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Greenhouses Plants as a Landmark for Research and Innovation: the Combination of Agricultural and Energy Purposes in Italy

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Agriculture represents an economic sector that guarantees a certain degree of sustainability and of safe management of natural and forestry systems. However, some current challenges, such as the abandonment of agricultural land and soil sealing, are crucial issues. Greenhouses plants can be considered a local landmark where advantages and disadvantages coexist. It is known that their use, as well as for agricultural purposes, can also assumes energy aims. However, their study, as economic and local landscape indicator, is underdeveloped in Italy. Based on the contribution of other countries (e.g. Spain and the Netherlands) in which greenhouses are relevant for spatial analysis, the need for data is a continuing obstacle to research and innovation in Italy. In the latter context, nothing has been done to evaluate greenhouses plants as a part of the agricultural landscape with an energy potential. The requirement to build a database with the help of new technologies (such as Geographic Information System), characterises a real opportunity that implements research, spatial planning (in order to prevent environmental - natural risks and to know which crops are present in a local area) and for calculating energy efficiency from renewable sources installed on greenhouses (as photovoltaic system). The present study aims to give new scenarios, research inputs and actionable progress actions based on virtuous projects that have already combined greenhouses and energy from renewable sources.

1. Introduction

Greenhouse activities are relevant for the Italian agriculture owing to their production quality and technology development (Marucci et al., 2014). In Italy, with the rise of photovoltaic (PV) technology, the expansion of solar greenhouses led to a diversification of the agricultural production, energy efficiency and farmer’s specialization (Carlini et al., 2012). The extensive availability of surfaces guaranteed by greenhouses (and farm buildings) can be used to install PV systems promoting a new sustainable profile for agriculture (Tudisca et al., 2013; Sgroi, et al., 2014). The political support of PV modules would assist the regional progress by creating new job opportunities and supporting entrepreneurs' income (Schuetze, 2013). However, the elevated financial profits from PV energy production on greenhouses will exist until conspicuous public subsidies are available (Cossu et al., 2014). Preventing a new decline of the primary sector, a set of tools and strategies has to be planned with the aim to avoid conflicting and challenging realities. Unfortunately the legislative sphere does not help to reply to that question. In Italy, regulations for greenhouses are devoid of a national law in terms of land, structures and equipments (Bianchi and Sancilio, 1992). Greenhouses are regulated at the regional or municipal level with discretionary restrictions imposed by local authorities and technicians (Scarascia Mugnozza, 1995). With PV trend, national and regional administrations have planned several limitations useful to prevent speculative episodes regarding PV greenhouses (GSE, 2014).
Furthermore, PV systems can be considered as an everyday infrastructure in the Mediterranean landscape of Europe (Delfanti et al., 2016), as in Italy, where their diffusion has increased rural multi-functionality (Tudisca et al., 2013; Marcheggiani et al., 2013). However rural land has been designed to a non-agricultural function but an energy purpose (Marcheggiani et al., 2013), leading to an increasing rate of soil sealing and

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degradation, landscape deterioration and other speculative actions (e.g. Delfanti et al., 2016). To deal with this situation, since 2013 governments have promoted the realization of PV systems integrated into existing structures (such as greenhouses or farm buildings) rather than on the ground (GSE, 2014; Castellano, 2014). PV panels installed on greenhouses can be a solution (Tudisca et al., 2013), appeasing the debate on the intended land use, especially in the long term, because they do not subtract agricultural soil without compromising its quality and fertility (Sgroi, et al., 2014).
Given such background, the present paper aims to give new research inputs and actionable progress actions based on virtuous projects that have already combined greenhouses and energy from renewable sources. Greenhouse plants can be considered a local landmark that indicates where advantages and disadvantages coexist in a specific area. However, their study, as economic and local landscape indicator, is underdeveloped in Italy. Nothing has been done to evaluate PV greenhouse plants as a part of the agricultural landscape with a potential energy, due to restricted database and very local research studies (e.g. Sgroi, et al., 2014; Tudisca et al., 2013).
Based on the contribution of other countries (e.g. Spain and the Netherlands) in which greenhouses are relevant for spatial analysis, the lack of opportune tools is a continuing obstacle to investigation and innovation in Italy. The requirement to build a database with the help of new technologies (such as GIS) may characterise a real opportunity that implements research, spatial planning (in order to prevent environmental - natural risks and to know which crops are present in a local area), policy making and for calculating energy efficiency from renewable sources installed on greenhouses.

