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Farm Buildings as Drivers of the Rural Environment

Pietro Picuno *

University of Basilicata—SAFE School, Potenza, Italy

Farm buildings play a central role in the sustainability of the rural environment. Conceived to host biological productions, the farm building constitutes indeed an unparalleled example in the wide epistemological construction sector. Due to its peculiar interactions with the indoor and outdoor built environment, it raises architectural and technical issues different from other buildings. The role that these buildings have historically played is strictly connected with the surrounding context, due to the need of the farmer to live in close contact with agricultural land and animal husbandry. Human activities have then decisively influenced the rural environment as well as the visual perception of its landscape. The increasing sensitivity to the concept of sustainable development of the built environment is currently stimulating the valorization of farm buildings. In the present review paper, a general literature analysis of the peculiarity of farm buildings and their internal and external environmental conditions is presented. Several cases of survey, reuse and valorization of farm buildings around the world are reported as well, with special attention being paid to Southern Italy, where the results are extrapolated or generalized to other regions. Focus is also given to the wider opportunities enabled by the implementation of new technologies for the survey, analysis and planning of the interactions between farm buildings and the rural environment. The main conclusions are that farm buildings play a driving role in the rural environment, thanks to the ecological function they perform, as well as to their socio-economic and cultural heritage at the base of the rural development.

Keywords: farm buildings, rural built heritage, sustainable construction, indoor microclimate, outdoor environment, ecological sustainability, landscape impact

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***Correspondence:**
Pietro Picuno
pietro.picuno@unibas.it

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INTRODUCTION

A farm building is, according to the Encyclopedia Britannica, any structure used in farming operations, which could include buildings to house families and workers as well as livestock, machinery, and crops [https://www.britannica.com/topic/farm-building]. A general classification of agricultural and agro-food buildings, depending on their function, is reported in **Table 1**.

The historical roots of the farm building stretch far back in time; they are connected to the task of the farmer to produce and manipulate products coming from activities like procuring foods, fabrics etc. This task has been supported by the progressive development of new technologies. During the last century, mechanization, irrigation and—in recent times—computerization have been developed and implemented to improve the productivity of the primary sector while reducing human effort. Even before these new applications, the first attempt of farmers to improve their activities was to overcome breeding in the wild state, working as much as possible inside confined airspaces, able to provide shelter from external adverse weather events and at the same time creating suitable internal working conditions. In this way, the human race has created constructions that are characterized by

TABLE 1 | Main categories of farm buildings.

Animal breeding	Crop production	Agro-food
-) Cattle stables	-) Glasshouses	-) Flour factories
-) Pig-sheds	-) Plastic-covered greenhouse/tunnels	-) Wine factories
-) Sheep/goat folds	-) Low/medium tunnels	-) Olive oil factories
-) Hen/rabbit houses	-) Wide plastic-covered shelters	-) Cheese factories
-) Shelters for other animals	-) Other protected cultivation methods	-) Slaughterhouses
		-) Alcohol factories
		-) Other agro-food industries

specific targeted features in which animals, crops and other agricultural goods may be produced and/or processed.

Created to host living produce, the agricultural building is a unique example within the vast epistemological sector of constructions. The birth, growth and development of living vegetal and/or animal organisms contained inside these volumes raise architectural and technical problems that are deeply different from those of other building sectors. Designed to produce optimal environmental conditions for plants and animals, while protecting the hygiene and health of workers involved in daily operations for the care of living organisms at different stages of their development, the rural building is therefore an incomparable technological model of human interaction with the indoor built environment (Tassinari et al., 2008; Picuno, 2016).

As much original are the issues raised by rural buildings inside their volumes, as similar very particular conditions occur in the relationship they have towards the surrounding outdoor rural environment. The role that these buildings play is in fact connected with the surrounding context due to the need of the farmer to live in close contact with agricultural land and animal husbandry (Cañas et al., 2009; De Montis et al., 2017). While the organization of human beings involved in the activities of other production sectors (i.e., industrial, commercial, etc.) allowed aggregation in urban centers, the need to live in constant contact with agricultural production developed a synergetic function of the close proximity of the farmer with the extra-urban land. This aspect led to the spread in rural areas of many examples of buildings that serve farming, storage and processing of agricultural products, which often constitute, at the same time, housing for the farmer and their family.

This form of settlement has been, and still is, a unique way by which humans have populated, in harmony with the natural elements, the agricultural territory, joining the primary production needed for human nutrition with the control and care of rural land. In this way, the activities of humans have strongly influenced the agricultural environment and the visual perception of the landscape (Statuto et al., 2018/a; Cillis et al., 2019/a; Velarde et al., 2019). Hence, the farm buildings, designed over the centuries to perform their primary agricultural function, today mark the surrounding environment in a special way, playing a central role in the formation of the rural landscape (van der Vaart, 2005; Torreggiani and Tassinari, 2012). In the present review paper, a study of the state-of-the-art interactions between farm buildings and the rural environment is presented through the scientific literature that has been produced by researchers and technical experts over the last decades.

