Examination and Assessment of the Environmental Characteristics of Vernacular Rural Settlements in Varying Topographies in Cyprus

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Abstract: *The proposed paper aims at examining the typological variations of typical traditional dwellings of Cyprus at Pera Orinis and Askas settlements -on the plains and on the mountainous areas respectively- and the ways in which these settlements are adapted to the natural environment. This study is part of a research program being carried out at the University of Cyprus and dealing with the implementation of sustainable design elements of vernacular architecture in traditional buildings, whereby case studies of rural settlements located in different climatic zones are examined. The ongoing comparative study indicates that the traditional dwelling is subject to morphological variations in varying topographies whereby different passive heating and cooling strategies are incorporated in the design of traditional buildings. Research outcomes aim to reveal design considerations for environmental refurbishment solutions of the vernacular built stock.*

Vernacular settlements, environmental adaptation, passive design strategies, thermal comfort

Introduction

The environmental design features that have been incorporated in the design of the vernacular buildings vary from their location in the plains to that in the mountainous areas in order to adapt to the local climatic conditions. Variations of local climate, depending on altitude and proximity to the sea, have created a variety of bioclimatic design solutions which are specifically adapted to vernacular rural dwellings of specific regions. Besides the local climatic conditions, the topography in which the rural settlements have been developed changed the building form and led to various configurations which reflect the specific habits, needs and the way of living of the locals. In addition to the accommodation of the family members, the traditional rural dwelling provides a shelter for the livestock and a storage space for food products. A number of various functions of the dwelling which have had to meet different comfort requirements have led to the division of internal dwelling spaces into multiple thermal zones offering thermal diversity in the traditional house.

The main objective of this paper is the examination and assessment of the bioclimatic strategies inherent in the design of vernacular rural buildings in varying topographies and

climatic zones of Cyprus. For this purpose two settlements –namely Pera Orinis and Askas villages– were selected for detailed study (Figure 1A, 1B & 1C). Pera Orinis is located in the Mesaoria plain in the interior of the island –at a latitude of 35°2´N and a longitude of 33°15´E – at an elevation of 400m above sea level, whereas Askas is located on the Troodos mountain range –at a latitude of 34°55´N and a longitude of 33°4´E – at an elevation of 900m. Research findings aim to reveal knowledge with regard to the bioclimatic design aspects of traditional architecture in relation to topography, climatic conditions, building typology and materials.

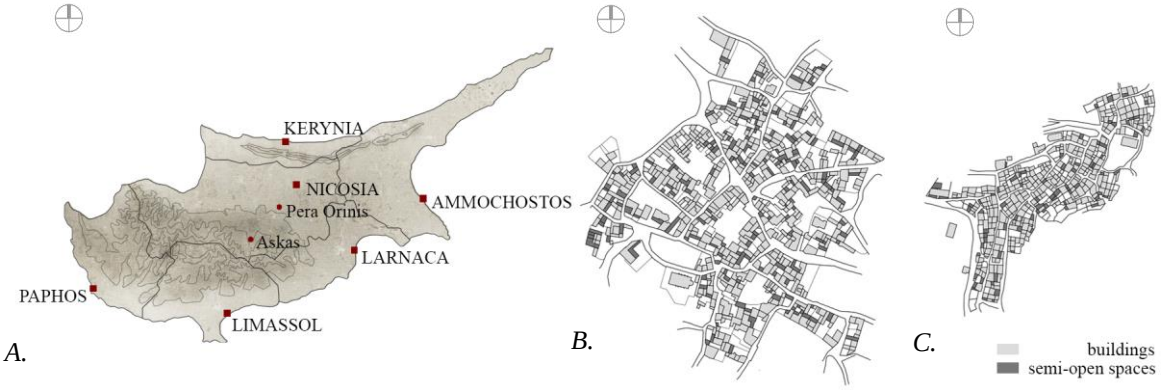

Figure 1 A. Map of Cyprus indicating the two case study settlements B. Pera Orinis village C. Askas village

