Agricultural landscapes and agrivoltaic systems: the key role of landscape planning

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Abstract
The spread of renewable energy sources (RES) is nowadays a key goal at European level, being “decarbonization” crucial to counterbalance climate change. However, current push towards energy transition is opening new questions, such as the need of balancing the positive environmental impacts arising from the spread of the RES and the landscape transformations it may entail. This contribution, with reference to the Italian context, explores the role of landscape planning tools in ensuring a proper balance between landscape quality and increase of energy generation from RES, with specific reference to agrivoltaic systems (APV), providing hints for their location, according to landscape quality, and criteria for designing APV. tailored to the peculiar features of the heterogeneous agricultural landscapes.

Keywords: agrivoltaic systems, landscape planning, agricultural landscapes

Introduction
Energy generation from renewable sources represents, nowadays, a primary goal at both European and national levels, being "decarbonization" one of the key solutions to counterbalance climate change. By 2030, the share of energy produced from renewable energy sources (RES) in the European Union is expected to reach 42.5% (binding) and 45% (indicative) with a key contribution from solar photovoltaics (European Commission, 2022). According to the data provided by Terna[1], in 2024 energy produced by RES recorded the highest ever demand coverage level of 41.2 percent (up from 37.1 percent in 2023). This level is up mainly due to the increase in hydroelectric and photovoltaic production. With the Integrated National Energy and Climate Plan, Italy aims at achieving a target of 39.4% of gross final energy consumption from renewable sources in 2030 (Ministero dell’Ambiente e della Sicurezza Energetica, 2024).
In line with the European and national targets to 2030, the Italian Ministry of Environment and Energy Security, in July 2024, issued a Decree setting the distribution among Italian regions of the national target of additional power from renewable sources to be achieved by 2030. The same Decree also established the criteria for identifying unsuitable areas,

1 TERNA manages the Italian Electricity Transmission Grid (NTG) and it is the largest independent grid operator (TSO) in Europe. Data are available at: https://www.terna.it/it/media/comunicati-stampa/dettaglio/consumi-elettrici-2024.

leaving it up to the regions to identify eligible areas, maximizing the achievement of the assigned targets in terms of energy production from renewable sources.
However, a recent verdict – issued in May 2025 by the Administrative Court of the Lazio Region, and namely by a competent judge for the matter whose decisions are valid for the entire national territory – has cancelled the articles of the Decree specifically related to the identification of the suitable and unsuitable areas, forcing the Ministry of Environment and Energy Security to re-edit the criteria for identifying areas suitable and unsuitable for the installation of plants for energy generation from RES[2].
Despite the significant uncertainty that characterizes current legal and regulatory framework, the push toward energy transition is opening issues related, first and foremost, to the need of balancing the positive environmental impacts of RES deployment with the territorial and landscape transformations that such deployment entails (Greco, Cresta, 2023). Although energy transition is nowadays an undisputed priority, also in relation to the goals set by Agenda 2030[3], the protection of landscape constitutes one of the fundamental principles of the Italian Constitution (Article 9), which has been more recently extended to the environment, ecosystems, and biodiversity.[4]
Thus, some authors, considering energy generation from RES as a matter relevant to environmental protection, state that when two principles, such as landscape and environmental protection, represent both foundational constitutional values, a non-hierarchical priority is established between them (Ferraro, 2012). Others, emphasize the existence of a "clear separation between environment and energy", even in the case of energy generation from RES, highlighting the conflicts between environmental/landscape protection instances and wind and photovoltaic energy development policies (Calabrò, 2021).
Based on the above, the thesis here supported is that landscape planning tools could represent key tools for achieving a proper balance between the conflicting instances of landscape protection and enhancement and the current policies for the development of energy generation from RES. According to the Legislative Decree 42 of 2004 (Art. 145, paragraph 3), in fact, the forecasts of landscape planning tools cannot be derogated from by national or regional economic development plans, programs and projects. Moreover, they are binding for urban planning tools issued by municipalities, metropolitan cities and provinces as well as for sectoral interventions; their forecasts immediately prevail over any dissimilar provisions included in urban planning tools; they establish safeguard rules applicable pending the necessary revision of the urban planning tool.
Hence, this paper explores the role that landscape planning could and should play in ensuring a balance between landscape quality and the spread deployment of energy generation from RES, with specific reference to agrivoltaics systems (APV). In detail, this

