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Analysis and regeneration strategies for the abandoned villages of the Santerno valley in Tuscany

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Abstract
The historical settlement system of the Mugello mountains in Tuscany is characterised by scattered rural stone villages and houses. In the past these villages housed communities mainly dedicated to the centuries-old cultivation of chestnut. The process of abandonment can be traced back to the 50s and 60s, when the inhabitants left these isolated places to head towards the cities in search of better economic and living conditions. This paper illustrates the research carried out on three abandoned settlements in the municipality of Firenzuola, with particular reference to the Santerno valley. Pratalecchia, Brento Sanico and Castiglioncello were taken as case studies to carry out a typological and constructive analysis, comprising state of conservation and vulnerability maps of their vernacular heritage. The first part of the investigation analyses the context and the environmental resources; identifies the characteristics of the recurring architectural types; and carries out a classification of the building techniques. The main classes of stone-masonry types were recorded and mechanical parameters of the masonry types were determined through the application of the masonry quality index (IQM) method . In the second part of the research, the state of conservation of the buildings was assessed. According to a risk-based approach, a vulnerability level was determined for each building, considering the quality of the construction elements, the degree of damage and the relation with adjacent buildings. The research made it possible to outline a first methodological approach in order to plan future intervention priorities and to identify strategies for the sustainable conservation, enhancement and rehabilitation of this architectural heritage.

Keywords: *abandoned villages; stone architecture; vulnerability assessment; sustainable regeneration.*

1. Introduction

The territory of Upper Mugello is characterised by small towns located along the main roads, while the inland areas of the mountain are dotted with isolated houses and small villages that today, in some cases, are completely abandoned. The phenomenon of depopulation and consequent abandonment is a process common to many areas of the hinterland, marked by peripheral position, lack of essential resources and services, and deep changes on traditional economic and social balances. The settlement structure and the evolutionary dynamics of the villages of the Santerno Valley in the municipality of Firenzuola were deeply linked to the cultivation of chestnuts, in a strong relationship of balance with the environmental context. Over time, the territories of the villages have undergone a process of marginalisation that has slowly led to their depopulation and later abandonment. These villages are still the expression of a vernacular heritage that has developed thanks to a strong knowledge of the environment

and the adaptability to a context with few resources. They are part of a cultural landscape which includes a plurality of values, meanings and potentials. Today, considering the pandemic crisis and the climate emergency, it is necessary to reconsidering the capacity of these marginal contexts to trigger territorial, economic and cultural enhancement processes, generating new centralities (Fenu, 2020; Dipartimento per le politiche di coesione, 2020) both for quality and eco-friendly tourism, and for the development of new production chains based on local resources.

1.1. Research aims and methodologies

This study has the main objective of enhancing the knowledge concerning the system of values (architectural, formal, spatial, functional values, technical culture and construction systems, etc.) of the vernacular architectural heritage of the Santerno valley villages to be safeguarded. The interdisciplinary analysis we carried out is aimed at identifying strategies and guidelines for an appropriate regeneration according to a sustainable development of the area. In fact, the absence of shared guidelines and protocols for the regeneration – which has in part already begun –, risks compromising the technological and cultural authenticity of these architectures (Coppola & Dipasquale, 2022) and the balanced relationship between anthropogenic activities and landscape maintenance with a minimum environmental impact, which has characterised the existence of these settlements.

This study is based on multiscalar analysis, in order to understand the implicit rules that generated these architectures. The analysis of the documentary sources was supplemented by in-situ data collection, which allowed direct survey operations and the reading of the remains (Mannucci, 2021). The analysis have led to the identification of the urban and morphological characteristics of the settlements, the features of the recurring architectural types (Coppola, 2018), the traditional building systems, the state of conservation, and the main processes of decay and failure. An evaluation of the mechanical performance of the masonry structures was carried out and a vulnerability assessment model was developed to prioritize conservation actions. Finally, specific strategies and actions were identified to trigger a sustainable regeneration process of the settlements.

