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MULTI-TEMPORAL ANALYSIS OF VERNACULAR FARM BUILDINGS AND RURAL LANDSCAPE THROUGH HISTORICAL CARTOGRAPHY AND 3-D GIS

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ABSTRACT

Farm buildings, designed over the centuries in order to fulfil their primary agricultural goal, now often constitute a widespread heritage of vernacular constructions, endowed with an unreplaceable architectural value. Together with the concurrent action of natural events, human interventions and changes in natural cycles, they play indeed a central role in shaping the rural landscape.

In this paper, thanks to the use of a Geographic Information System in which historical cartography, aerial photos and other ancillary dataset have been implemented, the land use of the area of "*Monte Vulture and Monticchio lakes*" and its environmental components have been investigated through a 3-D modelling of the relevant rural landscape and its main features. This area, located in the Basilicata Region (southern Italy), is one territory with a great scenic interest, having been recognized as a landscape heritage thanks to some specific cultural and historical elements. This rural landscape also includes – similar as many other Italian rural landscapes - some vernacular constructions having a high historical and architectural value, that have contributed to create this traditional rural landscape. The analysis has involved a multi-temporal comparison of the vernacular constructions located in the study area, so as to evaluate the built heritage evolution in the framework of its rural landscape, as well as its interactions with the surrounding territory. With this aim, the historical reconstruction of the landscape before and after the year 1900 has been conducted through implementing digital terrain models enriched by draping land cover pictures over them.

The results which have been obtained enabled an evaluation in a scenic way of the morphological and vegetation variations during time of the rural landscape, allowing a virtual "*time jump*" back to periods when digital aerial photography was not yet existing. Thanks to these new technologies, able to exploit information included into old cartographic supports, some suitable tools have been then developed, skilled to support the sustainable planning and management of rural built heritage, enabling an analysis of their possible valorisation for cultural tourism purposes as well.

KEYWORDS: Vernacular heritage; farm buildings; rural landscape; geographical information systems; historical cartography.

1. INTRODUCTION

The design of vernacular constructions reflects traditional daily life and cultural values of a Country's past. In particular, rural buildings and their landscape have together evolved during time, reaching their final form and layout through a common evolution shared along with the socio-economic changes of the population. Indeed, buildings have been realized in rural territories to answer the needs of their residents, protecting from adverse climatic conditions, being included into the surrounding landscape at the same time. They are characterized by the simplicity of their building processes and techniques, as well as by the local materials employed [1]. Designed over the centuries in order to fulfil their primary agricultural role, farm buildings now constitute a widespread heritage, which in some cases possess an extraordinary architectural and cultural value [2]. These constructions also play a central role for the sustainability of the rural ecosystem, since they can influence natural and semi-natural habitats, both in terms of their structure and biodiversity [3]. The primary objective of rural buildings is the production of optimal environmental conditions for animals and plants. Since, at the same time, they host workers and inhabitants involved in the daily operations for the care of living organisms [4] [5], they constitute a distinctive technological model. The central role that the buildings have historically played is strictly connected with the surrounding context as well, due to the need of the farmer to live in close contact with agricultural land and animal husbandry. This form of settlement has always been in synergy with the environment and landscape, joining the primary production needed for human nutrition with the control and care of the rural land. So, the activities made by the Man have often strongly influenced the agricultural ecosystem and the visual perception of the surrounding landscape [6].

However, as suggested by Mennella [7], it is necessary to better understand the relationship between buildings and their landscape because, in recent decades, there has been significant and often discordant changes in this relationship. To this aim, it is essential to implement an integrated approach, able to take into account the different factors existing between vernacular constructions and landscape, through the use of geographical tools, multi-criteria analysis and decision support systems, so as to have an exhaustive view of all aspects characterizing each individual rural building [8]. One approach that can be used as the starting point is the historical one, *i.e.* to evaluate the evolution of rural constructions (buildings, roads, *etc.*) and the surrounding territory over time [9]. Hence, architectural aspects derived from field surveys, information retrieved from historical archives, *etc.* should be taken into account, as well as landscape components, analysed by elaborating the historical reconstruction of the rural environment around these buildings. This last assessment can be achieved through the integration of different cartographic supports (historical maps, aerial photos, topographic cartography, *etc.*) within a Geographic Information System (GIS). In addition, by integrating Digital Terrain Models (DTM), it is possible to create 3D reconstructions of the landscape, so as to allow an assessment of the aesthetic characteristics and scenic impact of a vernacular construction within the surrounding territory [10].

