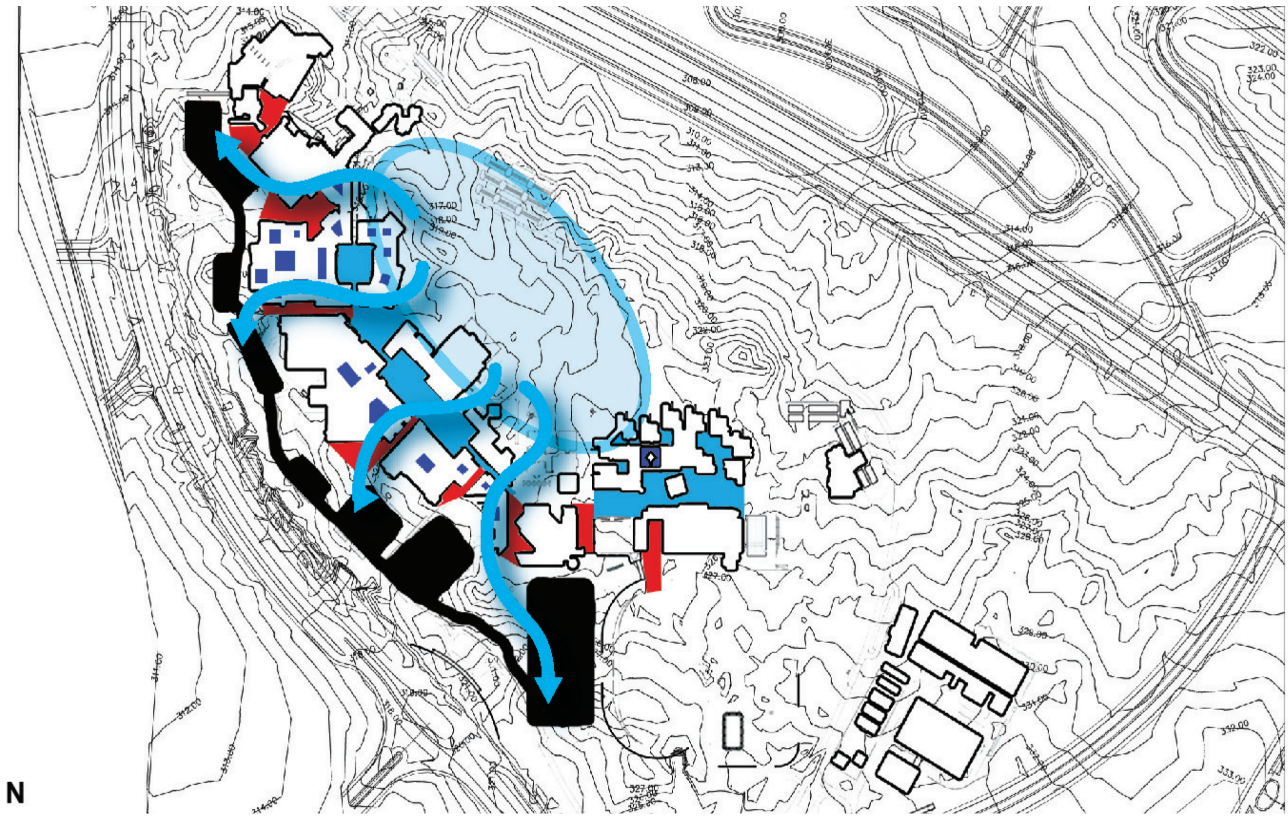

Fig. 5.34, The thermal unit concept in the AUC as proposed by Abdel Halim CDC and Sasaki Associates.

Load and Consumption Reduction by Shading

In order to reduce the amount of radiant energy absorbed and stored by the built surfaces and reduce the cooling load in the AUC buildings, I conducted a solar radiation study to know the impact of the sun movement during two times per summer and winter. See Figures 5.35, 5.36, 5.37 and 5.38. The result of the shade study was made to identify walls that are shaded most of the year, as well as the ones that are affected by solar radiation most of the year. The analysis also identifies areas that would need shading for the ground. The outcome of this analysis is four computer simulated building models in which the shade of the buildings has been investigated by the effect of solar radiation. Specific guidelines, principles and procedures have been outlined to guide the landscape design. See table 5.01.

Table. 5.01, Solar radiation angles.

	Noon		15:00	
	Altitude Ang.	Azimuth Ang.	Altitude Ang.	Azimuth Ang.
21 June	83	0	49	-88
21 Dec.	47	0	21	-45

North and North-West:
No need for shading trees or overhead canopies unless needed for aesthetical purposes.
East and North-East:
Provide shading trees or overhead canopies for east facing elevations through horizontal and vertical elements.
West and South-West:
Protection of upper floors in areas facing south is applicable.
South and South-East:
Provide shading trees or overhead canopies for west facing elevations through horizontal and vertical elements.

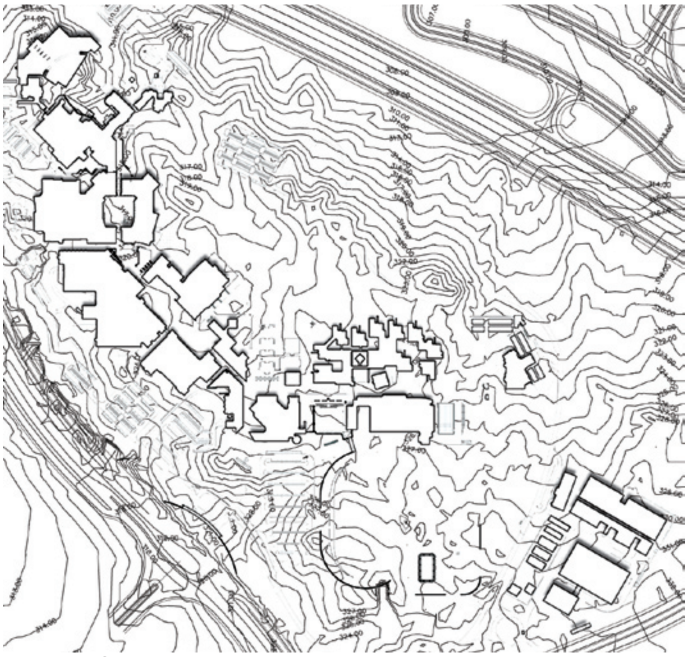

Fig. 5.35, Shade in 21 June, Noon.

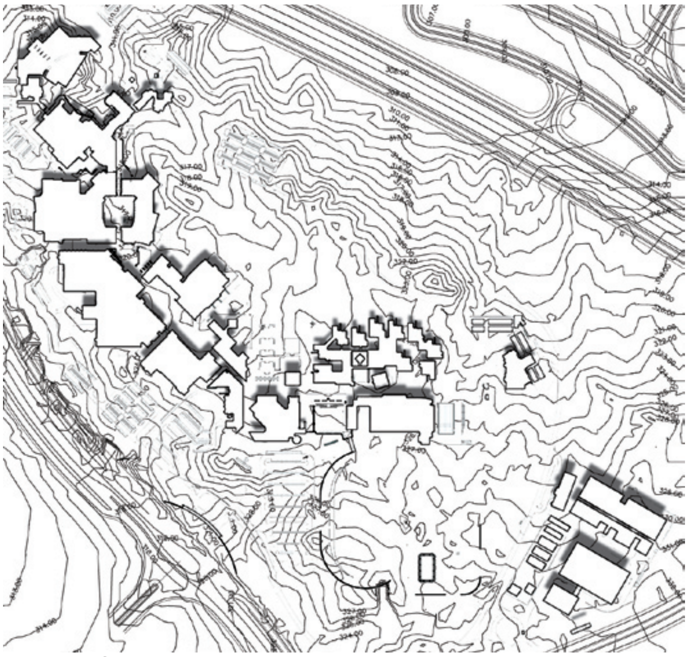

Fig. 5.37, Shade in 21 December, Noon.

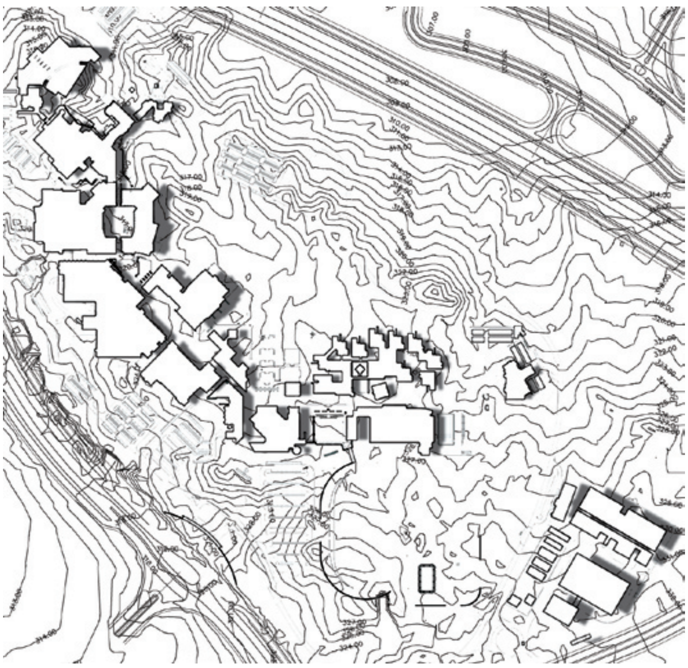

Fig. 5.36, Shade in 21 June, 15:00.

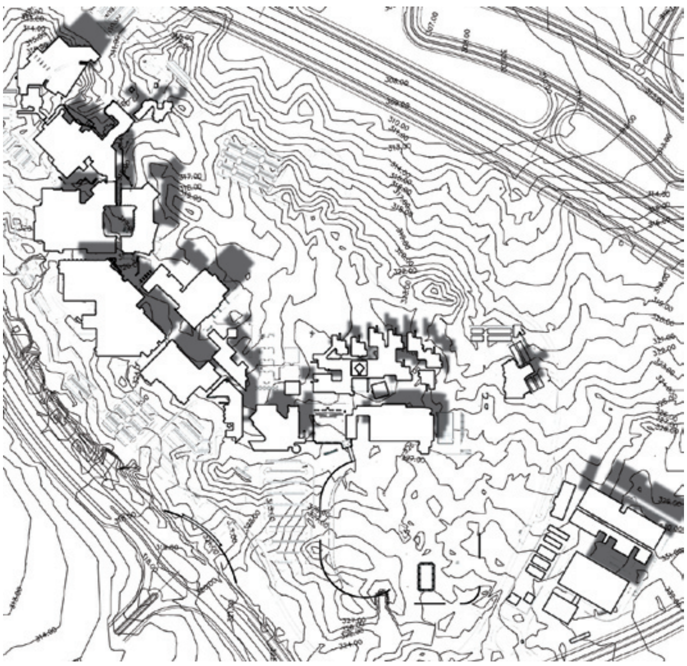

Fig. 5.38, Shade in 21 December, 15:00.

- It is important to benefit from the internal courts in terms of delighting and internal micro-climate improvement.
- Upper levels and roofs of the building are highly exposed to solar radiation. The use of shading trees (deciduous) and canopies is recommended.
- Internal courts are greatly affected by solar radiation in summer.
- Internal spaces overlooking internal courts should be shaded most of the year.
- The analysis outlined that some internal courts are shaded most of the years of the day. For courts, which are shaded in winter and affected by solar radiation in summer, high attention should be given to landscape.
- Provide pergolas that permit winter sun and prevent summer sun especially on roofs and terraces.
- Movable light weight canopies should be installed during summer.

Load and Consumption Reduction by Natural Ventilation

Using the prevailing wind direction could be one of the most important site potentials. Taking advantage of the prevailing wind direction, the northern tip of the site funnels in the air and further channelizes it with aid of the building orientation, massing and cracks of courtyards. Also with the well organized landscape in the internal as well as the external spaces. But ventilation rates needs to be high enough to provide cooling air movement. By locating water ponds and elements in strategically positions in the air path, the cool air will spread all over the space. Plants could be used also to guide the air movement or block it in order to achieve passive cooling and reduce the cooling loads of the buildings arranged around courtyards.

Load and Consumption Reduction by Efficient Technical Systems

In addition to previous mentioned techniques, the following ideas could be considered or discuss during the design development phase in order to minimize the energy consumption:

- Solar panels for collectors PV
- Heating pumps
- Landscpae & Cooling Loads
- Waste collection and recycling
- Wind power
- Bio Mass
- Earth energy
- Planted roof

See figure 5.39.

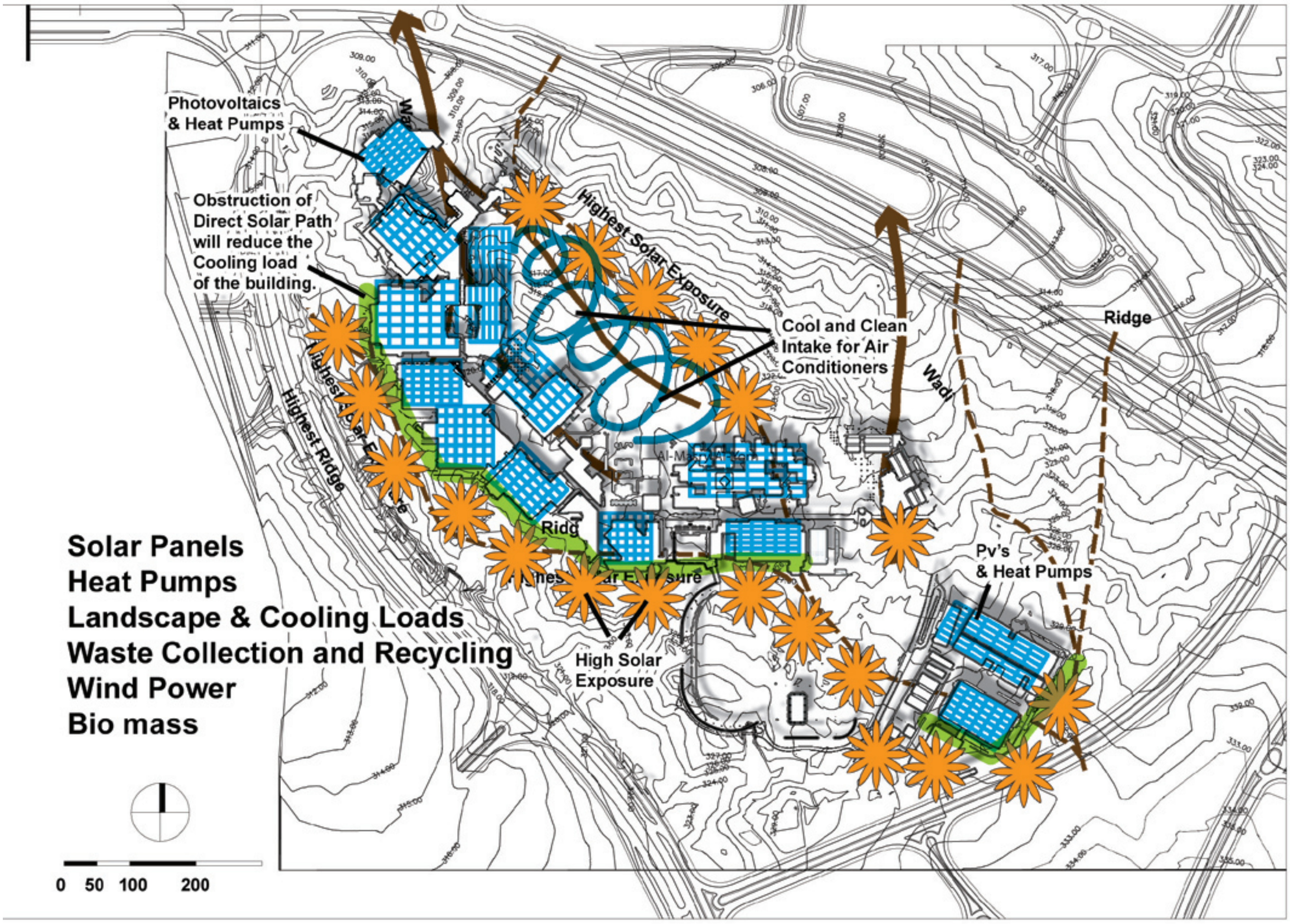

Fig. 5.39, Energy potentials.

5.2.3.3 Landscape Design and Water

Water in the new AUC Campus will be scarce. The major source of water will be the municipality potable water. Therefore it is very important to create the second degree or grey water network in order to treat the water and use it for irrigation of plants. The grey water should be also used for sanitations at least to flush the toilets. Despite the nearby water reservoir, the site should include it own water reservoir in order compensate any water shortage during summer. Another water strategy could be applied for the rainfall catchments during the few days of rain. As shown in Figure 5.40, there will be 6 water storage basins spread allover the site. These locations should be free from any constructions or pavements, only plants are allowed to grow in these locations.

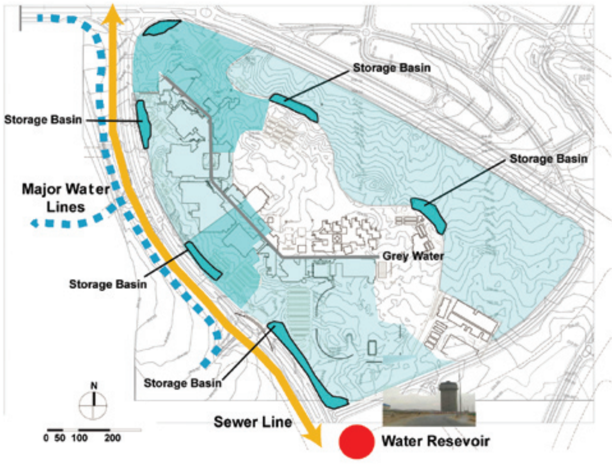

Fig. 5.40, Water Potentials.

5.2.3.4 Landscape Design and Materials

In order to achieve a sustainable landscape one of the important outdoor elements are materials. In the new AUC Campus it is important to keep the site clean, healthy and comfortable. This could be achieved by an Inventory of the types of available materials, defining the functional areas, as well as the areas. The second step is the inventory of for the environmental effects of each alternative based on available information such as use of materials resources, use of energy, emissions and production of waste. The third step is to classify the effects and transfer them into assessments on the five main relevant environmental aspects: resources, energy, emissions, damage and waste, as well as reusability, reparability and life span. The alternatives are compared by building a matrix on each aspect / future by means of assigning plus signs, zero or minus signs and an x-sign if the effect is very harmful. In the fourth step the matrix is the basis for determining the environmental preference of the possible options. There is no fixed weighting of the scores for each aspect as their

Table. 5.02, Material use rating (Abdel Halim CDC and Sasaki Associates, 2000b).

External Walls	Relative Preference	Cement Plaster & Paint	Artificial Stone	Brick Works	F.F. Concrete	Natural Stone (Limestone)	Natural Stone (Sandstone)	Granite /Marble Tiles
Scarcity (Availability in extraction /manufacturing)	*1	+2	+2	+1	+2	+2	+1	+2
Emissions (Manufacturing / construction / life span	*1	+1	+1	0	+1	0	0	+1
Durability for external condition	*2	0	+1	0	+1	0	+1	+2
Energy use (manufacturing / transport / construction)	*1	+1	+1	0	+1	+1	+1	0
Heat transfer / Climatic aspects / other factors	*2	-1	0	+1	-1	+1	+1	0
Waste (quantities related to original Manufacturing waste- extraction waste)	*2	0	0	+1	+1	0	0	+1
Re-use (primary or secondary	*1	-2	-2	-1	-2	-1	-1	+1
Life span and reliability	*2	0	+2	+1	+1	0	+1	+2
Total Preference Rating		0	+8	+6	+6	+4	+7	+14

relevance is not the same for every application. See table 5.02 (Abdel Halim CDC and Sasaki Associates, 2000).

Materials such as reed, straw, bamboo should be considered in the design of hardscapes and pavements. It is also advisable to reduce the material consumption in general and pave less. The utilization of natural Egyptian paintings and sandy stones could be an example for a better material use. Another example could be the utilization of recyclable materials. Finally the maintenance of the materials should be considered from the beginning and should have always a priority during the materials selection.

5.2.4 Design Recommendations

Water

The strategy for irrigation water relies on domestic water to irrigate the landscape. The master plan estimates irrigation water supply and demand by averaging over the year. In reality, the demand for irrigation water is at its highest in the summer and the supply of effluent is at its lowest. A more thorough supply/demand balance study based on monthly supply and demand estimates should be undertaken. Shortfall will mostly be greater because as much as 20% additional irrigation water may be required to flush the build-up of salts past the plant root zone.

Evapotranspiration, a measure used to estimate landscape irrigation demand, varies over the year. A number of empirical methods are used to estimate evapotranspiration (Eto). Based on a review of several methods, peak demand for July in Cairo is 8.8 millimeters per day (8.8 liters per cubic meter per day). Given a reasonable crop coefficient for turf and irrigation application efficiency, this compares favorably with the estimate of 10 liters per cubic meters per day presented in the report for the athletic fields. It appears that the master plan bases irrigation water demand estimates for prototypic areas on peak demand conditions. During December and January, Eto is estimated to drop to as low as 2.2-2.5 millimeters per day. The annual average is about 5.5 millimeters per day or approximately 63% of the peak demand. Based on this brief analysis, the irrigation demand estimates for the other prototypic areas appear to be reasonable for the peak portion of the irrigation season.

From an environmental perspective, raw sewage delivered to the city's collection system will probably be used for irrigation purposes after treatment. For this reason, the concept of promoting sustainability using on-site effluent for irrigation is more a matter of location.

Alternative approaches to reducing costs include decreasing the amount of landscaping and using more environmentally-compatible landscaping. Gardens use the most water in the landscape plan due to their high irrigation demand and large overall area. Careful research of a lower-water-use turf cultivar for the athletic fields could save up to 200 cubic meters per day. High-intensity landscaping in gardens can also be replaced with small ornamental water features. These can reduce irrigation demand because the water lost from a small water feature is considerably less than that needed to irrigate high-intensity landscape.

Water features should also be considered as alternatives to plants because of water's psychological benefits. It cools air through evaporation and has an animated and sparkling flow. Water has a traditional importance, and is associated with welcoming entryways, which tend to be good transition points from one area of comfort and conditioning to another. Water roughly evaporates about 1.2 times the rate of evapotranspiration. A lush planting scheme can survive well on about 0.8 times the rate of evapotranspiration. When the efficiency of an irrigation system is added in, the actual water use for a lush landscape is about 1.1 times the rate of evapotranspiration. The water use of a tree is 0.8 to 1.5 times the rate of evapotranspiration (estimating area by projecting the canopy on the ground). If a water feature is properly designed to use a minimum pool size, it can be a good alternative to plantings. Consider the following examples:

The area of a tree with a 3-meter canopy is about 7 square meters. If the tree is efficiently drip irrigated (90% efficiency), the total water use volume per tree is about 7.78 square meters times the rate of evapotranspiration; the equivalent water surface is about 5.8 square meters times the rate of evapotranspiration. The ratio of tree to water surface is about 1.33. A species that more-efficiently uses water might have a ratio of 2:1. A 3-meter-diameter reflecting pool with seat walls and plaza paving has a total area of about 8 meters in diameter. Radial walkways through small planting beds can further reduce the surrounding planted area (small lily-pond-type features might be added instead of landscape, which could probably be up to half the size of appropriately-sized landscaped areas). The water features and paving offset plantings that would have otherwise occupied the space.

Guidelines to minimize irrigation water demand at the AUC include:

- Focus water use at entrances and other small, important, highly-animated locations to provide traditional water greeting, sound, and animation as well as cooling.
- Use water that falls on the site or buildings for irrigation, either by storing and treating or by grading the site to deliver site and roof waters to wider planting areas.
- Mulch watered areas to improve water retention.
- Reduce lawn areas. Use desert paving in less-occupied areas and provide access to buildings that is as direct as possible.
- Eliminate interstitial areas that are landscaped by default. Only develop additional perimeter landscape when demand indicates the need and water is sufficient.
- Design desert, xeriscape, and low-water-demand native landscapes in non-public areas, non-focus areas such as perimeters. Limit high-water-demand areas to public pedestrian and vehicular entrances and linkages of open space and urban design importance.
- Use organic gardening techniques and integrated pest management programs to lessen soil and groundwater pollution and improve water quality.
- Incorporate a drought plan into the landscape design; minimize drought impacts by integrating plant and soil selection, maintenance techniques and grading and drainage design.
- Zone the irrigation system to meet the specific needs of plant materials and site micro-climate. Zoned irrigation allows the irrigation of expensive shrubs and trees while reducing irrigation of turf and other easily-replaceable plants during severe droughts.
- Match irrigation system operation times with the current supplemental needs of the plant material.
- Use controller timing and system zoning: multiple repeats, longer irrigation times for drip systems, seasonal

variation adjustment and tensiometers. Tensiometers can measure localized soil moisture to determine irrigation demand when properly placed.

Plant Selection
Flora native to the Eastern Desert region are listed in appendix VIII. These serve as the basis of the plant list. Associated plant palettes should be used over broad areas to minimize the need for zoning and related controls. Further in-country research is recommended to complete this list and identify local expertise, resources and sources of native plants. The plant list should include plants that are:

• Native to the region.
• Observed on the AUC site.
• Complements to the indigenous fauna.
• Beneficial to wildlife habitat, soil structure and fertility development.
• Drought-resistant and salinity-tolerant.
• Non-native, but non-invasive or infertile and naturalized with specific characteristic traits or uses and that are appropriate to the micro-climate regimes (see appendix VIII).

Soils and Drainage
Soil technology and amendments should consider the whole root zone, irrigation, fertilization and drainage. In courtyard and heavy-use pedestrian corridors, the soil panel should extend out underneath the paving system, with appropriate support of the paving to minimize compaction. Irrigation and drainage of these areas should take soil panel design into consideration. Continuous soil panels that connect the root zones of adjacent plants often improve plant viability by allowing root contact. Even the smallest courtyard should have at least two trees closely-sited for root contact. Guidelines for drainage and soil systems include:

• Limit the use of portland cement- and petroleum-based asphaltic products to improve drainage.
• Use unit-paver systems, which promote water infiltration and allow subsurface repairs without wholesale replacement of the surface. Loosely compacted soil under unit-paver systems allow root systems to breathe better.
• Consider porous pavements in interior courtyards and other small places. • Integrate grade-beam solutions under paving with soil panel design.
• Integrate surface-water runoff with paving and grading design.
• Direct courtyard drainage first to plants in the courtyard, then to other planting areas nearby, and then to larger or neighboring areas demanding water (landscaping).
• Use French drains, drain tile, soil profiling, and irrigation meters in planted areas where surface drainage is not possible to promote soil water recharge and irrigation.
• Design stormwater swales as landscape planting areas.
• Design roadways to drain into continuous, planted swales and infiltration areas, minimizing concentration points.