2. Local building culture

2.1 The Santerno valley: environmental and socio-economic characteristics

The Upper valley of the Santerno river constitutes one of the historic natural links between the regions of Tuscany and Emilia Romagna. The landscape of the valley, narrow and rocky, is deeply influenced by the presence of the river, which has created small and narrow bends. The slopes are wooded, with coppice and chestnut forests up to 800m a.s.l., while higher altitudes are covered in coppices of beech trees. The hilly areas, mainly those near water courses and along the sunniest slopes, are intended for self-consumption agricultural production. The phenomenon of depopulation that has characterised the mountain area for decades has caused a progressive abandonment of pastures, crops and agro-forestry pastoral practices which are inevitably followed by the processes of "re-naturalisation" of agricultural environments by the forest, with the loss of landscape and ecological diversification.

The centuries-old chestnut groves of the area were an important source of income for the local populations, who for decades cultivated and maintained plants and undergrowth, shaping a cultural landscape of considerable value. Starting from the 1950s, the abandonment of inhabited centers did not correspond to a systematic abandonment of the chestnut groves. In many cases the villages have been (and still are) inhabited (and limited to some intact buildings) only during seasonal work in the chestnut groves.

Another important resource that has played a central role over the centuries, becoming one of the most representative activities of the local culture and economy is sandstone. There are about 40

quarries in the municipality of Firenzuola, 25 of which are in operation. The stone, easily workable, gray-blue in color, has historically found various uses in architecture, from monumental to vernacular architecture, and even in recent years it has been widely used in the form of cladding or flooring.

2.2 Villages morphological features

The villages are located in the strip between the valley floor and 700 m asl, all in a position well exposed to solar radiation, protected from northern winds, and generally close to a water source. The trend of the slopes has imposed strong constraints on the location of the settlements which are often divided into several buildings located in different areas to better adapt to the contour lines, exploiting the variations in elevation to create access points to different floors of the same complex.

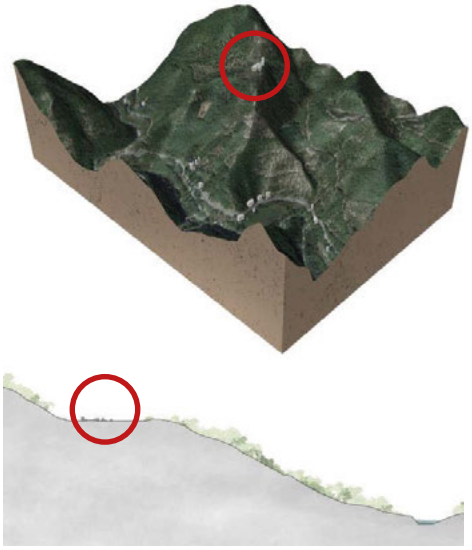

Fig. 1. Territorial model and environmental section of Pratalecchia.

The three analysed villages, Pratalecchia, Brento Sanico and Castiglioncello, have similar morphological characteristics: they all rise on mountain ridge (Fig.1) and have a linear distribution of the buildings along a main central axis, oriented in the north south direction. Pratalecchia (590 m a.s.l.) and Brento Sanico (625m a.s.l.) are located in the Monte Coloreta mountain, not far from the city of Firenzuola; Castiglioncello (340 m s.l.m.) is located further north, at the current borders between Tuscany and Emilia Romagna. Their strategic position has played since medieval times an important role in the control of trade between Florence and Bologna (Balducci, 1993). From the 18th century onward the construction of new roads axes led to a progressive exclusion of these rural areas from the main roads, which culminated in the abandonment of villages between the '50s and' 60s (Fig. 2), following the urban development processes after Second World War.