In this work, a diachronic survey of some vernacular farm buildings has been carried out using a GIS software. Thanks to specific functionalities of this tool, it has been possible to reconstruct the history and the evolution of the buildings in different temporal steps, through the integration of the updated datasets with historical orthophotos, aerial photos and historical cartographies. Moreover, considering the use of altimetric datasets and the potential of the employed open-source GIS tool, it has been possible to three-dimensionally reconstruct the landscape of the past, enabling a virtual analysis in periods when digital photography was not yet imaginable. Finally, a preliminary version of a webGIS has been implemented as well. This tool permits the virtual analysis of different scenarios of landscape and built rural heritage evolution, as well as to gather in a dynamic way all the information useful for the evaluation of each rural building. Hence, in this way it has been possible to create decision support tools able to take into account different survey criteria, therefore usable both for land monitoring, planning and management purposes, as well as and for general dissemination (*e.g.*, tourism) objectives [11].

2. MATERIALS AND METHODS

2.1. Study area

On the basis of a preliminary analysis of the rural building typologies of the whole Basilicata Region (southern Italy) [12], only those present in the study area of "*Monte Vulture and Monticchio lakes*" (Figure 1) have been considered. The main landmarks of this area, located in the territories of the municipalities of "*Atella*", "*Rionero in Vulture*" and "*Melfi*", are the Mount "*Vulture*" (1,326 metres) and the "*Monticchio lakes*". This area, studied from its ecological landscape perspective in a previous work [13], covers about 6,700 ha. It includes two main zones of great naturalistic and cultural importance, that make this landscape unique in Southern Italy. The first one is an extinct volcano, which has had a notable influence on the geographic, botanical, zoological and anthropological events of the surrounding natural environment. The second one has been formed in the original crater of the extinct volcano, completely reforested over the top of the volcanic cone. This area has always represented one of the most important zones of the Basilicata Region, as well as of the whole Southern Italy, thanks to the coexistence of areas and high natural, landscape and agricultural value.

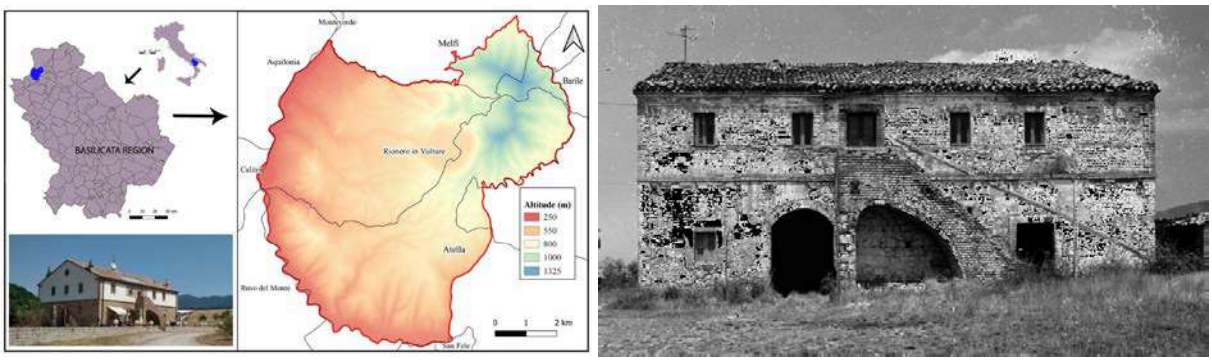

Figure 1: Location of the study area and an example of a typical rural building named "*Masseria Giannini*"

2.2. Farm buildings

All farm buildings present in the study area, traditionally known as "*masserie*", have been considered, evaluating their presence in the different years and their possible expansion or abandonment on time.
In this study area there are two types of vernacular constructions [12]: the first typology of rural building is often located in areas at a lower altitude, organized in basic forms of a compact type. These are small buildings, characterized by a very simple architectural typology, which were built during the first decades of the 20th century in order to host tenants drawn to the encourage farming of new agricultural fields obtained by a massive land reclamation (the so-called "*Land Reform Program"*). The second typology (Figure 1) is characterized by lodgings of a basic type, but with greater architectural value and more stylistic elements (*e.g.*, an external staircase). This geodatabase has been the starting point for the next phase of 3D modelling.