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[2] Sentence of the TAR Lazio n. 9155 of 13 May 2025
[3] See in particular Goal 7 (Clean and Affordable Energy), which identifies increasing energy produced from RES and improving energy efficiency as key strategies for combating climate change.
[4] https://www.riformeistituzionali.gov.it/it/la-legge-costituzionale-in-materia-di-tutela-dell-ambiente/

paper provides some hints to identify areas for the location of APV, based on landscape protection needs, and criteria to design APV tailored to the peculiar features of the heterogeneous agricultural landscapes.
Although APVs have a lower environmental impact than other types of RES, since they reduce the consumption of agricultural land and ensure a number of potential benefits to agricultural activities (shading, reduction of water demand, protection from extreme weather winds, etc.), their massive introduction can result in substantial transformations of agricultural landscapes, especially in regions characterized by a high extensions of agricultural land, also reducing the acceptability by local communities of APVs that are, in turn, carriers of innovation and fundamental tools towards a sustainable energy transition.

How to reconcile the location choices of APVs with the needs of landscape protection?

The latest generation of landscape plans in Italy has definitively marked the transition from a constraint-based approach towards a landscape plan intended as a tool to guide the sustainable transformation and enhancement of environmental, territorial and landscape heritage. It was precisely these plans that attempted to provide criteria and rules to guide both the localization and the landscape compatibility of renewable energy sources (Paolinelli, 2012; Magnaghi, 2016).
All the examined landscape planning tools (Apulia, Tuscany, Piedmont) recognize the significant changes to the landscape features that renewable energy production plants could cause and provide hints for their location and for minimizing their impact on landscapes. Nevertheless, most of them do not provide regulations specifically addressed to APV, focusing above all on wind farms and ground-based photovoltaic systems.
However, numerous European scholars have provided hints to determine suitable and unsuitable areas for APV, suggesting some useful landscape criteria. Among the latter, the studies aimed at assessing the agrivoltaics potential in Germany have to be mentioned (Rösch, Fakharizadehshirazi, 2024): they suggest, in detail, the widespread adoption of small-scale APV (<2.5 ha), privileging areas not easily visible and accessible, and minimizing visual impact through the planting of hedges. They also identify some typologies of areas in which the location of APV should be prohibited:

- biodiversity protection areas (nature reserves, national parks, biosphere reserves, landscape protection areas, natural parks, natural monuments, legally protected biotopes and Natura 2000 areas);
- water protection areas;
- floodplains;
- landscapes of special significance.

Finally, they identify as unsuitable areas for APV, the 200 mt. buffer zones around residential and commercial areas, to avoid visual interference with the most populated and frequently visited areas.
Similar studies have been conducted with reference to Sweden (Elkadeem et al. 2024): in this case, restrictive criteria for APVs' location include all protected areas, with a buffer zone equal to 1 km; water bodies, with a buffer zone of 100 mt. for rivers and 300 for lakes. In addition, with the aim of limiting the visual impact of installations, Elkadeem et al. consider a protected strip along roads equal to 50 mt. and a buffer value of 1 km with respect to urbanized areas.
Similar studies, carried out with reference to the Italian context, show some minor differences from those previously recalled, because they do not include, for example, the use of buffer zones, but provide similar exclusion criteria (Fattoruso et al., 2024):

- national and regional parks;
- areas included in the NATURA 2000 network;
- areas reserved for biodiversity conservation in European countries (established by the Habitats Directive) for the conservation of natural and semi-natural habitats and wildlife.