FARM BUILDINGS FEATURES

Over the last decades, several authors have focused their studies on farm building features as well as their relationships with the surrounding environment. Rural buildings, realized over the centuries to fulfill their role in agricultural activities, have been considered for the recovery of vernacular architecture as well, enabling new opportunities for sustainable inclusion in the rural environment.

One of the oldest historical proofs of the importance of farm buildings is currently available at the University of Pisa (Italy), where the first University course on Agricultural Studies was implemented in Italy on 1 March 1844 (**Figure 1**). On the third page of this document (see relevant zoom in **Figure 1**), it is reported that a course on "Rural Architecture" ("L'architettura rurale" in Italian) during the third year of this course was included in the education of new graduates in agricultural sciences at the university level.

The need for systematic scientific research on farm buildings began to be recognized in the 1950s. The work on "Farm Buildings" at Wrest Park ranged from the full-scale purpose-built "Building Sections" of the 1970s to the more famous Silsoe Structures Building of the 1990s (Wrest Park History Contributors, 2009).

The main results of the efforts made to produce a systematic analysis in Europe, aimed at including every existing typology of traditional farm building, were collected in 1996 in the Proceedings of the International Seminar of the Second Technical Section of the C.G.I.R.—International Commission of Agricultural Engineering: "New uses for old rural buildings in the context of landscape planning". This was held in Piacenza (Italy) from 20 to 21 June 1996; the most significant results are reported in **Table 2**.

All of these contributions from the scientific community, considered together with some more recent analysis conducted by experts in Agricultural and Biosystems Engineering, seem to agree that, mostly in Europe, unused or abandoned structures, shaped by the traditional building culture of their specific region, could serve as places to safeguard and preserve the surrounding rural environment that can at the same time stimulate education and culture within their communities. However, the traditional building styles are often no longer respected by rapid modern construction techniques and materials. The responsible building authorities often lack the capacity and expert knowledge at the local level to ensure certain quality standards for the planning and construction of new buildings and in the reconstruction or revitalization of existing buildings. New strategies have to be found to raise the awareness of these officials and the local