2.3. Data processing

The work has been organized in three phases performed in a GIS environment (QGIS 3.8). In the first phase, the land use datasets have been elaborated, so creating a database of *masserie* [14]. Starting from the open dataset of Basilicata Region of the buildings (elaborated in the year 2013), in the first phase only those related to the study area and containing the toponym "*masseria*" have been extrapolated through a specific query. All descriptive information has been maintained, as it represents an important source of information for the creation of the geodatabase and future spatial analysis. The second phase concerned the implementation into the GIS of the historical cartographic layers. To this aim, the following documents have been used: orthophotos (year 1988) supplied by the Italian Ministry of the Environment (WMS service), in 1:10,000 scales; grey-scale aerial photos (year 1955) of the Italian

Military Geographic Institute (IGMI), in 1:33,000 scale; topographic map (year 1875) created by the Italian Military Topographical Institute (currently converted into the Italian Military Geographical Institute) and preserved in the State Archives of the City of Potenza, in 1:50.000 scale.

Thanks to the integration of different techniques and methodologies [15] [16], the cartographic layers have been then georeferenced, so that they can be together implemented within the geodatabase created in the first phase. From this integration it was possible to evaluate the evolution of each rural building over time (Table 1).

Table 1: Historical rural buildings database.

Name of rural buildings	Current status (2013)	1988	1955	1875
Mass.a De Carlo	built up	enlargement	existing	not existing
Mass.a della Croce	built up	enlargement	existing	not existing
Mass.a Quercioni	built up	existing	existing	not existing
Mass.a Toppo Vallata	built up	enlargement	existing	existing
Mass.a Varco della Creta	abandoned	no longer existing	existing	existing
Mass.a Piana Ferriera	built up	existing	existing	existing
Mass.a Quercioni	built up	enlargement	existing	not existing
Mass.a Chiatte Capanna	abandoned	no longer existing	existing	not existing
Mass.a Piana Ferriera	built up	existing	existing	not existing
Mass.a Frattese	built up	enlargement	existing	not existing
Mass.a Riservata	built up	existing	existing	existing
Mass.a di S. Rita	built up	enlargement	existing	not existing
Mass.a S. Vito	built up	existing	existing	not existing
Mass.a la Fratta	built up	enlargement	existing	existing
Mass.a Lopes	built up	enlargement	existing	not existing
Mass.a del Campo Santo	built up	enlargement	existing	not existing
Mass.a Levata	built up	existing	existing	not existing
Mass.a Valle della Canala	built up	enlargement	existing	existing
Mass.a Giannini	abandoned	no longer existing	existing	not existing
Mass.a Quercia di Grocco	built up	enlargement	existing	existing
Mass.a Laretta	built up	existing	existing	not existing
Mass.a Morlino	built up	existing	existing	not existing
Mass.a Piano Fossa	built up	enlargement	existing	not existing
Mass.a Boccaglie	built up	enlargement	existing	not existing

In the last phase, these layers have been integrated with a Digital Terrain Model (DTM) having a 5-meters resolution, to assess the visual impact of the rural buildings on landscape [17]. This viewshed analysis allowing the realization of binary cumulative raster, reports the visible and not-visible areas by each rural building, to whom, respectively, value 1 and value 0 have been assigned. This approach allowed to set up a first 3D methodology useful both for the study of the impact of rural buildings on the landscape in relation to topographic variables, and for a virtual reconstruction of the landscape, useful for the realization of Webmap and WebGIS usable for the monitoring, planning and enhancement of the landscape and rural buildings. In fact, thanks to the tools integrated within QGIS, it has been so possible to make a single visualization of the 3D reconstruction, as well as to create web products that can be used for different purposes [18] [19].

3. RESULTS AND DISCUSSION

The first preliminary surveys have allowed to elaborate some data useful for an assessment of the relationships between rural buildings and landscape in the study area, highlighting the potential of this methodology and its applicability.