Fattoruso et al. provide also relevant insights into the heterogeneous regional distribution of the areas potentially suitable for agrivoltaics, that range from 12% of the total agricultural area in Apulia to 0% in Liguria and Valle d'Aosta. These data clearly underline the importance of adopting flexible criteria that can be adequately tailored to heterogeneity of landscapes that characterize at least the Italian regions.
In June 2024, a Ministerial Decree was approved in Italy to drive Regions in determining suitable and unsuitable areas for the installation of renewable sources energy plants. In detail, the Decree, in addition to establishing the regional distribution of the national 2030 target of an additional 80 GW of power from renewable sources compared to December 2020, asks Regions to identify:

a) suitable areas, where an accelerated and facilitated procedure is provided for the installation and operation of RES facilities and related infrastructure;
b) unsuitable areas, showing features incompatible with the location of specific types of RES;
c) ordinary areas, where ordinary authorization regimes set forth in Legislative Decree No. 28 of 2011 can be applied;
d) areas where the installation of photovoltaic systems with ground-based modules is prohibited.

According to the criteria set by the 2024 Decree, unsuitable areas are those included in the perimeter of properties subject to protection under Article 10 and Article 136, paragraph 1, letters a) and b) of Legislative Decree n° 42 of January 22, 2004. Such properties can be listed as follows:

- immovable assets having artistic, historical, archaeological or ethnoanthropological interest and distinguished by peculiar features of natural beauty or geological singularity;
- villas, parks and gardens of artistic or historical interest or distinguished by their uncommon beauty;
- all urban open spaces (streets, squares, etc. of artistic or historical interest); mining sites of historical or ethno-anthropological interest; rural architecture having historical or ethno-anthropological interest as evidence of the traditional rural economy.

The Decree provides Regions also with the opportunity to define as unsuitable all the areas included in the perimeter of other assets protected under the same Legislative Decree (n° 42, January 22, 2004). Regions can, therefore, exclude from suitable areas, additional areas, such as those protected by the article 142. Moreover, Regions may establish a buffer zone, having different width depending on the type of plant and protected asset, from the perimeter of the protected asset up to a maximum of 7 kilometres, but only if this choice does not compromise the possibility of achieving the production targets set for each Region by the Decree.

Finally, Regions are required, following the identification of the suitable areas, to update all energy, environmental and landscape planning acts and any other regulations, programs, plans or legislation previously approved at the regional, provincial or municipal level. Hence, according to the Decree, the identification of suitable areas prevails on any previously made provision, including those referred to landscape protection.

In this sense, the 2024 Ministerial Decree entails a substantial reversal from Ministerial Decree 219/2010, aimed at providing Guidelines for the authorization of plants powered by RES. The latter assigned, in fact, to the Regions the task of identifying unsuitable areas, taking into account what already established in the landscape regional plan, and indicated a broader list of areas that for their sensitivity/vulnerability features could be identified as unsuitable for the location of specific types of plants.

It seems useful to remind that, according to current Italian legislation, the main task of landscape planning tools is the identification of necessary measures to ensure a proper integration in the different landscapes, of any intervention, with the aim to guarantee the compatibility between territorial development and the different recognized and protected landscape values, with particular attention to the preservation of rural landscapes and sites included in the UNESCO World Heritage List (Dlsg. 42/2004).

Moreover, as previously mentioned, the articles of the 2024 Decree related to the identification of suitable and unsuitable areas have been currently cancelled and will have to be re-edited.