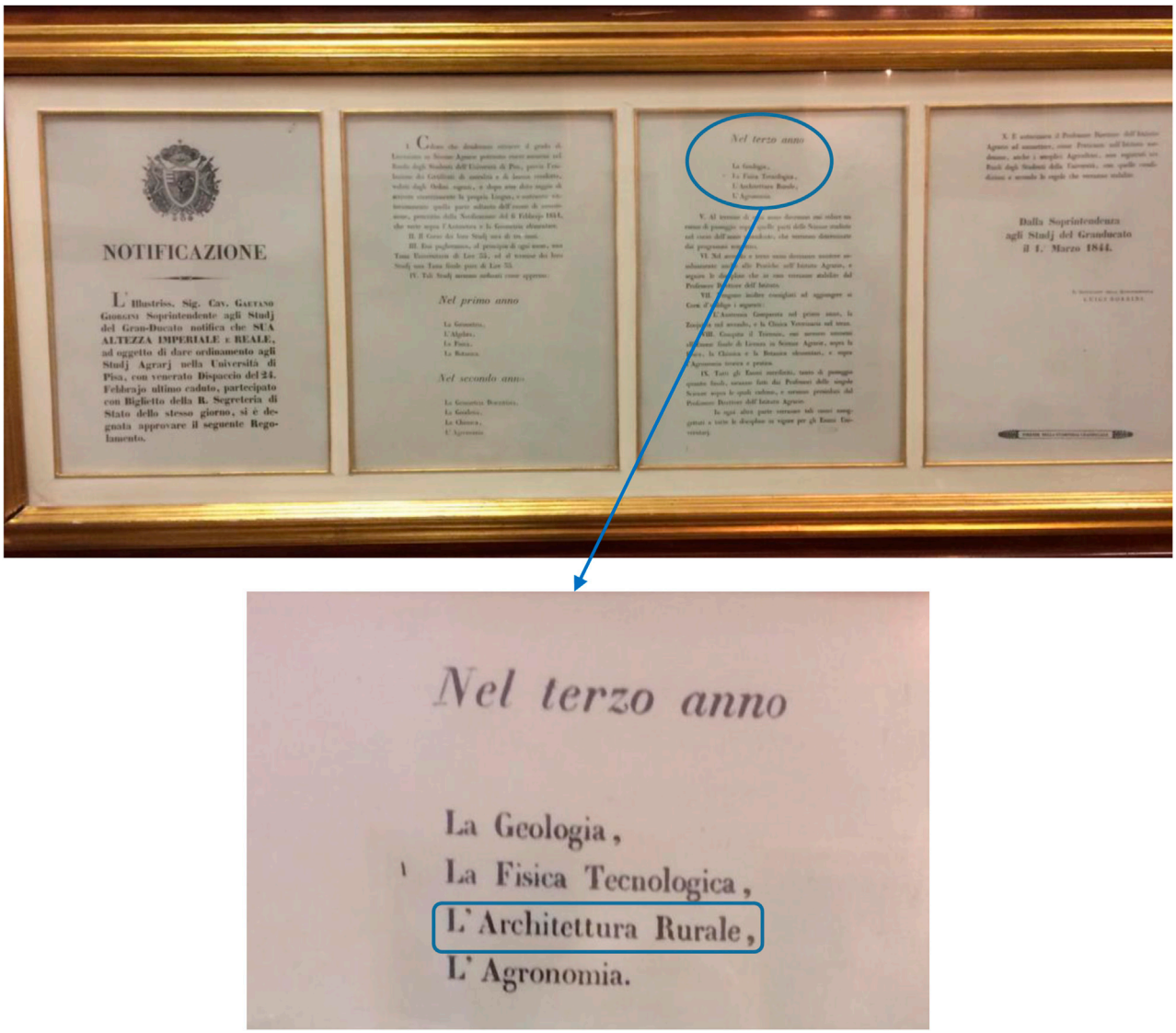

FIGURE 1 | Rules of the first study course on Agricultural Studies in Italy, 1 March 1844, University of Pisa.

population to ensure respect for traditional buildings and the landscape as well as to advise persons requesting a building permit. Decay starts the day after restoration. Most damages are small at first and easy to repair if noticed. However, small damages grow rapidly if no measures are taken. Consequences can be severe, such as loss of historical value, high costs of restoration and even loss of the monument. Yearly visual, non-destructive inspections and immediate repair of small-scale damage have proven to reduce restoration costs and the risk of damage caused, for example, by neglect or fire. Half of the activity of the construction industry is spent on repairing and maintaining existing heritage. To successfully carry out preventive maintenance, we need information and data. Our heritage is in a constant state of change. Monuments decay, buildings are demolished or adapted to new uses, agricultural fields are abandoned or aggregated, and traditions and customs evolve or are forgotten. This is especially important in rural communities where this change has been accelerating in recent decades as transportation becomes easier and less expensive, urban areas offer more attractive opportunities for young people and globalization reaches into every corner.

On the other hand, a recent analysis has shown that painting the façade of a rural building in an appropriate color can be a decisive choice even from an economic point of view (Montero-Parejo et al., 2020). A small variation in the cost of a building can then significantly increase the value of its integration while respecting the surrounding environment, giving an added value to its restoration. Therefore, modernization should be both a way of improvement of life quality and a practical method for the continuation of local regional building tradition. In this way, original houses will not only be "reused" but naturally, permanently "used on", without sharp changes of expectedly beneficial modern technology. Using the

TABLE 2 | Main results of the typological analysis of old farm buildings in Europe.

Country	Main results	Authors
Belgium	An analysis focused on the region of Flanders where, due to an explosive development after World War II and consecutive state reforms, a policy on structural planning and conservation of open space and rural patrimony has not been conducted. The decreasing number of farmers has been however the main reason loss of many valuable buildings. Since the number of farms is anyway very high in that region, and their size often exceeds the private investor budget, supportive legislation would attract other functions and initiatives, aimed not only to save farm buildings with their architectural heritage but also to improve the environmental sustainability of the regional landscape	Wauters E. and Goedseels V.
Denmark	Farm buildings are not convenient in conventional animal production, but as shown by some examples, it is possible to preserve many of the old farm buildings that make up an important part of Denmark's environmental and cultural heritage	Birkkjær, K. O. and Pedersen, S.
England	British attitudes and approaches to the problem of finding appropriate new uses for old rural buildings have been focused on the development of more enlightened approaches to the re-use and renovation of the rural built heritage with a specific focus on the Peak National Park	Light R. and Withman A.
Finland	A great number of empty rural buildings—both dwellings and production buildings—have been abandoned due to the reduction of employees and active farms, a process that has increased in Finland since its joining the EU	Kivinen T.
Italy	Many laws about the protection of natural beauties and landscape planning have been promulgated in Italy. In addition to another law about cultural and historical characteristics, those rules crowned a number of statements concerning the guardianship and the use of goods widespread in the territory. They stated, indeed, that the town exterior has to be the site not only of agriculture or sheep-rearing but also of many other resources that are worth being recovered, defended and brought up. In this situation, the more important tasks are the regulation of the even more diversified urban functions and the connection of the city to exterior sites as well as the regulation of planning activity on the whole territory, where also the urban centers are situated. In this way, the recovery of farm buildings is based not only on the recovery of agriculture but also on the recognition of non-traditional agricultural activities and a new cultural unity	De Montis, V.
Netherlands	A number of studies of the functions of farm buildings that are no longer used by commercial farmers have been undertaken. Some of these studies focused on the factors that determine the appreciation of rural buildings by rural and urban residents of the area. These studies contributed to a more practical attitude among rural planners towards the various uses to which the owners wish to put their farms, shed, barns, mills, forester's homes, brick factories and other rural buildings	Van den Berg and Coeterier
Norway	The development of farm buildings, farmhouses and steadings during two centuries has been analyzed; the conclusion was that a more comprehensive planning system, aimed to stimulate cooperation and management responsibility, is needed	Väge J.
Poland	The modernization of existing farmhouses in the Sudeten Mountains, comprising both repair actions and functional-space modifications, is an achievement of outstanding useful and aesthetical values at maximum utilization of existing material values. Another aim of modernization, apart from the fulfillment of modern technical and usable requirements by the selection of appropriate repair methods, is also the restoration of architectonic values for unique wooden structures	Trocka-Leszczynska E.
Spain	Around 20–25% of flour factories of the early 20th century in Spain have been demolished since the 1970s when there were some legal and economic difficulties for flour milling activity and also due to the high price of urban soil. The remaining parts have been restored and continue with their industrial activities or are still standing, although abandoned, waiting for restoration and reuse	Ayuga and Garcia
Spain	New uses of slaughterhouses associated with emerging cities and the evolution of construction techniques from the past to the present time have been analyzed; many of these buildings may be conserved thanks to their architectonic and industrial interest	Cabezal L., Garcia-Vaquero E., Ayuga F. FanjulM. J.