Research methodology

The research methodology followed is based on a qualitative investigation of the architectural design aspects of traditional buildings located in the plains and in the mountainous areas of the island. The investigation focuses on a selected sample of traditional dwellings in the two settlements under study. More specifically, an examination of how climatic conditions, topography and available building materials influence the typological, structural and morphological solutions of the buildings is being carried out. Environmental data, architectural drawings and topographical maps as well as on-site observations and interviews with occupants have been collected in order to provide detailed information on the documentation and evaluation of the comfort conditions of traditional dwellings. The layout and orientation of the building mass, the orientation and arrangement of semi-open spaces, the location and size of the openings, the height and the depth of the internal spaces are investigated in order to assess the overall comfort of traditional dwellings.

Climatic context

The hot and semi-arid Mediterranean climate of Cyprus –characterized by long summer duration, intense summer insolation, great temperature fluctuation and high summer temperatures– has regional variations according to altitude, topographic and geographical factors that demonstrate a variety of composite local climates. Pera Orinis village has short mild winters and hot dry summers with minimal annual rainfall of 342mm and high summer aridity. Minimum temperatures reach 5.7°C whereas maximum temperatures reach 35.5°C. The village of Askas experiences moderately cold winters and mild summers while annual total precipitation is significantly higher compared to Pera Orinis –reaching 698mm. Lowest and highest temperatures are 3°C and 30.9°C respectively. In the case of Askas village the

range of temperatures for user comfort is 1°C lower compared to Pera Orinis village (Table 1) [1]. This indicates a difference in thermal perception whereby higher temperatures are acceptable during summer (28.9°C) in the case of Pera Orinis village while lower temperatures are tolerable during winter (17.5°C) in the case of Askas village.

Traditional dwelling - Environmental design aspects

An overview of the evolution of the typology of the rural traditional architecture of Cyprus shows that the *monochoro* (i.e. single space room) typology, most often in the form of a longitudinal space (*makrinari*) is the archetypical shelter of Cyprus. The need for a larger space led to the development of the *dichoro* (i.e. double space room) with an arch or timber beam dividing the room into two parts (Figure 2 & 3). The addition of other rooms for the storage of food products known as *sospito* (i.e. inner house), *sende* (i.e. mezzanines) for crop storage as well as of *anoi* (i.e. upper floor) created various typological configurations [2]. Additionally, the mild winter climate and the harsh summer conditions of the country prompted the incorporation of open and semi-open enclosures in the evolution of the house typology: internal courtyards and transitional spaces such as a semi-open often arched space known as *iliakos* (i.e. solarium) and a pass through semi-open entrance known as *portico* are typical configurations in the traditional house (Figure 2 & 3) [2]. The vernacular dwelling typology has evolved in different forms while adapting to terrain –whether located in the plains or in mountainous areas– to local climate and to the activities of the occupant (e.g. vine-grower, cereal producer etc.). The environmental design features of the traditional house will be discussed below through the comparative investigation of the building stock layout, function, morphology and construction materials of the two settlements under study.

Settlement compactness, building arrangement and orientation

Settlement compactness and building massing are significant aspects in the thermal performance of buildings. The semi-compact configuration of the village of Pera Orinis allows indirect and direct solar gains during the heating period (winter) while desirable shading from neighbouring surrounding buildings during the cooling period (summer) can be achieved. In contrast, the compact built form of Askas village is more advantageous during the cooling period. It provides protection from intense summer insolation both of the building envelope and of the indoor spaces. However, during the heating period shadows cast by neighbouring buildings causes a significant reduction in useful direct solar gains. With regard to orientation, southern exposure ensures thermal comfort while it offers better availability and distribution of solar radiation throughout the year compared with other orientations [3]. South, southwest and southeast facing buildings account for 44% and 31% of buildings in the

Table 1 Neutral temperature and comfort zone limits (90% acceptability limits) in the four seasons for Pera Orinis and Askas villages using Ashrae Standard 55-2013 (Tn= 17.8+0.31Tav)