Green Open Spaces
Visibility of green and open space from windows has been shown to be important to contemplation, relaxation, and spiritual rejuvenation. This is one of the primary functions of the University Gardens and its plazas. Landscaping provides interest on many levels. The active, varied shade of tree canopies is contrasted by the still, consistent shade of buildings. All occupied exterior spaces should be shaded. Traditional hot climate gardens have full tree canopies—the full and higher the better—that create optimum conditions for cool air reservoirs. Cooler air is drawn from the gardens into the hotter open spaces of the campus core. Air movement corridors should also be fully canopied to preserve thermal convection into the core. The gardens function better with a defined and contained perimeter and limited, narrow entrances. Roof gardens improve the surrounding micro-climate by decreasing the heat island effect and stabilizing indoor temperatures. They require only 7-10 centimeters of soil, need little maintenance and can be easily incorporated into building design. Roof retention membranes prevent building leaks, provides protection from plant roots and improve drainage. Roofs do not need to be flat; pitches of up to 40 degrees are possible. The most suitable plants are succulents and indigenous grasses as well as dry habitat plants such as lavender, sage, daisies and phlox. The AUC should seek to create a campus that is a model of sustainability and landscape healing. Some guidelines for landscaping include:
• Orient fenestration on the outside of the core campus to specific landscape areas, preferably to heavily-landscaped areas associated with campus entrances.
• Design entranceways into the core built campus as cool oases to draw people; they should be narrow and shaded.
• Develop a diverse planting scheme based on vertical and horizontal relationships to water availability and exposure.
• Use plant materials to define boundaries and enhance and delineate spatial boundaries.
• Vegetate the surfaces of walls (especially western-facing) to shade buildings. This engages biotic ecosystem services such as thermal tempering, biomass production, carbon sequestration, storm water management, and nutrient cycling, as well as furthering other environmental goals such as managing scarce resources and increasing biodiversity.
• Plant trees in regimen for ease and efficiency of water use, canopy production and shade delivery. Use plant materials that will provide significant groundplane shade in five years in the major open spaces. Planting on the north side of such spaces and planting in an asymmetrical pattern will improve shading.
• Canopy smaller courtyards, corridors and similar spaces with trees or flexible awning structures to provide continuous shade.
• Design and phase landscaping to minimize water use. Use landscaping appropriate to the desert climate and cultural context, such as orchard-style plantings. Informal suburban landscaping is wasteful of water and resources and inappropriate to Cairo’s cultural tradition. Focus preliminary development on entrances and core

pedestrian areas. Phase infill landscape and public walks and amenities as effluent water becomes available in sufficient quantities, not as pre-developed, unsupported amenities.
• Avoid using raised planters, as they are susceptible to heat gain. Ground-based planting benefits from ground temperature moderation and simpler irrigation demands. Layout of ground-based planting in smaller areas is based more on functional relationships than climatic considerations.
• Use water features for their psychological benefit.
• Use native flora whenever possible.
• Integrate drainage systems into paving, grading and planting design.
• Use deep ground areas for habitation and as reservoirs of cool temperatures.
• Shape the earth to block undesirable solar radiation and winds. Effects are most useful within 5 times the height of berm away from windbreak.
• Fully canopy parking areas with trees and/or shade structures. Perimeter berming and planting enhance human comfort and thermal performance in these areas.
• Create nurseries in outlying areas.
• Use the perimeter fence as an integral part of shelterbelt planning and planting, replacing the groundplane component of screen and shelterbelt. Continuous shrub massings are inappropriate in this zone. The security strategy will need to accommodate the full ground-to-canopy shelterbelt. Continuously plant slopes to earth-shelter buildings, integrate parking canopy with shelterbelt canopy.
• Plant roof gardens to minimize solar impacts on buildings and improve the surrounding micro-climate. Habitable roofs can also be used in conjunction with vegetated ones.

Landscape Construction

The use of recycled and renewable resource material is expected in all facets of landscape construction. Research on locally-available materials will be required to identify useful sources. Soil preservation will be important if significant soil or soil elements are present on the site. Soil preservation will be improved if surface water runoff is kept constant or reduced. Construction sequencing and planning should include:
• Erosion, dust and sediment control.
• Precise staking and enforcement of construction disturbance areas.
• Proper topsoil stockpiling, using minimally-compacted lifts to preserve organic structure and soil for fauna.
• Irrigation of stockpiled topsoil.
• Stockpiling of desert pavement materials (cover that forms over time as a result of the action of wind, solar radiation and surface water run-off) for future use. Desert pavement can be used in desert restoration and xeriscape landscaping.

Infrastructure

Providing on-site amenities to facilitate people's use of public transit, ride-sharing, carpooling and other multi-occupancy modes of commuting reduce the land area required for parking and circulation. The university should continue to work with the local municipality to create a traffic management plan promoting public transit. Cooperative efforts include:
• The master plan creates pedestrian links to the surrounding community and its public transportation systems.
• Provide shuttle service to and from train, light rail and bus stations.
• Provide comfortable facilities for public transit users, including all-weather shelters and well-lighted and secure facilities and routes.

Non-motorized forms of transportation should be encouraged. Bicycle pathways in the campus and its surroundings should be safe and clearly-defined. Some possible amenities include:
• Separate, designated routes on site for cyclists and pedestrians.
• Well-lit, sheltered parking and locking facilities near supervised or well-used public areas for bicycles and showering facilities in adjacent buildings.

Parking lots consume large amounts of land and have many negative environmental impacts. Reducing the quantity of parking provided has many benefits, including more open green space, reduced stormwater surface runoff, increased groundwater recharge, lower surface temperatures, more vegetated surfaces and cleaner air. Optimize necessary parking lots:
• The layout of surface parking allows for sheet drainage to infiltration and bioremediation strips and swales, minimizing points of concentration and piped flow, groundwater recharge and plant and soil containment of parking area pollutants.
• The plan should follow the site topography, leaving sloped areas between parking terraces and dispersing runoff.
• Natural swales have been proposed to encourage infiltration and recharge, minimizing runoff concentration to pipes and inlets.
• A shelter belt to the south has been proposed to help protect the campus from the harsh southwestern winds. However, when appropriate, plant additional windrows and hedgerows of trees and use lighter-colored paving materials to lessen the micro-climatic impact of solar radiation absorption.
• Use parking structures when climate, site size or a significant environmental issue (stormwater, wetland, historic area) suggest it.
• Provide privileged parking locations for carpoolers.
• Provide safe and clearly-defined pedestrian pathways across and around the facility and to entrances.

Chapter 5

Case Study and Design

Section 3

Design Concept

5.3.1 Design Concept

Design entails a finer degree of analysis and decision making than the previous general research steps in the design process. In the design stage, landscape architect deals with solutions in an abstract way, but he deals with specific decisions as exact size, configuration, and materials. The design phase begins with a schematic design (SD) that will pass on the design development (DD) phase before finally reaching the detailed working drawings phase (WD).
But in this section, I will introduce only a schematic design that had been developed during the research process. Because the research methodology of this thesis was 'Research by Design', it is very important to present a design concept that entails the design guidelines and design principals that were presented in the previous chapters. Therefore, the aim of this section is to illustrate how my research findings, including the analysis results and design recommendations, are used in my design concept.

5.3.1.1 Design Strategies

There are many findings that came out from the research. Many of these findings dealt specifically in detail with climatic control issues but the most important influential design strategies are what I call:
1. The Zones Concept,
2. The Wall Concept,
3. The Thermal Unit Concept.
In my opinion, those strategies are the hardcore of any design development that seeks for micro-climate improvement in hot arid climates. Therefore, I selected these design strategies even before exploring any thematic design scenario.

The Zones Concept

Based on the analysis and inventory study, I prefer to determine the comfort conditions for the new AUC Campus as a primarily part of the design process. In order to achieve an improvement in the micro-climate of the outdoor spaces, as recommended in the conclusion of chapter 4, a strategy needs to be applied to provide certain comfort conditions. Figure 5.42 illustrates the zones concept in which the desired comfort conditions for each place in the new AUC Campus is determined. In table 5.03 we can see the detailed design decision in relation to the expected climatic impact. The zones concept is a direct translation to the landscape potential and energy potential analysis maps of section 5.2. The need for a shelter belts and wind filtering zone on the north tip of the project is essential. Canopy trees are provided around parking places and in places adjacent to south-west building facades. But in order to provide a large and comfortable outdoor-space or garden for students and staff the outdoor-spaces should be enclosed or at least semi enclosed.

The Wall Concept

The wall concept is another important strategical design decision, which was made to assure a minimum climatic control. In the harsh desert climate, it is difficult to provide a green lush outdoor environment unless this open space is contained. The historical examples described in Chapter 3 strongly recommend such strategical decision. The benefit of the wall relies in its ability to minimize the hot-dusty wind penetration in the open garden. This may reduce the wind cooling effect but because the temperatures in the AUC

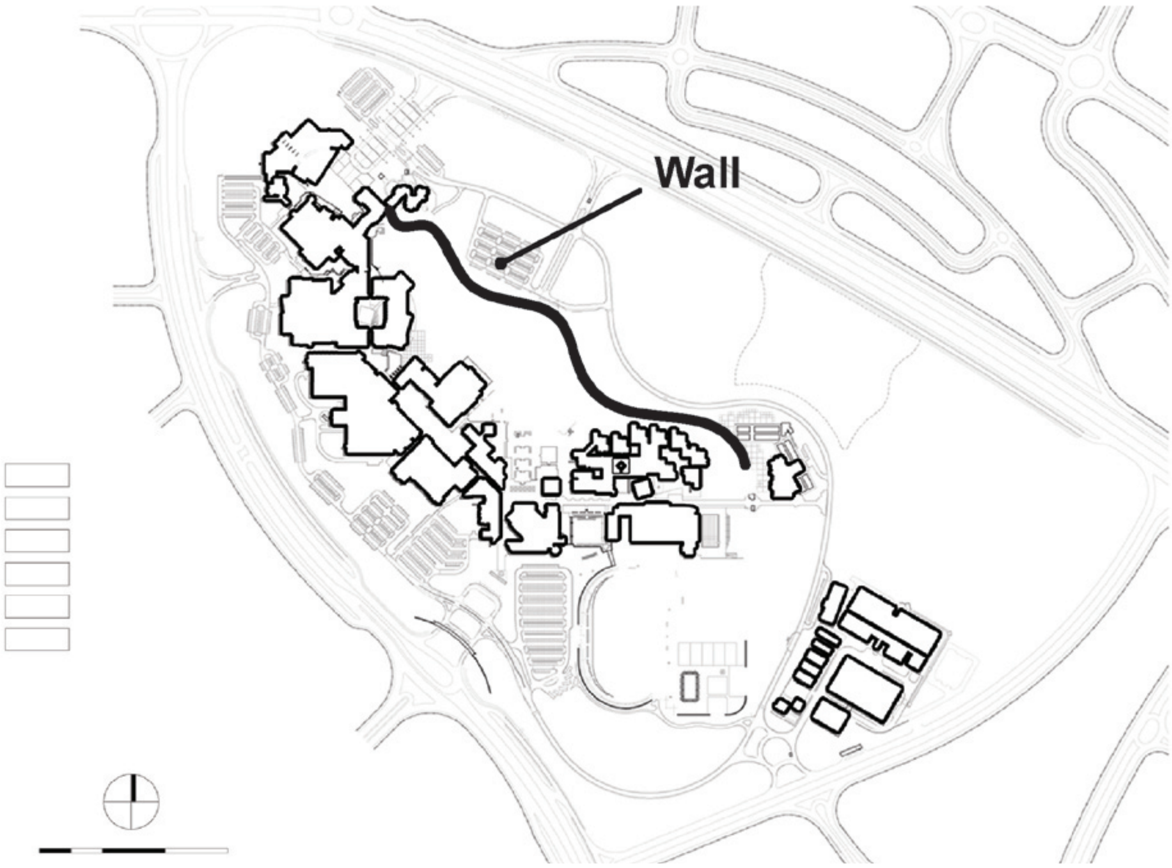

Fig. 5.41, The Wall design strategy.

Fig. 5.42, The Zones strategy, adapted from Abdelhalim CDC by author.

Table. 5.03, Design Decision and Climatic Impacts, adapted from Abdelhalim CDC by author.

	Zone Name		Design Decision	Climatic Impact
Extensive Landscape	1. Filter		Shading Ground Cover	Sand Filtering Lower Temp. Better Comfort
	2.Shelter belt & Boundaries		High Barrier Trees	Wind, Sand Storm Protection
	3.Parking and Roads		Shading	Minimize Solar Intensity
	4. Entries		Water Surfaces Vegetation	Reduce Solar Radiation Better Comfort
	5. Building/Landscape interface		Shading Green Ground Cover	Reduce Direct Radiation Reduce Indirect Radiation
Intensive Landscape	a. Formal garden		Green Ground Cover Shading Water Surfaces	Lower Temp. Cool Reservoir Better Comfort
	b. North East Facing Garden		Ground Cover Shading	Cool Reservoir Promote North Wind Lower Temp.
	c. Canopy of trees		Shading Sand Filtering	Clear Air Reduce Solar Radiation Lower Temp
	d. Desert landscape		Boundary Layer Minimum Water	Drought Tolerant Vegetation Soft Barrier
	e. Boundary and Edge		Barrier Zone	Hard Barrier
	f. Reserved Land		Desert conditions	

Campus will be mostly above 30ºC during summer, this is necessary. The wall will allow the green shrubs, water elements and canopy trees to reduce the temperature and raise the wet bulb temperature. But despite my choice of a physical 6 meter-high wall as shown in figure 5.41. The wall concept might a wall made by trees and plantings or any other solution that achieves the desired climatic control.

The Thermal Unit Concept

The Thermal Unit Concept was already set in the early phases of the design. The original Master Plan for the AUC Campus was based on using the existing *wadi* as a cool air reservoir. However, the idea behind this Thermal Unit Concept lies in creating high and low pressure areas in order to force the wind to funnel from the east to the west. As shown in figure 5.43, we can see that the red colored cracks are the areas which have a higher wind flow and better comfort conditions. The role of landscape was essential in activating this concept and therefore the design concept integrated and adapted this strategy as shown in figure 5.44.

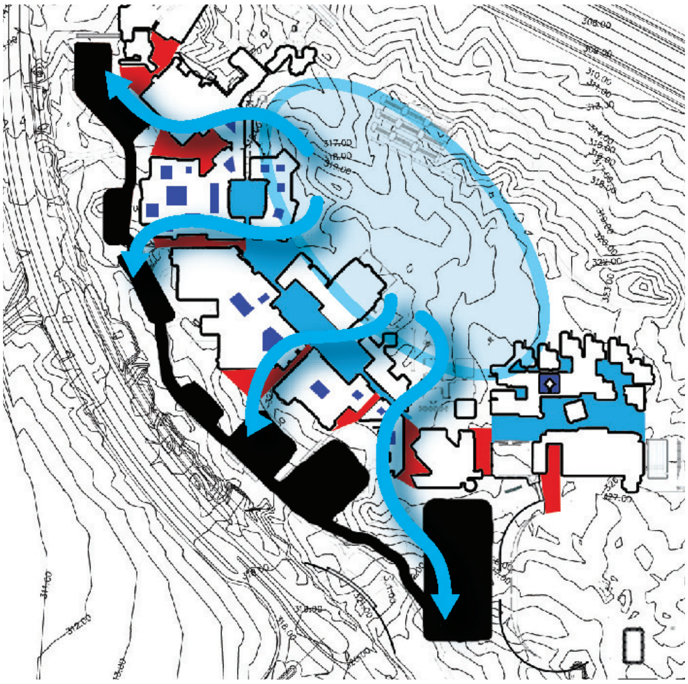

Fig. 5.43, The cool air reservoir and the thermal unit concept. adapted from Abdelhalim CDC by author.

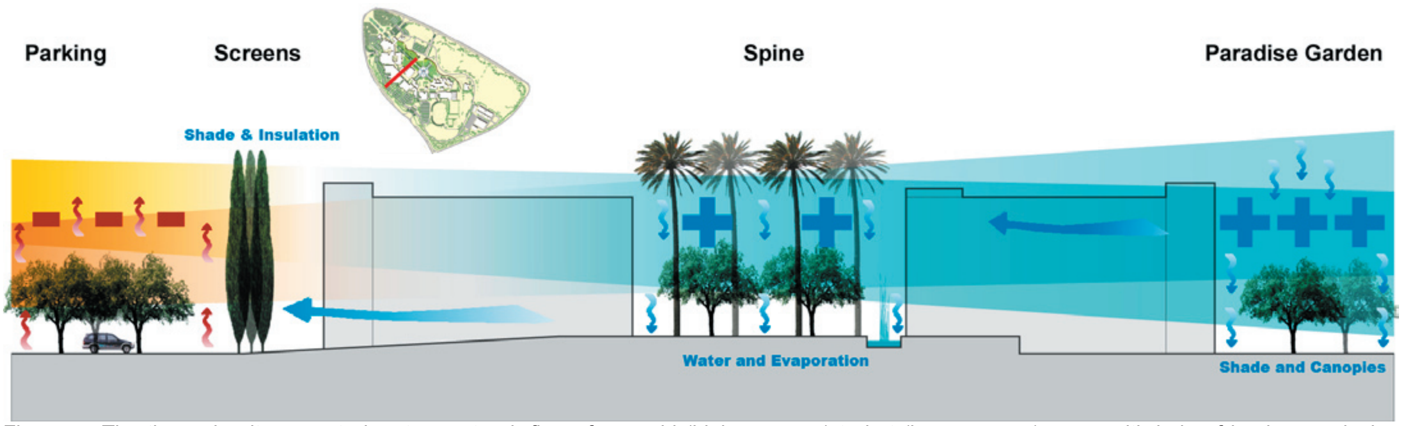

Fig. 5.44, The thermal unit concept aims to create air flows from cold (high pressure) to hot (low pressure) areas with help of landscape design elements.

5.3.2 Design Scenarios

As part of the brainstorming phase, for ideas and concepts, several design scenarios might be investigated and tested in order to come out with the creative and innovative ideas that are also related to the design objectives. I will not go far into detail for each scenario because the main aim here is not finding the best design alternative. Or even the selection of a style out of different historical styles such as the Pharonic or Arabic or even the Modern approach are not meant. The aim is mainly to generate design ideas and concepts that are suitable for the projects environment by exploring different scenarios. Therefore I prepared 3 different spatial scenarios that might trigger me as a designer before deciding for the final design concept.

The Park

The Park scenario is based on the central core or heart that brings everyone together. A central park in the north tip will include multiple spatial centers that will bring the AUC student and community together. This park will serve as a planting nursery and will act as a protective layer against the hot *khamaseen* winds and could allow for light activities (walking, jogging and biking) for the community in the near future. A green belt will be designed around the site's western and eastern edges as boulevards. Gates and kiosks placed along the northern highway could also heighten social and cultural interaction with the surrounding community (fig. 5.45).

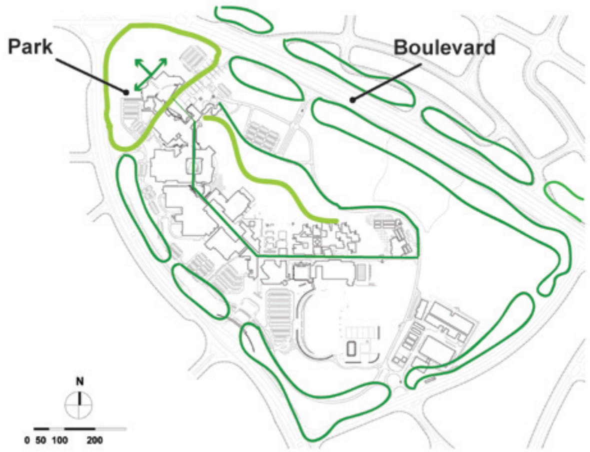

Fig. 5.45, The Park scenario.

Lotus

The Lotus scenario is based on a central axial water line including several small water lakes. The design is based on ancient Egyptian landscape planning principals where symmetry is important. The lotus garden till be a public central garden at the north tip of the project adorned by lotus pools. The lotus garden will be the formal university entrance which leads to a bookstore, information booth, newsstands and above all the university art performance center. Next, the Sacred Garden will be the main outdoor space for student and staff and it will include a central axe. The vegetation, plants and a large wall will form a counter movement for the buildings in order to create a Pharonic planned central garden. The whole campus will be also surrounded by an Orchard including all edible plants that where used by the ancient Egyptians. The Orchard will allow the light activities and will be considered as an environmental shield (fig. 5.46).

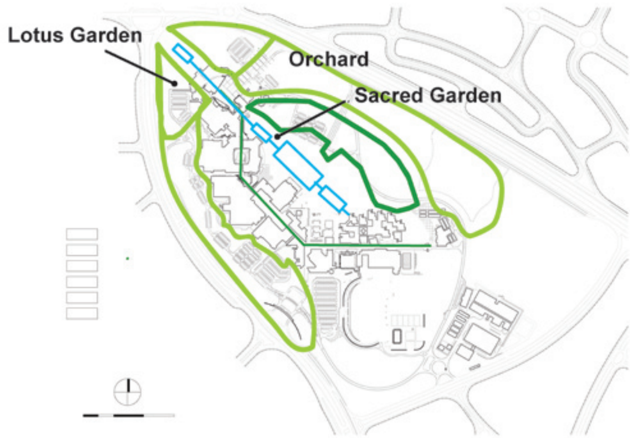

Fig. 5.46, The Lotus scenario.

Oasis

The oasis scenario will include mainly the Arabic desert features. On the northern tip, an orchard or as it is called *Bustan* will be located including famous indigenous fruit trees. The Orchard will be followed by a large scale garden, which represents the oasis concept. Surrounded by high walls and including a lush densely planted landscape, the Oasis will create a contrasting landscape image with the surrounding landscape. This concept will be more emphasized by the idea of creating a desert landscape in the eastern edge of the AUC Campus (fig. 5.47).

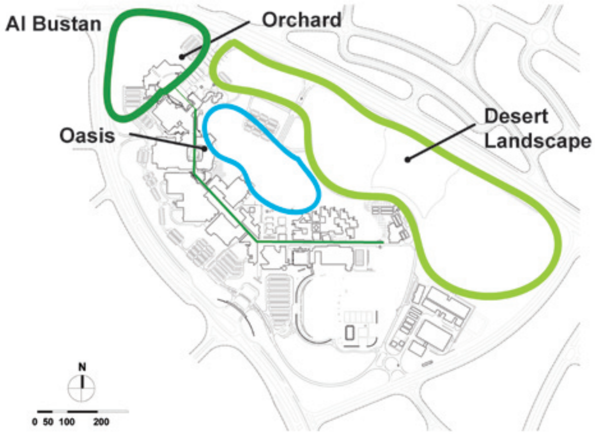

Fig. 5.47, The Oasis scenario.

Conclusion

In short, exploring the different scenarios showed different ways, potentials and ideas that could be implemented in the final design concept. As a landscape designer who is aiming to achieve a better outdoor environment by taking control over the harsh desert climate I would rather select the Lotus or Oasis Scenario. Maybe also because that these two scenarios are originated from the same desert environment, in regards to the Pharonic and Arab-Islamic background. But I would rather prefer to select the Oasis scenario for the following reasons. The first, is that the Oasis scenario's roots are still continuing in contemporary live of Egypt, secondly because the students, which are representing the client, preferred to be in an Campus that incorporates the Arabic-Islamic style elements (Questionnaire, appendix I).

5.3.3 Design Concept

The Extensive Landscape Strategy

As part of the Zones Concept and due to the scarcity of water I decided to create two types of landscapes. The first was an extensive landscape that includes drought tolerant and indigenous species. The second was an intensive landscape that includes fruit and shade trees for the Garden Paradise. Therefore, any landscape design outside the Paradise Garden was considered as an extensive landscape. The extensive landscape is a direct translation of the design decision that was made in table 5.03.

As shown in figure 5.48 and 5.65 the south-west side of the project is surrounded by a shelterbelt to prevent the undesired hot and sandy wind storms. Then in the north tip of the project, fig. 5.49, a sort of wind catcher was created through palm grooves. The aim of this palm grooves was to guide and deflect the air up in order to reach the Paradise Garden. Based on several discussions with my study advisor and other experts I was convinced that the Palm trees with some trees located in the wind flow direction will work on lifting and funneling the air to reach the Paradise Garden. Next, a group of vertical shade screens were located on the south-west facades of the Campus buildings to provide shades and create isolative dead air areas that can later reduce the delivered energy to cool the spaces behind these facades (fig. 5.50 and 5.65).

Finally, the loop road, surrounding the buildings and the parking areas are all planted with canopy trees. See figure 5.51 and 5.65. While the Wall present in figure 5.52 and 5.66 is not part of the extensive landscape strategy but it is part of the decision that was made in the Zones Concept to enclose and control the climate of the Garden Paradise.

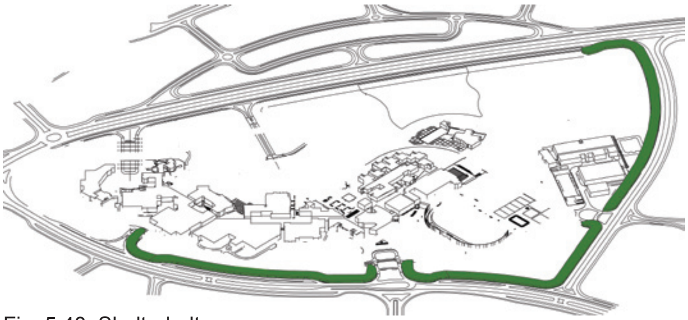

Fig. 5.48, Shelterbelt.

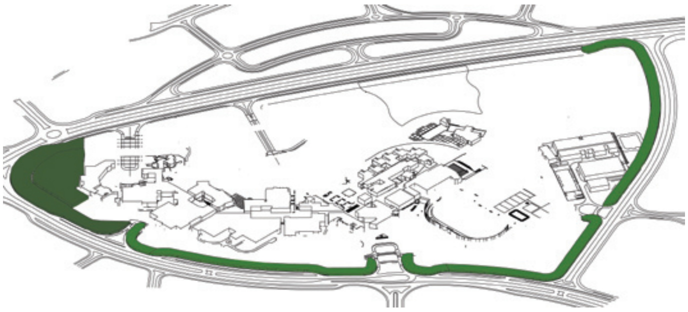

Fig. 5.49, Windcatcher.

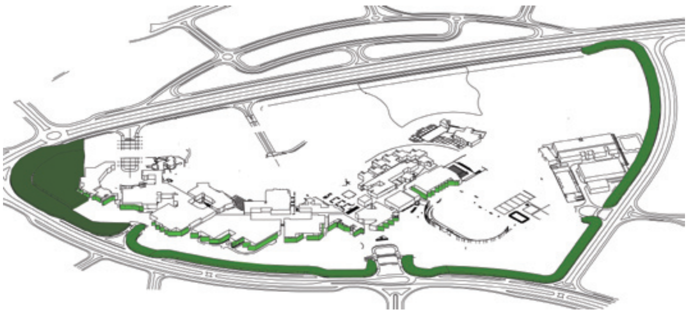

Fig. 5.50, Shade Screens.

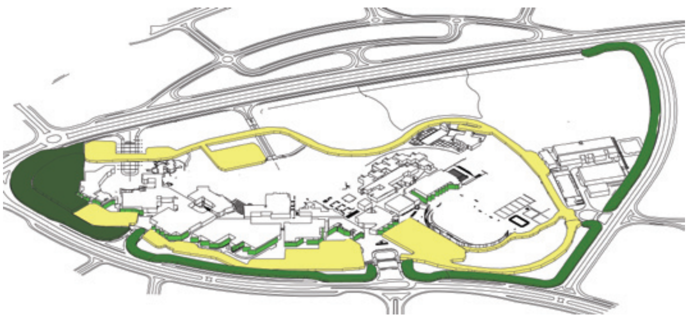

Fig. 5.51, Loop Road and Parking.

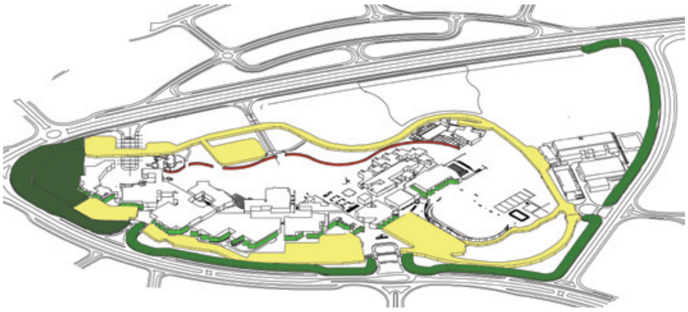

Fig. 5.52, The wall.

The Oasis

The oasis, its physical generation and the traditional social practices employed therein, constitutes a reference for contemporary practice. Typical oasis sites were characterized by topographical depressions with access to underground water and shelter from desert storms. Improvements to selected natural sites included the building of a well and irrigation canals at the center of the oasis and the consolidation of heavy planting in its canopy and periphery. The planting strategy protected both site and community from the harshness outside and within the shelter, the landscape was developed for pasture or farmlands. Dwellings were built for shading, shelter and human interaction. A social counterpart to this organization of the land corresponded to the arrangement of properties guided by organizational rules and social hierarchy.

Because of the scarcity of water in New Cairo's desert environment, the AUC open-space structure will be built on concepts responsive to that scarcity and at the same time supportive to a comfortable human environment: conservation, sustainability, and functionality. Within the open-space structure, plant materials will be carefully used to be fully effective in the environment in which they are placed. Their use is based on their function, and species are selected to conserve water, optimize solar benefits, and control wind. Each plant is highly valued and is part of an overall irrigation and thermal strategy developed to create a comfortable environment in hard conditions.
The elements creating the AUC landscape consists of the spine, AUC Oasis, the shelter belt, the Garden of Paradise and the connectors. Each is discussed in detail below.