Thus, despite the lack of certain regulatory references, it is here considered of paramount importance to identify unsuitable areas for the location of APVs, in compliance with the protection regimes and requirements already set by the landscape plans. Nevertheless, it is possible to identify some relevant landscape assets, whose quality could be altered by the installation of APVs, that were only partially included by the articles, currently eliminated, of the Ministerial Decree issued in 2024. In particular:

- landscape assets regulated by Articles 10 and 136 of Legislative Decree 42/2004;
- landscape assets regulated by Article 142 of Legislative Decree 42/2004;
- landscape assets as identified in accordance with Article 143, paragraph 1 (d) and (e) of the 2004 Legislative Decree ;
- areas included within the Natura 2000 network;
- wetlands falling under the Ramsar Convention;
- Important Bird Areas (I.B.A.);
- UNESCO sites;
- rural landscapes listed in the National Register of Rural Landscapes of Historic Interest, Agricultural Practices and Traditional Knowledge by the Ministry of Agriculture, Food and Forestry (Decree No. 17070, November 19, 2012).

Nevertheless, an adequate attention to the quality of landscapes does not imply only the exclusion of selected areas from the possibility of installing APVs; it requires, first and foremost, the definition of criteria aimed at guiding the design of APVs towards a greater attention to the features and quality of the agricultural landscape in which each AVP will be located (Toledo, Scognamiglio,2021; Fattoruso et al., 2023].

To this end, this contribution aims at providing some landscape criteria useful to guide the APVs' design towards a better understanding, and consequently to a greater respect, of the peculiarities of each agricultural landscape, especially in selected "*warning"* areas**,** where the compliance with detailed landscape criteria must be mandatory. The identification of these areas, which must be carried out within the framework of regional landscape plans too, can be based on some general criteria:

- presence of quality agricultural and food production;
- historical-testimonial value;
- presence of visual cones drawn from viewpoints located in scenically unsuitable areas and/or in historic centres or along roads, pedestrian or bicycle paths that have historical and/or scenic value;
- presence of protected areas of local significance.

In the "*warning"* areas, the potential for the location of APV has to be determined through detailed analyses at local scale, aimed at identifying areas that, due to their landscape-cultural value, relevance in the local agricultural tradition (traditional crops that currently survive only in limited portions of the regional territory), visibility from routes characterized by a high landscape value or from relevant points of the territory, cannot be considered suitable to the location of APV, falling into the category of unsuitable areas. Within all the other "*warning*" areas, the respect of landscape criteria in the design of the APVs must be considered always mandatory.

Figure 1 summarizes the suggested methodological path to ensure that both location and design of APVs are compatible with the features of the agricultural landscape they will be included in.

