Examination and Assessment of the Environmental Characteristics of Vernacular Rural Settlements. Three Case Studies in Cyprus

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ABSTRACT: The paper aims at examining the passive responses of the vernacular rural settlements of Cyprus. This study is part of a research program undertaken by the University of Cyprus and concerned with the investigation of the thermal comfort of vernacular settlements at both the scale of residential buildings as well as the agglomeration of structures that accounts for the built fabric and open spaces. The proposed methodology examines the environmental parameters that affect the microclimate as well as the bioclimatic principles incorporated in the design of the outdoor spaces in the case of three traditional settlements, namely Maroni, Pera Orinis and Askas villages. Software simulation and meteorological data are used to investigate solar and wind exposure and the sky component of the streets and of the topography of the study area.

1 TRADITIONAL RURAL SETTLEMENTS-A MODEL FOR SUSTAINABLE DESIGN

The investigation of outdoor comfort conditions in vernacular settlements of Cyprus is the primary objective of this paper. The outdoor space is a part of everyday life in Cyprus due to its mild climate which has led the people to live much of their time in the open air. Sociability at the open spaces is the order of the day and private, interior life takes second place (Christodoulou, 1959). The analysis of the microclimatic conditions of the vernacular outdoor spaces would address opportunities to improve pedestrian comfort and identify lessons learned from traditional architecture that could also be applicable in contemporary urban planning. Special considerations for achieving thermal comfort were incorporated both at the scale of the traditional settlement as well as at the building scale. Topography, settlement location and morphology, materials and methods of construction were incorporated in regulating the microclimate of traditional architecture.

1.1 *Factors affecting settlement morphology: topography and climate*

Traditional settlements have always been related to specific localities, where a meaningful correspondence between climatic conditions, topography and settlement morphology exists. Different surface reliefs derive different physical forms and growth patterns in rural settlements (Norberg-Schulz, 1991). For instance, settlements in a valley usually take linear forms parallel to the direction of the land contours, settlements on a plain may take on the form of a dense cluster or of an enclosure while settlements on a hill often have the form of concentric or longitudinal clusters, forming a series of semi-circular terraces perpendicular to the slope. However, apart from the topographical and environmental factors, socio-economic issues such as the lifestyles of the locals, concerns for safety and privacy as well as construction and material issues, play a major role in affecting the morphology of rural settlements.

The Mediterranean vernacular built fabric is characterized by enclosures, continuous arrangements of buildings, compactness, high density and an adherence to a specific topographical organization that responds very well to the encountered climate. The enclosed public and private open spaces moderate the extreme summer temperatures and provide a shelter from the intensive insolation during the summer period. The narrow streets and compact organization of buildings are typical in vernacular settlement layouts in hot and dry climates, while they provide shade to the streets and facades of the buildings during the summer period (Decay & Brown, 2001), a phenomenon that causes the mean radiant temperature to significantly drop, thus providing comfort to pedestrians during summers.

2 RESEARCH METHODOLOGY

This study examines how the environmental parameters and topography influenced the outdoor comfort in three rural settlements in Cyprus. More specifically, the proposed research methodology is based on a quantitative and qualitative environmental assessment of the microclimatic conditions prevalent in the built fabric at a variety of localities - namely the villages of Maroni, Pera Orinis and Askas. The selection of the settlements has taken into account both traditional character and climatic diversity (Fig.1).

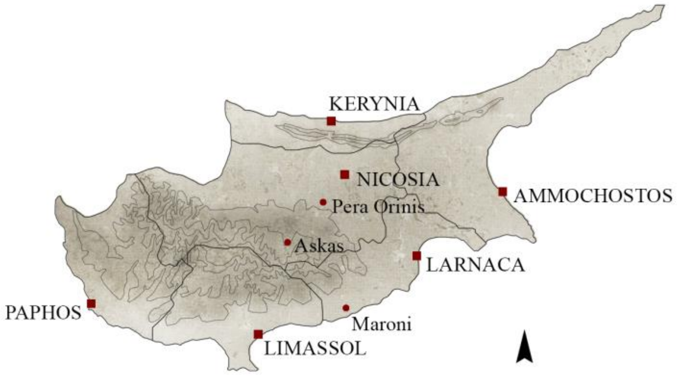

Figure 1. Map of Cyprus with the five cities and the three case study settlements