• *Spine:* Based on Architect will and the original master plan, a network of plazas and walkways forms the central spine of the campus, starting at the AUC Oasis continuing past the student housing complex and athletic facilities. The plazas and walkway are shared among schools and are not exclusive. In this way, scholars from more than one school will use the same space throughout the day, increasing the probability for interaction between scholars of differing disciplines. The Main Plaza acts as a meeting area and a place for formal outside gathering.
Off this central spine, within the buildings, is a series of smaller courtyards serving more intimate gatherings (fig. 5.50 and 5.53).

• *AUC Oasis:* The northwestern tip of the site represents the area of maximum exposure and community interaction. Due to the configuration of roads and plots, it is the first part of the campus seen by drivers and pedestrians approaching from the direction of Cairo. The AUC Oasis is an interface between the university and the community—a place of activity and exchange accommodating the following civic facilities: the AUC theater for performing arts, the art gallery, an area for sculpture, the AUC bookstore, cafes, and a multi-media information center.
This public space is an offering from the university to its community—an offering that will be maintained and controlled by the AUC for the benefit of the community, guaranteeing security and upkeep (fig. 5.48, 5.51, 5.52 and 5.54).

• *The Garden Paradise:* In the garden, located to the leeward of the warm and dusty *khamasin* and to the windward side of the cool and refreshing breezes from the north, there is a space for relaxation, reflection and contemplation. This garden will be surrounded by building from the west side and a high wall from the east side. A quadripartite layout will divide the garden in top four compartments providing shades and relatively cool and humid environment. Each quarter will be specially designed to address the five senses through fruit trees, canopy trees and scented vegetation. In each quarter a group of open spaces and gathering squares will be located to hold the students outdoor activities. Next, the quadripartite layout will represent four rivers of honey, water, milk and wine. The intersection point of the four rivers is considered as a climax experience where a pavilion or heavenly palace will be the source of the four rivers. Moreover, a natural winding walkway will connect the four garden quarters. The winding walkway will crossing the four quarter and provides the users with diverse visual experiences (fig. 5.50, 5.55, 5.56, 4.57 and 5.58).

The AUC Oasis

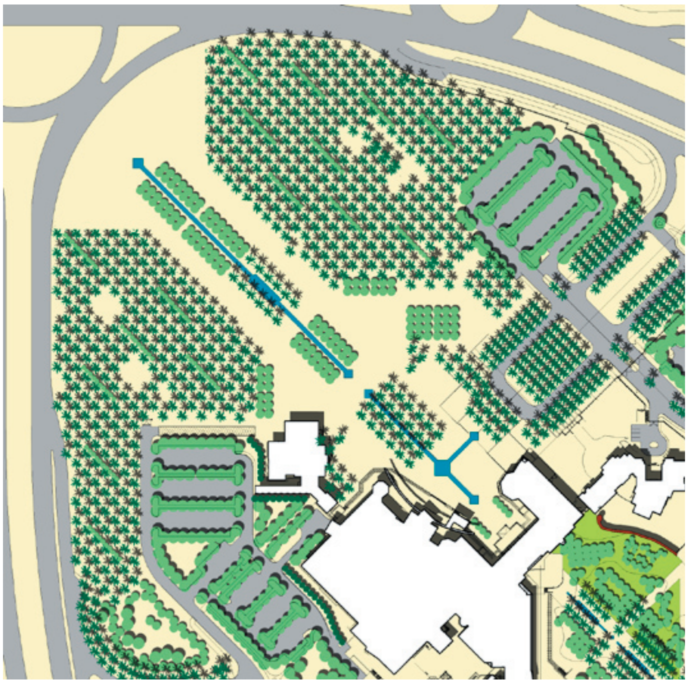

Fig. 5.53, The AUC Oasis.

The Garden Paradise

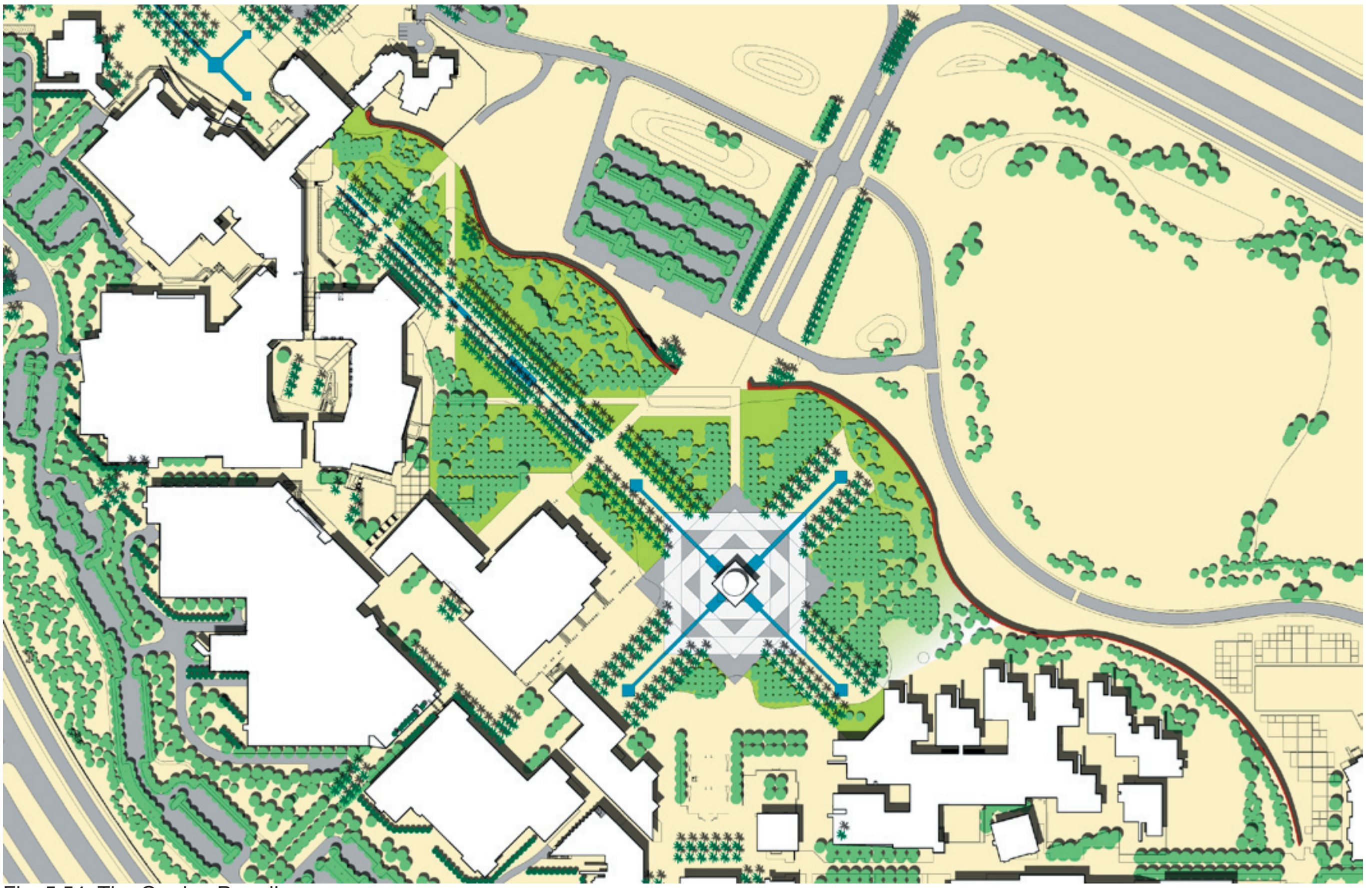

Fig. 5.54, The Garden Paradise.

Master Plan

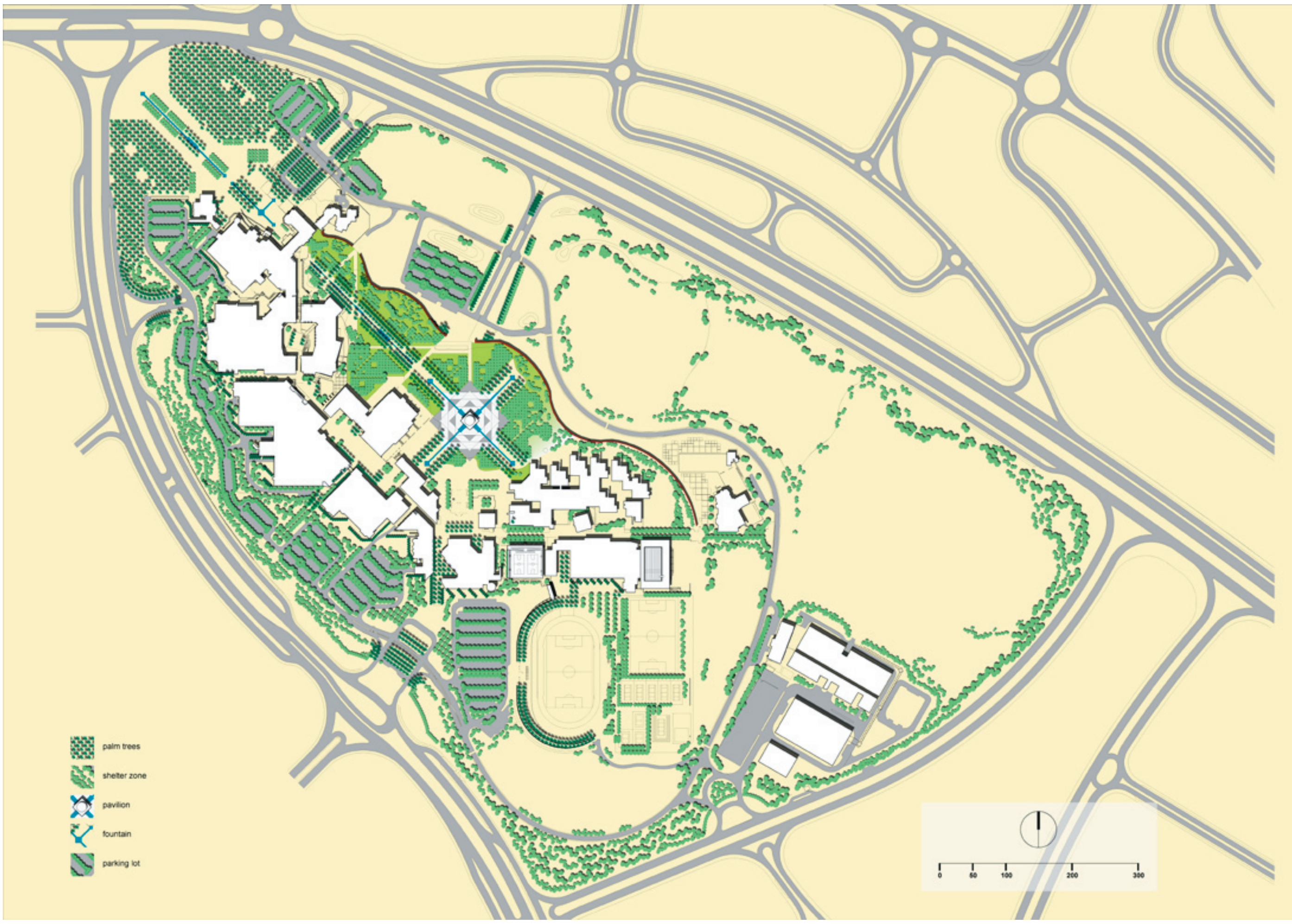

Fig. 5.55, Master Plan.

Images I

Fig. 5.56, Image 1, AUC Oasis.

Fig. 5.57, Image 2, AUC Oasis entrance axe.

Fig. 5.58, Image 3, Landscape in a Spine courtyard.

Fig. 5.59, Image 4, A tent in the AUC Oasis.

Fig. 5.60, Image 5, The Garden Paradise.

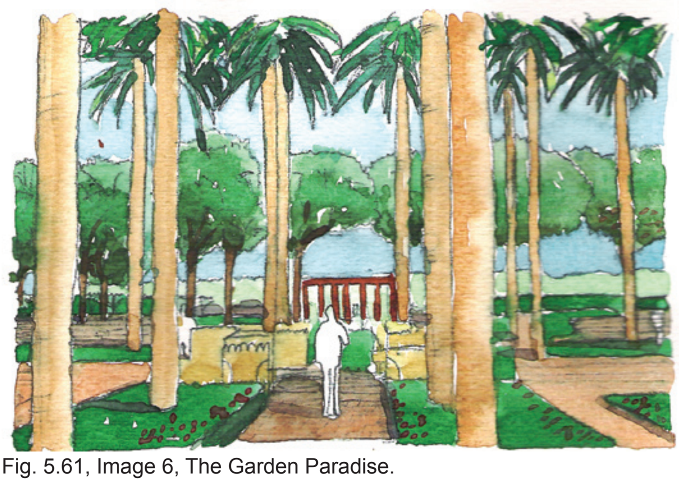

Fig. 5.61, Image 6, The Garden Paradise.

Fig. 5.62, Image 7, The Paradise Pavilion.

Images II

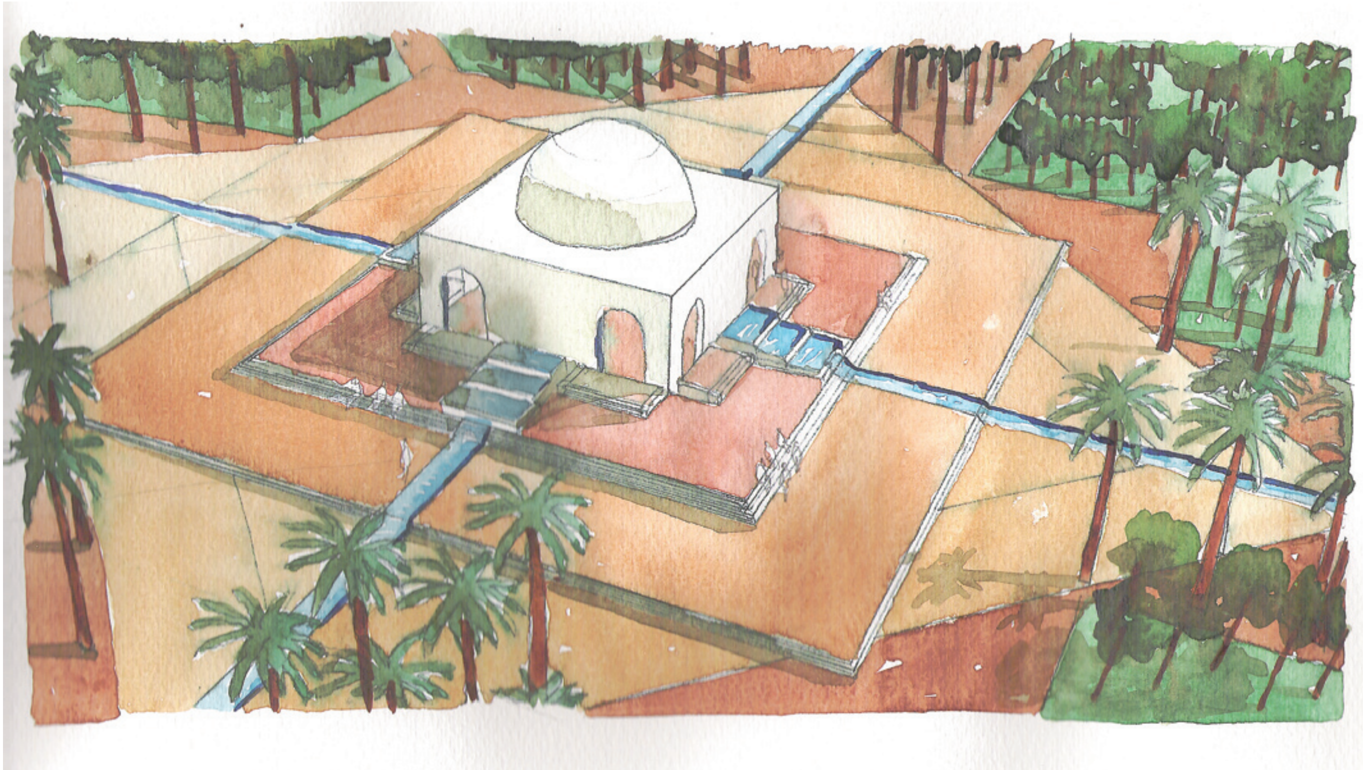

Fig. 5.63, Image 8, The four rivers and the Paradise Pavilion in the Garden Paradise.

Sections

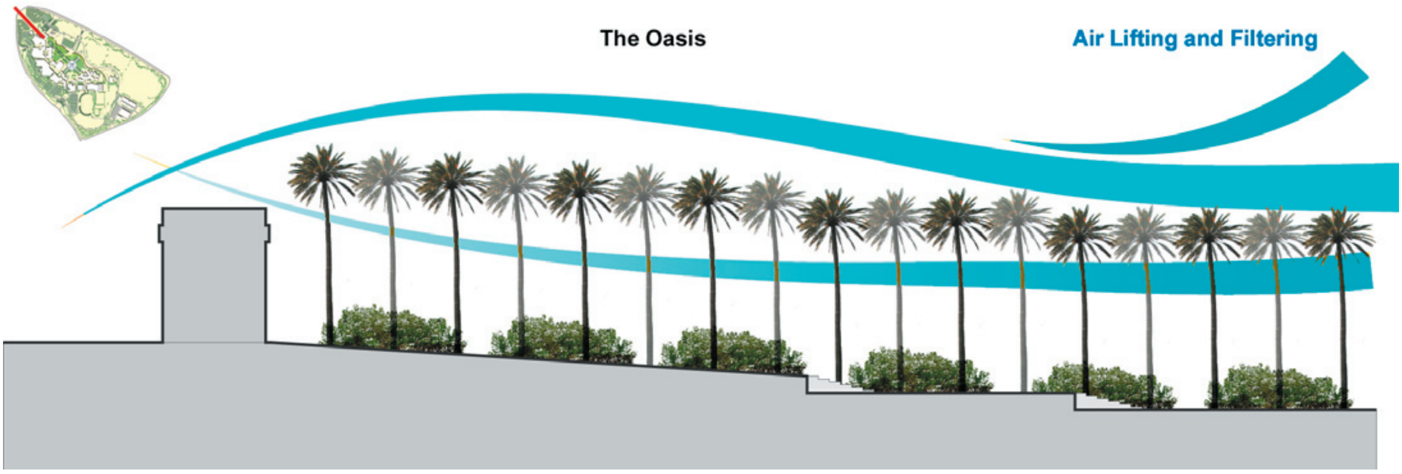

Fig. 5.64, Shrubs and palms in the AUC Oasis, to lift the air up and filter it.

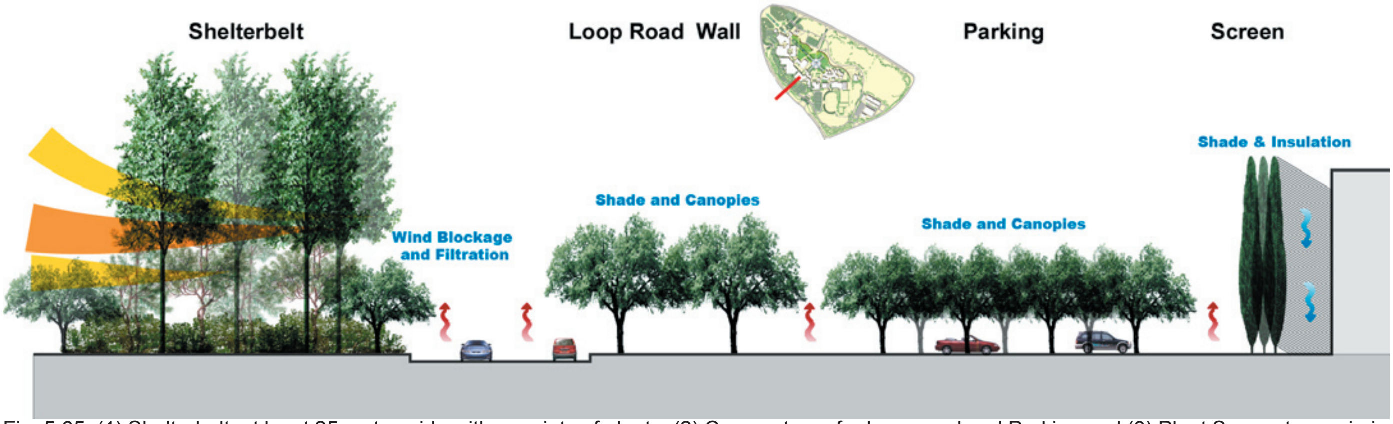

Fig. 5.65, (1) Shelterbelt, at least 25 meter wide with a variety of plants, (2) Canopy trees for Loop road and Parking and (3) Plant Screen to maximize shades on south west building facades.

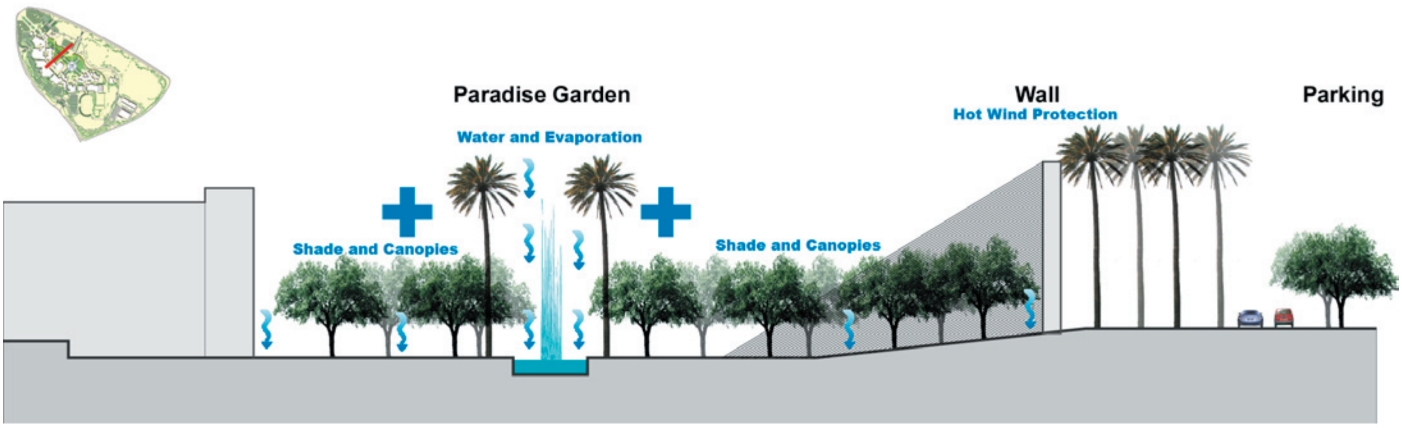

Fig. 5.66, The Garden Paradise enclosed between the wall and AUC buildings. Water elements and canopy trees work also to improve the micro climate.

5.4 Conclusion

After exploring the design concept, it is important to reflect on the design and define the research findings that were tested and used in the design. I would like to admit that during the design process and due to the time limitation, I made sometimes many design decisions unconsciously but also based on the findings of chapter 3 and 4. But after handing in my design concept my study advisor forced me to reflect back on my design decisions in relation to my findings. Actually this step was very important because it helped me to clarify and define the tested and developed strategies during my design. This step was very important because it highlights the thesis methodology 'Research by Design'. Also this gives landscape architect an example of how to use the developed research findings and recommendations in a practical way.

I started this step and I might find it close to the processes of Reverse Engineering. Reverse Engineering often involves taking something (e.g., a mechanical device, an electrical component, a design) apart and analyzing its workings in detail, usually with the intention to design a new device. Similarly, I looked back to my design in order to define the design decisions that were made in relation to the research findings. Finally, I came out with 7 main strategies or findings that came out from the research. The 7 strategies were tested and applied in the design concept in order to improve the micro-climate in an energy conservative way. Each is discussed in detail below:

1. Zones
2. Wind Blockage
3. Vegetation Pattern and Wind Cooling (Thermal Unit Concept)
4. Vegetation Pattern and Wind Flow
5. Vegetation and Shade
6. Evaporation and Water Distribution – Water Surfaces and Wind
7. Architectural Elements and Energy.

1. Zones

The major and first strategy that I adapted in my design was based on dividing the project into zones related to the function and activities in each zone. Moreover, each zone was named and linked to a design decision that should specifically fulfill a desired climatic improvement. As shown in figure 5.67 the Zones Concept formed the most important backbone for the design.

Fig. 5.67, The Zones Concept adapted from Abdelhalim CDC by author.

2. Wind Blockage

The second important strategy that was implemented in the design was dealing with blocking undesired winds. One of the research findings was the shelterbelt. The shelterbelts were used as a design strategy for wind blocking and wind filtration through drought tolerant plants (fig. 5.68a). Another way for wind blockage was made through the large wall which was built to enclose the Garden Paradise (fig. 5.68b). The illustrations of Miller and Robinette are the main source for creating a wind blockage strategy in my design.

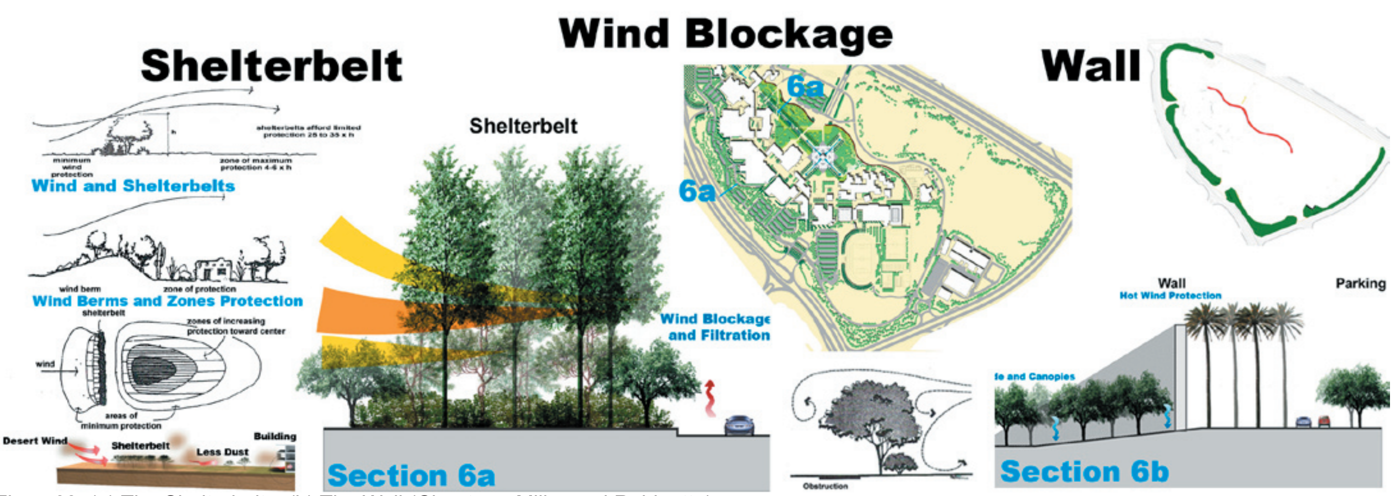

Fig. 5.68, (a) The Shelterbelts, (b) The Wall (Chapter 4,Miller and Robinette).

3. Vegetation Pattern and Wind Cooling (Thermal Unit Concept)

Figure 5.69 illustrates the thermal unit Concept developed by Sasaki and Abdelhalim in addition to Robinette's schemes that deals with vegetation patterns and wind cooling techniques. The thermal Unit Concept was based on the idea of creating a relatively cool enclosed air reservoir through intensive landscape (canopy trees and water elements) in contrast to an open hot extensively planted area. This idea even influenced the landscape design of the courtyards and spine depending on there location and position which might fall in a high or low pressure zone. Finally, this Concept might not function always or all over the year times and most importantly, it functions only in combination with buildings and solid masses. But I consider it as important design strategy in improving the micro-climate.