old and the modernization cannot be two ways of life, but the only one way to develop the rural environment.

FARM BUILDING SUSTAINABLE CONSTRUCTION

Architectural Typologies and Survey Techniques

The architectural typology of a farm building is usually closely linked to local traditions, always governed by the need to reduce construction and maintenance costs as little as possible. All over the world, a widespread heritage of vernacular farm buildings, showing in their architectural expression the culture, traditions and ways of life of several generations of the rural population, is currently noticeable. Some of them are now abandoned, unfortunately showing a situation of structural and functional degradation that makes their restoration difficult and expensive. Their survey, finalized as a typological analysis of their main architectural characteristics, is therefore essential. One example in this way has been proposed by Picuno [Picuno P., 2012] concerning Italy, one of the countries hosting the largest part of old farm buildings with an important architectural value, which in some cases have been even fortified. Their

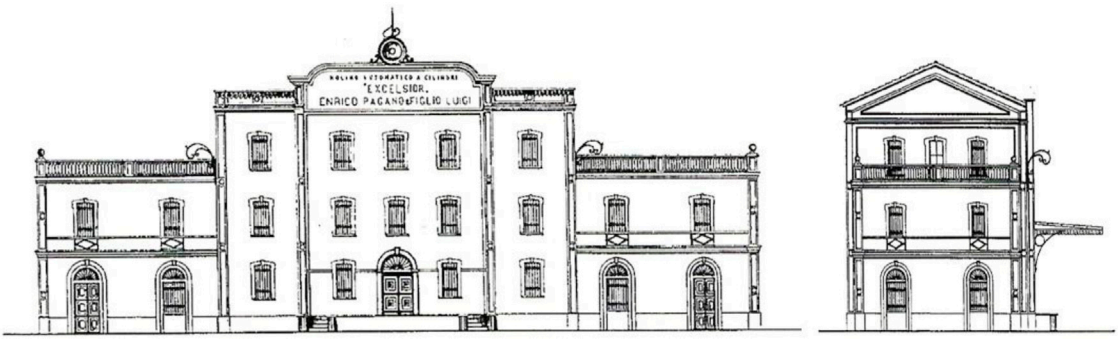

FIGURE 2 | Flour mill "Excelsior" located in southern Italy (Apulia region).

FIGURE 3 | Flour mill "Alfredo Pagano" located in southern Italy (Apulia region).

restoration and safeguarding may proactively impact the sustainability of the rural environment.

Several examples of vernacular farm buildings have been analyzed with reference to their typological characteristics and architectural solutions, such as those for protecting animals in fenced spaces (Picuno et al., 2016) or for agro-industrial production, such as flour mills (Fuentes et al., 2011), wineries (Fuentes et al., 2010), slaughterhouses (Fuentes et al., 2015) etc. In **Figure 2**, the main technical drawings of the flour mill "Excelsior" located in southern Italy (Apulia region) are shown (Dal Sasso and Picuno, 1996), while **Figure 3** shows a picture of the flour mill "Alfredo Pagano," which is located in the same area.

Terrestrial photogrammetric techniques may reveal a useful tool for surveying isolated farm buildings, mostly for documenting those having an important historical value. Farm buildings have particular characteristics that often require an alternative approach to graphic and metric documentation, which is quite different from those used for architecture in general. A comparative study of traditional methods has led Arias et al. (Arias et al., 2006) to conclude that they are not entirely suitable for surveys of traditional buildings, as some are too complex and expensive and others are not accurate enough. That is why a simple close-range photogrammetry survey tailored to the needs of the agro-industrial sector buildings has been designed, which does not require expensive sophisticated or expert equipment (Arias et al., 2007). These authors performed a survey using simple plumb lines, a conventional digital camera and a monoscopic photogrammetry station. Accuracies greater than 5 cm have been obtained, which can be considered adequate for this kind of building.

A similar analysis has been performed in Italy, with special attention to the Basilicata region, where the main typological examples of rural architecture have been surveyed through photogrammetric analysis by Manera et al. (Manera et al., 1990). In **Figures 4**, **5**, the façades of two vernacular farm buildings (traditionally named: "masseria") located in southern Italy (Basilicata region), both of which are of cultural interest and are protected by specific regulations, are reported. Both have been surveyed through close-range (terrestrial) photogrammetric methods.