The organisation of these historic towns is strongly related to the management of pastures, chestnut groves, groves and other agricultural activities. The vegetable gardens were located in areas with a lower slope, taking advantage of the difference in height to naturally convey rainwater. The number of production buildings equal or exceed those for residential use and every house always has a space for production or storage activities (Guccini, 2011).

Fig. 2. Castiglioncello village.

2.3 Main building types

The traditional buildings of the villages examined have elementary volumes, with a rectangular plan and two or three floors above ground. The roof has usually two inclined and slightly protruding pitches covered with stone slabs. The dwelling, in its simplest form, consist of a base unit on two levels, connected by an internal staircase: the kitchen is located on the ground floor, while the first floor is reserved for the bedroom. In cases where the building is located on sloping ground, an additional room accessible from an independent entrance, serving as a cellar, barn or stable, can be

located below the kitchen. The kitchen is the place of social life of the family. It houses the fireplace and is always located in a central position and in direct contact with the outside. Over time, and depending on the needs, the basic cell of the house has undergone transformations through lateral or posterior doubling of the main volume, leading to a redistribution of spaces, but always keeps the living area separated from the sleeping area on overlapping floors.

The spaces for productive activities are the barn, the stable, the dryer and the furnace. The barn and the stable are often included in a single building on two levels. It is generally located in the steepest areas of the settlement, in order to take advantage of the slope to obtain two overlapping rooms that are accessible from separate entrances.

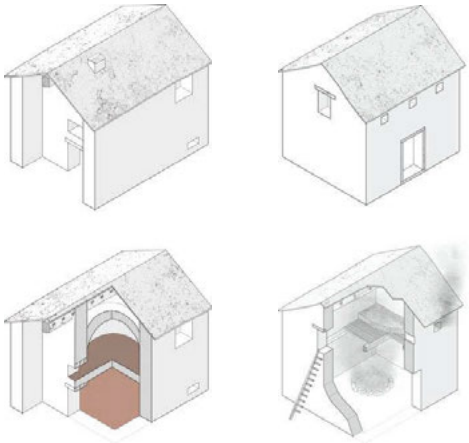

Fig. 3. Scheme of a oven (left) and a dryer (right) in Pratalecchia village.

A typical building of this area is the chestnut dryer (Fig. 3). The structure is single-celled on two floors divided by a horizontal trellis made of chestnut wood shafts: in the lower room a weak fire is lit; in the upper compartment, through a window accessible with an external staircase (or through the natural unevenness of the ground), chestnuts were placed to be dried. The drying operation, which required constant surveillance to prevent the fire from developing a flame (thus burning the chestnuts), lasted about forty days, then the wooden boards of the attic were removed and the chestnuts fell into the lower compartment.

The oven also plays a fundamental role in these settlements and can be external or integrated into the house. When separated, it often includes a small room below the oven, which, taking advantage of the heat of the fire, was used as chicken coop, pigsty, dovecote, but also as a well or woodshed (Guccini, 2011).

2.4 Construction techniques

The building materials are closely linked to the resources available in the area: the masonry is always made of sandstone blocks walled with earthen mortar. The stone blocks are generally hewn, while square blocks are used where a better performance of the masonry was needed, such as the corners of buildings. Three main classes of stone-masonry types have been recorded, using a set of parameters (Dipasquale et al., 2020): general dimensions, laying criteria, type of blocks, use and nature of mortars, etc. The openings are generally characterised by stone lintels and cornices, sometimes decorated with simple engravings. The openings of the service annexes are made with simple chestnut wood architraves placed side by side to cover the entire thickness of the masonry.

Floors have single or double framed timber structure. The elements are obtained from simply debarked and roughly hewn chestnut trunks with a maximum diameter of 30 cm. The floors with a simple frame consist of wooden beams embedded in the load-bearing masonry, a wooden plank placed in an orthogonal direction to the underlying beams, an infill layer in earth and crushed stone of variable thickness and a finishing layer in stone slabs. The beams generally cover lengths ranging from 3 to 5 meters and they are placed directly on the masonry using stone scales that ensure the interlocking between stone and wood.