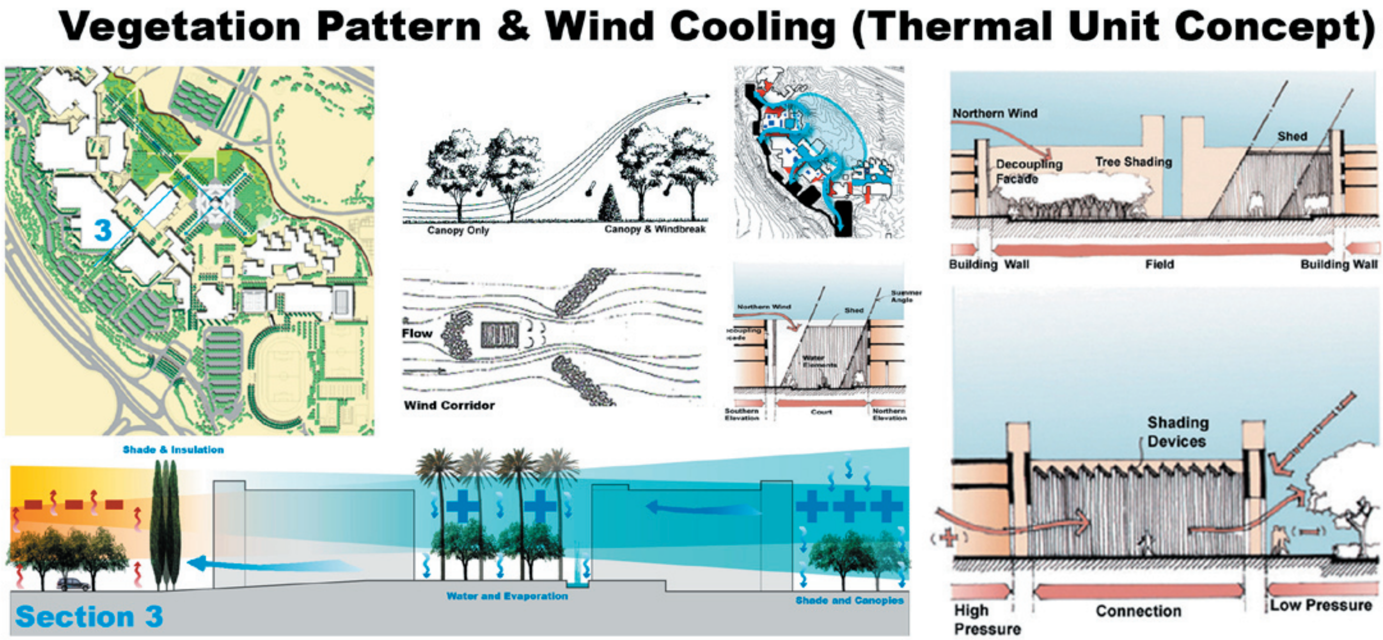

Fig. 5.69, Vegetation and Cooling (Thermal Unit Concept) (Chapter 4, Abdelhalim & Sasaki and Robinette).

4. Vegetation Pattern and Wind Flow

Many findings of the research described the relation between vegetation and wind flows. For instance Robinette referred to techniques in which we can guide the air as shown in figure 5.70a. In my design concept the air movement in the horizontal plane was directed through a kind of wind catcher created by palm grooves while the Paradise Garden directed the air direction through the axial corridor and the winding wall. On the other hand, I also worked on lifting the air up by deflection through the palm trees as shown in figure 5.70b. In order to prevent wind blockage and assure the wind lifting from down to up a group of canopy trees were located under the palm trees in the flow direction. The aim of this strategy was to provide the Garden Paradise with cool and fast air as possible.

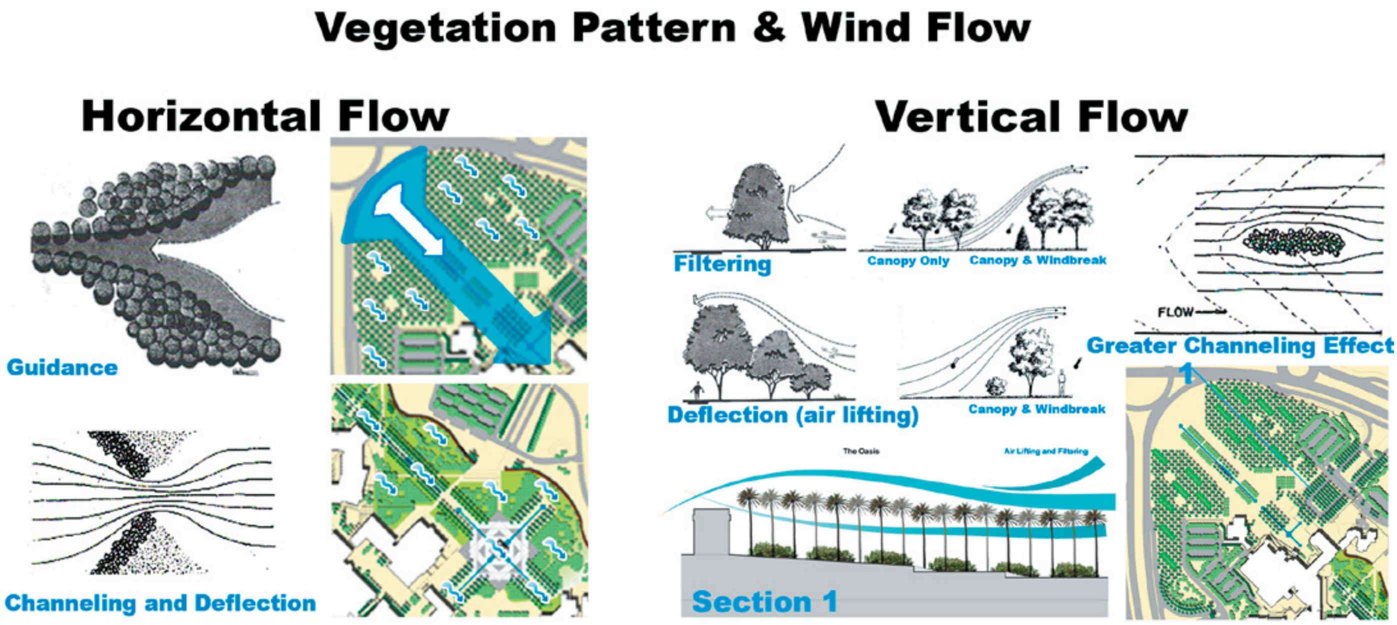

Fig. 5.70, Vegetation Pattern and Wind Flow (a) horizontal flow, (b) vertical flow (Chapter 4, Robinette).

5. Vegetation and Shade

The use of vegetation for shade might be the most common strategy for micro-climate improvement. Robinette and many others classified two ways to create shades. The first is mainly related to creating shade on the vertical level in order to shade buildings or even by creating dead air areas to insulate the attached buildings. As shown in figure 5.71a, the whole south-west facades were adjoined with columnar tall plants in order to maximize shades on the facades. On the other hand, figure 5.71b shows the use of vegetation to shade the horizontal plane. Through canopy trees all parking areas and walkways were covered by canopy trees. Above all, the Garden Paradise was intensively covered by canopy trees. Approximately more than 50 percent of the Garden Paradise was shaded through canopy threes. Therefore, the use of vegetation for shade might be the most efficient way to improve the micro-climate and conserve energy.

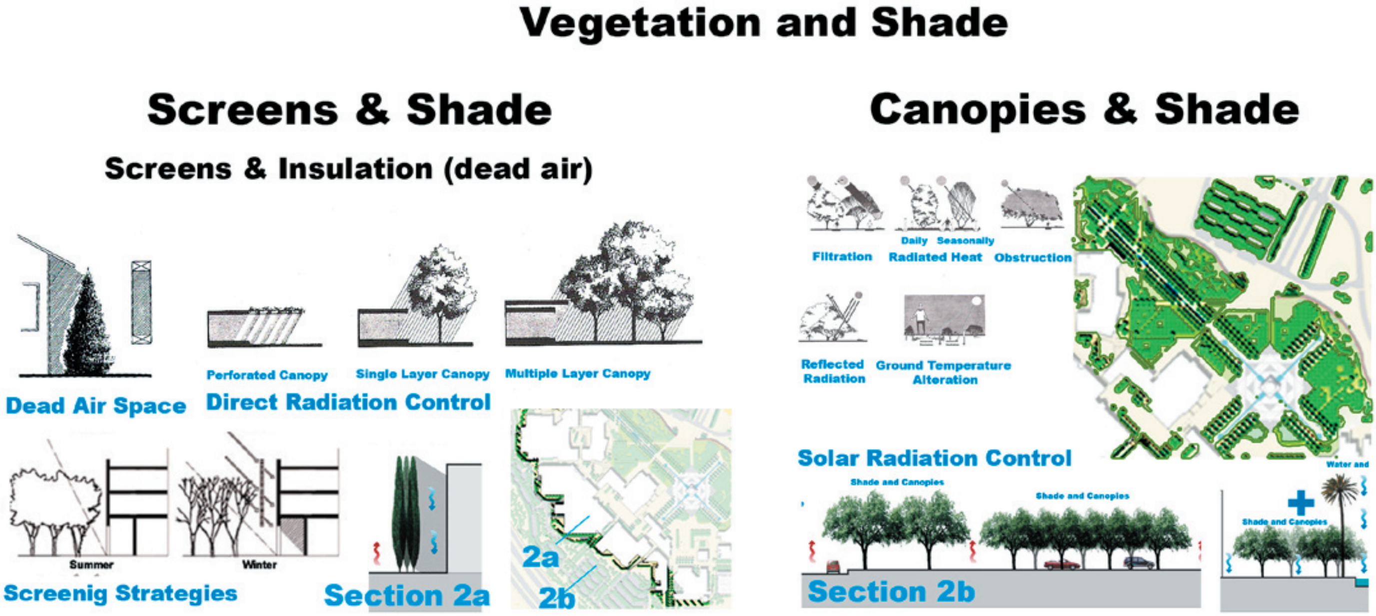

Fig. 5.71, Vegetation and Shade (Chapter 4, Abdelhalim & Sasaki and Robinette).

6. Evaporation and Water Distribution – Water Surfaces and Wind

The sixth strategy used in my design was related to water. Due to the scarcity of water I could not create large water surfaces that face the wind and cool the air before reaching the outdoor or buildings. But at least I created a cool air reservoir area that works for relatively cool air intakes. This has been done by distributing water fountains, cascades and surfaces all over the Garden Paradise and sometimes in the AUC Oasis. At least 5 to 7 percent of the Garden Paradise surface was covered with water as shown in figure 5.72.

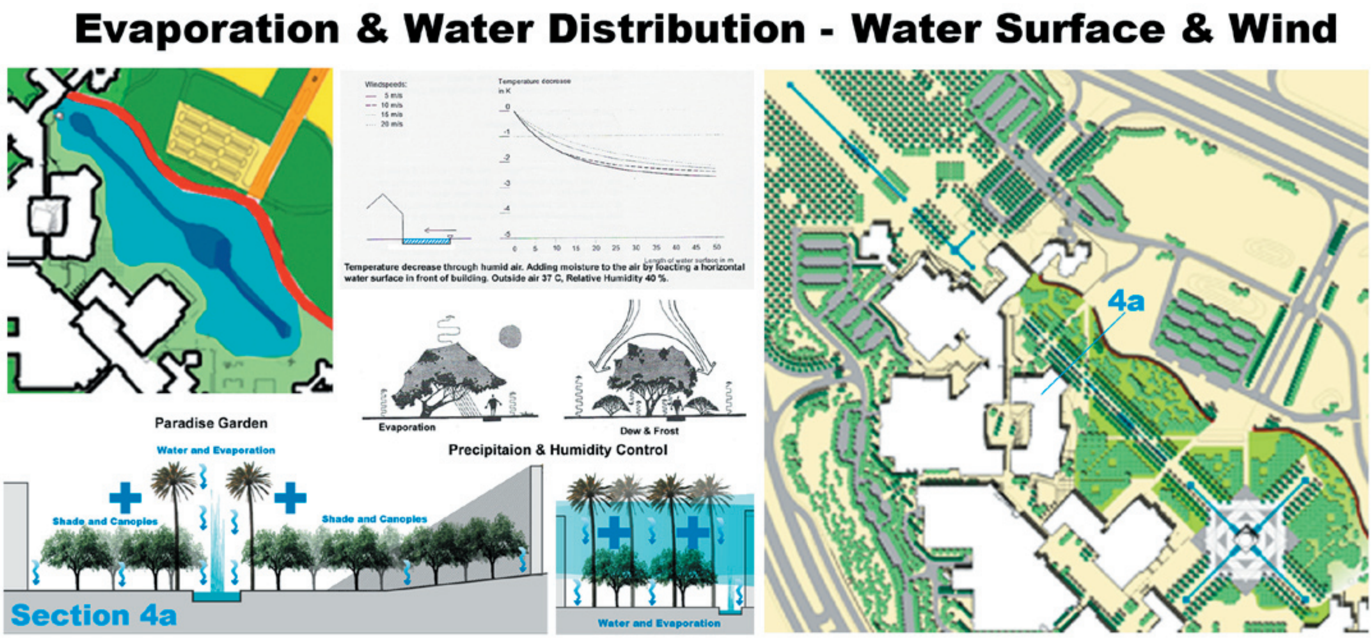

Fig. 5.72, Evaporation and Water Distribution – Water Surface and Wind (Chapter 4, Abdelhalim & Sasaki and Robinette).

7. Architectural Elements and Energy

Finally, I used different architectural elements such as trellis, pergolas, ramadas, tents, canopies, car ports and other elements that can enhance the micro-climate or create protected outdoor spaces. Sometimes even solar panels were integrated in these elements in order to maximize the energy gain. Figure 5.73 shows some examples that were used in the design.

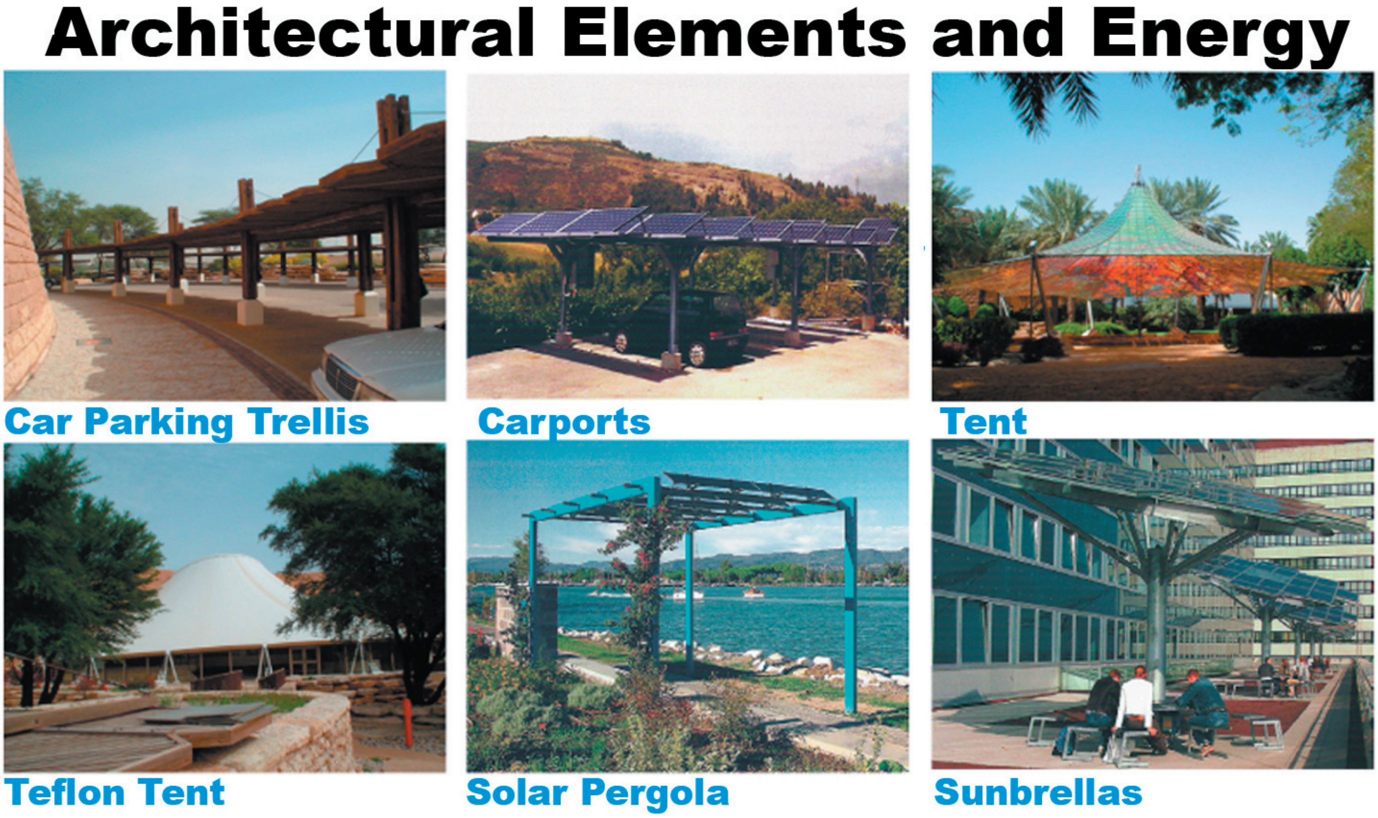

Fig. 5.73, Architectural elements and energy, (Chapter 4, Hermannsdörfer, Author).

Conclusion

Finally, I would like to state that these 7 strategies could be very efficient in order to enhance the micro-climate and conserve energy. Landscape architects must be aware of these strategies. Also the landscape architect should create a balance between these strategies in order to achieve a maximum improvement with the lowest energy and water consumption rates. Figure 5.74 is illustrating all strategies used and tested in my design concept. Some of these strategies are verifiable before implementation and other are not verifiable. Therefore, the assessment or verification of the design itself might be an important step in order to achieve an efficient design.

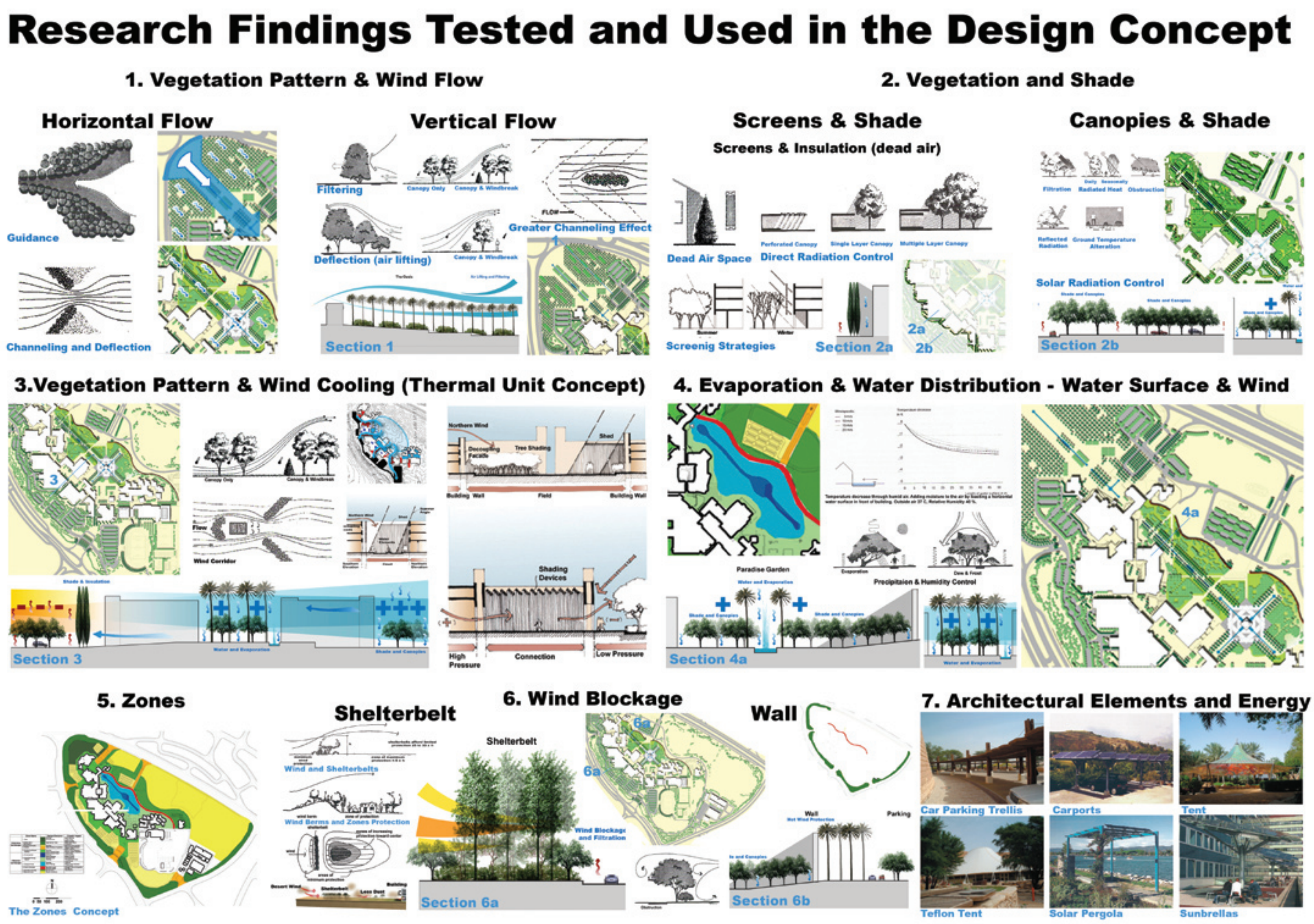

Fig. 5.74, The 7 main Strategies. (Collective references).

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Chapter 6

Conclusion

Chapter 6

Chapter 6: Conclusion

As a final chapter, this chapter will highlight the most useful design guidelines and principals for energy conservative landscape design in Egypt. Besides, this chapter will discuss the ways to verify a design in relation to the applied guidelines in order to check the suitability and effectiveness of the applied design decisions.

6.1. Design Criteria for Micro Climate Improvement and Energy Conservation

Many people activities take place in bounded outdoor spaces. The duration and intensity of the use of an outdoor space may be greatly affected by the comfort (or discomfort) conditions existing in the area. Therefore minimizing the duration and level of uncomfortable conditions can greatly increase the benefits derived from the outdoor space. Therefore the landscape architect should be prepared with a group of design principals and design guidelines that can help him to improve the micro climate and conserve the energy. During the design of the outdoor environment landscape architects should consider some environmental factors. The below listed environmental factors are the main factors that can affect human comfort:

1. Solar Radiation/Shade (Radiation Control, Heat Control, Albedo Control and Glare Control).
2. Wind/Natural Airflows (Dust Control, Soil Erosion Control and Natural Ventilative Cooling).
3. Evaporation/Water (Evaporative Cooling and Diurnal Cooling).

In Egypt, exposure to the sun and high temperatures outdoors is the major environmental factor that often causes heat discomfort and stress during summer. The first and most essential role of landscape design is to (1) provide protection from direct and indirect exposure to solar radiation. In Egypt, shade is a perquisite for improving the outdoor spaces and there are two reasons for that. Firstly, protection from solar radiation has a larger physiological effect in reducing heat stress than the effects that can be expected from lowering the air temperature without providing shade in outdoor spaces. Secondly, shading does not involve any expenditure of energy or water for irrigation, as do almost all systems that can lower the temperature in an outside area. The second and third important issues that landscape design should deal with are (2) providing comfort through the cooling effect of the wind and (3) lowering the air temperature in the outdoor space by evaporation and evapotranspiration.

Therefore the first decision considered in hot arid areas is to provide shading. Also designers attempt to lower the temperature by a water source. But in order to lower the air temperature in an outdoor space, the wind flow through this space should be minimized. Because the lowering of the air temperature in outdoor space requires that the warmer wind penetration is minimized. The conflict between the two approaches exists because minimizing the wind penetration in an open space usually is accomplished by fixed devices. The wind blockage can not be turned on and off, as is possible in a building. Therefore, once the space is semi enclosed by such devices as surrounding walls, shrubs, or earth berms, the wind cooling effect is minimized even during periods when wind would be desirable (Givoni, 1996).
In arid regions, the choice between the two options depends on the local typical maximum air temperature. In places where the maximum temperature is below about 30 degrees centigrade, wind can be very effective as a comfort element. In such regions shading the space, while leaving it open to the wind, might be the best approach to minimize heat stress. In places where the daytime temperature are higher, the humidity is lower than 50% and water is available, lowering the temperature and blocking the wind may be the preferable approach. This could be accomplished by the various mean discussed in this chapter. But in all cases, quantitative comparisons and measurements of the comfort conditions should be always done after the implementation by the use of the comfort indices.

Finally, planting trees, vegetation and shrubs within and around the periphery of an outdoor space can effectively reduce the reflected solar radiation and the long wave radiation emitted from the surrounding area. Moreover, if the surfaces of the surrounding element are wetted, while shaded, their temperature will drop toward the ambient wet bulb temperature and in arid regions, these temperatures can significantly lower than the ambient air. Lowering the air temperature of an outdoor area below the ambient air level during air time involves, directly or indirectly, some form of water evaporation and or some expenditure if energy. On the other hand, wind blocking minimized direct physiological cooling effect of the wind. This conflict between “ventilative cooling” and temperature lowering” should be considered while the choice between the two options should depend on the local typical maximum air temperature as mentioned before.

The following list is a summary of the Design Criteria presented in this thesis. The design criteria are classified based on Chapter 4’s classification system and are in related references follows:

6.1.1 Site Design

- Use earth forms to shade or screen the exposed walls of buildings.
- Use earth forms as windbreaks.
- Use earth forms to channel winds or breezes.
- Hard surfaced materials should be used for terraces and other outdoor sitting areas, since solar heat on hard surfaced terraced, patios and courtyards will increase the length of the evenings.
- Employ medium colours on sun exposed surfaces, use dark colours only in recessed places protected from summer sun. Light colours will generally be too reflective in the hot arid region. Dark colours, except in special places, absorb more radiation than desired.
- The total non-permeable paving areas, such as parking lots, side walks, and street should be kept to a minimum. Those paved areas which must be used should be shaded through the use of vegetation, landforms, walls, screens, canopies and overhangs. Grass ground cover, gravel or other permeable surfacing material should be used in place of non-permeable paving around all walls of a building since the lower light reflectivity may be employed as an element of cooling. Place trees so that they overhang and shade roof areas.
- Lighter coloured materials should be used on the north side of structural elements, with darker colours on the south side.
- Orient buildings to minimize the impact of excessive solar exposure on east and west walls. Glazing should be kept to a minimum and shaded where possible. Shaded glass transmits to interior spaces approximately one-third as much heat as an unshaded window surface, depending on location and orientation. Screens prevent direct radiation from heating interiors and help reduce glare both inside and outside.
- Keep paving to a minimum. Paving should be reserved for streets and heavily travelled pedestrian ways. Where paving must be used for outdoor social or recreational activities use strategically placed pergolas, vegetation, or other shading devices, to protect key areas. Consider breaking up paved areas with grass or other groundcovers that grass or other groundcovers that are less reflective and radiate less heat. Locate areas with excessive paving away from or leeward of buildings to allow prevailing breezes to carry away unwanted heat.
- For high density developments structures can be situated so as to shade one another as well as outdoor living areas and circulation ways, especially if buildings are close, walkways are narrow, and open spaces are small. To realize the fullest benefits from shade produced by the clustering of structures, streets should kept narrow and generous rights of ways avoided. Opt for small parking bays and interior courtyards that are easily shaded. Buildings with cantilevered overhangs and deep-set walls provide natural shade.(Miller, 1980)

Summer

- Avoid valley or bowl-like settings which tend to overheat during day without the benefit of cooling day breezes. High, exposed hillside settings are subject to high winds, dust pollution, and increased solar radiation.
- East and west exposures are subject to heat buildup; west-facing slopes experience the highest annual temperatures of any slope orientation.
- Location on site to east of a high land feature will decrease hours of solar exposure and protect from wind and dust.
- Need to cool hot desert breezes.