From all the rural buildings defined as "masserie" in the 2013 dataset of the whole Basilicata Region, n.24 fall within the study area. From the comparison of this georeferenced dataset and those made by the digitization of the different information layers of 1875, 1955 and 2008, the evolution of each rural building has been evaluated diachronically. This allowed to evaluate - case by case - if, for example, a building is currently present but had not yet been built in 1875; if a building has undergone an enlargement; *etc*. Moreover, from this elaboration, it has been noted that in 1955 all the rural buildings (n.3 of which are currently abandoned) were existing and used, while only n.7 of the n.24 total were present in 1875 (Table 1).

With the viewshed analysis it has been then possible to evaluate the inter-visibility areas of the landscape studied for each rural building. In this test, a radius of 2 kilometres was used to delimit the area of visibility around each building (Figure 2). This methodology is very useful at the level of landscape planning and rural buildings, because it can be calibrated on the basis of the aims and objectives of the analysis, appropriately modifying the basic parameters, so the results can be easily incorporated into the database thanks to the specific function of the GIS.

In addition to the spatialization of the inter-visibility areas, it was also possible to calculate their area in square kilometres, in order to compare the situation for each rural building (Table 2).

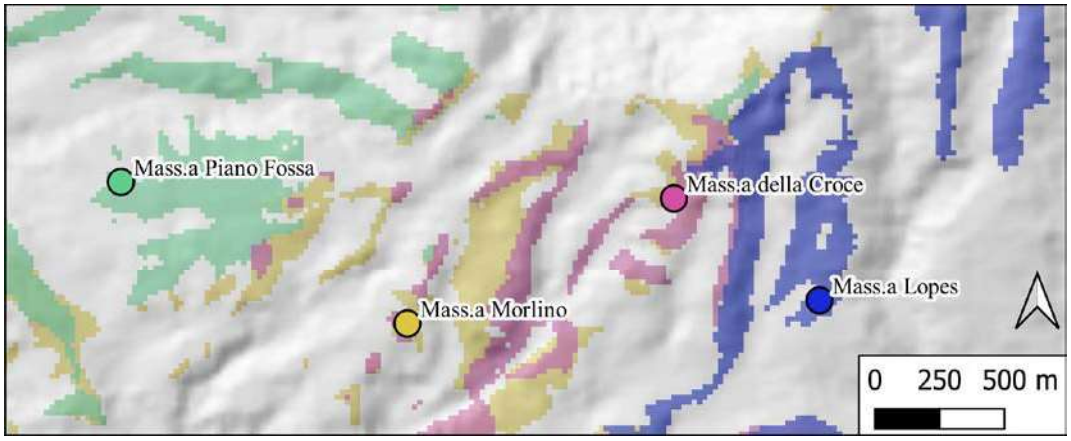

Figure 2: Extract from the viewshed analysis showing, for each of the example rural buildings, the portion of the landscape from which it is visible. Each colour of the visible area is associated with a different rural building.

Table 2: Square kilometers of the intervisibility area and percentage of visible surface respect to test area with a radius of 2 kilometres of some rural buildings represented in the Figure 3.

Name of rural buildings	**Surface visible (km^2)**	**Surface visibile (%)**
Mass.a Lopes	1.06	8.4
Mass.a della Croce	0.86	6.9
Mass.a Morlino	1.70	13.5
Mass.a Piano Fossa	2.35	18.7

Finally, through spatial analysis and image processing, by using aerial photos dated 1955 as the orographic pattern and land use of 1875, an historical reconstruction of 138 years back by image processing operations was obtained, enabling a virtual reconstruction obtained thanks to an *ante-litteram* flight [20]. So, it is possible to appreciate qualitatively, in term of morphological and vegetation

variations, the agro-forestry landscape changes, as well as to analyze how the relationships of each rural building with the surrounding landscape have changed on time, starting from a comparison between three-dimensional reconstructions of the area during different chronological layers (Figure 3). Data from this methodology may be then used to assess landscape transformations in the area around each rural building [21].