Sustainable Construction Materials

Construction material plays a crucial role in the environmental sustainability of the farm building. The valorization of the locally available material used in agriculture for construction is one of the main characteristics which differentiate rural buildings from other typologies (Grano, 2014). This choice has its roots in the tradition left by our predecessors since they had no choice but to realize farm buildings and ancillary elements using the local material. It positively contributes to the formation and perception of the rural landscape since the color of the building is similar to the surroundings (Garcı´;a et al., 2003; Garcı´;a et al., 2006). Moreover, this material may be, at the end of its useful life, incorporated in the same environmental context.

A review of the most common traditional materials that are used for the construction of rural buildings has been conducted by Picuno (Picuno, 2016), who has shown that dry-stone constructions and earth buildings constitute materials that may be profitably considered for the realization of farm

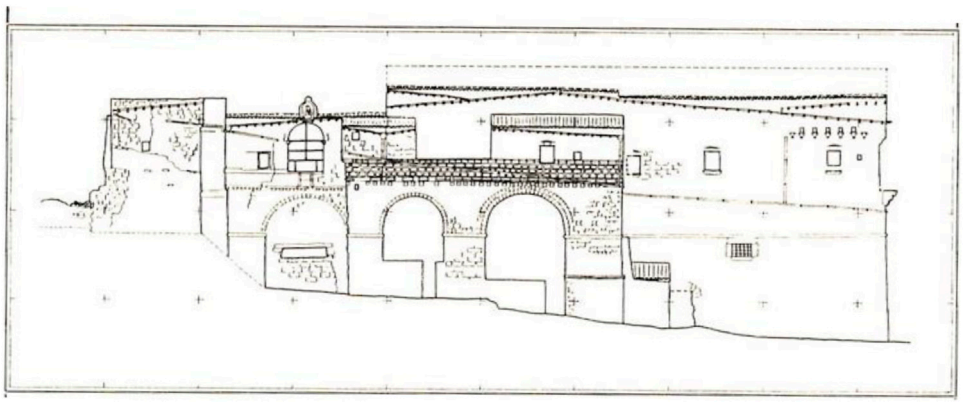

FIGURE 4 | Façade of Masseria "Jesce" located in southern Italy (Basilicata region), surveyed through terrestrial photogrammetric techniques (Manera et al., 1990).

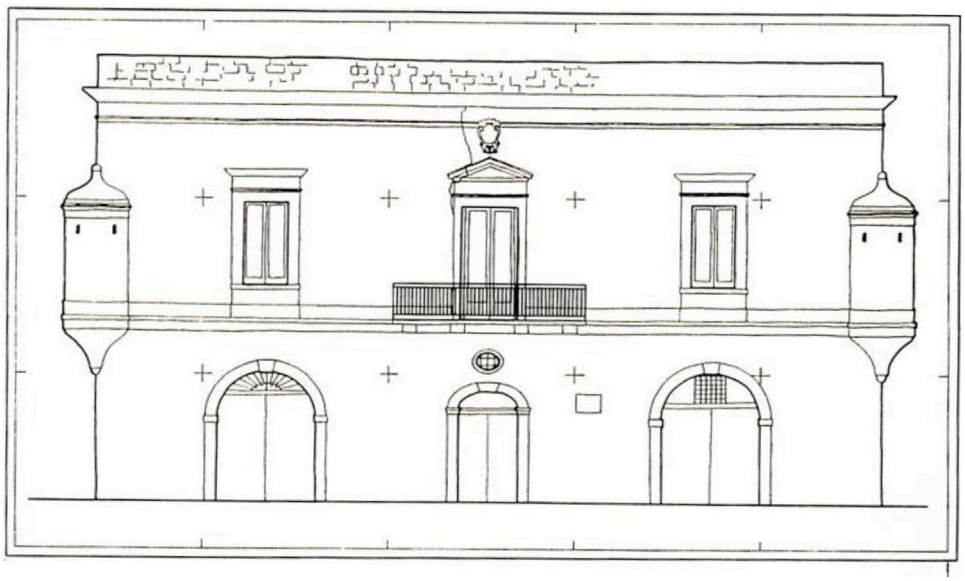

FIGURE 5 | Façade of Masseria "La Marchesa" located in southern Italy (Basilicata region), surveyed through terrestrial photogrammetric techniques (Manera et al., 1990).

FIGURE 6 | Adobe bricks, i.e., sun-dried earth bricks, reinforced with natural fibers.

FIGURE 7 | Plastic-covered greenhouses.

FIGURE 8 | Plastic covers impacting the rural environment.

buildings. The "adobe" bricks, i.e., sun-dried earth bricks made of raw clay soil mixed with barley or wheat straw, are among the most interesting elements of earthen construction as a walling material, especially if they are reinforced through the addition of some specific natural fibers (**Figure 6**).