Double frame floors are often used for agricultural buildings. The main structure consisting of beams is superimposed with square joists placed at a distance of 60 cm from each other and by a final layer

of stone slabs. A second variant, found only in the residential buildings of the village of Castiglioncello, is more complex because, while following the main structure of beams and joists, brick tiles and a thin filling soil are interposed between the joists and the stone slabs.

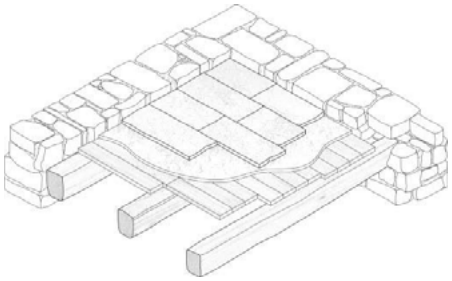

Fig. 4. Axonometric view of a single-joisted floor.

The gable consists of a double warp of beams and joists and a covering of stone slabs. The slabs are laid without any anchoring: the installation starts from the bottom where the heaviest slabs were laid, and then proceeds towards the ridge line following horizontal rows and making sure to sufficiently overlap the upper and lower slabs, thus avoiding infiltration of rainwater. The roof required a careful execution in order to find a balance between the overlapping of the slabs and the economy in the use of the material: a greater overlapping of the stone slabs, in fact, ensures greater resistance to infiltration by water, but at the same time causes increased weight and material consumption.

3. Analysis and assessment of the quality and vulnerability of traditional buildings

3.1. Analysis of the masonry quality of the main masonry types

With the aim of evaluating the mechanical quality of the identified masonry types, the Masonry Quality Index, MQI, method (Borri & De Maria, 2019; Rovero et al., 2016) was applied to three walls (M1, M2 and M3) which were identified as representative of the masonry types. The MQI method describes the capacity of walls in contrasting different actions, evaluating the presence, partial presence, or absence of constructive features linked to the so-called "rule of the art". The MQI method allows a robust estimation of Young's modulus, compression strength and shear strength, using correlation diagrams obtai-ned through wide experimental analysis.

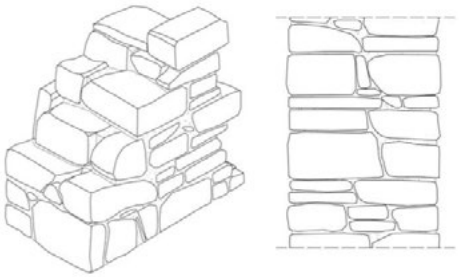

Fig. 5. Axonometric view and section of a M1 type masonry.

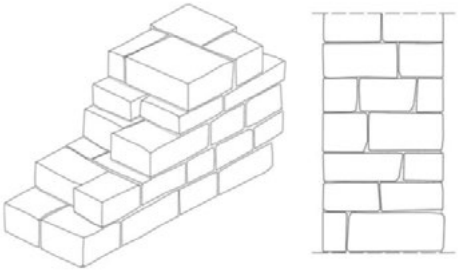

Fig. 6. Axonometric view and section of a M3 type masonry.

M1 masonry (Fig. 5) presents rough-hewn ashlars, of various shapes and sizes. The mortar is powdery, the bed joints are wide and the use of stone scales is not adequate to ensure sufficient adhesion between the elements. The horizontal nature of bed joints is partially respected, but the absence of headers and the insufficient staggering of vertical joints make the masonry uneven and susceptible to instability and disintegration. According to the MQI method, M1 masonry belongs to category C, that means inadequate behaviuor of the masonry, with 754-1082N/mm^2 Young's modulus, 1.38-2.34N/mm^2 compression strength and 0.029-0.064N/mm^2 shear strength. M2 masonry belongs to a barn that has been well preserved over time and has no particular critical issues. The blocks are mostly squared in shape; the earth-based mortar is powdery and eroded in some areas but this critical issue is compensated by an efficient use of scales. The connection between the two faces of the wall is ensured by the presence of headers and the head

joints are properly staggered. M2 masonry is classified as category B, that means an average quality behaviour of the masonry, with 1095-1559N/mm^2 Young's modulus, 2.20-3.57N/mm^2 compressive strength and 0.127-0.241N/mm^2 shear strength.