2.1 *Selection of case studies*

The village of Maroni is located 35km southwest of the city of Larnaca, at an average elevation of 70m and 2km far from the seashore (Fig. 1 & 2A). The village is sited on the south side of the Troodos mountain range, on the east bank of Maronios river. The shape and the layout of the settlement follow the landscape formations. The shape of Maroni village is a combination of a semi-circular configuration that follows the contours of the immediate site and of rows parallel to the direction of the sloped land. The village, has existed since the Medieval era and is referred to as Marova on older maps.

The village of Pera Orinis extends on the east bank of the Pedieos river at an elevation of 400m, and lies within the boundaries of the Nicosia district, in the high Mesaoria plains (Fig. 1 & 2B). The various development concerns for the settlement over time have led to irregularly built clusters. In this case the growth pattern of the village is less related to the topography. Pera Orinis and the neighboring villages of Politiko, Episkopio and Ergates were suburbs of the ancient city of Tamassos (Camelaris, 2011).

The village of Askas lies in the Nicosia district, in the Pitsilia region, 900m above sea level on the North side of the Troodos massif, at the foot of mount Papoutsa (Fig. 1 & 2C). The village of Askas extends alongside the valley of Askas river, surrounded by a barren, rugged and mountainous topography. The topography channeled the growth pattern and subsequent shape of the village to follow the landscape contours into a linear configuration. Askas is initially mentioned during the Frankish occupation of Cyprus (1191-1489B.C.) (Ioannou, 2007).

2.2 *Data collection*

Observations, mappings and data have been collected on natural and man-made physical conditions that affect the comfort of the outdoor public spaces. Natural place characteristics include local climate and the topography of the area. Man-made characteristics of the built form include such aspects of cluster organization as: building orientation, density, level of compactness and street layout and orientation. The total sunlight hours, the sky view factor and wind

MARONI VILLAGE	
Latitude	34°45′N
Longitude	33°21′E
Number of occupants	710
Total number of dwellings	420
Unoccupied or temporary occupation	166

PERA ORINIS VILLAGE	
Latitude	35°2′N
Longitude	33°15′E
Number of occupants	1372
Total number of dwellings	546
Unoccupied or temporary occupation	111

ASKAS VILLAGE	
Latitude	34°55′N
Longitude	33°4′E
Number of occupants	170
Total number of dwellings	128
Unoccupied or temporary occupation	56

Figure 2. A. Maroni B. Pera Orinis C. Askas village Source: Demographical Report (2011), Statistical Service of Cyprus

exposure of the streets of each settlement have been simulated using environmental performance analysis software. Meteorological data from the nearest weather stations to the locations of the case studies have also been recorded. Following data collection, the simulated and meteorological data were tabulated for comparative analysis. Additionally, the research includes the selection of representative buildings in order to examine their level of compactness and their orientation.

3 ANALYSIS OF ENVIRONMENTAL PARAMETERS AFFECTING THE OUTDOOR COMFORT

The data collection and analysis have revealed useful information on the environmental impact of the climate, building configuration and street layout on thermal comfort, as explained in more detail in the thematic paragraphs below.

3.1 *Climate*

According to the Köppen climate classification, Cyprus has a Mediterranean hot and semi-arid climate. Hot and arid climates are characterized by large diurnal fluctuations, by high amounts of impinging solar radiation, high summer temperatures and mild winters with predominant clear skies. According to the directive on Energy Performance of Buildings (2002/91/EC) the island is divided in four climatic zones: climatic zone 1-coastal areas (CZ1), climatic zone 2-plain regions (CZ2), climatic zone 3-semi-mountainous areas (CZ3) and climatic zone 4-mountainous areas (CZ4). The village of Maroni lies in climatic zone 1, Pera Orinis in climatic zone 2 and the village of Askas in climatic zone 4. Climatic zone 3 was excluded from the present research due to close similarities observed in the analysis of settlements in that zone to similar environmental conditions observed in climatic zone 4. Data from the nearest weather stations of the Cyprus Meteorological Service at the three case study settlements are presented in the study. The meteorological data cover a 20 year period that ranges from 1984 to 2003.