	Tav (°C) Pera Orinis	Tav (°C) Askas	Tn (°C) Pera Orinis	Tn (°C) Askas	Comfort limits (±2.5) Pera Orinis	Comfort limits (±2.5) Askas
Winter	10.2	7.2	21	20	**18.5**-23.5	**17.5**-22.5
Spring	16.8	13.7	23	22	20.5-25.5	19.5-24.5
Summer	27.7	24.6	26.4	25.4	23.9-**28.9**	22.9-**27.9**
Autumn	20.5	17.7	24.2	23.3	21.7-26.7	20.8-25.8

settlement of Pera Orinis and Askas villages respectively (Table 2). Deviations from true south orientation (by more than 30°) incur loss of useful solar heat gains but can still offer benefit from southern solar exposure. In the case of Askas village due to the southeastern-facing slope on which the settlement is located the eastern and southern orientations prevail by 67% of the stock. Eastern orientation (37%) of buildings in the village of Askas is more prone to overheating that may lead to discomfort in case of lack of suitable shading devices [3]. The overall south (S, SE, SW) building orientation in the case of Pera Orinis village offers a better environmental potential whereas topographic challenges in the case of Askas village restrict building location according to prevalent environmental criteria.

Building form

In the village of Pera Orinis the *dichoro* typology with an attached *sospito* is predominant. The courtyard and *iliakos* that constitute essential parts of the dwelling are fundamental bioclimatic elements integrated in the design [4]. The courtyard provides a buffer zone against cold winter winds, while a southerly orientation ensures desirable solar access to the indoor and outdoor spaces during heating period (winter) and enhances the potential for cross-ventilation in building interiors. The residential buildings of the village have been built to serve the needs of farming where stables, barns and *sende* for crop storage are also incorporated in the building layout (Figure 2A). From the environmental perspective, the traditional house of Pera Orinis while divided into multiple thermal zones (i.e. dark and cool storehouses for the preservation of the food products, enclosed spaces for the main living, semi-open enclosures and outdoor spaces) offers thermal diversity and adaptive opportunities to the occupants. The traditional dwelling of the region is characterized by high ceiling main spaces of approximately 3.5-4.5m and deep spatial layouts. High ceilings reduce the negative effect of excessive solar heat gains through the roof, maintaining indoor spaces cooler during cooling period while at the same time enhance the potential for natural ventilation. On the other hand, deep rooms with openings solely on the front of these spaces restrict uniform distribution of natural light and cause poor daylight conditions to the rear interior spaces.

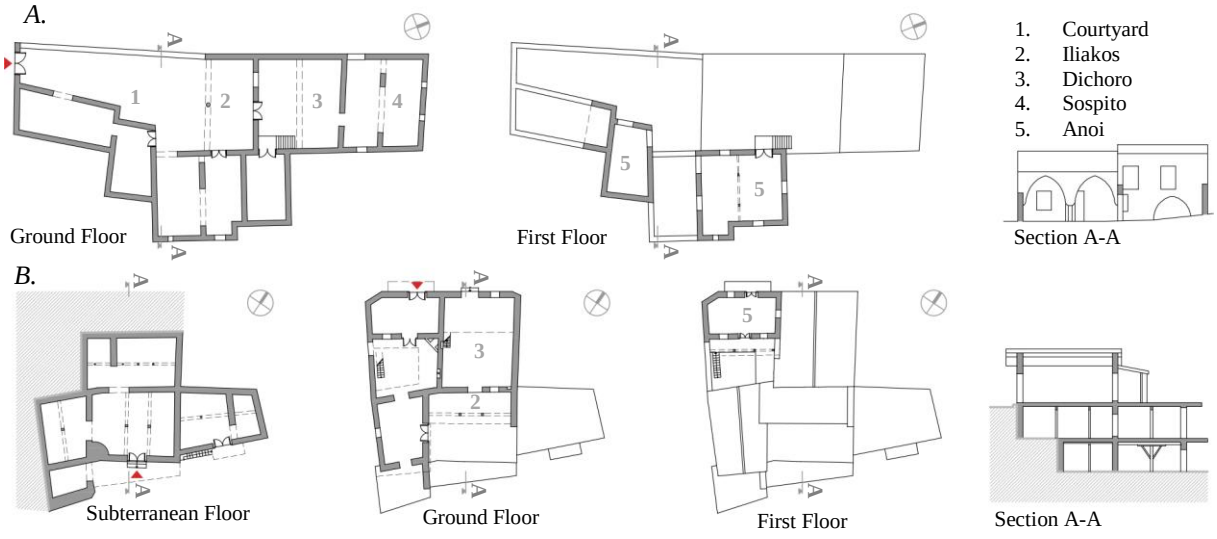

Figure 2 A. Typical plan layout and section at A. Pera Orinis settlement and B. Askas settlement

