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Bioclimatic study of Feng Shui principles in the ancient Chinese village of Chuandixia

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***Abstract* – Environmental design can play a key role in the study of historic areas as it allows the investigation of traditional settlement principles according to the *Genius Loci* and the reconstruction of their original functioning processes. Feng Shui is an ancient body of knowledge and practices that evolved from Chinese philosophy embodying the Chinese ecological practice to harmonise people with the environment. This study presents a methodological approach for the bioclimatic numerical analysis of the urban microclimate of Chuandixia, a small village near Beijing (China), built during the Ming era following traditional design principles of Feng Shui. ENVI-met simulation software was used to check the environmental effectiveness of the relationship between the landscape, the local climate conditions, and the morphology of the streets, dwellings, and public spaces of the village. Thanks to a better understanding of the historical settlement, this study serves as the basis to propose design solutions to improve thermal comfort and reduce energy consumption of the building units, enhancing their passive behaviour while respecting the historical, architectural, and cultural significance of the traditional landscape.**

Keywords: Built heritage, ancient settlements, Feng Shui, environmental design, numerical simulation, China

I. INTRODUCTION

Archaeological evidence, such as the Banpo settlements of the Yangshao period (circa 5000-3000 BCE), shows that ancient Chinese villages were characterised by a particular environmental sensitivity towards the selection of the appropriate sites for settlement foundation and the planning of urban spaces [1]. Indeed, although settlement foundation was based on availability of resources, defence, and communication, it was also influenced by the topographical characteristics of the site and the quality of the natural and climatic environment. The origin of the concept of Feng Shui dates from the Yangshao period [2] and embodies the ancient knowledge related to architecture and the built environment [3]. By defining taboo and symbology for the creation of these sites, it acted as a "comprehensive environmental evaluation system" [4] closely linked to astronomy, climate, geology, topography, ecology, and landscape [5]. Based on the observation of the landscape, the orientation of the settlements followed the Chinese territory configuration, optimising climatic considerations regarding the sun path and summer breezes.

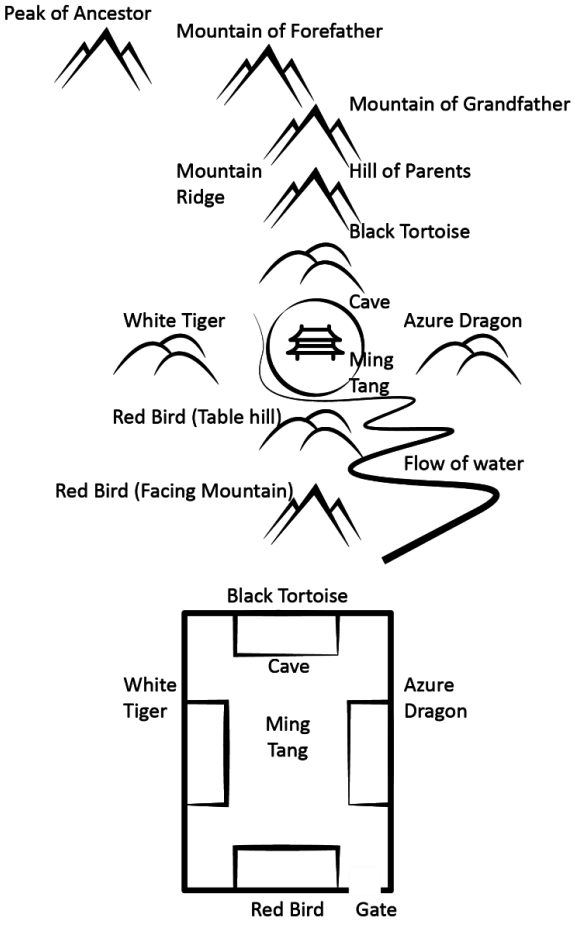

Fig. 1. Four Emblem Theory's scheme of Feng Shui. Source: new version based on [6].

Feng Shui is based on six settlement principles [6]: i) Qi Theory, stating that the earth is the source of all living natural events; ii) Ancestral Theory, where the destinies of descendants and ancestors are related; iii) Wind and Water Theory, which ascribes water a key role in the choice of a site; iv) Theory of Form, according to which a good site is determined by the correct proportion between its horizontal and vertical extent; v) Theory of the Four Emblems, for the choice of a settlement position with favourable environmental morphology and climate characteristics; vi) Direction Theory, affirming that the settlement should be in an elevated position and have an orientation benefitting from optimised solar radiation. The Theory of the Four Emblems is key to understanding the role of environmental design in the Genius Loci, which, as stated by the architectural-philosophical theory of Norberg-Schultz, represents the sense people have of a place, understood as the sum of all physical as well as symbolic values in nature and the human environment [7].