2. Methodology

2.1 Case study

The area studied covers the entire Italian national territory (301,330 km^2), subdivided into 20 regions and 8,092 municipalities. Although its coastline (counting islands) extends nearly 7,400 km, most of the continental land is hilly or mountainous. Topography, latitudinal range and proximity to the sea coast have had a great influence on local climate, soil, vegetation and landscape (Salvati and Bajocco, 2011). Thanks to its favourable geographical position and climatic features, greenhouse structures and PV fields have been widely dispersed along the country, identifying a relevant production quality and technology progress (Marucci et al., 2014).

2.2 Statistical data

Italian available databases are disposed by the National Institute of Statistics (ISTAT), which reported statistics regarding the vegetables produced in greenhouses for each year, defining the total area (hectares), area in production (hectares), the total production (tons) and the harvested production (tons).
PV plants installed in Italy can be derived from the Atlasole database provided by the Italian Energy Services Manager (GSE) by municipality and plant power. For each administrative region, the surface area of rural land occupied by PV fields was provided by GSE (2014). Plants were classified by installation support (e.g. ground, building or greenhouse roof, infrastructures). The total surface area of PV fields (m^2) was provided separately for each region, together with the number of plants and their total power (MW) through GSE annual statistical report.

2.3 Spatial data

Currently geo-referenced elements of greenhouse and PV structures do not exist for Italy. Existing available spatial data are limited to local-scale study contexts (e.g. Sgroi, et al., 2014; Marucci et al., 2014; Tudisca et al., 2013; Pérez-Alonso et al., 2012; Sönmez and Sari, 2007).
The main studies that have focused on greenhouses concern two European contexts: Almeria region (Spain) and the Netherlands. Almeria, situated in the south-east of Spain, is considered the context with the highest concentration of greenhouses in the world (Molina-Aiz et al., 2004). Also the Netherlands are famous for their production of horticultural products in greenhouses. An open source is available on the website of the Netherlands government, where is possible to found data also on the spatial distribution of greenhouses. The latter, in shape file format, has consented to spatially investigate on greenhouse structures, identified at the local level, reporting for each item different information (e.g. current status, surface area). This information is useful to understand the degree of spatial distribution and occupation of greenhouses in the Netherlands, even if currently a detail data of PV systems has not been implemented.
In Italy, a similar database and spatial data to those of the Almeria region and the Netherlands does not exist. Based on the experience of these two contexts, taken as reference points, in the present paper the data collected were integrated with maps of land use (Corine Land Cover) and soil sealing available from the Copernicus Programme, using the GIS program in order to advance a spatial reflection.

3. Results

The distribution of PV systems on greenhouses and their energy production pointed out on a regional basis that Sardinia, Sicily and Puglia are those with higher values of PV greenhouses (GSE - statistical Report 2014) (table 1).

Table 1. Situation of PV energy on greenhouse plants. Source: own elaboration from GSE, 2014.

Region	MW	Gross irradiation (h)	Net radiation (h)	Production (GWh)	Number Practices*	Power (MW)*	Power greenhouse/ PV Power
Abruzzi	14	1630	1278	18	8	2.28	6.1
Basilicata	18	1790	1403	25	17	11.22	1.6
Calabria	94	1730	1356	128	120	72.90	1.3
Campania	35	1690	1325	46	54	12.61	2.8
Emilia Romagna	56	1430	1121	63	69	26.14	2.1
Friuli Venezia Giulia	10	1470	1152	12	10	1.00	10.0
Latium	84	1680	1317	111	43	36.27	2.3
Liguria	17	1560	1223	21	156	12.72	1.3
Lombardy	62	1470	1152	71	48	21.35	2.9
Marche	31	1660	1301	40	27	10.15	3.1
Molise	5	1710	1341	7	5	1.31	3.8
Piedmont	45	1560	1223	55	65	27.66	1.6
Apulia	102	1820	1427	146	98	36.61	2.8
Sardinia	200	1840	1443	289	86	162.15	1.2
Sicily	168	1870	1466	247	373	116.65	1.4
Tuscany	37	1540	1207	45	19	2.08	17.7
Trentino Alto Adige	8	1390	1090	9	24	2.52	3.2
Umbria	27	1600	1254	34	12	3.15	8.6
Valle d'Aosta	0	1600	1254	0	0	0.00	0.0
Veneto	69	1460	1145	79	66	26.04	2.6