The use of traditional materials (more or less processed) and extremely simple building techniques, as well as a finishing almost exclusively locally produced or of "natural" origin, give rural buildings a "naturalness" that differentiates them substantially from urban houses. Though basically serving the same function, rural residential buildings are not affected by the application of modern sophisticated technologies, nor by the use of new synthetic materials, which are generally used in the case of urban residential buildings, due to both their convenience and availability on the market and to a lack of awareness of the problems connected with indoor pollution. The traditional building techniques usually employed tended to show up the physical characteristics of the building materials available in the same area. The "naturalness" is often not considered in recovery operations since generally interventions are carried out in the same way (both in terms of materials and techniques) as those for the recovery of modern buildings by using modern technology and present-day materials (often synthetic and sometimes harmful for human health). The use of "modern" techniques and, above all, materials, can therefore lead to great discomfort in the use of buildings recovered in this way. Indeed, due to the use of particular materials, "indoor" pollution levels (chemical, physical and biological) have often been found to be above the acceptable threshold and even above the concentrations present in the outdoor environment. If this is intolerable in the urban space, it is even less acceptable in a rural environment, especially in building recovery operations. As far as rural buildings are concerned, it is thus considered suitable (for philological reasons) and necessary (for health reasons) to use bio-building criteria in recovery, both due to the ease in application, on account of the simplicity of building, and due to the coherence with the original structure (Candura et al., 1996).

Different issues are those raised by the realization of buildings for crop protection in which the need to maximize the solar radiation arriving at crops leads to the use of transparent covering materials (Picuno, 2014), like glass or, more frequently, plastic film and sheets (**Figure 7**).

In this case, the impact on the rural environment has important consequences at the micro-scale (changing the local microclimatic conditions, water flows, etc.), meso-scale (interfering with the movement of birds, insects, pollens, etc.) and macro-scale (with possible modifications of the visual impact of the landscape, if suitable threshold-values are not considered: **Figure 8**) (Picuno et al., 2011).

Indoor Environmental Control

The control of the indoor environment of a farm building is different from other types of construction since it requires, in addition to the same parameters that are typically considered for

the microclimatic control of ordinary buildings enabling human comfort - i.e., temperature, relative humidity, and air speed - also the consideration of some more important parameters connected to the biological activities occurring inside the farm building.

In the case of buildings for animal breeding, depending on the husbandry characteristics, the animals live in intensive conditions, often coexisting with their manure and the level of contaminants released by their breathing (mostly, CO_2) and by the fermentation of their own manure (gases like CO_2, NH_3, H_2S, CH_4, etc. as well as dust), have to be duly taken in consideration. Accurate technical control of these parameters is necessary not only for the well-being of animals (ethological reasons) and relevant productions (food consumer warranty) but also to ensure proper healthy conditions and hygienic workspaces for the continuous (almost 24 h per day, 365 days a year) activities of workers.

In the case of buildings for crop production, the situation is similar, despite some differences connected to the different biological behavior of vegetal organisms (Ermakov and Chernousov, 1996). Crops grown inside a greenhouse or other almost transparent buildings require the optimization of the light available to crops to perform photosynthesis. Therefore, the control of solar radiation is an additional crucial parameter that is possible to manipulate using the integration of artificial lighting systems. In terms of quality of the air, while there is no problem with the release of noxious substances, it is ordinarily connected to the usual daily operations of crop care. An integration of the CO_2 level in the confined airspace could be necessary due to the heavy consumption of this gas by the vegetal organisms during the photosynthesis process under the presence of adequate daylight levels.

Finally, in agro-food buildings, depending on the food product, particular conditions of the indoor environment would be taken into consideration, e.g., the darkness levels in the case of wineries and the control of noise and dust in flour factories.

One of the most interesting ways to find solutions to maximize the exploitation of natural sources of energy is bio-climatism, a technological approach that has led to the creation of its own technological sector, which has recently experienced renewed attention by several scientists (Singh et al., 2009). Bio-climatism has its roots in popular architecture, mostly when applied in rural areas, due to the historical need to design buildings in close relationship to their usefulness as a barrier against the climate. This has been a fundamental parameter since builders have had few technical resources, and the research of natural solutions has paid increased attention to the interaction of form and energy, leading to a "bioclimatic" approach in vernacular rural building techniques (Coch, 1998). In some cases (Cañas and Martìn, 2004) bioclimatic architecture was also proposed as a new model for the recovery of vernacular construction. Vernacular architecture in rural areas has involved the design of traditional-functional buildings for housing owners and/or their workers (Fuentes, 2010).

FARM BUILDINGS AND OUTDOOR ENVIRONMENT

Farm buildings are traditionally linked to the surrounding environment in which they are incorporated. According to Ruda (Ruda, 1998), the rural environment includes three components, i.e., the land for agricultural production, the natural surroundings and human settlements and the architectural area. The human, natural and architectural environments coexist, so contemporary projects should preserve and reconstruct the essence of tradition.