According to the Theory of the Four Emblems [2], to identify a promising place for the foundation of a city it is necessary to find the "Dragon Vein", a rock formation that constitutes a long chain starting from the “Peak of Ancestor” and ending to the “Hill of Parents” (Fig. 1). The "Cave" is the place where to build the first nucleus of the settlement in the “Ming Tang” (i.e., Bright Court), and should ideally be sheltered by surrounding hill formations (“Black Tortoise” to North, “Azure Dragon” to East, “White Tiger” to West, “Red Bird” to South). The “Red Bird” is subdivided into the formations “Table Hill”, smaller and closer to the “Cave”, and the “Facing Mountain”, bigger and more distant. Finally, the site must have a slow-moving water flow [3].

Over the last years, the attention towards Chinese villages has been growing, contributing to developing the concept of built heritage in China and to disseminating a holistic idea of the territory [8]. Since the traditional landscape and culture are threatened by the rapid development of urbanisation and industrialisation, in 2021 the Beijing Municipality issued the *Regulations on Protection of Beijing as a Historic and Cultural City* to strengthen the protection and development of municipal and national historic villages [1]. The scientific protection and rational utilisation of traditional villages can greatly benefit from the use of numerical simulation, which can provide a crucial decision support for their proper renovation through the evaluation and comparison of the performances of different design scenarios. Moreover, the climate change impact on Chinese rural villages, together with mass tourism as a contributing factor, needs to be addressed from a community-centred perspective to identify best practices for adaptation [9].

To approach Feng Shui from a scientific point of view and evaluate its soundness to select and optimise microclimatic conditions for urban settlements, Xiong *et al.* [10] used an ENVI-met simulation model for the analysis and improved understanding of traditional villages in the Jiangnan district (Southern China). It checked the accuracy and applicability of ENVI-met through the comparison of the simulation results with on-site measurements of air temperature and relative humidity. The study highlighted the significant influence played by the surrounding mountains and the narrow village streets in improving the microclimate through thermal insulation effect and in alleviating dampness and wind speed [10].

In this framework, the current ongoing study aims to identify strategies and methods for the sustainable renovation of historical centres and villages in China, to propose design solutions and suggest appropriate uses to improve thermal comfort and reduce the energy consumption of the building units, enhancing their passive behaviour while respecting the historical, architectural and cultural significance. To this aim, the influence of Feng Shui principles for effective use of the natural landscape and local climate is being investigated, also considering the effect of urban morphology features, such as street width, building density and orientation, and distribution of vegetation and public spaces.

The Chinese traditional village of Chuandixia (Fig. 2) is the subject of a bioclimatic study through the use of innovative technologies and approaches, involving considerations for its preservation in the face of the ever-growing tourist pressure and abandonment by the inhabitants that is affecting the area. An examination of the vulnerability of social-economic pressures is also carried out to design tailored solutions.

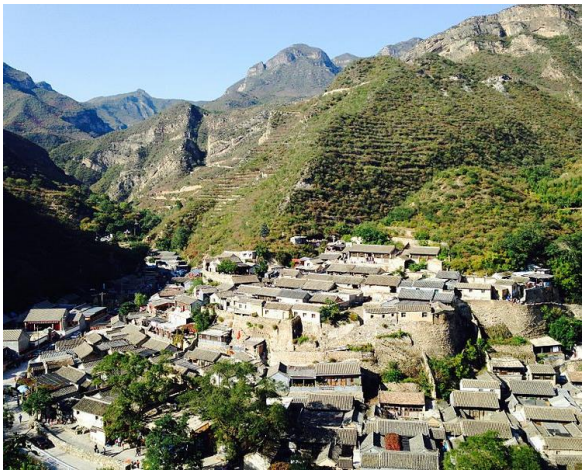

Fig. 2. General view of the traditional Chinese village Chuandixia in the Mentougou District (China). Source: Marine Diot, under CC BY-SA 4.0 license.