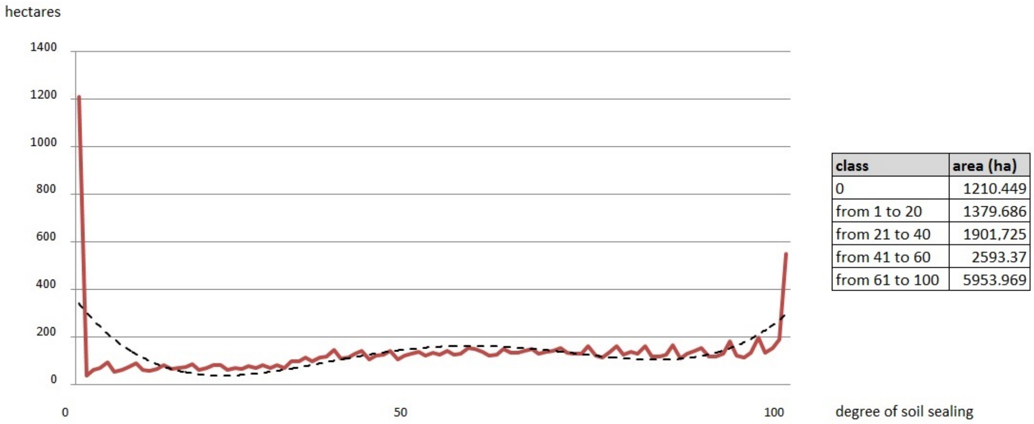
* with electricity accounts. The number of practices means how many PV plants have been authorized indicating the corresponding power.

Data regarding Italian context are limited to only give a statistical information, without geo-referenced items. Consequently, the work was oriented to analyze and examine the Dutch spatial data that identifies a total of 13,897 greenhouses occupying about 34,000 hectares (figure 1). Overlaying with the Corine Land Cover (CLC) map, greenhouses are mainly concentrated in agricultural areas (96.3%) highlighting a strong relationship between greenhouses and the rural context.

Figure 1. Satellite image shows a context with high concentration of greenhouses (left); inserting the vector data of greenhouses (right) (Source: own elaboration).

In addition to CLC coverage, the examination was continued by assessing how much greenhouses impact in terms of soil sealing rate. The spatial greenhouse vector was superimposed on soil sealing mapping, always available in the Copernicus site. From an initial analysis, most of the surface area occupied by greenhouses exists in an environment with the value '0', devoid of soil sealing (usually intended for agricultural use).

Polynomial trend line was used for trend analysis, based on test and error method for several orders of polynomial fitting and the resultant correlation coefficients (Mohan et al., 2011). A polynomial line showed the tendency of the land occupied by greenhouses according to the degree of soil sealing (figure 2): it decreases and grows, reaching high values for degrees of soil sealing equal to 0, 50 and higher scores. This data was checked by aggregating soil sealing rates into five classes ('0' for non-permeable soils, from '1' to '20' low sealing, from '21' to '40' medium sealing; from '41' to '60' medium-high sealing; more than '61' highly impermeable soils). Greenhouses on soil sealing equal to 0 are only 9% (occupying only 1,210.4 hectares), assuming that they affect the highest class (61-100), occupying a surface of 5,954 hectares. In conclusion, in area terms, the coverage of greenhouse plants lead to a strong degree of soil sealing and therefore an impact on the soil component. Results revealed a first reflection on the environmental impact that greenhouses may determine and, for that reason, the importance of having spatial data is crucial to examine a district at a detailed scale.



class	area (ha)
0	1210.449
from 1 to 20	1379.686
from 21 to 40	1901.725
from 41 to 60	2593.37
from 61 to 100	5953.969

Figure 2. A polynomial line indicates the trend of the degree of soil sealing (x-axis) and the surface occupied by greenhouses (ordinate axis), explaining the surface area intended for greenhouses on the soil sealing classes. Source: own elaboration.

For Almeria, the available studies have focused on the local level and a global greenhouse (and PV) data does not even exist in Spain. The province of Almeria highlights a strong presence of greenhouse plants (figure 3, circled in red). However, according to Corine Land Cover, the whole area is dedicated to agricultural activities (figure 3). Only an overlap with the imperviousness map brought out the impact on the soil component. In fact, the highest rates of sealing are recorded exactly where there is the strong concentration of greenhouses, with values greater than 60 (similar to those of an urban environment).