Currently, there is growing interest in the ecological effects of rural buildings on the outdoor environment and the importance of applying a sustainable rural development strategy to improve the protection of habitats and ecosystem services (Gontier et al., 2010; McKenzie et al., 2011; McCann et al., 2017; Statuto et al., 2019). As reported by Haller and Bender (2018), there is a strong link between biodiversity and conservation/restoration of grassland, which passes through the conservation of the rural building heritage. This is especially true for some Natura2000 priority habitats such as the semi-natural dry grasslands code 6210 (Calaciura and Spinelli, 2008; Eriksson and Cousins, 2014).

In most recent times, even pushed by the recent expansion of rural tourism currently registered in Europe, farm buildings, which in many countries there are often quite old, are registering a renewed interest since they express a widespread heritage that in some cases has an irreplaceable architectural value. This new trend makes it necessary to monitor rural buildings, both to preserve them as historical and cultural heritage and to redevelop them from the perspective of sustainable tourism planning (Cano et al., 2013; Picuno et al., 2015; Ana, 2017). In the framework of an international Project (Katun Project, 2017), some farm buildings located in mountain areas of the Adriatic-Ionian macro-region have been surveyed, with the aim to valorize the vernacular architecture in the framework of the sustainable development of marginal areas. Hence, these activities have paved the way for possible future planning of the restoration of these buildings, within the general framework of safeguarding their cultural heritage, at the same time improving their integration into the outdoor environment and combating the progressive abandonment of rural areas. Exploiting their unexpressed potential for tourist use (thanks to their significant historical value, rich tradition and ancient infrastructure) could thus prove to be an interesting and profitable way for enhancing their role in the sustainability of the rural environment (Statuto and Picuno, 2017).

Farm buildings decisively contribute to the formation of the rural landscape (**Figure 9**). A "landscape" may be considered as the final result of the effects on a given territory, stratified on time by the interaction among the components of the total environment, i.e., atmosphere, hydrosphere, biosphere, lithosphere and anthroposphere (Picuno et al., 2019). If specifically considering rural landscapes, the anthroposphere plays a pivotal role, because it strongly influences (and is influenced in turn) the other natural components. The environmental changes that have occurred during the last decades, mainly caused by human activities and changes in land use, have been dynamic since they "evolved" considering the needs and the socio-economic conditions but are also influenced by the natural forces and continuous interactions with the surrounding context. Under this approach, a "rural landscape" may thus also be defined as a "System of many concurrent ecosystems, in a bi-

FIGURE 9 | Aerial view of fortified ancient Masseria "Torre Spagnola" (southern Italy, Basilicata region).

univocal correlation with human activities". It is indeed the holistic result of the evolution of free natural elements and relevant human dynamics of land use, land management practices, agricultural policies and socio-economic modifications imposed by the populations living there.

Farm buildings strongly influence rural landscapes corresponding to specific cultural assets with high biological, scenic and recreational value. The role that agri-environmental support aims at preserving the traditional land-use systems and their resulting landscapes has been analyzed by Pinto-Correia (Pinto-Correia, 2000). Ledda et al. (2019) applied the effective mesh density (Seff) method and the rural buildings fragmentation index (RBFI) to six different landscape units in Sardinia (Italy), reporting on the least and the most fragmented Natura2000 sites. These authors found that these two indices are weakly and positively correlated.

Finally, also, the form of human settlement in rural areas has conveyed the particular vocation of rural activities, by focusing on a holistic approach able to consider the role of the external environment (Labaki and Kowaltowski, 1998; Vissilia, 2009). The settlement dynamics are especially interesting, having played an important role. Several traces of extinct settlements and their access routes are usually still visible in many of today's European landscapes. Some specific analyses have been conducted with the aim to assess how the colonization that occurred at a large scale during the past centuries has contributed to shaping the image currently perceived from a landscape, evaluating the impact on rural landscape of different settlement patterns and relevant accessibility routes (Olišarová et al., 2018; Ruggiero et al., 2019).

Promoting and accelerating the sustainable development of rural housing has a strategic meaning for improving the living conditions of rural people, reducing energy consumption, improving environmental quality and promoting economic development (Wang et al., 2017). Possible intervention strategies for the sustainable development of rural China to achieve "zero-coal" settlements have been proposed by Shan et al. (2015), who have concluded that achieving such results at the national level could provide important stable benefits to both China and the rest of the world, particularly in developing countries.

New Technologies for the Analysis of Farm Buildings as Drivers of the Rural Environment

The monitoring of the rural buildings and their surrounding environment, considering the multidisciplinary and the strong spatial component of the information, requires a suitable approach, which is now possible when implementing new technologies based on Geographic Information System (GIS), able to include and link all the information related to the rural buildings [Hermann and Osinski, 1999; La Rosa, 2011; Statuto et al., 2016; Cillis and Statuto, 2018]. In this way, it is possible to connect different datasets coming from both field surveys, e.g., direct measuring, photographic reports, field databases, remote-sensed/satellite data (Armesto Gonzalex et al., 2006), as well as spatial analysis work (studies on land use and surrounding landscape, socio-economic analysis, viewshed analysis, index creation) to create a single GIS-based model of rural buildings (Hernández et al., 2004; Statuto et al., 2018/b). This database model can be exploited for several purposes: planning and management; protection and conservation of the surrounding rural environment (Jeong et al., 2012; Statuto et al., 2013), valorization of the existing rural buildings; strategic decisions on the localization of new farm buildings, etc. The creation of a geodatabase has been the preliminary and fundamental operation for implementing and monitoring concrete valorization actions (Statuto et al., 2015).