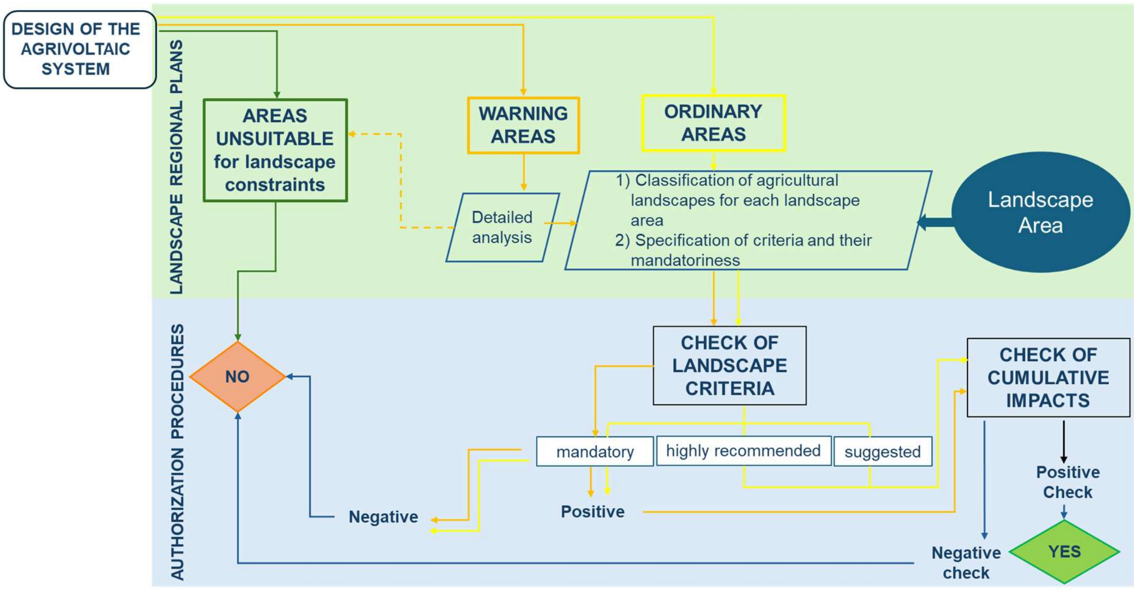


Figure 1 - The methodological path to ensure localization choices based on landscape protection needs and an APVs' design tailored to the peculiar features of the different agricultural landscapes. Source: Authors' elaboration

Landscape criteria to guide the design of agrivoltaics systems.

The definition of landscape criteria to guide the design of APVs has been the most challenging aspect of the research work, due both to the limited references in scientific literature, being this aspect a quite recent research field (Scognamiglio, 2016), and to the heterogeneity of agricultural landscapes that characterize, in particular, the Italian context. Indeed, there are few studies aimed at providing criteria for designing an APV according to the peculiar features of agricultural landscapes. Most of them focuses on the visual impact of APV, which is considered particularly relevant because of the elevated structure of PV modules, which are clearly visible even from a significant distance, especially in flat areas. Some studies examine, in particular, issues related to visual openness, visibility, and relationships between PV modules and crop patterns (Sirnik et al., 2023); others underline the importance of considering both the view from inside the agricultural area where the PV modules will be located, and the visibility of the PV modules from the surrounding areas; other studies consider visual openness, i.e., the amount of space visible from a user located in the centre of the APV, and its visibility from valuable assets located in the surrounding area (Weitkamp et al., 2011). The same authors suggest the identification of a 10-m buffer, around the perimeter of the area were the APV is located, and the check of the presence of valuable elements from which the system could be visible, regardless of the presence of infrastructural elements such as roads or pedestrian paths.

The few studies focusing on the relationship between the shape of agricultural plots and those of PV patches have identified three types of configurations: responsive, irresponsive, split, island, incidental (Figure 2) (Oudes, Stremke, 2021; Sirnik et al., 2023).

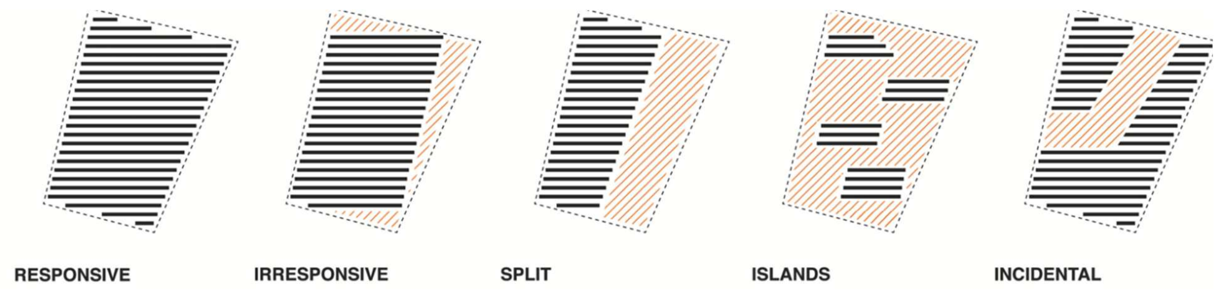


Figure 2 - Geometric relationships between agricultural plots and PV patches. Source: Oudes, Stremke, 2021

In the *responsive* configuration, the arrangement of PV patches conforms to the shape of the agricultural plot, covering its entire extent. This preserves the recognizability of both the shape and size of the agricultural plot.

In the *irresponsive* configuration, the arrangement of PV patches does not compare with the size and shape of the agricultural plot. As a result, there are residual spaces in the agricultural plot, but they do not reflect the shape of the plot itself.