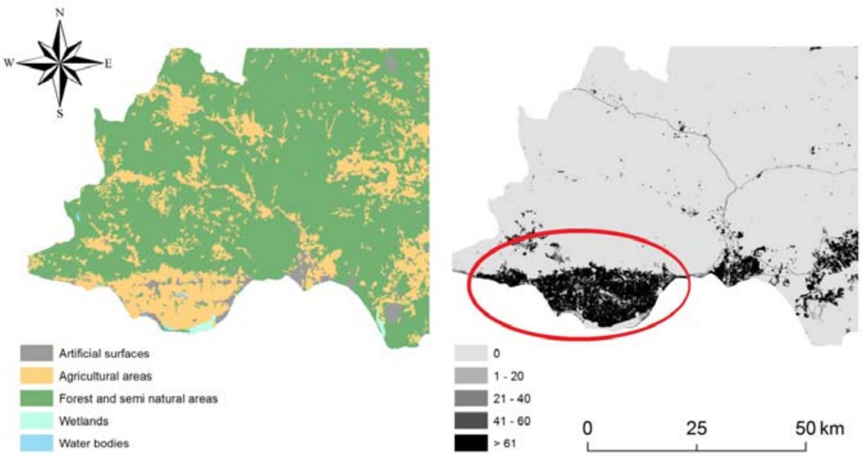


Figure 3. Focus on CLC (left) and soil sealing map of the Southern part of Almeria, indicating the strong concentration of greenhouse plants with a red circle (Source: own elaboration).

4. Discussion

Greenhouse plants have become more concentrated in several regions (Badgery-Parker, 2005), as Italy, Spain and Netherlands (Rogge et al., 2008). The reflection that emerges from this work is significant to define the role of greenhouses at spatial scale. While greenhouses allow profitable agricultural activities (Sönmez and Sari, 2007), they implicate a high soil sealing and a consequential risk to land degradation processes (Colantoni et al., 2015). A potential alternative in contexts with a strong concentration of greenhouses can be to integrate them with PV systems, leading towards a more sustainable development of an area (at least from an energy point of view) and avoiding the use of agricultural land for ground-mounted PV fields. As noted by the results emerged from the spatial analysis regarding the Netherlands, the territorial distribution of greenhouses can be considered an useful landmark which concerns an entire country at a very accurate scale, even if its greater integration with PV data would give more insights. However, it represents a methodological model to follow in order to build a spatial database of (PV) greenhouses in Italy.

Our study aims to reflect on the lack of application and methodological tools in Italy, demonstrating a progressing obstacle to research and innovation. The importance of having a statistical and spatial database about greenhouse and PV plants at a detailed level on a national scale (as for Netherlands) enables the prediction of further damage, a constant monitoring of an area both in economic, environmental and energy terms, a series of actions and policies planned in order to prevent future negative impacts and manage effectively the territory. The detection and localization of greenhouse plants represents an important chance for policy-makers and other stakeholders in order to take the appropriate decisions on the territorial and resource management (e.g. energy) (Carvajal et al., 2006). Continuous monitoring must be guaranteed by means of the GIS programs by collecting, processing, retrieving and displaying spatial data (Burrough and McDonnell, 1998; Rogge et al., 2008), combining and integrating them to produce information (Lee et al., 1999). The existing studies emphasize that GIS elaboration can support policy-makers in addressing key issues (Peccol et al., 1996) and to take effective decision-support systems that deal with the territorial planning (Bryan, 2003).

The originality of this work is based on the need to build spatial databases, at national level, able to offer new research developments in Italy. Greenhouses (and also PV systems) can represent reliable territorial landmarks that better describe contexts, with the purpose of studying, analyzing and evaluating its sustainable development (from a national to a local level) in economic, environmental, energy and landscape terms.

5. Conclusion

Greenhouses and PV systems represent new European infrastructures of the contemporary landscape. Their identification can be useful for: new fields and methodological research insights; having tools for evaluating an area and adopting accurate planning and policy decisions; improving sustainable methods and calculation of energy efficiency produced and predictable; managing recent Mediterranean landscapes. The research aims to fuel the debate on the role of new rural landmark, reflecting the integration of these two technologies to achieve both economic benefits but also environmental and energy externalities.

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Greenhouse source data from the Dutch BRT/Top10NL registry, as supplied by J.W. van Aalst (geo@imergis.nl).

Reference

Badgery-Parker J., 2005, Guidelines for the development of controlled environment horticulture: striving for consistency, consensus and community. Planning greenhouse and hydroponic horticulture in NSW. NSW Department of Primary Industries, Orange NSW. <www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/start> accessed 20.12.2017.

Benayas J. R., Martins A., Nicolau J. M., Schulz J. J., 2007, Abandonment of agricultural land: an overview of drivers and consequences, CAB reviews: perspectives in agriculture, veterinary science, nutrition and natural resources 2(57), 1-14.

Bianchi A., Sancilio C., 1992, Rapporto tra apprestamenti per colture protette e territorio nella pianificazione e normativa urbanistica, Colture Protette 21(11), 43-56.