3.1.1 *Temperature*

The temperature fluctuation between highest and lowest temperatures for Maroni (CZ1), Pera Orinis (CZ2) and Askas (CZ4) villages is 10.8°C, 7.8°C, and 7.1°C respectively during the winter and 13.8°C, 13.3°C, and 10.4°C during the summer (Fig. 3A). The highest mean maximum temperature of 35.5°C was recorded at the area of Pera Orinis village (CZ2) in July, higher by 2.3°C to the corresponding temperature of 33.2°C at the area of Maroni village (CZ1) and higher by 4.6°C than the highest temperature recorded at the area of Askas village (CZ4) for the same period (Fig. 3A). The lowest mean minimum temperature of 3°C was recorded at the area of Askas village (CZ4). The average temperature during winters at the area of Maroni village (CZ1) is 12.5°C, at the area of Pera Orinis village (CZ2) is 10.2°C whereas at the area of Askas village (CZ4) is 7.2°C. The average temperature during summers at the area of Maroni village (CZ1) is 25.7°C, at the area of Pera Orinis village (CZ2) is 26.7°C and at the area of Askas village (CZ4) is 24.6°C.

Overall, Maroni village has the mildest climate throughout the year due to the proximity to the sea with moderate maximum and minimum temperatures. The settlement of Askas has the coldest climate due to its high elevation; the cooling rate near the ground is about 0.8°C for each 100m of elevation (Decay & Brown, 2001). Pera Orinis village has the warmest climate of the above mentioned settlements.

3.1.2 *Relative humidity*

Relative humidity changes according to the distance from the sea and the altitude of a settlement. Humid-