Winter

- Valley or bowl-like settings become cold air pools at night and prolong under heated period. High exposed hillside settings are good for solar heat gain.
- Best winter exposures for solar heat gain range from SE to SW.
- Location of site leeward side of prominent land feature to block winter winds.
- Bodies of water tend to modify temperature extremes of adjacent land mass.

Balance between summer and winter

- Lower hillside locations are preferred to take advantage of modifying air movements in both summer and winter. Thermal belts make good sites for desert dwellings; these belts are located on sloping terrain between colder elevations above and temperature extremes in valley below.
- A south-east facing slope is the optimal, allowing good winter exposures and blocking summer afternoon sun.
- Locate site adjacent to high land form in order to thereby decrease sun and wind exposure and provide a psychological ‘place’ in desert vastness.
- Sites located leeward of large bodies of water or irrigated fields will benefit from evapotranspiration cooling and temperature modification.

(Clark, 1980; Cook, 1980; Fredrickson, 1980; Givoni, 1980; Golany, 1980; Legorreta, 1980)

6.1.2 Architecture and Urban Fabric Design

Summer

- A dense building configuration with small shaded open spaces is desirable. Unit buildings benefit from being grouped for mutual protection from the sun and heat while shading exterior spaces between them. Groups or clusters of buildings increase volume effect, providing mutual shading and minimizing sun exposure.
- Arrange grouped building clusters so that east and west exposures are minimized.
- Tall, massive buildings benefit from reduced solar exposure to roof while providing shade for microclimate around structure. Walls of buildings and gardens should be tall to create shade for exterior living and circulation spaces. Western exposures need to be sheltered from afternoon sun.
- Need to channel hot summer winds around building, while allowing night-time cool air to penetrate structure.

Winter

- A dense configuration is desirable, but with unshaded exposure of south facing walls; multi-story or grouped units benefit from reduced heat loss per unit.
- Buildings should be grouped so as to increase southern exposures.
- Tall buildings can be placed so as to serve as thermal heat storage for both interior and exterior spaces with the potential of increased southern exposure on 2 floor units. Walls of buildings and gardens should open to SE,S and SW to allow maximum penetration of winter sun. High walls that shade exterior living areas are undesirable.
- Winter winds need to be deflected around building and exterior living spaces.

Balance between summer and winter

- The single free-standing building is the most difficult to heat and cool, because all walls and roof must repel heat in winter. Multi-storey buildings can reduce total BTU gain and loss. Optimal from the desert individual houses would be row buildings, carefully arranged to provide mutual summer and winter protection.
- Design connected building groups along their east-west axis, with openings to E, SE, S, SW for optimal solar protection (summer) and solar exposure (winter). Avoid facing groups of buildings due west (undesirable exposure in summer).
- Tall, massive structures should be closely grouped so that shade is cast on public spaces in summer while allowing exposure to winter sun for heat build up in walls and exterior areas. The taller the house walls, the larger the courtyard. Two-story or stacked continuous units can benefit in both summer and winter. Orient building and garden walls generally north-south, with higher walls to west in order to block summer afternoon sun. Design overhangs and place structures to shade walls and walkways only during summer season.
- A staggered arrangement of buildings units with carefully arranged planting can discourage unwanted winds and encourage desired breezes.

Public Spaces Design

Summer

- Heat build up in man-made areas tend to elevate temperatures in down town areas, creating undesirable microclimatic effects. Downtown temperatures can average 12°C degrees higher than suburban temperatures for same day. Large concentrations of parking provide a heat sink during the day and radiate heat throughout the night. Parking should be covered or at least shaded. Large parking areas become a source of runoff during rainy season.
- Walking is considered a hardship except in early morning or at night.
- Fountains and pools of water in public areas have a great cooling effect and can reduce the harshness of the desert landscape.

Winter

- Heat build up in downtown areas during underheated period can have a positive effect by elevating night time temperatures. Large areas of parking increase glare from cars and collect water during rainy season.
- Walking during day is considered healthful and a pleasant experiences.
- Cooling from evaporating water during underheated days and nights is to be avoided.

Balance between summer and winter

- Design for summer critical condition, by restricting impermeable paving to traffic areas and heavily used pedestrian walkways. Break up large paved areas with shaded areas or with zones of vegetation and ground cover. Locate excessively large areas of paving on leeward side of structure so that any heat build up will be blown away from buildings by summer breezes. Break up parking into many small bays and parking into many small bays and parking pockets and shade with deciduous trees or shading constructions.
- Minimize distance between public and residential areas, and create half or full shade for walkways during summer.
- Operate fountain or spray on seasonal basis so that public spaces do not become uncomfortably cool in winter. A summer fountain can become uncomfortably cool in winter. A summer fountain can become a winter reflecting pool or heat sink.

6.1.3 Landscape Design

To make it cooler:

- Make extensive use of shade trees as an overhead canopy
- Use vines, either on an overhead trellis or canopy or on south and west facing walls
- Use overhangs, trellises, arbors or canopies where possible (this makes an area cooler in the daytime and yet warmer at night since it limits the release of colder air into the colder night air)
- Use ground covers or turf on earth surfaces rather than paving
- Prune lower braches of tall trees and remove or thin lower trees and shrubs to improve and increase air circulation.
- Provide for evaporative cooling from sprinklers and pools
- Use areas on the north and east sides of structures for outdoor activities
- Remove windbreaks, ether natural or man which would limit or hinder airflow especially during the warmer months.
- Locate activities on the leeward side of water bodies.
- Orient all activities to the north and east of structures.
- Use extensive coarse textured deciduous, shade trees and vines.
- Provide shade on the south side of all activities and areas.
- Do not block or curtail down-hill airflow.
- Use overhangs, awnings and canopies during the day which may be moved aside at night to allow for release of the trapped warm air.
- Use extensive turf and ground covers throughout the site.
- Use a minimum of hard, paved surfaces. Shade all paved surfaces with structural or vegetational canopies.
- Use raised decks for paving where possible.
- Use vines, shade trees or canopies over all exposed wall surfaces.
- Prune lower growth on all trees to allow for increased air circulation.
- Plant to divert winds or breezes throughout the site.
- Provide pools, fountains, spray devices and irrigation as extensively as possible throughout the site.

To make it breezier:

- Remove all restrictions to natural air flow patterns on a site
- Prune all lower branches of taller trees
- Curtail and limit all low plant growth between 30 cm and 3 meters high which would inhibit or limit wind flow.
- Locate outdoor activities in areas which have the maximum access to wind on a particular site
- Build decks or platforms on the windiest areas on the site in order to take advantage of natural breezes.
- Create natural wind tunnels or breezeways using either plant materials. Earth forms, architecture, fences or walls.
- Locate activities or areas on the sides of a valley wall to take advantage of the day and night wind flow patterns.
- Orient activities to the north and west quadrants of the site.
- Minimize or remove all windbreak elements or devices which block wind, breezes or airflow.
- Use structural, vegetational or geological elements to direct and focus desirable winds or breezes to areas desired.
- Prune lower branches of all trees in order to allow for easier air circulation
- Remove under story or low plant growth which blocks wind
- Locate activities ether on a hilltop, or a narrow valley floor or on a sloping hillside.
- Orient openings in mature vegetation to accommodate roadways and walkways so as to channel or direct wind flow.

Landscape and vegetation

Summer

- Rapid evapotranspiration of plants in hot sun and winds makes standard irrigation practices ineffective.
- Create cool air pools around house and in patio areas.
- Shading walls and windows is the most effective method of impeding solar heat gain on a structure.
- Vegetation can satisfy the need for visual privacy, glare reduction, reduced thermal gain on structure, night time radiation of heated walls.
- Shield house from sand storms and high winds.
- Large run-off from summer rainfall has to be channelled.

Winter

- Need for flooding or irrigation of non-native plants is less critical.
- Protect non-native plants from cold winter night time temperatures.
- Walls and openings on E, SE, S, and SW do not want to be shaded.
- In winter, house needs visual privacy, increased thermal gain of structure, decreased night time radiation.
- Deflect winter winds away from building openings and outdoor living areas.
- Run-off from water rainfall has to be channelled.

Balance between summer and winter

- Use native or drought-resistant imported plants and trees to conserve water and to harmonize with desert character. Use drip irrigation instead of flooding or sprinkling; flood periodically to rid soil of salt build up. Use mulch to retard evaporation around root zones of plants. Establish vegetation zones around structures according to water use.
- Concentrate planted areas in oasis fashion, adjacent to openings in house wall. Grouping vegetation provides efficient watering as well as protection from summer winds and winter frost.

- Deciduous planted should be used for shade in summer and transparency in winter. Foliage density determines the capacity to retain warm or cool air, and to create microclimate effects.
- The use of trees and vegetation requires proper and studied location. Simulate shadow seasonal shadow patterns before locating trees to insure desired shading. Misplaced vegetation can impede desirable heat loss by radiation during summer nights.
- Block unwanted winds by use of well placed earth forms, vegetation, and or architectural elements (fences, walls, buildings). Vegetated earth berms filter out noise and dust while deflecting wind. Use of shelter belts can block unwanted desert winds on flat sites horizontal protection will be 5 times the height of barrier.
- Rainwater catchment from drives, roof, and other paved areas should be channelled to vegetated areas or stored underground for later use.

(Clark, 1980; Cook, 1980; Fredrickson, 1980; Givoni, 1980; Golany, 1980; Legorreta, 1980)

6.2 The Seven Design Strategies

As a result of the 'Research by Design' methodology, the Design Concept was used as a verifying tool for the research findings. But the design recommendations were not enough to create an efficient design that corresponds to the research question of the research (how can landscape architects design a landscape that improves the micro climate in an energy conservative way?).Therefore, I looked back to my design in order to define the design decisions and strategies that were made in relation to the research findings. Finally, I came out with seven main strategies or findings that came out from the research. The seven strategies were tested and applied in the design concept in order to improve the micro-climate in an energy conservative way. Each is discussed in detail below.

1. Zones
2. Wind Blockage
3. Vegetation Pattern and Wind Cooling (Thermal Unit Concept)
4. Vegetation Pattern and Wind Flow
5. Vegetation and Shade
6. Evaporation and Water Distribution – Water Surfaces and Wind
7. Architectural Elements and Energy.

6.2.1 Zones

The major and first strategy that I adapted in my design was based on dividing the project into zones related to the function and activities in each zone. Moreover, each zone was named and linked to a design decision that should specifically fulfill a desired climatic improvement. See figure 6.01.

6.2.2 Wind Blockage

The second important strategy that was implemented in the design was dealing with blocking the undesired wind. One of the research findings was the shelterbelt. The shelterbelts were used as a design strategy for wind blocking and wind filtration through drought tolerant plants. Another way for wind blockage was made through the large wall which was built to enclose the Garden Paradise. The illustrations of Miller and Robinette are the main source for creating a wind blockage strategy in my design. See figure 6.01.

6.2.3 Vegetation Pattern and Wind Cooling (Thermal Unit Concept)

Strategy number three, is the thermal unit Concept developed by Sasaki and Abdelhalim in addition to Robinette's schemes that deal with vegetation patterns and wind cooling techniques were another main design strategy. The thermal Unit Concept was based on the idea of creating a relatively cool enclosed air reservoir through intensive landscape (canopy trees and water elements) in contrast to an open hot extensively planted area. This idea even influenced the landscape design of the courtyards and spine depending on there location and position which might fall in a high or low pressure zone. Finally, this Concept might not function always or all over the year times and most importantly, it functions only in combination with buildings and solid masses. But still I consider it as an important design strategy in improving the micro-climate. See figure 6.01.

6.2.4 Vegetation Pattern and Wind Flow

The fourth strategy, was based on many research findings that described the relation between vegetation and wind flows. For instance Robinette referred to techniques in which we can guide the air. In my design concept, the air movement in the horizontal plane was directed through a kind of wind catcher created by palm grooves while the Paradise Garden directed the air direction through the axial corridor and the winding wall. On the other hand, I also worked on lifting the air up by deflection through the palm trees. In order to prevent wind blockage and assure the wind lifting, from down to up, a group of canopy trees were located under the palm trees in the flow direction. The aim of this strategy was to provide the Garden Paradise with cool and fast air as possible. See figure 6.01.

6.2.5 Vegetation and Shade

The fifth strategy was depending on the use of vegetation for shade. This strategy might be the most common strategy for micro-climate improvement. Robinette and many others, classified two ways to create shades. The first, is mainly related to creating shade on the vertical level in order to shade buildings or even by creating dead air areas to insulate the attached buildings. The whole south-west facades were adjoined with columnar tall plants in order to maximize shades on the facades. On the other hand, vegetation was used to shade the horizontal plane through canopy trees. All parking areas and walkways were covered by canopy trees. Above all, the Garden Paradise was intensively covered by canopy trees. Approximately more than 50 percent of the Garden Paradise was shaded through canopy threes. Therefore, the use of vegetation for shade might be the most efficient way to improve the micro-climate and conserve energy. See figure 6.01.

6.2.6 Evaporation and Water Distribution – Water Surfaces and Wind

The sixth strategy used in my design was related to water. Due to the scarcity of water I could not create large water surfaces that face the wind and cool the air before reaching the outdoor or buildings. But at least I created a cool air reservoir area that works for relatively cool air intakes. This has been done by distributing water fountains, cascades and surfaces all over the Garden Paradise and sometimes in the AUC Oasis. At least 5 to 7 percent of the Garden Paradise surface was covered with water. See figure 6.01.

6.2.7 Architectural Elements and Energy

Finally, I used different architectural elements such as trellis, pergolas, ramadas, tents, canopies, car ports and other elements that can enhance the micro-climate or create protected outdoor spaces. Sometimes even solar panels were integrated in these elements in order to maximize the energy gain. See figure 6.01.

To sum up, I would like to state that these 7 strategies could be very efficient in order to enhance the micro-climate and conserve energy. Landscape architects must be aware of these strategies. Also the landscape architect should create a balance between these strategies in order to achieve a maximum improvement with the lowest energy and water consumption rates. Figure 6.01 illustrates the seven strategies used and tested in my design concept. Some of these strategies are verifiable before implementation and other are not verifiable. Therefore, the assessment or verification of the design itself might be an important step in order to achieve an efficient design.

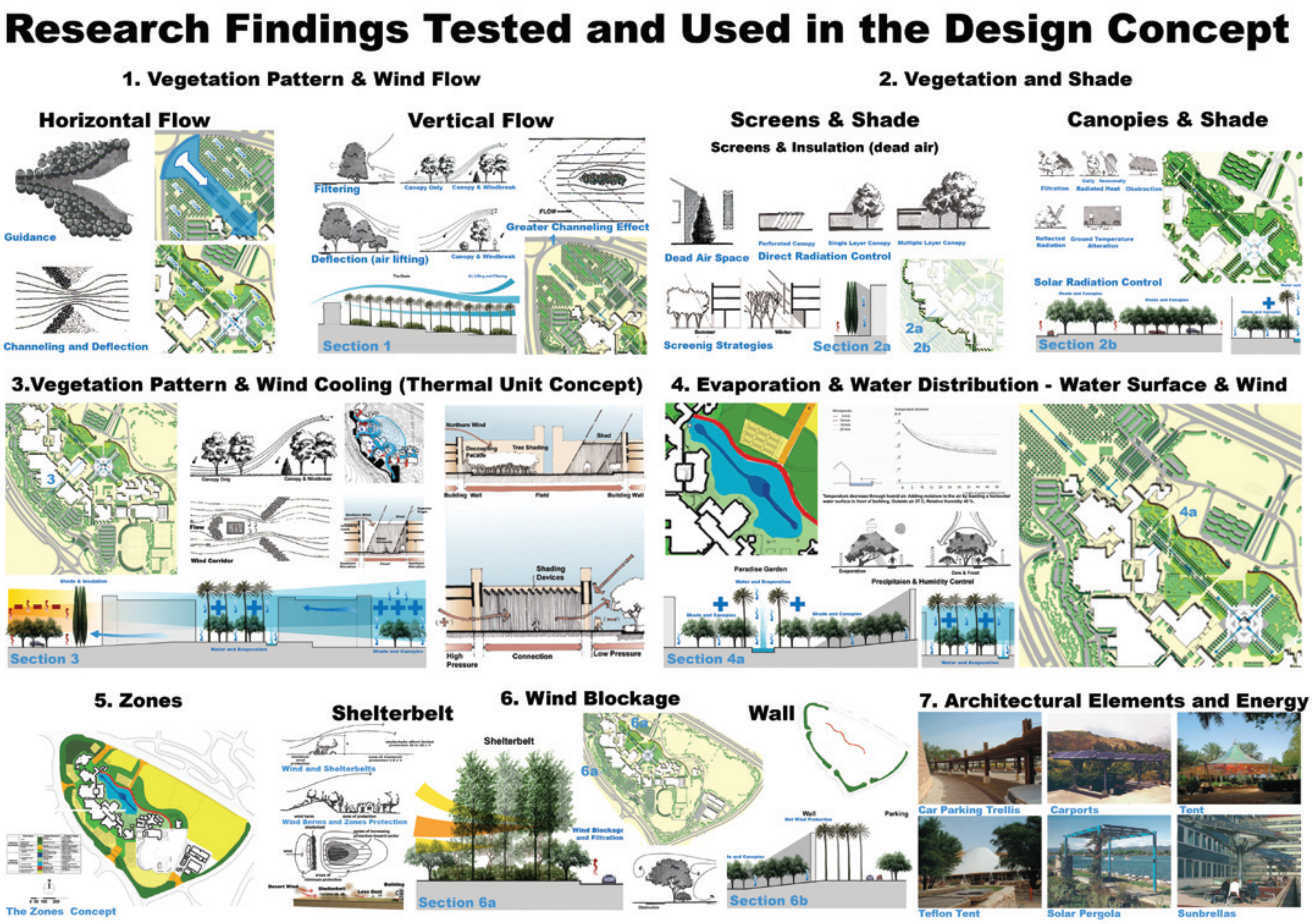

Fig. 6.01, The 7 main Strategies. (Collective references).

6.3 Assessment of Design:

The preceding chapters presented traditional and recent design principals and guidelines for micro climate improvement and energy conservation. In the same time, a design show case was presented as a tool for verifying these guidelines. During the 'Research by design' process, which was the research methodology, the design process was used as an evaluation tool for the generated principals the guidelines of the preceding chapters. But now, the design itself needs to be verified in order to close the last chain of the scientific cyclic research approach.

So, how can we know that this design achieved the expected results? The expected results were basically depending on a clear thesis: **Landscape architecture can improve the micro-climate and conserve energy.** But how far was this thesis applied in the design and did it effectively improve the micro climate and conserve energy? The answer to this question will be discussed in this chapter. The following text will try to answer these questions by exploring some assessment or evaluation techniques that might be applied to test the design concept.

Assessment

It is true that 'verification' or 'assessment' or ''evaluation' needs something tangible – data and statistics of all sorts to substantiate any kind of claim. However, in the case of passive landscape measures for micro climate improvement and energy conservation, this may not be entirely possible. The measurability may be assigned to several aspects; however, quite a few remain elusive in terms of quantification. Though the intangibles may be seen as iffy, there is no reason not to integrate such measures in the design that have been tried and tested for thousands of years. This echoes in the following statement:

"Since antiquity, man has reacted to his environment, using his faculties to develop techniques and technologies, whether to bake bread or make brick, in such internal psychological balance with nature that humanity historically lived attuned to the environment. Man's creations were natural when built of the materials offered by the landscape.

Hassan Fathy,1973.

Similarly to Hassan Fathy's way, of dealing with architecture, I believe that landscape architect should react on his environment using the traditional techniques for improving the micro climate passively while keeping harmony with the humanity and nature. In the same, the use of developed assessment techniques is very important, as long they are available and simple to use. Therefore, I intended to attend the Building Simulation class in Eindhoven during my study. This opportunity enriched my knowledge about simulation tools as a way of verification of the built environment. I shared opinions with experts about aerodynamics and natural ventilation in relevance to my design. I may state that it is still hard to measure the improvement but it is not impossible and for sure any positive feedback to the design is a plus in itself. The following methods are some investigation techniques that might be useful for verifying the master plan. By this I mean to list some tools that might be used in the future in reference to the design process.

6.4 Assessment Methods

There are many assessment methods that can help the landscape architect but the most important upon these tools is the visualizations that can help the designer to figure out directly the effect of his design decisions. But the most reliable assessment method is related to measurements. The disadvantage of field measurement relies in the difficulty of testing or evaluating the design before the implementation. There are different assessments methods or tools that might be applicable to verify the final landscape design. The following tools were described and explained during participation the Building Simulation Course in TU-Eindhoven. The participation was a trial to test the design and weather the plants can influence the air flows in the project. Besides, I was looking for a tool that can estimate the shade effect both on lowering air and minimizing the cooling loads of buildings. Finally, I would like to state the importance of these tools and how they are helpful in as integrated design support for landscape designers in order to improve the micro climate and conserve energy.

6.4.1 Wind Tunnels, Cigar Smoke, Soap Bubbles and Fog Generators

A wind tunnel is a research tool developed to assist with studying the effects of air moving over or around solid objects. In landscape architecture, a downscaled full model of the designed built environment should be constructed before being projected to wind flows. Threads can be attached to the surface of study objects to detect flow direction and relative speed of air flow. Dye or smoke can be injected upstream into the airstream and the streamlines that dye particles follow photographed as the experiment proceeds. Probes consisting of a Pitot tube can be inserted at specific points in the air flow to measure static and dynamic air pressure. See figure 6.02.

There are other easier tools using cigar smoke, soap bubbles or fog generators. The patterns in figure 6.03 were obtained as an aid to the designer to help him direct wind through or around his project. The patterns were obtained by drawing cigar smoke through steel wool trees which were denser than actual trees. The wind was travelling through the model at approximately one mile per hour. The effective model size was 4’’x 6’’ which was a limiting factor. The experiments were conducted in the hydraulics lab wind tunnel at the University of Wisconsin.

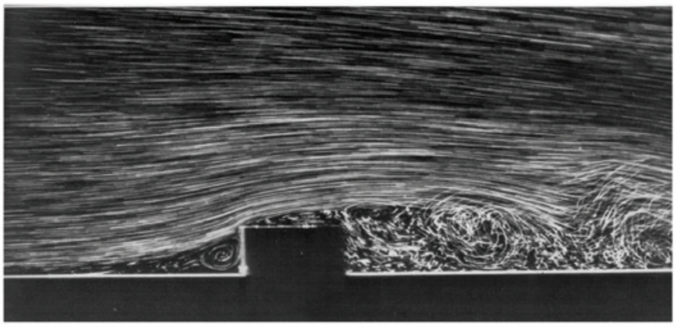

Fig. 6.02, Air flow around an obstruction, wind tunnel, (Van Dyke, M. 1997).

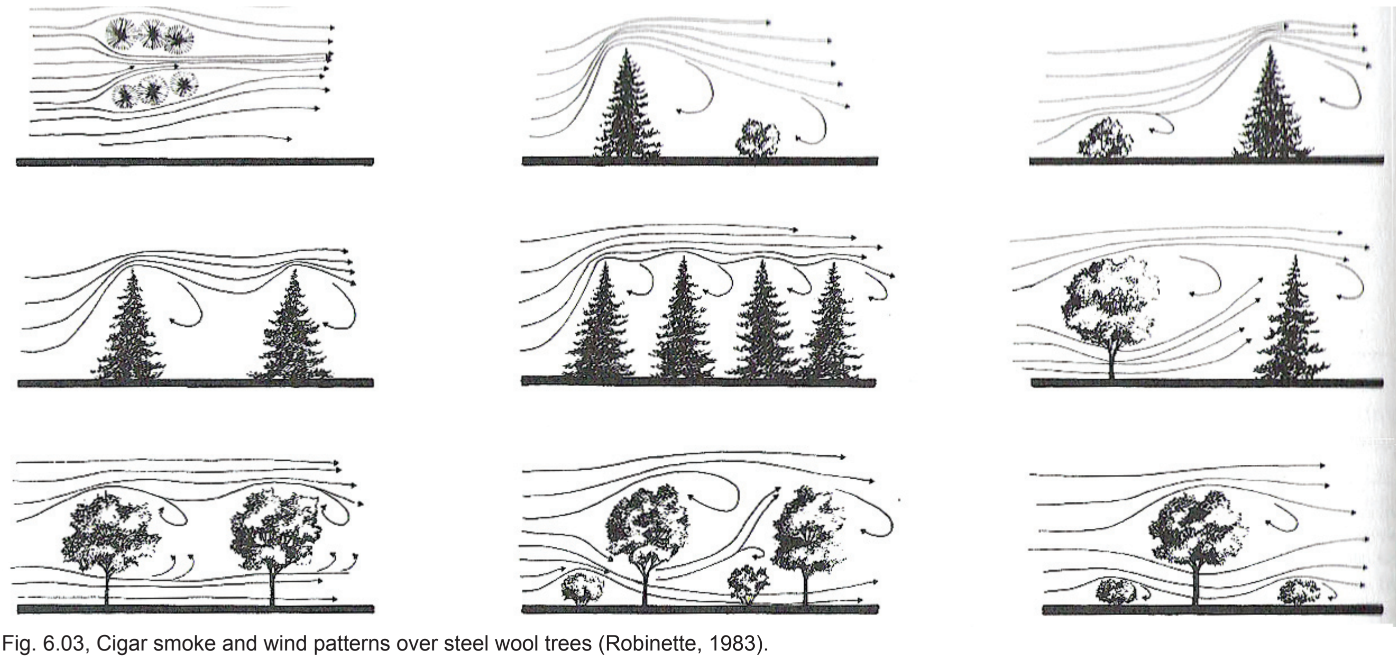

Fig. 6.03, Cigar smoke and wind patterns over steel wool trees (Robinette, 1983).

6.4.2 Simulations

Simulations are softwares for comprehensive building designs services. Data, for example on orientation and shading input manually on a room by room basis or can be imported from other software such as computer aided design (CAD) packages. The calculation equations will then calculate heating, cooling and energy loads. Some other methods, such as computational fluid dynamic softwares (CFD), calculated the air flows, temperatures and humidity without any measurements

CFD

Within the built environment, it is critical to assess a number of important outdoor characteristics at the design stage, including the ability to improve the micro climate of a open space, quantify solar radiation effects, analyze wind flow effects, study possible Buoyancy-driven flows scenarios, and predict occupant and pedestrian comfort. Computational Fluid Dynamics (CFD) software is a tool that allows you to create a "virtual airflow model" of your urban environment to assess and optimize these factors before construction commences. Modifications to an existing building can also be simulated using CFD prior to any physical alterations. This approach helps to prevent costly mistakes and minimize design risks while allowing innovation. See figure 6.04 and 6.05.

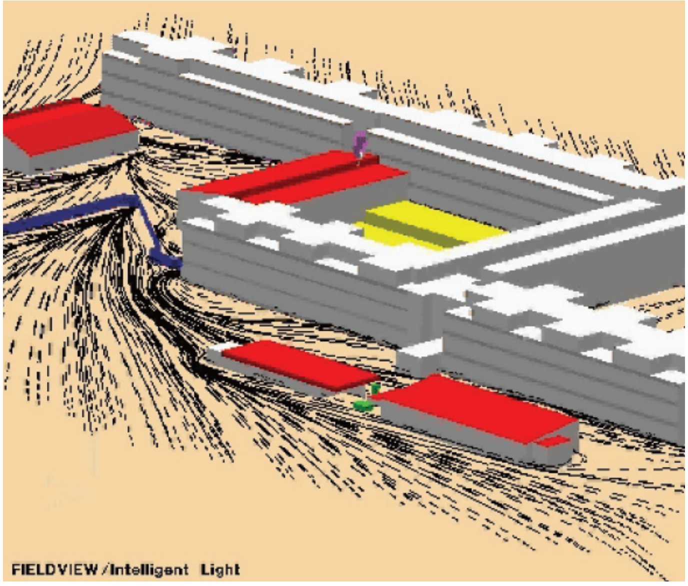

Fig. 6.04, Air flow presented outdoors represented by vectors (www.fluent.com).

Fig. 6.05, Artist's impression of Bullring in Birmingham, England, with superimposed CFD prediction of outdoor wind floor path lines coloured by local flow velocity.