II. METHODOLOGY

The village of Chuandixia (Lat. 39.99° Lon. 115.64°), located about 65 km west of downtown Beijing in the

Mentougou District, dates back to the Ming Dynasty (1368-1644) and prospered until the end of the Qing Dynasty (1644-1912) thanks to a strategic trading position between coal production areas, fur, and grain [11]. Chuandixia (Fig. 2) was built following the settlement principles of Feng Shui and embodies a rare example of the concomitance of several morphological site-specific factors it requires [1]. It is located in the South of a mountain range, protected on each side by a hill formation as in the Four Emblems' Theory (Fig. 1). The housing units of the settlement are organised around central courtyards, with four or three wings, sloping down to the south side. In a complex with three wings, the southern is lacking. The buildings of the village, given their reduced size and the morphology of the underlying terrain, show a fair degree of flexibility with regard to their deployment, resulting in a slightly asymmetric terraced configuration, which grants benefits in terms of natural ventilation and solar exposure.

The climate of Chuandixia (at an altitude of 652 m a.m.s.l.) is a temperate monsoon climate, cool in summer and cold in winter (Dwa according to Köppen classification [12]). ERA5 Land data [13], a high-resolution dataset of atmospheric variables (e.g., 10m wind components, 2m dewpoint temperature, 2m temperature, solar radiation, and total precipitation), was retrieved from the Copernicus Climate Change Climate Data Store for a typical summer and winter monthly data averaged over the thirty-year reference period from 1981 and 2010 with a temporal resolution of 1 hour.

Table 1 and Table 2 provide an overview of the values of main microclimate variables in the months of June and December according to ERA5 Land data [13].

Table 1 Summary statistics of temperature (T), relative humidity (RH), wind speed (WS) and wind direction (WD) in Chuandixia in a summer month (June).

Climate variable	25th percentile	Median	75th percentile
T (°C)	18.3	21.4	24.3
RH (%)	55.6	69.9	84.1
WS (m/s)	0.7	1.0	2.0
WD (°)	203.1	343.8	384.1

Table 2 Summary statistics of temperature (T), relative humidity (RH), wind speed (WS) and wind direction (WD) in Chuandixia in a winter month (December).

Climate variable	25th percentile	Median	75th percentile
T (°C)	6.8	8.2	10.3
RH (%)	74.8.1	81.9	85.0
WS (m/s)	0.8	1.2	1.6
WD (°)	159.8	190.1	225.7

For managing and planning a sustainable development strategy for a district or area, it is paramount to involve the contribution from different disciplines, with a leading role of environmental design both in the analysis and design phases. For this reason, the investigation started with a technical assessment on the structural, typological and environmental performance aspects of the whole urban settlement of Chuandixia, with on-site inspection of the village, field surveys (traditional, 3D laser scanner and photogrammetric surveys), interviews with inhabitants and government officials.

Moreover, a GIS connected with an HBIM model was created to synthesise the acquired data concerning the state of conservation, function use, building typologies, and period of construction (Fig. 3).

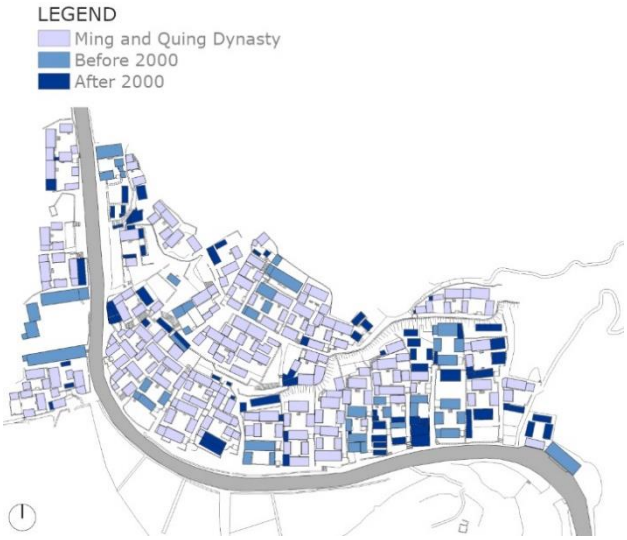

Fig. 3. GIS map of the buildings in Chuandixia and their period of construction. Source: own elaboration.

A numerical simulation model to study the environmental behaviour of Chuandixia is being developed using the software ENVI-met 5.5, a three-dimensional non-hydrostatic microclimate prognostic model based on the fundamental laws of fluid dynamics and thermodynamics. It allows to determine the influence, on the microclimate of the settlement, of topographical and physical aspects, linked to its position, as well as of anthropogenic elements, such as the settlement's morphology, materials, green and blue infrastructures, which strongly impact the radiative environment, air movements, and evapotranspiration.