In the case of Askas the *dichoro* typology is also prevalent among residential buildings while courtyards do not usually appear in the building layout due to the mountainous topography of the region. Due to the steep slopes of the village of Askas, houses have a smaller footprint on the ground level and rise two or more floors. In this building arrangement the semi-open spaces and living areas are usually found on the upper floors for better solar exploitation during the heating period (winter) (Figure 2B). The southeast-facing slope in which the village of Askas is sited resulted in the inclusion of partially subterranean, windowless spaces at the lower levels of buildings used as storage rooms for locally produced wine and food products. Due to this particular orientation of the settlement the north elevations of buildings which are partly earth bermed provide bioclimatic advantages such as: reduction of exposure of the north side of buildings, shielding of buildings from cold winter winds and thermal buffering due to the contact of the building with the soil mass.

A. *B.* *C.* *D.* *E.*

Figure 3 Typological features of the traditional dwelling at Pera Orinis village: A. typical dichoro B. iliakos C. courtyard and Askas village: D. typical dichoro E. subterranean storage space for the food products

Configuration and orientation of semi-open spaces

Transitional spaces are a vital part of the vernacular architecture of Cyprus. 95% and 53% of vernacular buildings studied at Pera Orinis and Askas villages respectively comprise semi-open spaces (Figure 3B & 3C). The study indicates that while semi-open enclosures are fundamental in the everyday life of the locals in the case of Pera Orinis village, they are comparatively less important in the case of Askas village. This fact is related to the occupant activities as well as to the local climate. The relatively colder winters (heating period) of Askas village discouraged the incorporation of semi-open spaces since such elements result in the reduction of useful solar savings in the heating period even when purposely designed.

In the case of Askas village semi-open spaces appear in the form of balconies, elevated covered verandas and deciduous vine pergolas. The covered part of semi-open spaces is usually narrow in order to allow sun rays to penetrate to the indoor spaces during the heating period and to provide protection from high solar altitude angle during the cooling period. Deciduous vine pergolas which allow solar access during the winter (heating period) and provide shading during summer (cooling period) are preferred in the case of Askas settlement. In the case of Pera Orinis village, the *iliakos* and *portico* are the most widespread forms of semi-open structures. The low- solar altitude angle during the winter (heating period) allows solar penetration to the indoor spaces through the *iliakos* or *portico*, while during the summer (cooling period) these elements prevent the unwanted solar rays to enter the interior rooms

[2]. Southern exposures account for 47% and 36% of semi-open spaces in the case of Pera Orinis and Askas villages respectively (Table 2). In the case of Pera Orinis semi-open spaces exploit the environmental benefits of a southerly exposure to a greater degree.

Table 2 Orientation of buildings and semi-open spaces at a sample of 122 and 89 traditional dwellings at Pera Orinis and Askas villages respectively

	N (%)	NE (%)	E (%)	SW (%)	S (%)	S (%)	W (%)	NW (%)
Building orientation- Pera Orinis	13	14	11	6	29	9	14	5
Building orientation- Askas	15	3	37	0	29	2	14	0
Semi-open space orientation- Pera Orinis	7	22	7	8	29	10	7	8
Semi-open space orientation- Askas	19	5	21	5	31	0	17	2