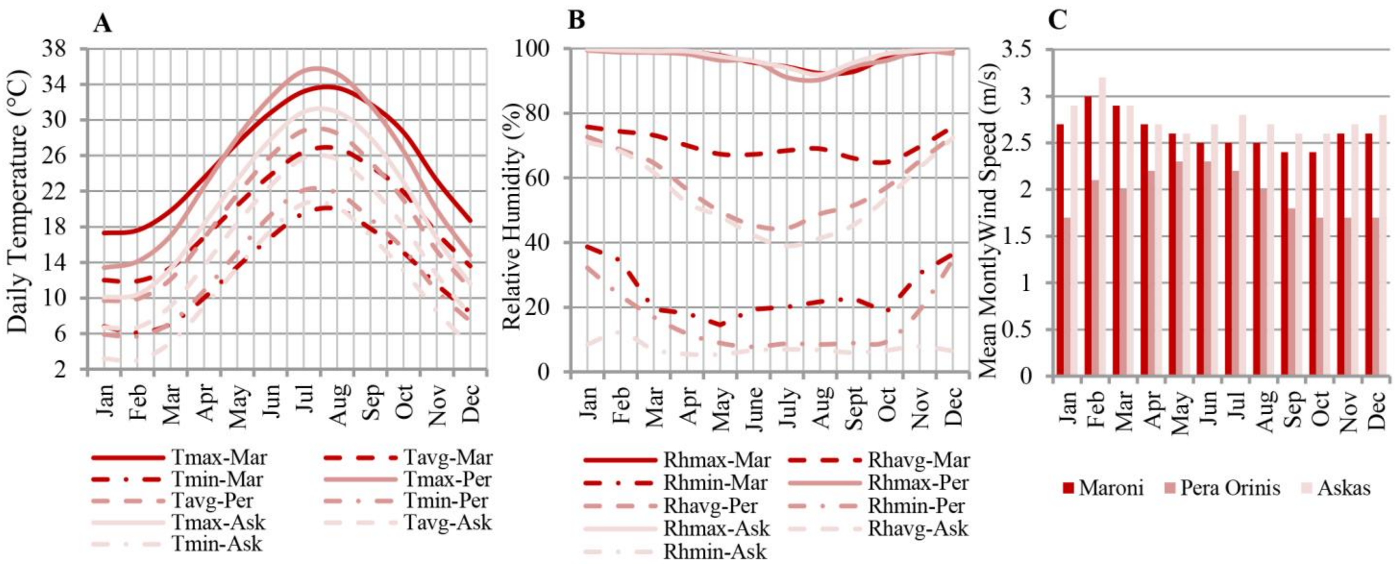

Figure 3. A. Minimum, average, maximum air temperature B. Minimum, average, maximum relative humidity C. Average wind speed for Maroni, Pera Orinis and Askas villages Source: Meteorological Service of Cyprus

ity significantly increases in the case of Maroni village due to the proximity to the coastal zone. Specifically, the annual average humidity at the area of Maroni village (CZ1) is 70%, whereas at the area of Pera Orinis village (CZ2) is 58% and at the area of Askas village (CZ4) is 55% i.e. 12% and 15% lower than the humidity at Maroni respectively (Fig. 3B).

3.1.3 *Wind*

The prevailing wind direction at the area of Pera Orinis blows from the west and east during the winter and from the west during the summer, whereas winds nearby the Maroni village are generally northwesterly in the winter and northwesterly-southwesterly in the summer. In close proximity to the test cases, medium wind speeds were recorded in the range of: 2.6m/s, 2.8m/s and 1.9m/s at Maroni, Pera Orinis and Askas respectively (Fig. 3C).

3.2 *Topography*

From the environmental perspective, topography influences wind flow and solar access relative to the physical form of a settlement. Regarding the wind, the different topographical features of the case studies create different air flow phenomena. Pera Orinis is situated in the Mesaoria plain which is located between the Troodos and Kerynia mountain ranges. Due to this spatial configuration, there is a funneling effect of the wind at the Mesaoria plain which creates high speeds especially in the case of westerly and northwesterly winds (Passiardis, 1995). At the Troodos massif - where the village of Askas is located - the wind blows uphill during the day; at nighttime the air flow reverses to a downward direction creating the phenomenon of cool air flowing down slope (Passiardis, 1995). Maroni village, which is located in the coastal zone, is affected by the summer sea breezes, which maximize the potential for natural ventilation.

The availability of solar radiation is also affected by topographic characteristics and orientation (Yannas, 1994). Mountainous settlements may be overshadowed partly or completely by the surrounding mountains causing a significant reduction of the impinging solar radiation. Other local topographical features, such as the orientation of a settlement, have an impact on the amount of incident solar radiation e.g. south slopes are exposed to higher amounts of solar radiation compared to northern slopes.

The village of Askas, which is situated on the southeastern slope of the valley of Askas enjoys the southern sun and avoids afternoon solar heat gains. However, the mountainous surroundings cast shadows on the settlement - especially during the winter where the sun angle is low - reducing the useful solar heat gains and the total sunlight hours (Fig. 4). Pera Orinis village is situated on high plains where no topographical and solar access restrictions apply. Hence, the total annual sunlight hours are maximized (Fig. 4). Maroni village is located on a plateau at the foot of Troodos mountain. The village orientation, which faces south, maximizes the penetration of sun into the settlement (Fig. 4).

3.3 *Level of compactness*

The harsher climatic conditions and the defensive nature of the village layouts in the mountainous settlements have led to more compact built forms compared with the villages on the plains which developed looser configurations (Apostolou, 2003). Lack of space on hilly landscapes has also led to compact configurations where everyday life and outdoor spaces are usually elevated to the upper floors.