The model includes the simulation of flow around and between buildings, exchange processes at the ground surface and at building walls, building physics, the impact of vegetation on the local climatology [14]. It is based on two main inputs of the given area: i) 3D spatial description of the site orography, morphology and material of buildings and horizontal surfaces, water and vegetation; 2) the geographical and meteorological data on the area for the given simulation dates.

Fig. 4. Spatial model of Chuandixia (DEM and buildings) in the ENVI-met environment. Source: own elaboration.

The simulation model was set to a fairly high resolution, i.e., 2 square meters, for a quite vast area covering a grid of 158*120 nodes. The digital elevation model (DEM) of the village was shaped starting from the orography of the area and refined on the basis of photographic documentation and altimetry maps. The buildings and vegetation are being modelled along the DEM on the basis of GIS maps of the area (Fig. 3); the materials of walls and roofs derive from a direct survey (Fig. 5). The analysis will be carried out on two typical outdoor microclimate conditions on a summer and a winter day. The simulations will focus on how prevailing winds and solar radiation interact with the buildings and the surrounding outdoor microclimate to investigate the relation between the local outdoor climate and the layout of the village in terms of building density, building orientation, and street width according to the Feng Shui principles followed.

This study will support the identification of potential sustainable solutions to preserve the existing structures (Fig. 5), adapting them to modern living standards while maintaining traditional building techniques and lifestyle. Based on the simulation results, it will be possible to define informed solutions, which need to be reversible, distinguishable, and above all compatible (such as removable shading systems, re-adaptation of the historical courtyards, improved natural ventilation, enhancement of existing ancient Kang, a traditional heating system, or water disposal systems) to enhance thermal comfort and reduce energy consumption throughout the year. The reuse of abandoned ancient technological systems, whose functionality can still provide invaluable results in terms of sustainability and cultural values, will be pursued whenever feasible. For instance, the ancient water management system could be recovered and upgraded along with the ecological management of water and waste.

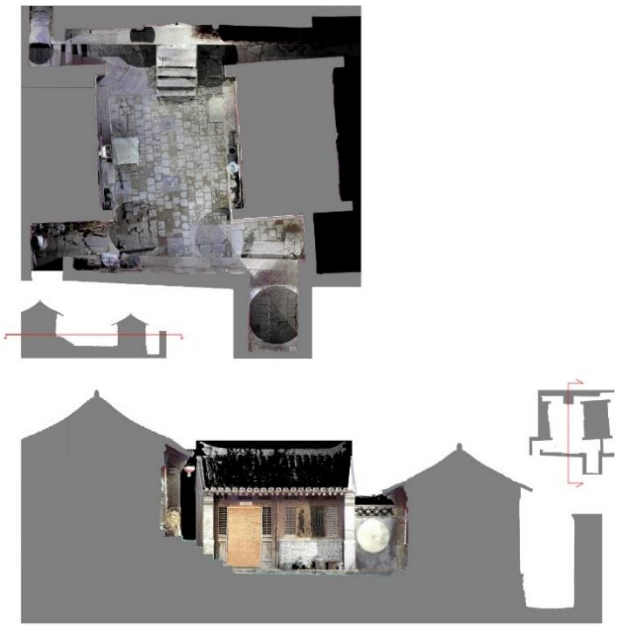

Fig. 5. Example of a traditional siheyuan *(single story courtyard housing units) in Chuandixia. Integrated survey (F. De Silla, R. Gabrielli).*

III. CONCLUSIONS

The village of Chuandixia is being the subject of a comprehensive bioclimatic study that is currently under implementation through the use of innovative technologies and approaches.

Overall, the use of an environmental simulation model, in addition to providing historical information on settlement principles, contributes a solid scientific basis to support tailored interventions of conservation and sustainable renovation, improving energy efficiency, thermal comfort, and preserving the distinctive features and identity of the built heritage of Chuandixia [15].

The final aim of the research is to support the definition of good practices for the conservation of traditional Chinese villages and of an innovative model for their revitalisation to design self-sufficient and resilient communities, while supporting these anthropic-and-natural systems as a whole. With this study, a knowledge-added value will be created, thanks to which it will be possible to reconstruct the natural functioning processes of ancient villages according to Feng Shui to enhance and better preserve their identities as built heritage, leveraging specific design strategies closely linked to the history of the sites, of the traditional construction methods and of their local microclimates.

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