Load and Consumption Reduction by Natural Ventilation and Shading

A number of methods exist for calculations the predicted energy consumption of proposed building at the design stage. These methods are based on the basic principles of heat loss calculations and energy efficiencies of heating and cooling and ventilation. Some these methods have been extended to formal a full environmental impact assessment incorporating energy, health and air flows. This type of information is useful in three ways:

1. It can be used to compare energy consumptions of alternative designs or the impact on energy consumption of modifications and new equipment.
2. The information related to the final design can be used as a standard against which act energy consumption in use can be compared for monitoring and targeting purposes.
3. The information related to the final design can be used as evidence to obtain building regulations approval.

Shading Analysis

Extensive studies could be conducted to determine the shading analysis for plants in relation to buildings. These studies identify the walls that are shaded most of the year, as well as the ones that are affected by solar radiation most of the year, as well as the ones that are affected by solar radiation most of the year. The analysis also identifies areas that would need shading for the windows. By the help of simulation programs we can examine the mutual shading between buildings and trees. Shading between buildings and other elements, like trees, may determine if a place will be pleasant or uncomfortable during the different times of day or throughout the year. This is because shading of walls in summer in hot climates is the most important design parameter to achieve good indoor climatic conditions with minimal energy consumption.

For example, solar gain reduction due to shade could be calculated from tree and building data with the Shadow Pattern Simulator (SPS) program. SPS calculates the percentage of each wall and roof surface shaded for each hour based on buildings and tree dimensions, orientation and distance of trees and adjacent structures from buildings, local time zone, latitude and, longitude, and time of the year. Shading could also be determined at monthly intervals for a year to be compatible with the building energy use simulation model. Shade from program trees could be classified based on predicted growth rate and size 30yr after planting, and characterized based on mature shape, bole and crown height, crown diameter and shade coefficient

6.4.3 Measurements

Finally, field measurements are the most reliable assessment tools to check the micro climatic improvement. Quantitative comparisons and measurements of the comfort conditions should be always done after the implementation by the use of the comfort indices. The depression of the wet bulb temperature (wbt) below the air temperature (dbt) in summer during the hot hours of the day is the most direct quantitative criterion for assessing the potential of evaporative cooling in a given location. The same could be done with measuring wind speeds, to assess cooling effect of natural ventilation. Similarly, albedo, glare and heat reduction are all measurable factors that can be related to the comfort indices in order to assess the micro climate improvement.

6.5 Conclusion

Out of all the above mentioned assessment tools, I tried to select some assessment measures that can be applied to my design. By reflecting on the Zones Strategy, which was developed and determined during the design in chapter 5.3, the effect of vegetation and water elements in the scheme were aiming to provide shading, cooling thorough evaporation and wind patterns (see fig 6.). In table () we can see that the expected climatic impact of each design decision could be quantified through by field measurement after the implementation. For example, the air speed, amount of heat absorbed and dry bulb temp. This assessment tool might be the most empirical and reliable way to evaluate the design, but still it can only be done after implementation. Therefore, I went to a simple shading pattern study for the new scheme. By calculating the shaded area of the outdoor garden I found that shades covered approximately 50 percent of the garden area. Obviously, the garden had to be shaded by deciduous trees or designed pergolas that allow winter sun and prevent summer sun. But this percentage of shade together with four water canals seems to lower the air temperature.
Besides, a CFD simulation can estimate the air movement while software like SPS can estimate the reduction of cooling loads in the spaces screened by plants and landscape elements.

Finally, I would like to say that simulations and assessment methods are just tools to help the landscape designer. The thesis of this study proofed that landscape design can improve the micro climate and conserve energy. Assessment tools are only a method that can take us to another level. In brief, traditional landscape design lessons should be adopted from history. But above all, the collected design criteria in this study are the main guidelines and principals for a landscape design that improves the micro climate in an energy conservative way.

Fig. 6.06, Zones Strategy scheme, adapted from Abdelhalim CDC by author.

Table 6.01, Measurements that can quantify the climatic impacts, adapted from Abdelhalim CDC by author.

	Zone Name		Design Decision	Climatic Impact	Measurements
Extensive Landscape	1. Filter		Shading Ground Cover	Sand Filtering Lower Temp. Better Comfort	Higher Air Speed Lower Ambient Temp. Lower Dry Bulb Temp.
	2.Shelter belt & Boundaries		High Barrier Trees	Wind, Sand Storm Protection	Less Wind Speed Cleaner Air (Dust)
	3.Parking and Roads		Shading	Minimize Solar Intensity	Less Direct Solar Radiation
	4. Entries		Water Surfaces Vegetation	Reduce Solar Radiation Better Comfort	Lower Temp. Lower Relative Humidity
	5. Building/Landscape interface		Shading Green Ground Cover	Reduce Direct Radiation Reduce Indirect Radiation	Less Direct Solar Radiation Lower Ambient Temp. Lower Dry Bulb Temp.
Intensive Landscape	a. Formal garden		Green Ground Cover Shading Water Surfaces	Lower Temp. Cool Reservoir Better Comfort	Less Direct Solar Radiation Lower Ambient Temp. Lower Dry Bulb Temp. Higher Air Speed Cleaner Air
	b. North East Facing Garden		Ground Cover Shading	Cool Reservoir Promote North Wind Lower Temp.	Less Direct Solar Radiation Lower Ambient Temp. Lower Dry Bulb Temp. Higher Air Speed Cleaner Air
	c. Canopy of trees		Shading Sand Filtering	Clear Air Reduce Solar Radiation Lower Temp	Less Direct Solar Radiation Lower Ambient Temp. Lower Dry Bulb Temp. Higher Air Speed Cleaner Air
	d. Desert landscape		Boundary Layer Minimum Water	Drought Tolerant Vegetation Soft Barrier	Less Wind Speed Cleaner Air (Dust)
	e. Boundary and Edge		Barrier Zone	Hard Barrier	Less Wind Speed Lower Ambient Temp. Lower Dry Bulb Temp.
	f. Reserved Land		Desert conditions		

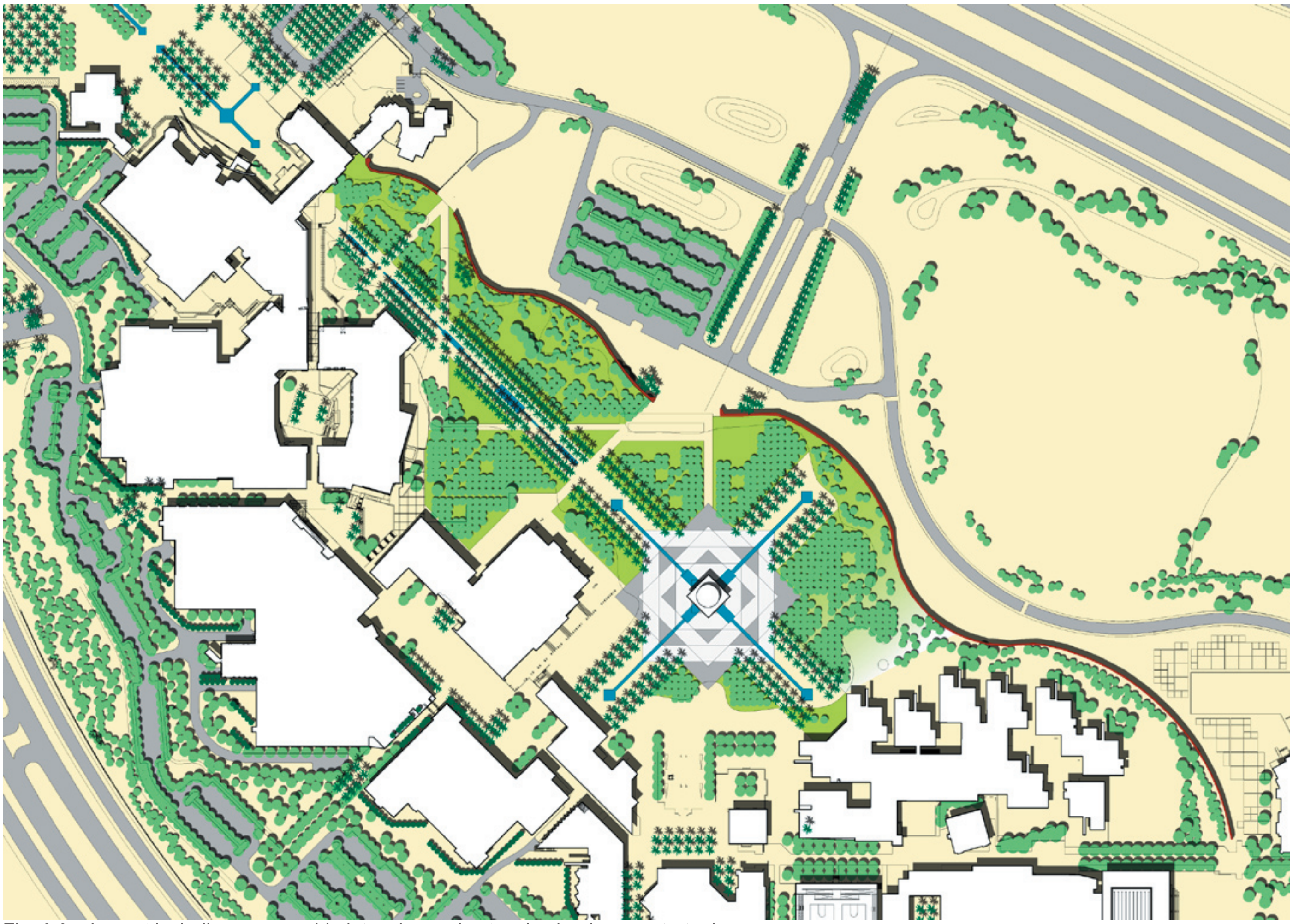

Fig. 6.07, Layout including measurable intensive and extensive landscape strategies.

Table 6.02, Concrete achievement to improve the micro-climate. .

Intensive Landscape Strategy			Extensive Landscape Strategy	
AUC Oasis	**Spine**	**Paradise Garden**	**Shelterbelt**	**S – W Screens**
Lifting Air	**Water Elements**	**Water Elements 5-7 % of area**	**Wind Blockage**	**Horizontal Shade**
Wind Filtering	**Canopy Trees**	**Canopy Trees 50% Shade**		
Palm Trees 66% Shade	Thermal Unit Concept	Thermal Unit Concept		

6.6 Epilogue

This study came to an end. Now, I would like to refer back to the preface and reflect my gained experience and thoughts from this study. The purpose of this discussion is to explore the lessons and models from this.

In Egypt, we must learn form our old experiences and desert culture and balance that appropriate experience with innovative contemporary design solutions to make it appropriate to us. For all of us, an energy conscious future will force us into patterns of landscape and architecture that we have recognized long ago. But to design effectively for the desert is not an easy task, although it is perfectly possible to achieve amazing reductions in cooling requirements for a desert building by careful study and planning. However, any landscape should be a reflection of natural, symbolic, technological and human patterns, factors that tend to emphasize regional quality in the desert environment.

As the Egyptian population is growing rapidly, there is increasing pressure to develop our arid lands, development that will tax these regions natural resources to their ultimate. In a time of global energy consciousness and concern for safeguarding natural systems, the real test for our desert communities will be to encourage growth and promote the unique quality of life that arid environments offer, while simultaneously preserving the very fabric of the desert ecology.

We can best accomplish this by working within the limits of the natural carrying capacities of arid lands. Physical planning must acknowledge the necessity to preserve water resources. Drought-tolerant vegetation must be chosen for landscapes over high water-demanding exotic species, and even rainwater must be captured and used as an important source of freshwater. Our dwellings need to be energy efficient, using passive solar energy designs that will eliminate our dependency on energy intense cooling and heating systems. Microclimates must be put to work for us, creating natural buffers against extremes of heat, cold, and desert winds. From all the above number of factors are obvious concerning the ability of landscape designer to moderate microclimate and thus to reduce energy usage and needs.

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Appendices

Appendix I: Rsearch Map.
Appendix II:The Questionnaire.
Appendix III: Interview 1 & 2.
Appendix IV: The AUC Design Program.
Appendix V: Plant List of Ancient Egypt.
Appendix VI: Plant List in Koran.
Appendix VII: Suggested Plants for Egypt.
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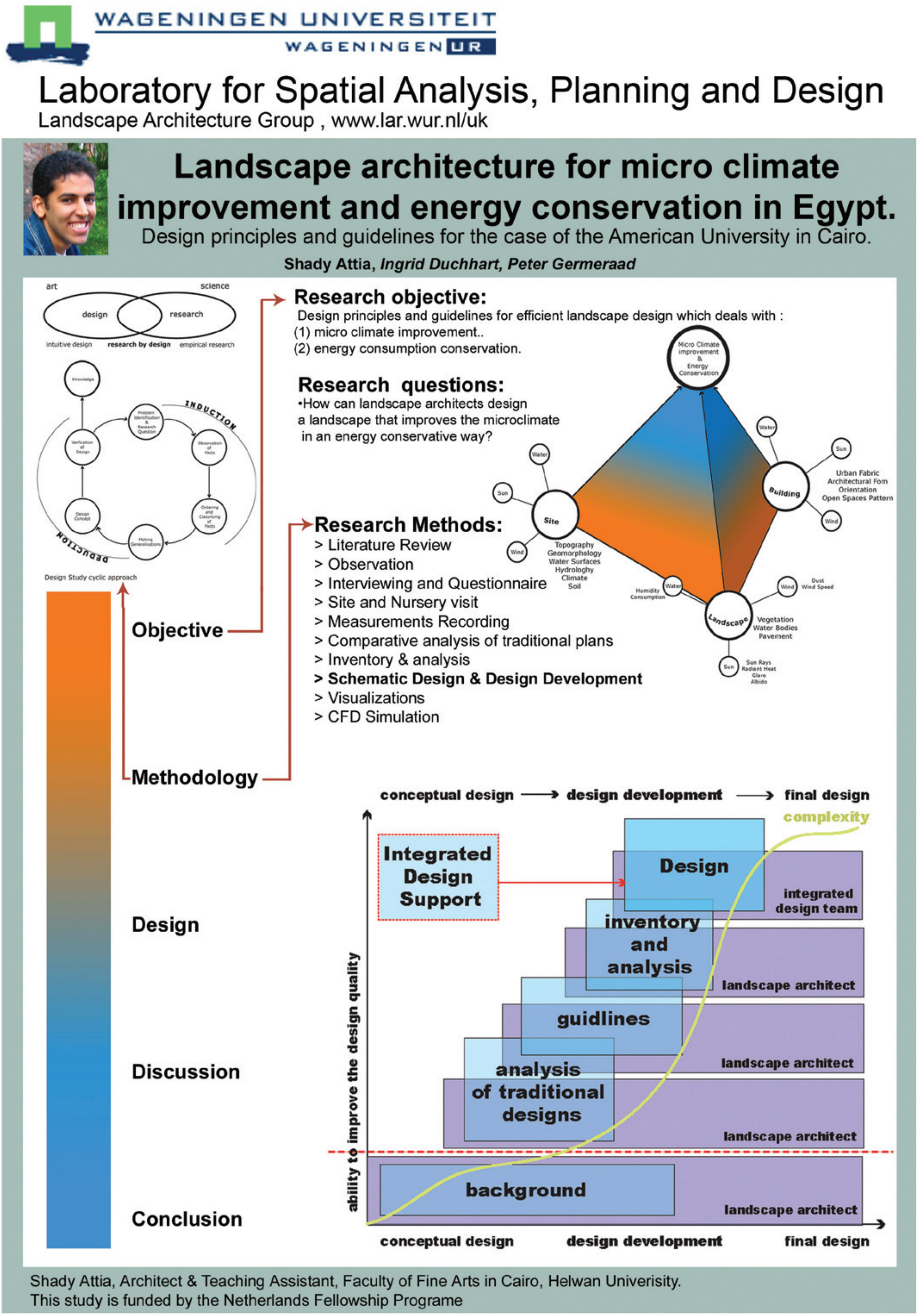
Appendices

Appendix I: Research Map



Appendix II: The Questionnaire

A. Questionnaire number one:
This Questionnaire was originally developed by the Trustee member Mrs. Edith Howe. It was first distributed to the Board of Trustee members, then adopted by the university in a slightly modified version that widely distributed among university constituencies. The following "tabulation" takes into account all the responses received (about 220).

Q.#1. What architectural features of the existing AUC campus would you like to retain?
The majority of responses listed the following features:
- The courtyards;
- Islamic/Oriental features; Arabic style; Fountains.

Q.#2. Which features of the existing AUC campus would you like to change?
The majority of responses listed the following features:
- Massive concrete style buildings;
- Lack of uniformity of design;
- The sense of clutter.

Q.#3. Is there a theme or image you envision for the architecture for the new campus?
Unfortunately, some people did not fully understand the question. The following represent most of responses:
- Arab style and Middle East.
- Modern;
- Lots of attention be paid to landscaping;
- Green spaces, palms and trees;
- Environmentally friendly;
- Blend of modern design with Middle Eastern element;
- The feel of "cool" oasis;
- Spacious, airy, "restrained" modern; practical and functional;
- Bridge between cultures;
- East meet the West in the land of Pharaoh;
- Village atmosphere;
- Smaller low rise buildings;
- Natural light;
- Stone and ceramic tiles, no concrete.

* In response to the same question, there were strong views of what the design should not be; of those:

- Not quick pre-fab look;
- Not Gothic, Pharaonic, Mamluk or Disney
- Not invasive, aggressive or arrogant;
- Not be a symbol of wealth or foreigner.

Q.#4. Which would you prefer to emphasise in the design of the new campus: the past or the future, the Middle East or the West, the desert or the suq ?
The responses to this three-part question were fairly balanced on the first two but showed a strong preference on the third one. The following are the majority responses:

- Past with future touch
- Past and future
- Combination of old and new, Middle East and the West;
- The feeling of Middle East on the outside and the West on the inside… a Western, pragmatic, technical core;
- Focus should be on the desert;
- American southwest but not adobe;
- Not suq

Q.#5. Should the design stand out or blend in?
Responses to this question were equally divided. Some felt that the new campus should stand out.

- Stand out for creativity;
- Stand out for excellence;
- Stand out for taste;
- Stand out but not be enormous.

Other thought it should blend in:

- Outstanding but not conspicuous;
- Blend in but be strong;
- Blend in, in terms of nature;
- Blend in with environment.

B. Questionnaire number two:
This Questionnaire was originally developed by Dr. Kenneth Toepfer the former Executive Vice President of AUC in an attempt to gauge the preferences/responses of the university community. It was posted on the new-campus web-site. It was slightly modified and distributed as a questionnaire to the various university constituencies.

Enclosed are the tabulated results of this questionnaire.

Questionnaire Number Two **To[illegible] responses received (60)**

General Planning / Design Guidelines for the New AUC Campus

	Strongly Agree	Agree
1. The new campus should be of a unified design which provides interest and variety within an overall scheme;	37	17
2. The new campus should create and enhance a sense of an interactive community in which students, faculty, staff and quests can communicate and work with one another in an hospitable environment;	47	13
3. Outdoor gathering and meeting places should be through courtyards and other devices to facilitate community interaction on a human scale;	36	24
4. The campus should for the most part be a "low rise" campus with a maximum of three stories unless usage otherwise requires a higher building;	37	18
5. The central campus should be a pedestrian campus with walkways, pergolas, and verandas that make moving about the campus on foot a pleasant experience;	45	15
6. All buildings will be designed to accommodate the needs of handicapped clientele and will meet or exceed U.S. and Egyptian building codes;	46	13
7. Student and faculty lounges should be provided in strategic locations to encourage interaction among colleagues within departments and buildings;	40	21
8. Adequate parking for faculty, staff and students should be provided;	53	7
9. Building and campus design better be compatible with local architectural traditions, but should not slavishly copy "ethnic" designs;	23	28
10. All buildings should be environmentally and user friendly;	46	12
11. Buildings design should respect the local climatic conditions;	51	12
12. Windows should open;	43	14

Appendix III: Interview 1

Interviewee: **Dr. Ir. Pieter W. Germeraad**
Occupation: **Landscape Architect**
Date: **31.01.2006** Place: **Wageningen**
Contact:**pw.germeraad@hetnet.nl**

1. **What is your experience as a landscape architect in the Middle briefly? What did you do and how much did you stay?**

I was teaching in the Middle East especially Saudi Arabia for about five years and since 1981 and 1980 I was involved in landscape design in Saudi Arabia and other Arabian countries Gulf countries.

And what kind of projects did you have?

Research projects yah of course municipal projects and that was … yah we did three administrational and even we had to work on different urban areas etc… social housing and for the rest it yah was design projects for whole cities yah smaller areas the premises of the hotels and retail and industrial financial centers.

2. **What kind of contemporary landscape or even historical landscape projects do you admire in Egypt?**

What I remember is already I think is more than eight or nine years ago, I was in Egypt in that time, I think especially the Cataract Hotel in Aswan it was a nice setting and it was as a landscape architect what you except of a place like that and from the botanical point of view I liked the Kissinger Island I think in Aswan too and there was another island and there was growing alpha alpha you know this color of alpha alpha they were using there it had a beautiful color because it was a landscape mode by the farmers but it has a radiation that I liked and that I was expecting in a region like Aswan, and then I think the big Island in Cairo what was in the middle ?

There is Zamalek?

And on the other side was a park on the left side. You have a park on the left side. But I remember this was then Island and there was a park which was close to the island ….. Forget it!

3. **How can landscape architecture improve the microclimate?**

I think yah there is different ways it can catch dust, it can catch cool if you have enough green mass, it can decrease the temperatures and the certain that it can guide cool air in certain direction if used in the right way that is in short…. And of course, as we discussed before that the combination of planting together with building…urban fabric and geomorphologic features they determine in fact how far the landscape elements will do one of the three things I mentioned before.

4. **Before starting design any project what kind of analysis do you do? And what kind of data you should always get before you start?**

There is a lot. I think the basic data regarding the living nature that is about existing planting there is of course, animals, birds etc….they have then the non living nature, soil, hydrology, geomorphologic layout, geology I think these are the four most important things. Then you look at the link of the site dealing with the surroundings. If it is related to urban or related to nature and then you do the analysis in fact you look at functional, you look at visual, you look at sounds, you look at…

And then there is in fact……So you understand the context of the site you are going to do something ……there are a lot of books about that but this is what I do anyway. And of course, you have to look to the historical parts. The historical aspects if it is related to certain area certain historical value. Then you have to look for whom you are going to make it. So you have to look at the culture of the people if there are people involved you are going to make a something for a certain group if you are dealing with children or with elderly there will be a different situation, but this is in short and there are a lot of books about that.

5. **What are your selection criteria for plant material?**

Soil and water availability.

How do you think it is important?

Well I think that the wrong plant on the wrong soil will die out so you will have no effect and I think that the water availability especially in the Middle East and Egypt is one of the most important factors because there is no water there is no plant so you have to consider that from the beginning and I think that the water is scarce. In most of the areas you have to be as *spaar* I mean you have to save water as much as you can.

6. **Then maybe what kind of plants do use most?**

That is not my field I have always someone who is an expert in planting because this is one of the parts I do not deal with.

So you think that landscape architects should know specifically the plants?

No, I know the main part what eucalyptus is and what I know what casuarinas is but when you really say that there are specific plants for landscaping then you have an expert in the office. And when I say I want this plant for example I mean this color and this flower, I give specifications then he finds me a suitable plant. Because you have to work every day with it and I'm more a planner and designer than a plant designer.

7. How do you deal with water as a design element and considering irrigation?
I try to do it. I always try to minimize the use of planting that needs that is going to be irrigated. So that means that you have to design in special ways for example a long road you have strong ambulances so you have to create like if you have a strong ambulated landscape but all this irrigated beautiful plant but in fact the first part is beautiful designs the rest you don't see it then you use special groups of trees and then you see it looks like heavily landscaped but it is like small pockets in such a way by using different heights and different levels so that you use minimum plants and water for irrigation by that you create maximum flowery. You know what I mean?

8. What is the importance of maintenance of landscape architecture?
I think the most important thing is to keep the cost as low as possible because they will come back every time so everything that should be designed should be have a low maintenance as possible. Maybe in Holland at the moment it is the extreme but I think that man power is still cheap in Egypt but in the future prices will go up. So I think you have to aim for the low maintenance on the long run. So you can now have a nice landscape because you still have the possibility for heavy maintenance for a low price but in the future I'm not sure because nobody designs for less than 5 years so you have to be aware. Anybody designs for at least a century.

9. How do you test your design?
Going back and then every couple of years I make a couple of photographs and talk to the people and see what they like of it and of course the media will give attention and the news papers will react if it is not good or good.
Do you have a way for testing the design before the implementation?
No.
No?
Well testing not the design what I do I go back the customers and the people then we discuss the design normally they are involved in the start making the design then we have the conceptual design and the feedback and then the final design and feedback then they have the possibility to say what they think about it. You change if necessary and if required and then yah you go for it and then at the end they just go look at it and use and if you find not good you can see it the newspapers. What I do myself I go every year or every two years I go make photographs and if there is something broken or not ok I send those back to the municipality and then I say hey you should change this and this to change the appearance and I give them a for advice and if they do it then its not my responsibility its not my responsibility.
10. What is the golden tip for a landscape architect in Egypt?
Understand the culture.
11. Would you like to say something more about the topic?
NO, its ok.
12. Dank u.

Appendix III: Interview 2

Interviewee: **Ehab Abd-ElAziz**
Occupation: **Design Manager, CDC**
Date: **06.02.2006** Place: **Mohandseen, Cairo**
Contact:**admin@cdchalim.com**

1. How did the New American University Campus project started?
The AUC wanted a new Campus and an architectural design competition was held in 1999. Firms from Egypt, Europe, and the United States submitted pre-qualifications to be considered for the planning-design of the new campus competition. A selection process, examining each firm's capabilities, previous experiences in similar projects, and quality of their previous planning and design work, resulted in a short list of 25. These 25 firms were asked to respond to a Request for Proposals, resulting in a second short list of 10 firms. Each of these 10 firms was rated independently by a panel of five persons. As a result, six firms were invited to participate in the competition. These firms were:

- Boston Design Collaborative (BDC) / Carol R. Johnson Associates (CRJA)
- Cannon
- Ellerbe Becket
- The Hillier Group
- RTKL Associates, Inc.
- Sasaki Associates, Inc./Community Design Collaborative (Abdelhalim CDC)

Sasaki Associates was the only international office with an Egyptian partner (Abdelhalim CDC). The architectural firm of Boston Design Collaborative (BDC) in partnership with the landscape firm of Carol R. Johnson Associates (CRJA) had been selected to develop the master plan for the New Campus Project. The AUC selected the design of BDC because their design was based on the idea of spine with surrounding courtyards, similar to the planning of the famous Fatimid Islamic street called 'el Moez le Din Allah".

After that, the AUC decided that Sasaki Associates & Abdelhalim CDC should work with the winner as a joint venture to include an Egyptian office the design. The new team worked for a year to develop the Master plan and they made more than five reports to develop the master plan. After that AUC wanted to divide the project buildings into packages so that every package will be designed by a different architect. BDC refused this packaging because they thought they will design the whole campus buildings alone. By then Sasaki Associates & Abdelhalim CDC took over and started to make a framework to group the campus into packages. Also Sasaki Associates & Abdelhalim CDC prepared a short list for a group of international architects who can join the design team.
Which means that the main objective of the competition was to create a master plan only?
Right. When the AUC started to think about buildings, we made framework to count and group the buildings of the Campus. Sasaki and CDC Abdelhalim share of the buildings was almost 50 percent of the total buildings. The rest of the buildings, an American office called Hardy Holzman Pfeiffer & Associates (HHPA) were assigned to design the library, they are a famous American office for libraries design especially in universities. The Campus Center and Students Housing was assigned to the Mexican architect Legoretta, Legorreta + Legorreta (L+L), who learned from the famous Mexican architect Luis Barragan. Ellerbe Becket (El Debrky), an American office, designed the Sport Facilities Center. Considering Abdelhalim CDC and Sasaki joint venture, Sasaki designed the Core Academic Center and the School of Business, Economics & Communications (BEC) and the school of Science and CDC designed the Performance and Visual Art buildings and the school of Humanities and Social Sciences (Huss) and Desert Development Center (DDC).