From the environmental point of view, compact organizations reduce wind flow and solar access whereas looser clusters enhance wind and solar penetration into built areas (Decay & Brown, 2001). Compact configurations provide protection from winds, reduce the solar heat gains of the buildings and increase shading of the streets. Compact forms also reduce heat losses through the building envelope, while exposed areas of the building to the outdoor climatic conditions are smaller (Yannas, 1994). On the other hand, looser clusters allow cool breezes to penetrate into outdoor areas and building interiors during the summer period and maximize solar access in the winter. A representative number of buildings in the three case studies of settlements were studied in order to extract the level compactness as the percentage of built to un-built area. In the case of Maroni village, 60% of the buildings studied have a 40-60% built-to-unbuilt ratio, which indicates a semi-sprinkled configuration for the settlement (Fig. 5). At the village of Pera Orinis the land coverage of 68% of the buildings ranges between 60% and 80%, which indicates a semi-compact configuration for the settlement (Fig. 5). In 70% of the buildings studied at Askas village land coverage lies between 80% and 100% (Fig. 5) which indicate a very compact rural core. The compact arrangement at Askas village represents a typical vernacular mountainous settlement configuration.

3.4 *Building and Street layout*

Regarding solar access issues at the street level, east-west laid streets receive higher amounts of solar radiation (midday sun angle is high) throughout the year, whereas north-south streets are more shaded. Wide east-west streets could provide winter solar access and narrow north-south street canyons may provide shade to the streets and to opposite building facades. However, narrow streets while having smaller sky view factors reduce the sky radiant cooling effect during nighttime. Moreover, the height-to-width ratio of the streets has an impact on the incident solar

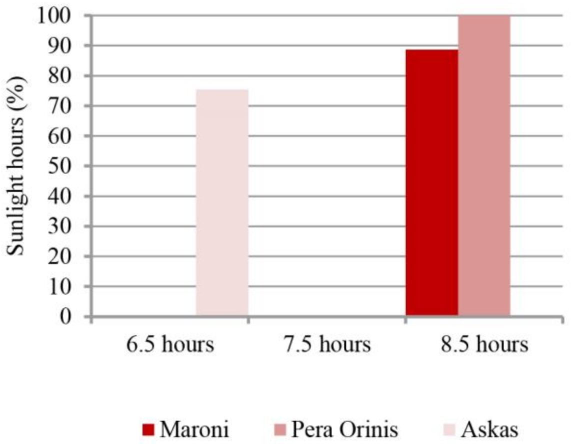

Figure 4. Average daily sunlight hours of the surface relief of the settlements under study for wintertime Source: Ecotect

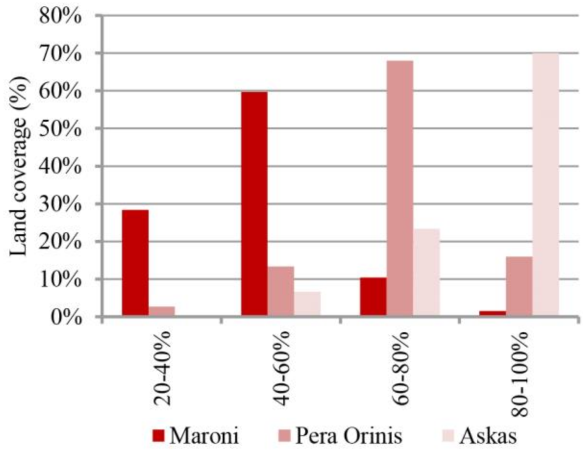

Figure 5. Land coverage of the case study settlements

radiation to the streets and on the portion of the visible sky exposed to the residents. The higher the height-to-width ratio, the more is the shade on the streets and building facades and the lowest the sky radiant cooling effect.

Concerning the wind flow, streets oriented along the predominant wind direction provide better wind movement through the built fabric. Specifically, to maximize cross-ventilation access and air movement streets should be oriented at angles of approximately 20-30° on either side of the direction of the prevailing summer breeze (Decay & Brown, 2001). The non-linear and segmented organization of streets reduces wind flow in passages and buildings alike, a strategy which is appropriate for cool climates in order to shield residents from direct cold winds.

The prevailing street orientation in the case of Askas which is along the South-North axis, and the high height-to-width proportions of the fabric at rates between 1.2 and 4, maximizes summer shading of the streets and adjacent buildings (Fig. 6B). On the other hand, solar access which is significantly restricted during the winter period might lead to indoor and outdoor discomfort. Specifically, 74% of the streets at the village of Askas enjoy the sun only up to two hours during the winter period (Fig. 6A). The high height-to-width ratios of Askas streets reduce the portion of the visible sky from 20-40% for the majority of the streets, while also decreasing the sky radiant cooling potential during summertime (Fig. 6C). Regarding wind flow, the curvilinear street pattern of the village blocks the undesirable cold winds during the winter period.