The analysis of geographical information derived from historical maps within a GIS has proved to be a very powerful tool for better informed decision-making and management of the rural environment (Statuto et al., 2017; Cillis et al., 2021/b). Three-dimensional reconstruction of the rural landscape during different time periods obtained through Digital Terrain Models (DTM) has enabled the evaluation of land cover changes, demonstrating how they have affected the quality of the forest

ecosystem in the area. The final results that were obtained comparing historical documents and current maps enabled the evaluation of the multi-temporal, morphological and vegetation variations in this rural landscape. The analysis that was conducted has a great potential for assessing and monitoring biodiversity and typical changes of vegetation even in different geographical locations, where appropriate interventions in the relevant rural environment may be so planned (Tortora et al., 2015).

A Geographic Information System (GIS) applied to the monitoring, conservation and enhancement of the rural built heritage of some southern Italian regions has been tested. With reference to the Apulia region, some authors (Parlavecchia et al., 2019) have analyzed the relationship between minor rural buildings and the most relevant communication routes of the area of a Local Action Group (LAG). The study of the connection between building types, roads and urban centers allowed them to better understand the spatial distribution criteria, acquiring useful information to outline suitable intervention policies.

Another southern Italian region, the Basilicata region, has been analyzed by Cillis et al., 2019/b who, after the creation of a preliminary geo-database of rural buildings and spatial data related to the rural environment, implemented two different methodologies. The first one aimed to evaluate the role and impact of rural buildings in the conservation of semi-natural environments in the surrounding context. The second one has been focused on the assessment of safeguarding the visual quality of the rural landscape through an inter-visibility assessment of rural buildings. The same authors have then extended the analysis to the assessment of land dynamics around rural buildings in terms of land cover, both qualitatively and quantitatively. Thanks to a large-scale detailed spatial analysis, the relationships between some rural buildings and the surrounding environment have been then assessed (Cillis et al., 2021/a).

Finally, some studies have employed a methodology combined with Multi-Criteria Decision Analysis (MCDA), which borrows GIS capabilities to evaluate the suitability of one Spanish region to optimally site a new agro-tourism building in the context of the surrounding rural environment (Jeong et al., 2013). The same authors have more recently developed a web-based Multi-Criteria Spatial Decision Support System (MC-SDSS), validating it to assess the suitability of new rural tourism buildings integration occurred in Spanish landscapes (Jeong et al., 2016). Other authors have used the Using Analytic Network Process and Dominance-based Rough Set Approach for sustainable requalification of traditional farm buildings in Southern Italy (Palmisano et al., 2016).

CONCLUSION

Farm buildings play a central role in improving the sustainable growth of agriculture. The role of rural buildings is indeed fundamental for enabling practices aimed to reduce resources consumption, combat environmental degradation and create better living environments, preserving at the same time architectural and historical assets that constitute a living witness of the building heritage left by our predecessors, who marked the rural territories, influencing and steering the spontaneous development of nature, while leading to production that enabled to get food.

The present analysis has shown how awareness of the unparalleled role played by farm buildings has grown over time, achieving a particular consciousness of how this cultural heritage may proactively contribute to rural development. The reuse of old rural buildings means saving the conventional balance between the natural and built environment. Indeed, rural communities everywhere are often susceptible to long slow declines if agriculture is no longer economically viable and younger generations move to cities in search of better opportunities. Rural heritage is a very important aspect of a country's identity. The spirit of a community is a combination of many seemingly unconnected elements—buildings, objects, natural landscapes and traditions. Very often this heritage is the most fragile and difficult to sustain. Without it, places lose their meaning, the natural environment is subjected to degradation, and connections within the community are lost.

The main results coming from the scientific analysis which have been conducted so far should be focused on the exploitation of the impact that farm buildings have on the surrounding rural environment. These competencies should be addressed through the development in the form of the follow:

1) Education: an increase in the level of scientific knowledge, competencies and skills of students, expert practitioners and other stakeholders in the management of rural development in respect of the preservation/valorization of the building heritage distributed in rural areas;
2) Research: stimulation actions, aimed to support researchers in completing and deepening their knowledge and scientific activities, mostly based on the use of cutting-edge tools (ICT; IoT; etc.) to support the preservation and valorization of rural building heritage;
3) Outreach: new actions aimed to valorize the results of the activities that are typical of academia (i.e.,: education/training and scientific/applied research) in civil society through specific actions (the so-called: Third Mission) aimed at involving every kind of stakeholder belonging to the Quadruple Helix, i.e., a) Public Institutions (Ministries; Regional/local Authorities; Development Agencies; etc.); b) RTD performers (Universities; Public/private research centers; Technological Parks; etc.); c) Private companies (Industries; SMEs; farmers; relevant associations; etc.); d) Civil society (no-profit organizations; Citizen associations; etc.).

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