After this the project went into phases from the schematic design to the design development and every office worked directly under the AUC supervision while CDC was the prime architects who coordinate between all these offices. After the design development phase the project was heading to the construction documents phase. But there was a problem facing the international firms. The international firms were not familiar with the Egyptian local conditions and norms. Therefore the University asked CDC for a list of local Egyptian firms who has an experience with construction documents and who can make construction documents for international offices with high quality. A list was including very famous architecture offices like Sabour and ECG and finally they choose IHAF and Saleh Hamdy and Okoplan. While our office, made the construction documents in cooperation with Galal Hosney and Ismail Fahmy

H&F, because we were making international documents with the American building code which was difficult for us, therefore we went for the joint venture with H&F. By this the university guaranteed a certain quality and that the designs will be accurately implemented. We helped the AUC as prime architects to achieve this goal.
And how was it with landscape architecture?
Considering the Landscape Architecture, the AUC administration liked the work of the famous American office **Carol R. Johnson & Associates (CRJA)** during the competition phase. So the AUC assigned the landscape design of the master layout for CRJA. Then during the design development and construction phase the AUC was looking for an experienced local Egyptian landscape office. Sites International was assigned for the mission to create the landscape construction

document of the project.

After that the project went into the bidding phase. The AUC administration was looking for an international firm for the project construction. Many firms submitted their tender documents but the best firm who won, technically and financially was the Korean firm Samsung international in joint venture with Samcrete Egypt.

2. Why was this location selected for the new AUC Campus?
The AUC administration was thinking about a new Campus away from crowded city center. The Egyptian government offered land on 6 October location, El Sherouk and New Cairo. The AUC excluded El Sherouk, due to the distance. But by comparing 6 October with New Cairo, the AUC found that New Cairo is closer to Maadi and Cairo Airport. Also the land area was larger and the surrounding developments of New Cairo had higher potentials.

3. Before the competition, how did the AUC address the issue of Identity for the new campus?
The AUC's mission was based on five principals:

- Liberal art education
- General class rooms
- Community oriented campus
- Urban Harmony and architectural diversity
- Environmental optimization

But first of all the AUC designed a questionnaire and asked the students about their wishes for the new Campus. The majority of students wanted a campus which is representing the Egyptian identity but also modern technology should be integrated. They did not want a copy of an American university in Egypt.

4. Can you talk about the environmental optimization process at the new AUC Campus?
From the beginning we consulted HL Technick AG (Germany) and we prepared some workshops to achieve an environmental optimization in the design. Hl-Technick worked mainly in the buildings, they were trying to minimize the cooling loads for buildings and provide passive cooling ways through shading devices and thermal walls and other ideas. In cooperation with CRJA they both created 3 environmental optimization reports. Other Egyptian consultants worked on the environmental optimization of the AUC campus. Dr. Momen Afifi (Cairo Uni.) worked on the thermal insulation and wall sections while Dr. Hanan Sabry (Ain shams Uni.) was working on a daylight study. Dr. Maher also joined the teams
for studies related to shading by trees and pergolas and shading for the southern facades and such things. In addition, we recruited some offices to create special studies for the kitchen facilities, swimming pools, Buildings Management systems, Theatre, acoustics and furniture.

But mainly the design concept was based on the thermal unit concept. The idea of organizing the spaces as a field, a container and a connector was mainly driving the design to the environmental optimization (you can see the environmental optimization reports).

Thank you.

Appendix IV: The AUC Design Program (Brief)

The Program for the Master Plan
The master plan has been developed from the *New Campus Facility Program* which remains the source document for program information. The master plan accommodates 5,500 students and 1,500 faculty and staff—the base population of the campus.
The main program elements, as developed by Dober, Lipsky, Craig and Associates, Inc., are summarized in the following table with the allocated gross areas (gross square meters). These elements have been placed in groups to create an efficient campus. The programmatic groupings and their relational requirements as set out in the *New Campus Facility Program* have been analyzed and tested during the master planning process. The interrelationship of program and curriculum as well as the relationships between academic, campus life, and university support programs are shown in the Program Adjacencies diagram:

- The Schools of Business, Economics and Communication; Humanities and Social Sciences; and Sciences and Engineering:
- The Core Academic Center:
- University Classrooms:
- Research Centers:
- The Desert Development Center:
- The Library, Media, and Technology:
- The Campus Activities Center

• **AUC Square***:* To develop stronger connections between campus and community, the more public uses of these Campus Center programmatic functions will be located on the periphery of the campus, making them more accessible. These more public functions migrating to the edge include the university bookshop, the art gallery, a cafeteria and restaurant (possibly operated by private vendors) and an information center. With the development of AUC Square, the Campus Center remains focused as a center of student life and supports conference facilities within the university, comprising large classrooms, the large and small auditoria and the dining facilities.

• **Auditoria**

• **Dining Facilities**

• **The Athletics***, Physical Education and Recreation Program:* This program has been severely constrained in the downtown campus due to lack of space, and will be accommodated on the new campus in a major indoor sports facility for team handball, basketball, tennis and volleyball and other indoor sports. The facility will have seating for up to 5,000 spectators and may also serve as performance or ceremonial space. In view of the fact that full capacity seating is only infrequently required (e.g., for commencement) it is possible that this space requirement may be reduced, especially if alternative accommodation can be found reasonably close to the campus. Outdoor facilities will be provided for swimming, water polo and diving, as will fields and courts for soccer, track, handball, volleyball, basketball and tennis. A recreational trail, including a jogging and bike track, encircling the entire campus is envisioned. Facilities must be regulation-size even though most sporting activities will be recreational and non-commercial. It is envisioned that the AUC facilities will become a venue for national and regional amateur events.
As with the theaters, the sports facilities will be an important focus of social and recreational life on campus and should be visible and within easy reach of the campus center and student housing. In addition, the sports facilities will be an excellent means for making connections between the AUC and the greater community. Some of the facilities—particularly the fields and courts—might be considered for early construction to inaugurate the site prior to completion of the main campus facilities. In this regard, the siting of the facilities in relation to the neighborhood will be particularly important from the point of view of visibility, access to the site and car parking.

- **Student Housing**
- **Information Center**
- **Student Services**
- **Administrative Offices**
- **Support Services**
- **The Physical Plant**
- **The President's House**
- **Day Care**

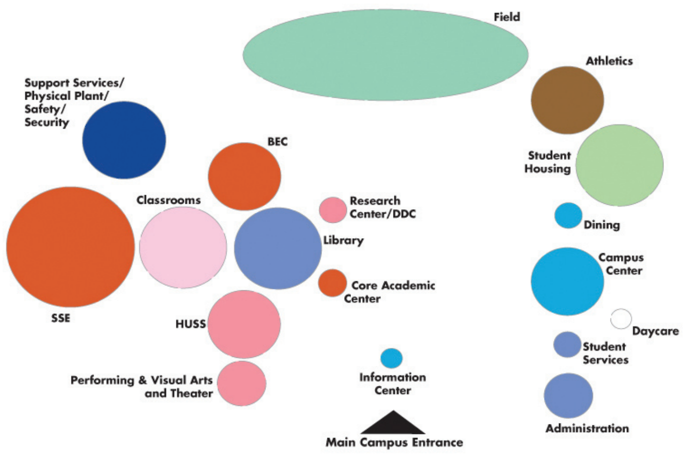


Fig. a.01, Programme adjacencies (Abdel Halim CDC and Sasaki Associates, 2000).

Outdoor Spaces
In many ways, AUC can take advantage of the warm and relatively dry climate to create outdoor spaces to supplement and enhance the academic and campus life experience. Strategically placed and environmentally protected, these outdoor spaces can be used for teaching and learning, gathering, socializing, lounging, studying, recreation, parking, and for quiet reflection.
In addition to the indoor facilities, the university requires the following outdoor resources. The table to the right identifies facilities and courts needed for athletics and recreation. For the spectator sports, the numbers of seats, envisioned as modular, movable bleacher units, has been included. In addition to defined outdoor campus life spaces, there should be provision for more casual

activities or occasional events that involve an influx of people. An example of the latter might be an attractive outdoor space near Student Services where students could queue at registration time. Vending kiosks might locate near small outdoor eating or lounge spaces, and student lockers might be accessed from the outside.

Parking
The university currently has no on-site parking. This will not be the case on the new campus. The initial target number of spaces on university land will be 1,500, distributed in parking lots convenient for students, faculty, staff and visitors. Provision will be made for safe and secure parking lots wherever the location. Parking within the campus will be strictly limited and controlled. Essentially, only vehicles related to service, delivery and emergency will be permitted inside the security fence. There will also be bus stops with adequate loading areas for buses transporting students and those who work on the campus. The buses will park in the carpool parking area when not in use.

Space Size Square Meters* Number Total of Spaces Square Meters

Team Handball/Basketball 46 M x 26 M 1,196 2 2,392 : 500 spectators 50 1 350
Pool: 50-M/water polo with diving ell 56 M x 84 M 5,264 1 5,264 :500 spectators 700 1 700
Soccer: 116 M x 75 M 8,700 1 8,700
Tennis: 6-court block 80 M x 54 M 4,320 1 4,320
Track: 400-m with soccer field in center 190 M x 90 M 17,100 1 17,100: 2,00 spectators 1,400 1 1,400
Volleyball: 28 M x 19 M 532 2 1,064
Academic Spaces
Amphitheater: 350 seats 400 1 400
Campus Life Spaces
Dining (adjacent indoor food service): 100 seats 150 1 150
Lounge (various locations and sizes)

References:
Abdel Halim CDC, Sasaki Associates. 2000. The Campus master plan. Cairo.

Appendix V: Plant List of Ancient Egypt

Common name	Scientific name	Dynasty or period
Date palm	Phoenix dactylifera	Pre-dynastic
Doum palm	Hyphaene thebaica	Pre-dynastic
Sycomore fig	Ficus sycomorus	Pre-dynastic
Jujube (Christ's thorn)	Ziziphus spina-Christi	I (Old Kingdom)
Fig	Ficus carica	II (Old Kingdom)
Grape	Vitis ainifera	II (Old Kingdom)
Hegelig	Balanites aegyptiaca	III (Old Kingdom)
Persea	Mimusops shimperi	III (Old Kingdom)
Argun	Medemia argun	V (Old Kingdom)
Carob	Ceratonia siliqua	XII (Middle Kingdom)
Pomegranate	Punica granata	XII (Middle Kingdom)
Egyptian plum (mokheit)	Cordia myxa	XIII (Middle Kingdom)
Olive	Olea europea	XIII (Middle Kingdom)
Apple	Malus x domestica	XIIII (Middle Kingdom)
Peach	Prunus persica	Greco-Roman
Pear	Pyrus communis	Greco-Roman
Cherry	Prunus avium	5 BCE
Citron	Prunus cerasus	2nd century CE

Source: Adapted from Darby et al., 1976.(Darby et al., 1977)

References:

Darby WJ, Ghalioungui P, Grivetti L. 1977. Food: The gift of Osiris. Academic press.

Appendix VI: Plant List in Koran

Manna, Al-Mann, Alhagi maurorum
date-palm , Botanical name: Phoenix dactylifera Family Arecaceae
olive Olea europea
pomegranate Punica granatum
grapes Vitis vinifera
Tamarix mannifera, Tamarix aphylla
Fig, Al-Teen, Ficus carica Linn
Cedar, Sidrah, Sidr
Tamarisk, Athl (Tarfa, Gaz etc., in Arabic), Tamarix aphylla
Tooth-Brush Tree, Khamt (Mustard tree, Shajr Miswak, Arak, Khardal), Salvatora persica L
Henna or Camphor, Kafur (henna, Kopher,,Copher, Yoranna, Hinnan), Lawsonia inermis
Ginger, Zanjibil, Zingiber officinale
Lentil, Adas, Lens culinaris
Onion, Basal, Allium Cepa
Garlic, Fum, Allium sativum
Cucumber, Qiththa, Cucumis melo
Acacia, Talh, Acacia seyal
Gourd, Yaqtin, Lagenaria siceraria
Mustard, Khardal, Brassica nigra
Sweet Basil, Al-Rehan, Ocimum basilicum
Zaqqum, Al-Zaqqum, Euphorbia species

Reference:

http://www.ummah.net/islam/taqwapalace/fitness/health2.html

Appendix VII: Suggested Plants for Egypt.
List of Plants Codes

- Tree
- Conifer
- Palm or Cyad
- Climber
- Shrub
- Fern
- Herbaceous perennial
- Bamboo & Grasses
- Succlent
- Acuatic Plant

- Narrow Columnar
- Frastigiate
- Oval
- Weeping
- Narrow Pyramid
- Puramid
- Wide Pyramid
- Spherical
- Single stemmed palm
- Multiple stemmed palm

- Color of Flower
- Berry or fruit
- variegated leaf
- coloured leaf
- bipinnate leaf
- treadlike filament
- Palmate leaf
- simple flower
- double flower

- little water
- medium water
- abundant water
- PH Acid
- PH Medium acid
- PH Neutral
- PH Medium alkaline
- PH Alkaline
- Berry or Fruit

Earth formation
- Light
- Medium
- Hard

- D Drought tolerant
- S Shade tree
- A Aroma
- I Indigineous

- Diciduous
- Evergreen

Appendix VII: Suggested Plants for Egypt.

Palms

Phoenix dactylifera; Date palm, hayani

Ornamental palm with a long trunk and pinnate leaves; drought tolerant.

0.1 m3/d

Height	Diameter	Root	Spacing
30	6-12	1-1.5	6
	PH		I

Phoenix dactylifera; Date palm, zaghloul

Ornamental palm with a long trunk and pinnate leaves; drought tolerant.

0.1 m3/d

Height	Diameter	Root	Spacing
30	6-12	1-1.5	6
	PH		I

Hyphaene thebaica; Ginger bread palm, doum

Ornamental palm with a long trunk and pinnate leaves; drought tolerant. The only palm several stems.

0.1 m3/d

Height	Diameter	Root	Spacing
30	6-8	0.75	4
	PH		I

Roystonia regia; Cuban royal palm

Stately feather palms with long, straight trunks suitable for avenues; for rich fertile, moist soil.

0.1 m3/d

Height	Diameter	Root	Spacing
25	4-8	1-1.5	6
	PH		

Washingtonia filifera: Fan palm

Handsome fan palms from arid areas of Arizona and Mexico. They are of rapid growth and transplant well.

0.1 m3/d

Height	Diameter	Root	Spacing
15-20	3-6	1-1.5	6
	PH		

Phoenix canariensis Cannary island date palm

Classic Rivera palm with a long trunk and pinnate leaves; drought tolerant.

0.1 m3/d

Height	Diameter	Root	Spacing
10-15	6-12	1-1.5	6
	PH		

Sabal palmetto Blue palmetto

A genus of palms from tropical marshland, used in parks and streets.

0.1 m3/d

Height	Diameter	Root	Spacing
30	6-12	1	6
	PH		

Caryota mitis: Fish tail palm

The Fish tail palm has a curious shape of leaves, the grow quickly in hot arid climates.

0.1 m3/d

Height	Diameter	Root	Spacing
3-12	3-7	0.75	2.5
	PH		

Cycas revoluta Sago Palm

Cycads are slow growers they closely resemble and are cosidered the aristocrates of foliage plants.

0.1 m3/d

Height	Diameter	Root	Spacing
5	1-2		6
	PH		

Appendix VII: Suggested Plants for Egypt.
Trees 01

Delonix regia:
Royal poinciana

Flamboyant: one of the most spectacular ot tropical trees with enormous scarlet flowers. For gardens, parks and streets.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-15	5-10	1.5	7
	PH		S

Cassia nodosa
Carnaval tree

Mainly tropical trees, highly ornamental with a long flowering season and showy flowers.

0.08 m3/d

Height	Diameter	Roots	Spacing
15	3-6	1.5	7
	PH		S

Jacaranda ovalifolia
Jacaranda

Superb sub-tropical trees with delicate feathery foliage. Fast growing shade tree.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-15	6-10	0.75	5
	PH		S

Peltophorum africanum:
Yellow flamboyant tree

Stately evergreen trees, cultivated for their heavy foliage and panicles of scented summer flowers.

0.08 m3/d

Height	Diameter	Roots	Spacing
15	6-10	0.75	8
	PH		S

Ficus benghalensis:
Banyan tree

Evergreen tree grows fast. Could be used a solitaire but, otherwise easy to trim.

0.08 m3/d

Height	Diameter	Roots	Spacing
20-30	200		7
	PH		

Ficus infectoria
Ficus Infectoria

A large expansive fast-growing tree with leaves about 10 cm long, commonly grown alongside avenues.

0.08 m3/d

Height	Diameter	Roots	Spacing
15-20	6-10	1	7
	PH		

Ceratonia siliqua:
Carob Tree

Carob: St. John's Bread: A picturesque Mediterranean tree with shiny leaves and long pods from which sweetmeats are made.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-15	6-8	0.75	7
	PH	D	I

Ficus religosa:
Sacred Tree

A medium sized tree with a relatively short trunk and a large crown with wonderful wide spreading branches.

0.08 m3/d

Height	Diameter	Roots	Spacing
8	8	0.75	7
	PH		S

Albizia lebbeck:
Woman's Tongue Tree

May be a noxious weed or invasive This plant is attractive to bees, butterflies and/or birds Flowers are fragrant

0.08 m3/d

Height	Diameter	Roots	Spacing
15	6-8	1-1.5	7
	PH		A

Appendix VII: Suggested Plants for Egypt.
Trees 02

Prosopis juliflora:
Mesquite

Grows as a multi-branched tree or shrub, and can be pruned into a lovely shade tree. It is s dense wood tree, and will grow slowly at the beginning .

0.08 m3/d

Height	Diameter	Roots	Spacing
10-15	5-10	0.75	7
	PH		S

Chorisia speciosa:
Floss Silk Tree

Tree from subtropical America with spectacular flowers, spiny, bottle-shaped trunk and fruit filled with silky fibers.

0.08 m3/d

Height	Diameter	Roots	Spacing
15	2	0.75-1	7
	PH		

Koelreuteria paniculata:
Golden Rain Tree

Ornamental, drought resistant tree, suitable for small spaces; handsome flowers and autumn colour, for light soils.

0.08 m3/d

Height	Diameter	Roots	Spacing	
10-15	6-10	0.75	5	
	PH		S	D

Kigelia pinnata:
Sausage tree

Mainly grown as a curiosity and ornamental, both for its beautiful red flowers and its strange fruit.

0.08 m3/d

Height	Diameter	Roots	Spacing
20			7
	PH		S

Tipuana tipu:
Tipu Tree

A fast growing evergreen with weeping panicles of yellow flowers good for shade. Tolrate poor soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-30	8-15		7
	PH		S

Cordia myxa:
Sebesten

This is a small tree with large, entangled branches. Looking from the ground. The fruits will show up in autumn.

0.08 m3/d

Height	Diameter	Roots	Spacing	
5-7		0.75	7	
	PH		S	A

Ficus sycomorus:
Egyptian sycamore

a tree of great importance and very extensive use. It has wide-spreading branches and affords a delightful shade.

0.08 m3/d

Height	Diameter	Roots	Spacing
20	6		7
	PH	I	S

Azadirachta indica:
Neem Tree

This broad-leaved evergreen thrives in hot dry climates .The tree can withstand drought and infertile, stony, shallow, or acidic soils.

0.08 m3/d

Height	Diameter	Roots	Spacing
30			7
	PH	H	S

Enterolobium cyclocarpum:
Elephant's ear

Spreading deciduous tree. In the dry season,when bare of its feathery foliage, the brown ear-shaped seedpods can be seen dangling high on the tree.

0.08 m3/d

Height	Diameter	Roots	Spacing
30	15-20		7
	PH		

Appendix VII: Suggested Plants for Egypt.
Trees 03

Morus alba: White Mulberry

Grown as fodder for silk-worms; and for fruit. Today they are grown primarily as extremley valid, spreading ornamental trees; normal soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-16	5-10	0.75	6
	PH		S

Pinus halepensis: Pine Tree

Excellent trees for gardens and parks and are grown for timber and pine nuts and resins. Like warm climates and are drought tolerant.

0.08 m3/d

Height	Diameter	Roots	Spacing
20	6	0.75-1	6
	PH		D

Populus alba: White Poplar

Trees of graceful habit used as windbreaks and barriers, cope well with heavy soils but should not be plced near buildings,invasive roots.

0.08 m3/d

Height	Diameter	Roots	Spacing
20-40	10-15	0.75	6
	PH		

Acacia nilotica: Gum Arabic Tree

Acacia nilotica is easy to recognize by its bright yellow flowers in round heads.The bark exudes an edible gum and is used medicinally.

0.08 m3/d

Height	Diameter	Roots	Spacing
7-10	8		5
	PH		I

Bauhinia variegata: Orchid Tree

Highly ornamental subtropical trees and shrubs with large, orchid like flowers, often scented.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-12	3-8		5
	PH		

Parkinsonia aculeata: Jerusalem Thorn

From tropical America, grown for its habit, pretty foliage and scented flowers, in dry sandy soil.

0.08 m3/d

Height	Diameter	Roots	Spacing	
8-10	5-8	0.75	5	
	PH		S	A

Melia azedarach: Chinaberry Tree

Graceful tree with pretty, scented flowers and translucent berries. Drought & Salt tolerant.

0.08 m3/d

Height	Diameter	Roots	Spacing	
10-15	5-8	0.75	5	
	PH		S	D

Cassia fistula: Golden Shower Tree

Mainly tropical tree, highly ornamental with a long flowering season and showy flowers.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-20	3-5	0.75	5
	PH		S

Ficus retusa: Ficus Nitida

Spreading deciduous tree. In the dry season,when bare of its feathery foliage, the brown ear-shaped seedpods can be seen dangling high on the tree.

0.08 m3/d

Height	Diameter	Roots	Spacing
25	30		5
	PH		S

Appendix VII: Suggested Plants for Egypt.
Trees 04

Schinus molle:
Pepper Tree

Extremley graceful trees, with airy foliage and thick pendulous clusters of coloured fruits; well-drained soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-15	5-10	0.75	5
	PH		S

Ficus macrocarpa:
Ficus Nitida

Popular ornamental tree grown widely in many tropical regions.

0.08 m3/d

Height	Diameter	Roots	Spacing
6		0.75-1	5
	PH		

Zizyphus spina-christi:
Indian Plum

Of picturesque habit with zigzag branches, attractive light green leaves & edible fruit; suited to well-drained soils; highly drought resist.

0.08 m3/d

Height	Diameter	Roots	Spacing
20-40	10-15	0.75	5
	PH	I	D

Salix aegyptiaca:
Musk Willow

Ornamental trees in habit, leaf, in their stems, often coloured, and in their catkins, good when planted to water, suited to heavy soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
10-20	8		5
	PH		I

Magnolia grandiflora:
Southern magnolia

Highly ornamental subtropical trees and shrubs with large, orchid like flowers, often scented.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-12	3-8		5
	PH		A

Sterculia diversifolia:
Sterculia

Bottle tree seeds and young taproots eaten by Aborigines in Australia.

0.08 m3/d

Height	Diameter	Roots	Spacing
15-20	5-8	0.75	5
	PH		

Cupressus sempervirens:
Cipres Comun

Conifer tree, narrow conical habbit of growth. Massed as a windbreak or screens.

0.08 m3/d

Height	Diameter	Roots	Spacing
40	1-6		
	PH		

Ficus elastica:
Ficus Decora

0.08 m3/d

Height	Diameter	Roots	Spacing
	PH		S

Acacia farnesiana:
Spone Tree

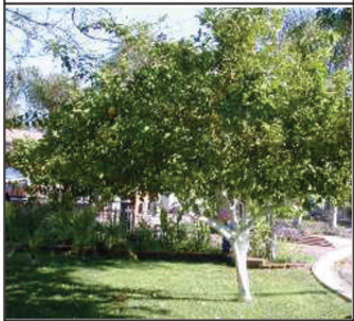
Highly decorative tree valued for foliage and flowers. Highly scented and used as a screen

0.06 m3/d

Height	Diameter	Roots	Spacing
6-8			3
	PH		A

Appendix VII: Suggested Plants for Egypt.
Trees 05

Citrus limon: Lemon



With their shiny leaves and scented flowers they are invaluable as trees to embelish garden and courtyard.

0.08 m3/d

Height	Diameter	Roots	Spacing
7		0.75	4.5
	PH		A

Citrus reticulata: Mandarin

Grow well in pots and a famous for their fruits and scente.

0.08 m3/d

Height	Diameter	Roots	Spacing
7		0.75	4.5
	PH		A

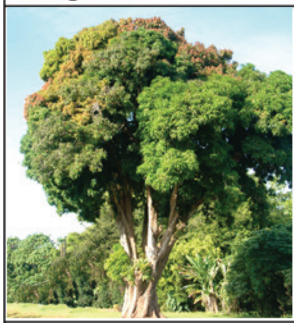
Citrus sinensis: Sweet Orange

With their shiny leaves and scented flowers they are invaluable as trees to embelish garden and courtyard.

0.08 m3/d

Height	Diameter	Roots	Spacing
13		0.75	4.5
	PH		A

Mangifera indica: Mango Tree



A tropical tree known for its delicious scented fruits. Grown in light moist but not sodden soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
24	8		7
	PH		A

Olea europaea: Olive tree

Emblematic Mediterranean tree in wonderfully twisted shapes, with silverly foliage and totally oblivious drought.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-10	3-8		4.5
	PH		

Prunus mume: Apricot

Fruiting Prunus which are beautiful and useful for any well-drained soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
15-20	5-8	0.75	4.5
	PH		

Prunus persica: Peach

Fruiting Prunus which are beautiful and useful for any well-drained soil.

0.08 m3/d

Height	Diameter	Roots	Spacing
8			4.5
	PH		

Pyrus communis: Common Pear

0.08 m3/d

Height	Diameter	Roots	Spacing
8-10	3-8		4.5
	PH		

Carica papaya: Melon Tree

The fruit sprouts directly from the trunk of this tropical tree, grwon also for its fan-shaped foliage.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-10			3
	PH		A

Appendix VII: Suggested Plants for Egypt.
Trees 06

Prunus domestica: Plum

With their shiny leaves and scented flowers they are invaluable as trees to embelish garden and courtyard.

0.08 m3/d

Height	Diameter	Roots	Spacing
7		0.75	4.5
	PH		

Psidium guajava: Guava Tree

Grown for both ornament and fruit.

0.08 m3/d

Height	Diameter	Roots	Spacing
8-12		0.75	4.5
	PH		A

Punica Granatum: Pomegranate

One of the best small, Mediterranean trees in its habit, flowers, attractive bark and superb fruit.

0.08 m3/d

Height	Diameter	Roots	Spacing
13		0.75	4.5
	PH		A

Albizia julibrissin Silk Tree

Known for their feathery foliage and profusion of tasel-like flowers in summer.

0.06 m3/d

Height	Diameter	Roots	Spacing
24	8		3
	PH		A

Callistemon spp.: Bottlebrush Tree

Ornamental Australian shrubs with exotic flowers.Drought and salt -resistant.

0.06 m3/d

Height	Diameter	Roots	Spacing
			3
	PH		D

Cassia glauca: Cassia Glauca

Mainly tropical trees, highly ornamental with a long flowering, season and showy flowers.

0.06 m3/d

Height	Diameter	Roots	Spacing
5-10	3-5	0.75	3
	PH		

Lagerstroemia indica: Crape myrtle

Extremley decorative and easy tree with lovely bark, panicles of flowers and autmn leaf color.

0.06 m3/d

Height	Diameter	Roots	Spacing
8			3
	PH		A

Macadamia ternifolia: Queensland nut

Ornamental, drought-resistant, spring flowering Australian trees with gleaming foliage.

0.06 m3/d

Height	Diameter	Roots	Spacing
8-10	3-8		3
	PH		

Plumeria alba: Indian Jasmine

Exotic shrub with lovely flowers for subtripical gardens, salt resistant.

0.06 m3/d

Height	Diameter	Roots	Spacing
8-10			3
	PH	D	A

Appendix VII: Suggested Plants for Egypt.

Trees 07

Tamarix articulata: Athel Tree

Trees from coastal areas & saline soils, which are grown for their fine foliage & generous displays of flowers, comabt errosion & suitable for screens.