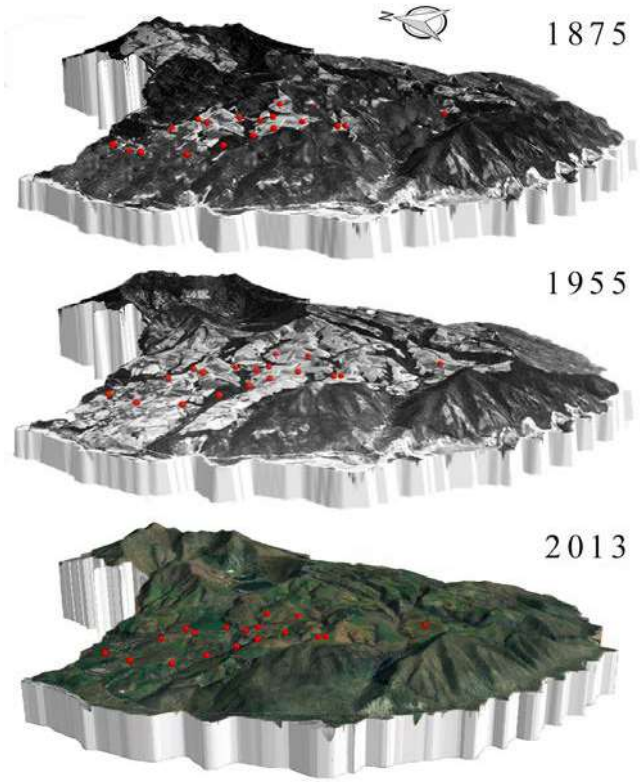

Figure 3: Three-dimensionally reconstructed land with rural buildings location for 1875-1955 and 2013 years.

Finally, thanks to the data included in the GIS, it has been possible to associate every information with those useful for analysing the interconnections between rural landscape and farm buildings [22]. In addition, the interoperability of modern GIS tools allows a rapid and effective implementation of products useful for the promotion of heritage, such as a Web-GIS. Starting from the main database, a demonstrative Web-GIS platform has been therefore created, and a navigable 3D system has been realized, so as to be used both for monitoring and planning purposes and for planning tourist activities more engaging and "immersive" (Figure 4).

Figure 4: Example of a webGIS implementation.

4. CONCLUSIONS

Vernacular farm buildings play a central role for improving the sustainable growth of agriculture, even through new alternative ways for living the extra-urban land, as the rural tourism. Their role is fundamental for supporting actions aimed to reduce resources consumption, fight land degradation and create better living environments, preserving at the same time the vernacular architectural and historical assets. Farm buildings constitute in fact a living witness of the heritage left by our forefathers, who marked the rural territories, influencing and steering the spontaneous development of nature, while leading to production that enabled to get food.

In this study, an approach based on geographic technologies has been proposed, in order to implement new methodologies useful for the enhancement and conservation of agricultural built heritage and rural landscape through an historical comparison and reconstruction of landscape dynamics. The implementation of a GIS for cataloguing historical rural buildings with geo-referenced information, and subsequently using them as a basis for more complex spatial analysis and 3D modelling, has allowed the assessment of the role and impact of these buildings within the surrounding context.

Considering that one of the main factors analysed when discussing about landscape is related to its visual perception and to its scenic characteristics, the aesthetic quality aspects have been considered as a parameter of investigation for a three-dimensional spatial analysis. Then, using a viewshed analysis, it has been possible to assess the visual impact that each rural building has on the landscape. This approach would reveal a suitable tool for future possible application in rural heritage analysis, planning and management. Indeed it guarantees an integrated and multidisciplinary methodology that allows the identification of critical areas; it can be calibrated in relation to the specific needs and objectives set by the public decision-maker.

5. BIBLIOGRAPHY

[1] Vissilia A.M. Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics. *Building and Environment*, 2009; 44 (6), 1095-1106, https://doi.org/10.1016/j.buildenv.2008.05.026.

[2] Picuno P. Use of traditional material in farm buildings for a sustainable rural environment. *International Journal of Sustainable Built Environment*, 2016; 5 (2): 451-460.

[3] McKenzie, P, Cooper, A, McCann, T, Rogers, D. The ecological impact of rural building on habitats in an agricultural landscape. *Landscape and Urban Planning*, 2011; 101 (3), 262-268. https://doi.org/10.1016/j.landurbplan.2011.02.031.

[4] Fuentes, JM, Gallego, E, García, AI, Ayuga. New uses for old traditional farm buildings: The case of the underground wine cellars in Spain. *Land Use Policy*, 2010; 27: 738–748.

[5] Fuentes, J.M. Methodological bases for documenting and reusing vernacular farm architecture. *Journal of Cultural Heritage*, 2010; 11: 119–129.