Bryan B.A., 2003, Physical environmental modelling, visualisation and query for supporting landscape planning decisions, Landsc. Urban Plan. 65, 237–259.
Burrough P.A., McDonnell R.A., 1998, Principles of Geographic Information Systems. Oxford University Press, New York.
Carlini M., Honorati T., Castellucci S., 2012, Photovoltaic greenhouses: comparison of optical and thermal behaviour for energy savings, Mathematical Problems in Engineering.
Carvajal F., Crisanto E., Aguilar F. J., Agüera F., Aguilar M. A., 2006, Greenhouses detection using an artificial neural network with a very high resolution satellite image. ISPRS Technical Commission II Symposium, Vienna.
Castellano S., 2014, Photovoltaic greenhouses: evaluation of shading effect and its influence on agricultural performances, Journal of Agricultural Engineering 45(4), 168-175.
Colantoni A., Ferrara C., Perini L., Salvati L., 2015, Assessing trends in climate aridity and vulnerability to soil degradation in Italy, Ecological Indicators 48, 599-604.
Copernicus Programme. Land-use Corine Land Cover. <http://land.copernicus.eu/pan-european/corine-land-cover > accessed 25.01.2017.
Cossu M., Murgia L., Ledda L., Deligios P. A., Sirigu A., Chessa F., Pazzona A., 2014, Solar radiation distribution inside a greenhouse with south-oriented photovoltaic roofs and effects on crop productivity, Applied Energy 133, 89-100.
Delfanti L., Colantoni A., Recanatesi F., Bencardino M., Sateriano A., Zambon I., Salvati L., 2016, Solar plants, environmental degradation and local socioeconomic contexts: A case study in a Mediterranean country, Environmental Impact Assessment Review 61, 88-93.
EC (European Commission), 2012, Guidelines on best practice to limit, mitigate or compensate soil sealing. Commission staff working document, Brussels, Belgium.
Gestore dei Servizi Energetici (GSE), 2014, Rapporto Statistico Solare Fotovoltaico.
Lee J.T., Elton M.J., Thompson S., 1999, The role of GIS in landscape assessment: using land-use-based criteria for an area of the Chiltern Hills Area of Outstanding natural Beauty, Land Use Policy 16, 23–32.
Marcheggiani, E., Gulinck H., Galli A., 2013, Detection of fast landscape changes: The case of solar modules on agricultural land. International Conference on Computational Science and Its Applications, Springer Berlin Heidelberg, Berlin.
Marucci A., Cappuccini A., Petroselli A., Arcangeletti E., 2014, Mathematical Modeling and GIS Applications for Greenhouse Energy Planning in Italy, Applied Mathematical Sciences 8, 132, 6651-6664.
Mohan M., Kandya A., Battiprolu A. 2011, Urban heat island effect over national capital region of India: a study using the temperature trends, J. of Environmental Protection, 2(4), 465.
Molina-Aiz F.D., Valera D.L., Alvarez A.J., 2004, Measurement and simulation of climate inside Almerı´a-type greenhouses using computational fluid dynamics, Agricultural and Forest Meteorology 125, 33–51.
Peccol E., Bird A.C., Brewer T.R., 1996, GIS as a tool for assessing the influence of countryside designations and planning policies on landscape change, J. Environ. Manage. 47, 355–367.
Pérez-Alonso J., Pérez-García M., Pasamontes-Romera M., Callejón-Ferre A. J., 2012, Performance analysis and neural modelling of a greenhouse integrated photovoltaic system, Renewable and Sustainable Energy Reviews 16(7), 4675-4685.
Rogge E., Nevens F., Gulinck H., 2008, Reducing the visual impact of ‘greenhouse parks’ in rural landscapes, Landscape and urban planning 87(1), 76-83.
Salvati L., Bajocco S. 2011, Land sensitivity to desertification across Italy: past, present, and future, Applied Geography 31(1), 223-231.
Scarascia Mugnozza G., 1995, Sustainable greenhouse production in Mediterranean climate: a case study in Italy, MEDIT (CIHEAM-IAMB).
Schuetze T., 2013, Integration of photovoltaics in buildings-support policies addressing technical and formal aspects, Energies 6, 2982–3001.
Sgroi F., Tudisca S., Di Trapani A. M., Testa R., Squatrito R., 2014, Efficacy and efficiency of Italian energy policy: The case of PV systems in greenhouse farms, Energies 7(6), 3985-4001.
Sönmez N. K., Sari M., 2007, Use of remote sensing and geographic information system technologies for developing greenhouse databases, Turkish journal of agriculture and forestry 30(6), 413-420.
Tudisca S., Di Trapani A. M., Sgroi F., Testa R., Squatrito R., 2013, Assessment of Italian energy policy through the study of a photovoltaic investment on greenhouse, African Journal of Agricultural Research 8(24), 3089-3096.