M3 masonry (Fig. 6) belongs to the church of Brento Sanico's village and is characterized by large square ashlars, with vertical joints properly staggered and continuous horizontal bed joints. he only parameter that is not perfectly respected concerns the mortar that, also in this case, retains its characteristic powdery consistency. The analysis leads to classifying this masonry in category A, with 2269-3184N/mm^2 Young's modulus, 5.49-8.15N/mm^2 compressive strength and 0.22-0.40N/mm^2 shear strength.

3.2. Analyses of the state of conservation of the buildings

In order to define a framework for the assessment of the state of conservation of the existent buildings, a series of parameters have been defined. Factors relating to the masonry (collapses, cracks, material degradation and weeds) and factors relating to floors and roofing floors (collapses and material degradation) have been evaluated. Through this process, five levels of damage have been defined and reported in form of a map: intact building; slightly damaged building; damaged building, severely damaged building and building in a state of ruin. The worst conditions, observed above all in Castiglioncello, are affected by the high degree of degradation and damage of the floor and roof structures: the horizontal structures, in fact, play a leading role in the box-like behaviour of the building. If these horizontal structures are missing or are compromised, the masonry 'box' tends to open and disintegrate.

3.3 Analysis of the main degradation phenomena and collapse mechanisms

The Apennine territory in which the three villages are located is a highly seismic area. For this reason, after the observation of the instabilities and the survey of construction features, the main mechanisms that may have been activated in buildings due to the seismic action have been hypothesized.

The most frequent collapse mechanisms are "first mode mechanisms" These are kinematic systems triggered in wall panels affected by orthogonal seismic actions which tend to produce the overturning (Fig. 7) (Avorio et al., 1999). These kinematic systems may occur in buildings where the lack of stable connections between walls and floors and between the wall panels themselves does not guarantee the establishment of an overall behaviour of the structure.

Fig. 7. Vertical bending and overturning mechanisms.

The buildings which present masonry with insufficient wall leaf connections primarily record instability and collapses linked to phenomena of simple overturning or horizontal bending, which manifests itself with the expulsion of material from the summit area of the wall and the detachment of cuneiform objects accompanied by the formation of oblique and vertical cylindrical hinges (Beolchini et al., 2005). Complex overturning mechanisms, generally affect, buildings that have vulnerable corners made with small stone elements: in these cases it is common that deep cracks are created at the edge of the building that are precursors to an upcoming overturning and disaggregation of the masonry.

Finally, the vertical bending mechanism has been detected at the level of doors and windows, which represent weak points in the masonry, appearing in the form of a horizontal cylindrical hinge that divides the wall into two blocks and is described by the reciprocal rotation of the same around this

axis (Beolchini et al., 2005). The signals that reveal the activation of this mechanism are the bending and the out of plumb of the wall, the presence of horizontal and vertical cracks and the slippage of the floor beams.