[6] Statuto, D, Cillis, G, Picuno, P. Visual quality indicators for assessing landscape characteristics and managing its protection. Proceedings of Public Recreation and Landscape Protection - With Sense Hand in Hand. Křtiny, Czech Republic; May 13-15 2019; 476–480.

[7] Mennella, V. Qualità dell'ambiente e sviluppo delle aree rurali. *Genio Rurale*, Edagricole, Perugia; 1997.

[8] Jeong, JS, García-Moruno, L, Hernández-Blanco, J. Integrating buildings into a rural landscape using a multi-criteria spatial decision analysis in GIS-enabled web environment. *Biosystems Engineering*, 2012; 112: 82-92.

[9] Olišarová, L, Cillis, G, Statuto, D, Picuno, P. Analysis of the impact of settlement patterns on landscape protection in two different European Rural Areas. Proceedings of Public Recreation and Landscape Protection - With Nature Hand in Hand. Křtiny, Czech Republic; May 2-4, 2018; 34-39

[10] Hernández, J, García, L, Ayuga, F. Integration methodologies for visual impact assessment of rural buildings by geographic information systems. *Biosystems Engineering*, 2004; 88: 255-263.

[11] Picuno C.A., Laković I., Roubis D., Picuno P., Capetanović A. (2017). Analysis of the characteristics of traditional rural constructions for animal corral in the Adriatic-Ionian area. *Sustainability*, 9, 1441..

[12] Picuno, P. Vernacular farm buildings in landscape planning: a typological analysis in southern Italian region. *Journal of Agricultural Engineering*, 2012; XLIII-e20: 130-137.

[13] Picuno, P., Cillis, G., Statuto, D. (2019). Investigating the Time Evolution of a Rural Landscape: How Historical Maps May Provide Environmental Information When Processed Using a GIS. *Ecological Engineering* 139C (2019) 105580.

[14] Statuto, D, Picuno, P. Valorisation of vernacular farm buildings for the sustainable development of rural tourism in mountain areas of the Adriatic-Ionian macro-region. *Journal of Agricultural Engineering*, 2017; 48, 21–26.

[15] Cillis, G, Statuto, D, Picuno, P. Historical maps processed into a GIS for the assessment of forest landscape dynamics. Proceedings of Public Recreation and Landscape Protection - With Sense Hand in Hand. Křtiny, Czech Republic; May 13-15 2019; 180–184.

[16] Statuto, D, Cillis, G, Picuno, P. GIS-based Analysis of Temporal Evolution of Rural Landscape: A Case Study in Southern Italy. Natural Resources Research, 2019; 28 (Suppl 1): 61, 61-75. https://doi.org/10.1007/s11053-018-9402-7.

[17] Hernández, J, García, L, Ayuga, F. Assessment of the visual impact made on the landscape by new buildings: a methodology for site selection. *Landscape and Urban Planning*, 2004; 68:1, 15-28. https://doi.org/10.1016/S0169-2046(03)00116-6.

[18] Cillis, G, Statuto, D. Landscape protection and tourist valorisation of the cultural and natural heritage of the UNESCO site of Matera (Italy). Proceedings of Public Recreation and Landscape Protection - With Nature Hand in Hand. Křtiny, Czech Republic; May 13-15 2018; 226–231.

[19] Statuto D., Tortora A., Picuno P. (2013). A GIS approach for the quantification of forest and agricultural biomass in the Basilicata region. *Journal of Agricultural Engineering*, XLIV(sI):e125: 627-631.

[20] Statuto, D, Cillis, G, Picuno, P. Analysis of the effects of agricultural land use change on rural environment and landscape through historical cartography and GIS tools. *Journal of Agricultural Engineering*, 2016; 47, 28-39.

[21] Cillis G, Statuto D, Picuno P. Valorisation of historical farm buildings for protecting the rural landscape. Proceedings of the 43rd Symposium on: "Actual Tasks on Agricultural Engineering—ATAE. Opatija, Croatia; March 5-7, 2019. pp. 535–544.

[22] Cano, M, Garzón, E, Sánchez-Soto, P.J. Preservation and Conservation of Rural Buildings as a Subject of Cultural Tourism: A Review Concerning the Application of New Technologies and Methodologies. *Journal of Tourism & Hospitality*, 2013; 2:115. 10.4172/2167-0269.1000115.