In the case of Pera Orinis village, the rotation of the streets from the cardinal directions increases shading and provides evenly distributed solar access to the facades. The height-to-width ratios of the streets - ranging from 0.7 to 1.4 - allow better solar access to the streets during wintertime but less shading during the summer as compared to Askas village (Fig. 6A & 6B). Also, the linear organization of the streets of Pera Orinis and the orientation of primary streets towards the prevailing summer western breezes enhance air flow in the settlement and the potential for natural ventilation.

The height-to-width ratio at Maroni village ranges between 0.8 and 2.6. The sunlight hour pattern onto the streets of Maroni village is similar to the one at Pera Orinis village despite the more compact built form of the latter (Fig. 6A & 6B). The linear arrangement of the buildings and the smaller sky view factor of the streets of Pera Orinis village may offer an explanation for this observation. The primary

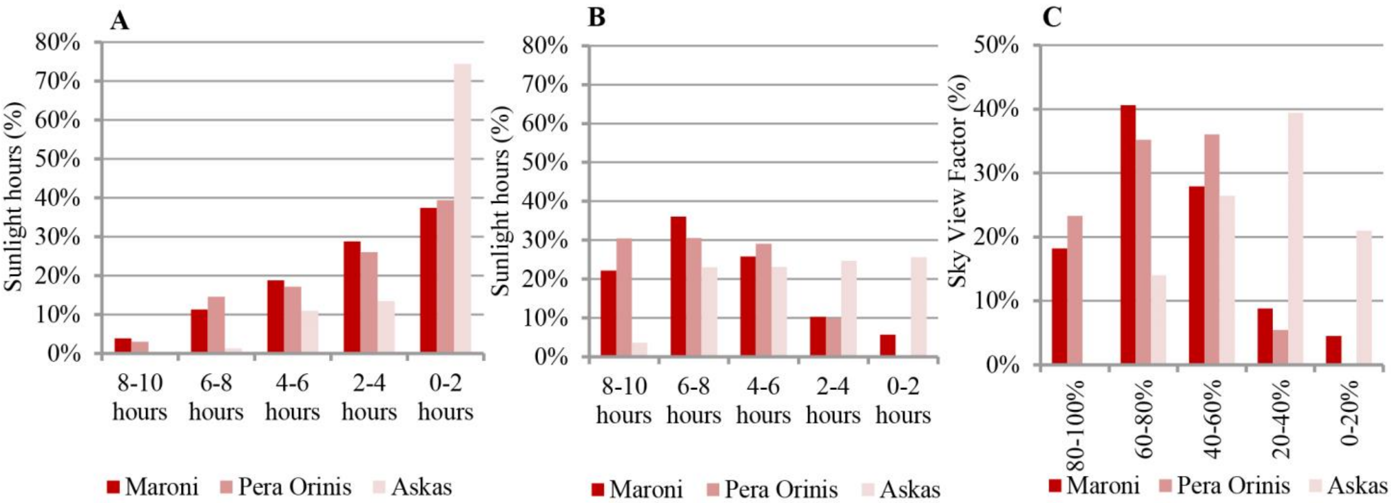

Figure 6. A. Average daily total sunlight hours of the streets and squares for the winter period B. Average daily total sunlight hours of the streets and squares for the summer period C. Sky view factor Source: Ecotect

streets at Maroni village, which are oriented along a North-South axis, allow the predominant southwesterly cool breezes to penetrate during summertime.

A significant number of buildings were also studied regarding their orientation. South facing buildings dominate the settlement at Maroni and Pera Orinis at a percentage of 35% and 29% respectively, whereas the southern and eastern aspect of buildings at a percentage of 29% and 37% respectively is predominant among buildings at Askas village. The data reveals that the arrangement of the building to the South has insolation criteria and reflects the bioclimatic concerns of our ancestors for passive heating.