Building construction materials

Traditional building structure was mainly based on the availability of building materials in the region. The vernacular residence of Cyprus is built exclusively by thick masonry (50-70cm) that provides benefits in terms of its thermal inertia and thermal insulation. Adobe and stone are the most typical building materials found in traditional settlements in the plains and mountainous areas respectively. Both materials are appropriate for hot and dry climates while they act as thermal and humidity regulators. Adobe, made of clay, earth and water mixed with organic substances, is the most common wall material in the case of Pera Orinis village. The measured values of volumetric heat capacity and thermal conductivity, at 336Wh/m³K and 0.55W/mK respectively, indicate that adobe is a high-mass material with high heat insulating properties. The local volcanic stones –diabase and gabbro– are the two main building materials in the case of Askas village [4]. The corresponding measured values of volumetric heat capacity and thermal conductivity of the gabbro stone are 522Wh/m³K and 1.97W/mK respectively while for diabase are 490Wh/m³K and 3.76 W/mK respectively [5]. The volumetric heat capacity of gabbro and diabase indicates that these materials have the ability to store larger amounts of energy in their mass compared to adobe while the higher thermal conductivity value of stones indicates worse heat-insulating properties compared to adobe.

Sun, daylight and wind access

Moreover, the rural vernacular architecture of Cyprus is characterised by small and sparse openings which are usually inward facing (towards the central yard) due to issues of safety, constructability and environmental performance. Opening sizes and arrangement are significant determinants of daylight and thermal conditions of indoor spaces. In hot and semi-arid climates the ratio of window area to floor area must not exceed 15-20% to avoid overheating during hot summers [3]. Moreover, the minimum net glazing area should not be lower than 10% of floor area to allow sufficient daylight. Studies in traditional buildings at Pera Orinis and Askas villages have shown that traditional dwellings have average window-to-floor ratios of 5% and 4% respectively. Thus, the window openings fail to ensure adequate daylight into rooms but offer protection from undesirable summer sun. With regard to wind penetration, the building mass and window openings arrangement affects natural ventilation conditions of the indoor spaces. The compactness of both settlements restricts cross-ventilation where windows are only placed on one side of the building. Additionally, the

dimensional characteristics of the indoor spaces -ceiling height and plan depth- are significant factors affecting natural ventilation. For sufficient single-sided natural ventilation the plan depth should not be more than 2 to 3 times the height of the space while for cross-ventilation plan depth can be up to 6 times the height [6]. In the case of Pera Orinis and Askas villages the high ceiling main rooms and the thin plan layout arrangements respectively provide the circumstances for sufficient air flow. Average plan depth is 2 and 1.7 times the height of the building (single-sided ventilation) for Pera Orinis and Askas villages respectively.

Conclusions

The present study identifies and assesses the varied environmental design aspects of the traditional rural dwellings of Cyprus in the plains and mountainous regions. In the case of traditional dwellings at Pera Orinis village –located in a plain– the short mild winters (heating period) and harsh summers (cooling period) result in the enhancement of passive cooling strategies through the semi-compact settlement arrangement, the semi-open and open spaces, the limited openings, the high-mass building envelopes, the high ceilings and a southerly layout prevalence. On the other hand, in the case of Askas village –located in a mountainous region– the moderately cold winters (heating period) and mild summers (cooling period) have led to balanced environmental concerns for both summer and winter periods. The compact arrangement, the high-mass building envelopes, the thermal buffering through the soil mass, the geometrical characteristics of semi-open spaces for optimal solar exploitation, the thin plan layout and the additional consideration for direct solar gains during winter (heating period) and solar protection during summer (cooling period) are the main passive strategies inherent in the design of the Askas traditional house. The analysed passive responses have revealed that the integration of semi-open and open spaces in the building layout of Askas village is relatively less important compared to Pera Orinis village. Topographic challenges in the case of Askas village restrict the predominance of southerly exposures while small window-to-floor ratios observed in the traditional buildings of both settlements cause daylighting problems. The above preliminary study revealed that the vernacular dwelling of Cyprus is adapted to the natural environment offering a variety of environmental design solutions specifically applicable to a region. However, topography, construction and security reasons lead to some limitations in this process. Further investigation is being conducted in selected buildings for an in depth, quantitative documentation of the bioclimatic features of vernacular architecture. This study will help towards the establishment of a bioclimatically based approach in the rehabilitation of the built heritage.

Acknowledgements

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