In the *split* configuration, the arrangement of PV patches conforms to the shape of the agricultural plot, but they cover only partially the plot. The result is a subdivision of the agricultural plot that, however, does not alter the shape of the plot itself.

In the *island* configuration, only small parts of the agricultural plot are covered by the PV patches, with shapes completely independent of the plot itself.

In the *incidental* configuration, the arrangement of PV patches depends on the presence of specific elements, such as buildings or infrastructure.

Some scholars have also investigated the relationship between the orientation of the PV modules and that one of the crops*: so* far mainly related to optimizing energy performance, this relationship could be usefully varied, using criteria for consistency between crop and PV modules orientation, both in the case of vertical and inclined modules, to meet different objectives (Toledo, Scognamiglio, 2021).

Birò-Varga et al. (2024) carried out studies on the perception of different types of APV by those who enjoy a given landscape, using questionnaires. The authors, with reference to an overhead and a vertical interspace agrivoltaics power plant, examine the different perception of the two systems: in both cases the attractiveness of the landscape is considered lower, but it is perceived as drastically lower in the case of the overhead agrivoltaics power plant, Studies specifically aimed at providing criteria for better integration of APV into the landscape include the work of Fattorusso et al. (2023) who identified three general criteria related specifically to:

– the relationships between the size of APV and the size of other landscape elements;
– the relationships between the geometrical features of the PV modules and those of the landscapes' elements;
– the different densities between the PV pattern and the landscape pattern.

The study, based on the principles of *landscape ecology*, provides some metrics to quantify analyse the landscape structure (e.g., size and number of patches within predefined areas) and suggests the possibility of using these criteria to guide the integration of APV into the landscape.

However, the variety of agricultural landscapes requires careful consideration regarding the appropriateness of general criteria and metrics: the latter should be outlined, on the opposite, taking into account the morphological, geometric, cultural and contextual peculiarities of each landscape typology in which each APV has to be located.

Therefore, a classification (certainly not entirely exhaustive) of the most widespread typology of rural landscapes, at least in Italy, has been outlined to define, for each typology, adequate landscape criteria, characterized by different levels of compulsoriness depending, above all, on the urbanization level of the considered agricultural area. In addition, some criteria for the assessment of cumulative impacts have been defined for each typology of agricultural landscapes.

Agricultural landscapes are composed of cultivated areas and their features depend on the peculiarities and different aggregation of some "structuring" elements"; in particular (Table 1):

- the morphology of the area;
- the agricultural plots;
- the type of crop;
- the presence of historical remains;
- the road network;
- the water network;
- the natural vegetation.

However, a correct classification of agricultural landscapes cannot disregard the complex relationships between agricultural areas and urbanization processes: the latter induced, in fact, significant changes in rural landscapes, especially in lowland areas, where there has been the greatest growth of both settlements and infrastructure. Data from the 7° General Census of Agriculture (ISTAT, 2021) show that in Italy, between 1982 and 2020, almost two out of every three farms disappeared, while the total agricultural area shrunk by more than 20%. Therefore, starting from the analysis of the recurring relationships between agricultural and urbanized areas, four typical contexts in which rural landscapes can be placed have been identified, as highlighted in table 2.

The different contexts identified in Table 2 are useful both for a better classification of agricultural landscapes and for assigning different levels of compulsoriness to the landscape criteria for the design of APV (Table 3). In areas where settlement pressure is very low, in fact, the adoption of landscape criteria in the design of APV must be mandatory, while such adoption can be only suggested, in case of APV to be located in agricultural areas enclosed or located in peri-urban areas, where the spread of APVs should be largely "favoured", being them useful to counteract the abandonment of agricultural activities and in promoting their multifunctionality.

Regarding the criteria useful to improve landscape compatibility of APV in different types of agricultural landscapes, also based on the available scientific literature, four categories of criteria were identified: morphological, dimensional, geometric and visual criteria (Table 4).