3.5 *Surface albedo*

Pedestrians are exposed to direct, diffused and reflected solar radiation from external surfaces, which may significantly increase the radiant heat load of a location (Givoni, 1998). The reflectance properties of the finishing materials can reduce the heat stress of the surrounding space and contribute to pedestrian comfort; high reflectance materials mitigate the surrounding ambient temperature during hot summers acting as climatic regulators. In the Mediterranean, hot climates, where designing for harsh summer weather constitutes a priority, high reflectance materials are recommended. Regarding the case study settlements, high absorbance dark pebbles (reflectivity 0.2) from the Pedieos river, medium reflectivity local volcanic stones (r=0.4-0.5) and high reflectivity local limestone (r=0.7), were used as outdoor floor finishes in the case of Pera Orinis, Askas and Maroni villages respectively. The light-colored materials, as in the case of Maroni village, appear to be the most appropriate in order to decrease the unwanted solar heat gains during the summer period.

4 CONCLUSIONS

The present study showed how the topography and climate affect the layout of the streets and buildings, the level of compactness, the size and shape of the rural settlements and the spatial configuration of the residential buildings, which create different microclimatic conditions. In the case of Maroni (CZ1) and Pera Orinis (CZ2) villages, the small height-to-width ratios of the streets, the topography and the mild winters offer good environmental potentials of the outdoor spaces during wintertime. During the summer, the sea breezes, the moderate extreme summer temperatures and the enhancement of street shading of Maroni village compared to Pera Orinis settlement demonstrate a better potential for thermal comfort in the former. In the case of Askas (CZ4), the compact form of the village blocks cold winds and reduces heat losses through building envelopes during winters. Additionally, the mild summer climate and the predominant narrow North-South orientated streets of the village, offer shade to the public spaces and create a desirable microclimate during the summer period. However, the mountainous topography and the high height-to-width ratios of the streets restrict solar access to the settlement creating unfavorable outdoor thermal conditions during wintertime.

Overall, the hot climate of the country has led to the enhancement of cooling strategies and techniques. Local wisdom in the settlement planning and the design of buildings indicate a bias for addressing summer conditions more so than winter ones, perhaps because of the extended periods of high temperatures and insolation in the climatic cycle of the island. The climatic considerations which are applied to the design of the selected case studies is a southerly orientation of buildings for direct solar gains and at the same time, narrow streets and a compact built form in order to increase shading. There is also predominance in the orientation of primary streets along prevailing summer winds to enable natural ventilation. However, the available dark-colored coating and finishes and the lack of open spaces and planting in the vernacular settlements have a negative impact on outdoor comfort.

Future research will focus on field measurements at open spaces of the settlements under study. Analysis of on-site measurements will address the contribution of the bioclimatic strategies incorporated in the design of rural settlements to thermal comfort and will identify challenges and opportunities for thermal improvement of open public spaces.

5 ACKNOWLEDGEMENTS

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REFERENCES

Apostolou, P. 2003. *Traditional settlements of Cyprus*. Athens: N.T.U.A.

Camelaris, G. 2011. *Pera through pictures: a traditional village of Cyprus*. Nicosia: Detorakis.

Christodoulou, D. 1959. *The evolution of the rural land use pattern in Cyprus*. Bude: Geographical publications.

Decay, M. & Brown, G.Z. 2001. *Sun, wind and light: architectural design strategies*. New York: John Wiley and Sons.

Givoni, B. 1998. *Climate considerations in building and urban design*. New York: John Wiley and Sons.

Ioannou, S. 2007. *Askas over time*. Nicosia: Chr. Ioannou.

Norberg-Schulz, R.M. 1991. *Genius loci: Towards a phenomenology in architecture*. New York: Rizzoli.

Passiardis, S. 1995. *Statistical analysis of wind speed in Cyprus*. Nicosia: Republic of Cyprus.

Yannas, S. 1994. *Solar energy and housing design Volume 1:Principles, objectives and guidelines*. London: AA