0.06 m3/d

Height	Diameter	Roots	Spacing
7		0.75	3
	PH		

Tecoma stans: Yellow Elder

Shrubs of upright habit with glorious, big funnel-shaped flowers.

0.06 m3/d

Height	Diameter	Roots	Spacing
		0.75	3
	PH		A

Thevitia nerifolia: Yellow Oleander

Tropical shrubs, graceful in habit with strongly scented flowers. For well drained soil.

0.06 m3/d

Height	Diameter	Roots	Spacing
		0.75	3
	PH		

Caesalpinia pulcherrima: Barbados Pride

Mainly tropical trees from diverse habitats, grown for the fine foliage and, in some cases, the spectatular flowers.

0.06 m3/d

Height	Diameter	Roots	Spacing
			2
	PH		D

Cassia didymobotrya:

Mainly tropical trees, highly ornamental with a long flowering season and showy flowers,

0.06 m3/d

Height	Diameter	Roots	Spacing
			2
	PH		D

Nerium Oleander Oleander

Oustanding summer blooming, sturdy shrubs with leathery foliage, the majority scented, very draining soil.

0.06 m3/d

Height	Diameter	Roots	Spacing
2-6	1-3	0.75	3
	PH		D

Ricinus communis: Castor Bean

0.06 m3/d

Height	Diameter	Roots	Spacing
8			2
	PH	I	D

Lawsonia intermis: Henna

0.06 m3/d

Height	Diameter	Roots	Spacing
8-10	3-8		2
	PH		

Plumeria alba: Indian Jasmine

Exotic shrub with lovely flowers for subtripical gardens, salt resistant.

0.06 m3/d

Height	Diameter	Roots	Spacing
8-10			3
	PH		A

Appendix VII: Suggested Plants for Egypt.
Shrubs

Botanical Name	Common name	Spacing		Water
Adhatoda vasica	Justica	1m		$0.02m^{3/day}$
Agapanthus africanus	African Lily	1m		$0.02m^{3/day}$
Anisacanthus vulgare	Desert honeysuckle	1m		$0.02m^{3/day}$
Atriplex halimus	Mediterreanena salt Bush	2pm	I	$0.02m^{3/day}$
Barleria cristata	Philippine violet	2pm		$0.02m^{3/day}$
Bougainvillea glabra	Bougainville	1m		$0.02m^{3/day}$
Cestrum elegans	Lady of the night	1m	A	$0.02m^{3/day}$
Chilopsis linearis	Desert Willow	1m		$0.02m^{3/day}$
Clivia miniata		1m		$0.02m^{3/day}$
Cyperus papyrus	Papyrus	2pm	I	$0.02m^{3/day}$
Dodonara viscose	Hop bush	0.3		$0.01m^{3/day}$
Duranta plumieri	Sky flower	0.3		$0.01m^{3/day}$
Euryops pectinatus		4pm		$0.01m^{3/day}$
Gardenia jasminoides	Common gardenia	2pm	A	$0.02m^{3/day}$
Hibiscus-rosa sinensis	Shoe Flower	1m		$0.02m^{3/day}$
Jasminum humile	Yellow Jasmine	1m	A	$0.02m^{3/day}$
Lantana camara	Lantana	2pm		$0.02m^{3/day}$
Lantana camara nana	Lantana Yellow	4pm		$0.01m^{3/day}$
Lantana montevidensis	Creepng lantana	4pm		$0.01m^{3/day}$
Lonicera japonica	Japanese honeysuckle	1pm	A	$0.02m^{3/day}$
Murraya exotica	Murraya	1m	A	$0.02m^{3/day}$
Myrtus communis	Common myrtle	1m		$0.02m^{3/day}$
Phylantus atroporporius		0.3		$0.01m^{3/day}$
Pittosorum tobira	Japanese Mock Orange	4pm	A	$0.01m^{3/day}$
Punica granatum nana	Pomegranate	2m		$0.02m^{3/day}$
Rosmarinus offcinalis	Rosemary	10p		$0.01m^{3/day}$
Russelia juncea	Firecracker Plant	1m		$0.02m^{3/day}$
Tecomaria capensis	Cape honeysuckle	1m		$0.02m^{3/day}$

Ground Cover

Botanical Name	Common name	Spacing		Water
Alternanthera versicolor	Parrot leaf	16p		$0.01m^{3/day}$
Aspargus sprengeri	Aspargua fern	6pm		$0.01m^{3/day}$
Carissa grandiflora	Green carpet	4pm		$0.01m^{3/day}$
Carissa macrocarpa	Natal plum	4pm		$0.01m^{3/day}$
Chlorophytum comosum	Spider Plant	6pm		$0.01m^{3/day}$
Gazania splendens	Gazania	10p		$0.01m^{3/day}$
Hedera helix	English Ivy	4pm		$0.01m^{3/day}$
Hemerocallis aurantiaca		4pm		$0.01m^{3/day}$
Ipomoea palmata		4pm		$0.01m^{3/day}$
Majorana hortensis	Majoram	10p	A	$0.01m^{3/day}$
Mentha vindis	Spearmint	10p	A	$0.01m^{3/day}$
Ocimum basilicum	Sweet Basil	8pm	A	$0.01m^{3/day}$
Pelargonium graveolens	Rose geranium	10p		$0.01m^{3/day}$
Pelargonium pelatum	Ivy Gernaium	4pm		$0.01m^{3/day}$
Plumbago capensis	Cape leadwort	1pm		$0.01m^{3/day}$
Poliunthus roses	Rosa polyantha	2pm	A	$0.01m^{3/day}$
Salvia farinacea	Blue salvia	8pm		$0.01m^{3/day}$
Salvia splendens	Scarlet Sage	8pm		$0.01m^{3/day}$
Senecio cineraria	Dusty Miller	10p		$0.01m^{3/day}$
Verbena hybrida blue	Garden Verbena	12p		$0.01m^{3/day}$
Verbena hybrida purple	Garden Verbena	12p		$0.01m^{3/day}$
Verbena hybrida red	Garden Verbena	12p		$0.01m^{3/day}$
Verbena hybrida light pink	Garden Verbena	12p		$0.01m^{3/day}$
Vinca rosea	Periwinkle	4pm		$0.01m^{3/day}$
Wedelia trilubata	Wedelia	4pm		$0.01m^{3/day}$

Climber

Botanical Name	Common name	Spacing		Water
Bignonia jasminoides	Bower plant	2pm		$0.01m^{3/day}$
Bougainvillea spp.	Bougainvillea	1pm		$0.01m^{3/day}$
Bougainvillea spectabilis	Bougainvillea	1pm		$0.01m^{3/day}$
Clerodedrun inerme	Wild jasmine	2pm		$0.01m^{3/day}$
Clerondedrum splendens		2pm		$0.01m^{3/day}$
Jasminum grandiflorum	Common jasmine	2pm	Al	$0.01m^{3/day}$
Jasminum sambac	Arabian Jasmine	2pm	A	$0.01m^{3/day}$
Quisqualis indica	Red Jasmine	2pm		$0.01m^{3/day}$
Vitis vinifera	Grape vine	1pm		$0.01m^{3/day}$

Grass

Botanical Name	Common name	Spacing		Water
Cortaderia selloana	Pampas grass	4pm		$0.012m^{3/day}$
Cymbopogon citratus	Lemon grass	4pm		$0.012m^{3/day}$
Festuca glauca	Blue fescue	4pm		$0.012m^{3/day}$
Paspalum	Lawn			$0.012m^{3/day}$
Pennisetum setaceum	Fountain grass	4pm		$0.012m^{3/day}$
Pennisetum purpureum	Fountain grass	4pm		$0.012m^{3/day}$

Succulent

Botanical Name	Common name	Spacing		Water
Euphorbia candelabrum		3m		$0.01m^{3/day}$
Euphorbia tircualii		3m		$0.01m^{3/day}$
Opunita ficus-indica		2m		$0.01m^{3/day}$
Agave Americana	American Aloe	1m		$0.01m^{3/day}$
Agave attenuta		1m		$0.01m^{3/day}$
Fouricaraea gigantean		1m		$0.01m^{3/day}$
Yucca aloifolia	Spanish bavonet	1m		$0.01m^{3/day}$
Yucca filamentosa	Adam's needle	1m		$0.01m^{3/day}$
Aeonium arboretum		0.5		$0.01m^{3/day}$
Agave victoriae-reginae		0.5		$0.01m^{3/day}$
Echinocactus grusonii	Golden barrel cactus	0.5		$0.01m^{3/day}$
Espostoa lantan	Old man cactus	0.5		$0.01m^{3/day}$
Mammillaria geminispina	Solitary cactus	0.5		$0.01m^{3/day}$
Aloe vera	Medicinal aloe	4pm		$0.01m^{3/day}$
Aptenia cordifolia		16p		$0.01m^{3/day}$
Carpobrotus acinaciformis	Ice plant	4pm		$0.01m^{3/day}$
Cereus jamacaru		0.5		$0.01m^{3/day}$
Cotyledon orbiculata		10p		$0.01m^{3/day}$
Euphorbia milii	Crown of thorns	4pm		$0.01m^{3/day}$
Kalanchoe mamorata		6pm		$0.01m^{3/day}$
Lampranthus spectabilis	Trailing Ice Plant	10p		$0.01m^{3/day}$
Mesembranthemum edule	Ice Plant	10p		$0.01m^{3/day}$
Portulaca afra		10p		$0.01m^{3/day}$
Portulaca grandiflora	Sun Plant	10p		$0.01m^{3/day}$
Sanseveria cylindrical		4pm		$0.01m^{3/day}$
Sanseveria trifasciata	Mother's in law tongue	4pm		$0.01m^{3/day}$

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Appendix VIII: Thermometer and Hygrometer Specifications.

In out Thermometer with indoor humidity gauge (Hygrometer):

Resolution: 0.1 C
Accuracy: +- 1.8 C from 0/+40 C
+- 3.6 C -40/+50 C
+- 5.4 C -50/+70
Temperature Operating Range:
Main Unit: 23° to 122° F (–5° to 50° C)
Outdoor External Probe: –58° to 158° F (–50° to 70° C)
Relative Humidity Operating Range: 25% to 95% RH
Temperature Compensation Range: 14° to 140° F (–10° to 60°C)
Resolution: 0.2° F (0.1° C)
Sampling Cycle (Approximate): 10 Seconds
Accuracy: ± 1.8° at 32° to 104° F (0° to 40°C)
+3.6° at –40° to 122° F (–40° to 50°C)
+5.4° at –58° to 158° F (–50° to 70° C)

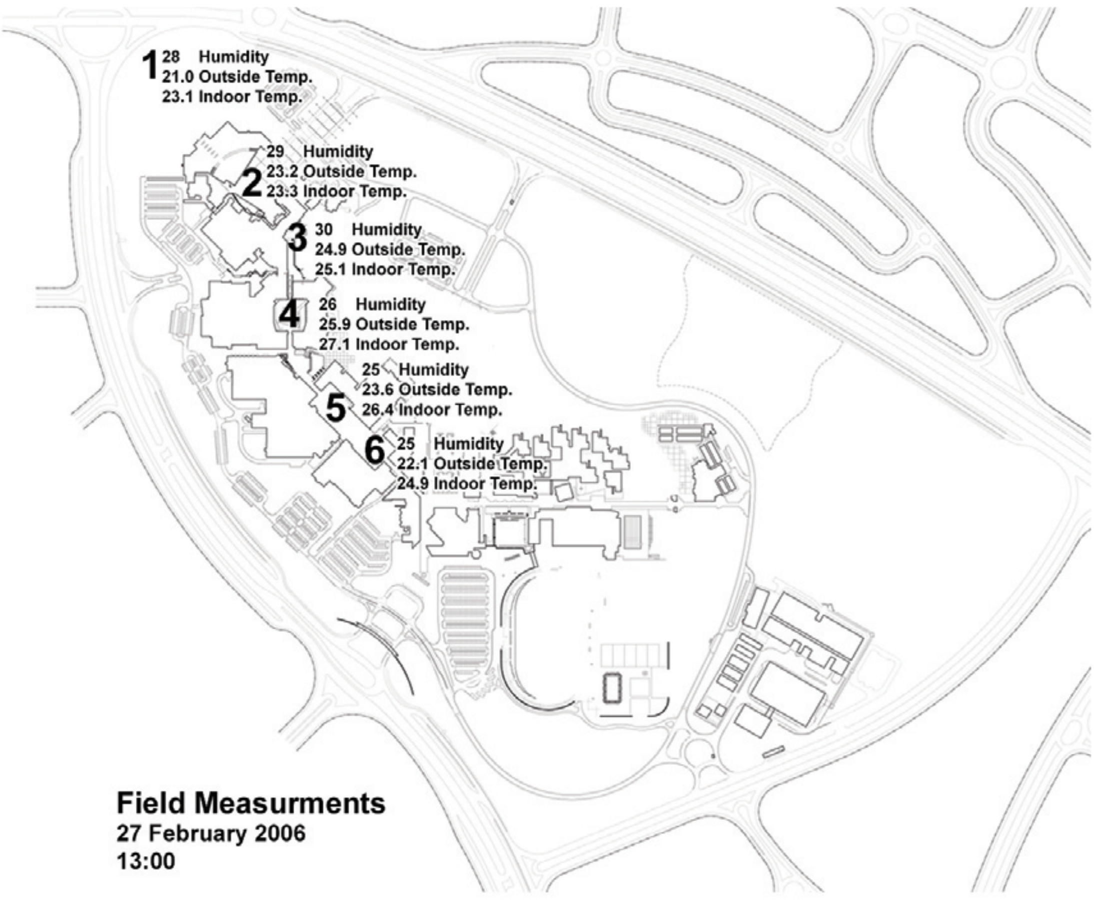

Fig. a.02, Field measurement path on the AUC, February 2006.

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Glossary

Glossary

Glossary:

absorption cycle (solar) cooling A mechanical refrigeration cycle that utilizes a liquid desiccant and a heat source that regenerates (dries) the desiccant. This system can be particularly environmentally friendly because it does not rely on electricity, but can utilize any source of low temperature heat (such as solar energy) to operate.
active In building systems, a highly-augmented mechanical system (as opposed to passive).
active solar heating A method of heating in which the solar thermal energy flow is assisted by fans or pumps for the forced distribution of heat.
albedo The fraction of incident electromagnetic radiation reflected by a surface, especially of a celestial body. [Late Latin, whiteness, from Latin albus, white.]
alternative energy source Energy sources, commonly referred to as renewable energy sources such as solar, wind, and geothermal, produced from sources other than finite fossil fuel based sources such as coal, oil and gas.
ambient temperature A balanced level of thermal comfort.
ASHRAE Acronym for the American Society of Heating, Refrigeration and Air Conditioning Engineers.
atrium Open courtyard surrounded by a roofed arcaded or colonnaded walk.
axiality A layout disposed symmetrically about an axis.

berms Rammed earth used for retaining or as a landscape feature.
biodiversity The variety of organisms found within a specified geographic region.
biomass Plant material, vegetation, or agricultural waste used as a fuel or energy source.
biotic growth Biological growth, especially referring to the increase of mass in floras, faunas, and ecosystems.
biotic ecosystem services The role played by biological organisms in creating a healthful environment for human beings, from the production of oxygen to soil genesis and water detoxification.
Btu British thermal units. A unit commonly used to measure heat. One Btu is about equal to the heat released from one kitchen match. kBtu is one thousand Btu. MBtu is one million Btu.
bustan Arabic word for fruit gardens.

carbon sequestration The process by which carbon compounds that are freely cycling in the environment are "locked up" or temporally taken out of the active flow. This typically occurs through absorption by plants or reaction with water to form carbonates, which may become deposits in bottom sediments. Carbon incorporated into trees may remain out of circulation for hundreds of years. This is significant because a balance of carbon in the atmosphere is required to maintain the earth's temperature and environment in a state habitable for humans. The amount of CO_2 in the atmosphere has been increasing since the Industrial Revolution, because of the reintroduction of massive amounts of carbon into the atmosphere through the burning of fossil fuels and the clearing of forests.
climate refers to the weather situation over a long period of time, usually 30 years or more.
colonnade A row of columns supporting an entablature or roof.
conductive To transmit [heat or electricity]; a conductive substance is one that facilitates the transmission of heat or electricity.
convection The transfer of heat by the upward flow of hot air or the downward flow of cold air. A convective element is one that facilitates the transfer of heat.
cul de sac Alley, lane, passage, street, etc., closed at one end, with no exit except the entrance.

deciduous In botany plants, principally trees and shrubs, are those that lose all of their foliage for part of the year. In some cases, the foliage loss coincides with the incidence of winter in temperate or polar climates, while others lose their leaves during the dry season in climates with seasonal variation in rainfall. The converse of deciduous is evergreen.
diurnal Relating to or occurring in a 24-hour period; daily.
dry bulb temperature The temperature of the ambient mixture of air and water vapor measured with a thermometer.

ecoclimate is the climate inside vegetation.
eddy In fluid dynamics, an eddy is the swirling of a fluid and the reverse current created when the fluid flows past an obstacle. The moving fluid creates a space devoid of downstream-flowing water on the downstream side of the object. Fluid behind the obstacle flows into the void creating a swirl of fluid on each edge of the obstacle, followed by a short reverse flow of fluid behind the obstacle flowing upstream, toward the back of the obstacle.
emissivity The ability to radiate [heat or light].
enthalpy The sum of internal energy and energy related to the pressure and specific volume of a substance. Warm moist air contains more enthalpy (energy) than the same volume of cool dry air. An economizer damper may return to its minimum opening position when the outside air enthalpy exceeds the return air enthalpy. Such a control strategy may be used rather than a temperature
based economizer for moist conditions.
equinox An equinox in astronomy is the moment when the Sun passes over the equator. The event occurs twice a year, around March 21 and September 23.
epistemology The theory of knowledge, particularly with regard to its methods and validation.
espalier tree growing against wall: a plant, especially a fruit tree, trained to grow flat against a wall or other upright

support.
evaporative cooling The exchange of sensible heat in air for the latent heat of water droplets of wetted surfaces.
evapotranspiration The process by which water moves through a plant, driven by the evaporation from surfaces, especially leaves, exposed to air. Plants adapted to dry climates have lower rates of water consumption due to evaporation than plants from moist climates.

geomorphology: the configuration and evolution of landforms.
groundwater The water beneath the earth's surface, often between saturated soil and rock, which supplies wells and springs.
groundwater recharge The process of introducing water into the ground in order to add to or complement existing ground water at the water table or in an aquifer lying below the ground.

hadith are traditions relating to the sayings and doings of the Islamic prophet Muhammad. Hadith collections are regarded as important tools for determining the Sunnah, or Muslim way of life.
hardscape The paved surfaces of the ground.
haud: Arabic word for a pool or tank often in the centre of the courtyard of a mosque.
heat island An area, such as a city or industrial site, having consistently higher temperatures than surrounding areas because of a greater retention of heat, as by buildings, concrete, and asphalt.
HVAC Acronym for heating, ventilation, and air conditioning. HVAC systems are the building's mechanical systems for heating, cooling, and air conditioning.

isotacks lines of equal wind velocity.
iwan In traditional Islamic architecture, carving into the mass of a building's facade. Usually associated with main entrances or prominent building elevations.

Jebel Arabic word for mountain or hill.
jenna Arabic word for paradise

LEED Acronym for the Leadership in Energy and Environmental Design Building Rating System, developed by the United States Green Building Council.
liberal arts The arts as distinct from science and technology. Liberal arts education emphasizes the study of art, literature, music, philosophy, history, etc., in addition to the sciences and mathematics. The goal of a liberal arts education is to instill in the student the widest possible range of knowledge.
locality The position of a thing; the place where it is.
litho sols: zoned shallow soils consisting of imperfectly weathered rock fragments.

maidan (Arabic) In Islamic architecture, a public open space surrounded by buildings. Similar to the Western plaza.
macroclimate is the weather situation over a long period of time, usually the average of 30 years or more. Macroclimate is independent of local topography, soil type and vegetation and may extend for hundreds of kilometers. Typically, macroclimate temperatures are measured 1.5 meters above the ground and wind speed is determined at 10 meters above ground. Macroclimate considerations are important for the study of biogeography.
mashrabiyya: Interlaced wooden screen work.
malqaf Arabic woed for wind catcher.
mesoclimate or topoclimate is a local variant of macroclimate caused by topography and sometimes by vegetation or human action. Mesoclimates are found in ravines, over large lakes, and in big cities. The focus of mesoclimate studies is usually horizontal surfaces which may extend from kilometers to hectometers. Typically, mesoclimate temperatures are measured at 1.5 meters and/or at 0.5 meters above the ground, humidity is measured at 0.5 meters above the ground, and wind speed is determined at 1-2 meters above the ground. Mesoclimate considerations are important for the study of urban ecology and bioclimatology.
microclimate is the climate of the lower two meters of the atmosphere and the upper 0.5 to 1 meter of the soil. Vegetation has considerable influence on microclimate. Other important considerations are aspect (compass direction) and inclination. A microclimate typically extends over meters to hectometers. Typically, microclimate temperatures are measured at 1.5 meters and/or at 0.5 meters above the ground, humidity is measured at 0.5 meters above the ground, and wind speed is determined at 1-2 meters above the ground. Microclimate considerations are important for studies of vegetation ecology and population dynamics of plants and animals.

night flushing Ventilating a building interior at night in order to cool internal thermal mass.
night sky radiation cooling Radiative cooling is the transfer of heat from a warmer surface to a cooler surrounding surface by electromagnetic wave radiation. In dry climates the night sky can be a nearly perfect black body, and provide a very effective absorber to use for cooling building surfaces.
nutrient cycling This refers to the course of any particular substance essential to life as it moves through the physical

and biological environment. The nutrient cycle is a basic concept in ecology. Essential nutrient cycles include the carbon cycle, the nitrogen cycle, and the water cycle.

orangeries Groves of orange fruit trees, often planted to complement buildings such as in the Cathedral of Seville, Spain.

paradigm An example or pattern.
passive That which may receive action but does not itself act. In architecture, for example, passive
passive cooling A method of cooling in which the thermal energy flow is by radiation, conduction, or natural convection.
passive solar heating A method of heating in which the thermal energy flow is by radiation, conduction, or natural convection.
pergola kiosk or umbrella made of light structures and located in the outdoor environment providing seats and shade.
pharonic Arabic word for the ancient Egyptian period.
PPD An acronym for percentage of people dissatisfied, a unit of measure used in thermal comfort studies.
psychometric chart A graphic chart that indicates the interactions of air, moisture, and heat.

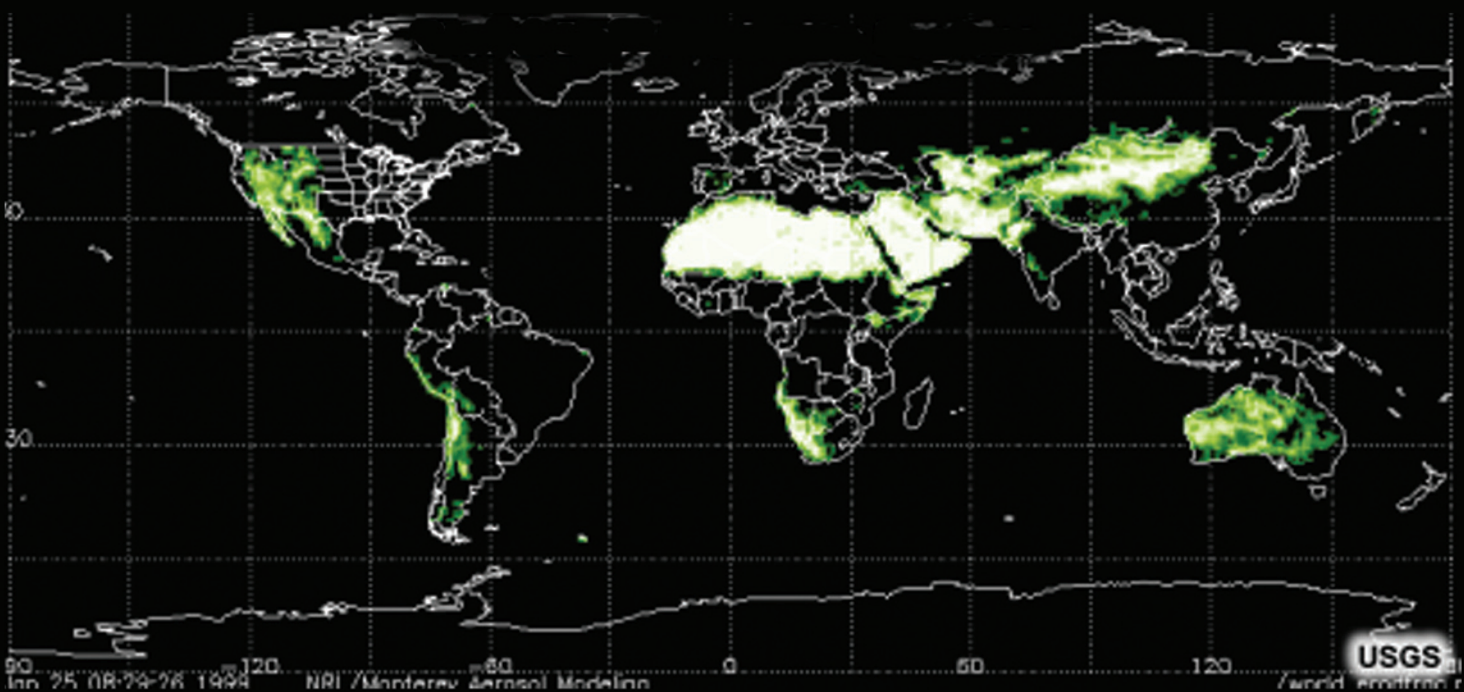
ROOM program This is a single cell dynamic thermal model developed by Ove Arup which utilizes computers to analyze the thermal behavior of spaces.

sabilles (Arabic) In Islamic architecture, a water feature or fountain incorporated in a building facade (associated with buildings designed for educational uses).
sahabi. The definition of Sahabi is someone who companioned the Prophet Mohamed PBUS and believed in him as well as died as Muslim.
saqiya Arabic word for a water mill.
shaduf Arabic word for a device to move water upwards.
shelter belt A planting of varying depth used to shelter buildings, structures or agricultural areas from winds and weather; typically composed of species of varying heights to create a "ground to crown" sheltering effect with vegetative cover.
skytherm concept The patented cooling and heating system developed by Harold Hay that consists of a roof system that contains water that can be covered or exposed by movable insulating panels. By exposing the roof system during the day, the water will absorb solar heat, and covering the roof with the insulating panels at night, will conduct the stored solar energy to the interior spaces. The process can be reversed by covering the roof system during the day to prevent solar heat gain, and removed
during the night to promote cooling by radiation and evaporation to the exposed night sky.
solar heating is the collection or distribution of the sun’s energy without the use of machinery.
softscape Ground area destined for landscape; surface covered by earth, grass or other plant material.
storm water management The management of surface runoff waters to lessen the negative impact on water quality from the sediment and contaminates contained within, as well as the reduction in need for infrastructure and conveyance systems to transport storm water volumes to receiving waters.
sura Arabic word a chapter in Koran.
sustainability The ability to maintain (or be maintained) continuously.

takhtaboosh a space annexed to the court for receiving male visitors during the summer.
tectonic In architecture, relating to large-scale structural features.
thermal comfort A condition of mind in which satisfaction is expressed with the thermal environment.
thermal unit Temporal organization of spatial elements to create thermal comfort.
turf cultivar A variety of turf grass, as designated by name, trademark, weir overflow A weir is a landscape element that can be used to control the flow of water or create an aesthetic effect. A weir overflow is the volume of water overflowing the weir.

wadis: Arabic word for dry river beds.
wind catcher Building element that draws air into the building. Typically built as a rooftop tower with an air intake placed at the leading face of the building.

xeriscape A process or product of landscape and irrigation design that minimizes plant dependency on and use of water; a number of strategies may be invoked: site planning for efficient water use taking advantage of microclimate conditions and character; grading and soil design to maximize conservation of water for plant use; planting design using native and naturalized (but never invasive species) species that are adapted to local regime and have a low water demand for evapotranspiration; use of mulching and other ground covering materials and techniques to lessen water loss by evaporation.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