3.4 Vulnerability Assessment

The analyses carried out on the state of conservation, on the structural system and the construction defects led to the assessment of the state of vulnerability of the buildings in the three villages. Vulnerability is obviously not only a function of seismic phenomena but is also strongly influenced by the action of atmospheric agents (wind, rain, snow, water infiltration,ect.), which, due to the state of abandonment and advanced degradation of many buildings, are decisive factors in the risk of collapse of buildings. The vulnerability assessment (Fig.8) was conducted on the basis of the following parameters: factors related to masonry (portions of non-connected walls, crack pattern, roof and floor belts, corners, presence of "waiting stones" at the edge of the building); factors related to floors and roofs (portions of non-connected floors, absence of floors and roofs) and factors related to the location of the architectural structure (proximity to buildings with high-risk levels); state of conservation of the building. The assignment of different values establishes a matrix through which it is possible to determine vulnerability levels, divided into four groups: low, average, high and very high. Low vulnerability characterised those buildings that do not present elements at risk of collapse; buildings that belong to the second category do not present serious deficiencies yet present a risk of collapse related in particular to their proximity to very vulnerable buildings; high vulnerability characterises buildings with parts in a heavy state of deterioration and structural weakness that can lead to a consequent instability of the entire wall box; finally, very high vulnerability concerns buildings presenting conditions where a strong instability of the masonry may lead to sudden collapses as a result of any external action.

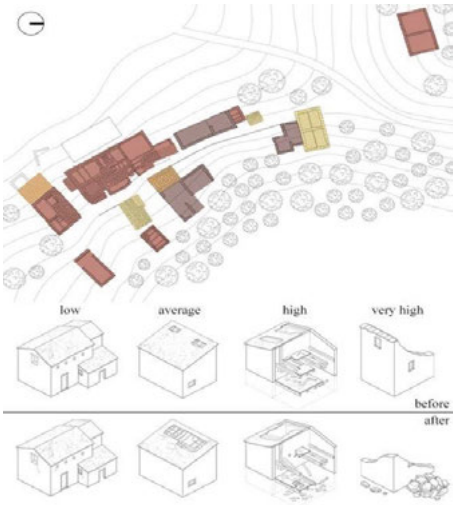

Fig. 8. Map of the vulnerability of buildings in Pratalecchia. Yellow: low vulnerability; orange: medium; red: high; brown: very high.

4. Identification of strategies for a sustainable regeneration

The identification of critical issues and the assessment of the quality of the construction elements was an essential step for determining intervention criteria for the rehabilitation of buildings, in ways that are as compatible as possible with the existing heritage. Based on the type of critical issue involved, intervention actions were determined, aimed at restoring the structural behaviour of the building and improving the anti-seismic and energy performances, by acting on the envelope without modifying the authenticity of the building. The proposed interventions involve the use of local materials or materials similar in terms of physical, mechanical and hygrometric characteristics to those already used.

In addition to the determination of intervention proposals, the authors conducted a reflection on a larger scale to define a plan of strategies to be used as the basis of guidelines for the sustainable regeneration of the cultural and environmental heritage of these places, that can be replicated to similar cases. The strategies aim at ensuring sustainable development based on culture and nature and have been identified starting from the three axes of sustainability: environmental, socio-cultural and

socio-economic. Beginning from these strategies, some concrete proposals have been identified. A first proposal concerns the enhancement and strengthening of the network of paths to create new cultural itineraries, which connect these abandoned and mostly unknown contexts to the main places of interest and the most relevant hiking trails, so as to trigger processes of enhancement and knowledge of these territories. Another proposal concerns the activation of training activities, aimed at learning construction techniques and the recovery of stone masonry buildings, taking advantage of the possibility of having a site as an experimental training field, where workshops and internships for students, professionals, technicians, and owners, can be carried out.

5. Conclusions

The complex interdisciplinary analysis conducted on the three villages provides quite a clear picture of the characteristics, risks and potential of the built heritage of the villages of the upper Santerno valley. Considering the critical conditions that have emerged, with a state of advanced widespread degradation, the importance of intervening urgently is underlined, first of all by sharing guidelines for appropriate rehabilitation interventions and more broadly for a sustainable regeneration capable of respecting the delicate balance between environmental resources, built heritage and thesocio-economic and cultural context. Starting from the intervention criteria and the strategies identified, a series of specific actions could act as a driving force to trigger a process capable of increasing the attractiveness of places, in a perspective of sustainable development based on the cultural identity of the places, in full respect of the environmental context in which they are located.

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