Table 1 - Structuring elements of agricultural landscapes. Source: Authors' elaboration

Elements	***Description***	
Morphology	Lowland or hillside landscapes have heterogeneous characteristics and determine distinct categories of agricultural landscapes, which are also decisive for the characterization of additional elements (plots, crops, etc.), as well as for different visibility conditions.	
Plots	Agricultural plots are highly dependent on the morphology of the site and area characterized by different shapes, sizes and type of aggregation. They also depend on the road network and on the type of cultivation, and show different geometries, more or less regular.	

Crops	The different crops can be distinguished into four macro-types: arable land, stable grassland, woody crops, arboriculture, and floricultural crops. The different crops result in variations in texture, size, grain, and colour, which are also very important in the characterization of agricultural landscapes.	
Remains	Traces of the historical stratification, which can be both buildings (e.g. historical farms, rural villages) or linear elements (such as historical tracks, or forms of organization of the agricultural territory, such as the Roman "centuriatio"). Other types of remains are, for example, the drystone walls, which were included in the UNESCO heritage list in 2018.	
Networks	Networks constitute decisive elements in the structuring of the agricultural mosaic: the main roads and the dense network of inter-modal roads, together with the possible presence of waterways and the more or less dense network of irrigation canals constitute fundamental elements in the design and characterization of agricultural plots.	
Natural vegetation	It is made up of the set of arboreal or shrubby elements bordering the field (hedges, isolated trees, tree patches or trees in rows) and plays a fundamental role from both a landscape and environmental point of view, representing elements with high ecological value within the cultivated areas.	

Table 2 - Different types of agricultural landscape contexts. Source: Authors' elaboration

Type of contexts	***Description***	***Images***
Agricultural landscapes in peri-urban areas	They are generally characterized by multiple uses, where agricultural tracks intersect with fragmented settlements, industrial areas, landfills, etc. and/or characterized by extensive urban *sprawl* and the presence of major infrastructure axes.	

Enclosed agricultural landscapes	Residual agricultural areas surrounded by densely built urban fabrics	
Agricultural landscapes in areas characterized by medium to low settlement pressure	Agricultural areas characterized by the presence of historically established rural settlements and more recent urban fabrics, generally concentrated along secondary road networks	
Agricultural landscapes in areas characterized by very low settlement pressure	Agricultural areas characterized by a very limited presence of settlements and a high presence of natural vegetation	

Finally, with exclusive reference to landscape aspects, some criteria to limit the cumulative impacts, resulting from the albeit desired spread of APVs, have been defined.

Table 3 - Types of contexts and level of compulsoriness of landscape criteria for the design of APVs. Source: Authors' elaboration

Type of contexts	Compulsoriness of landscape criteria
Agricultural landscapes in «warning» areas	●
Agricultural landscapes in peri-urban areas	○
Enclosed agricultural landscapes	○
Agricultural landscapes in areas characterized by medium to low settlement pressure	◉
Agricultural landscapes in areas characterized by very low settlement pressure	●

● *Mandatory*
◉ *Highly recommended*
○ *Suggested*

To date, apart from the guidelines provided by the Apulia Region in 2012 (Resolution of the Regional Council 2122/2012) for the assessment of cumulative impacts of projects for electricity production from wind and ground-mounted photovoltaic systems, which also explicitly consider cumulative impacts on landscape views, no guidelines specifically addressed to APVs are available.

Table 4 – Landscape criteria for APV design. *Source: Authors' elaboration.*

Criteria	Description
Morphological	These criteria refer to the coherence between the design of APV and the morphological features of landscape, determined by the morphology of the site and of the agricultural plots, by the organization of the networks (road, irrigation channels) and/or by presence of historical traces (centuriatio, paths, etc.). These criteria are also aimed at ensuring that the layout of PV modules does not induce a loss of continuity of non-crop vegetation networks (hedges, rows, swaths of spontaneous vegetation, wooded patches, etc.), ensuring that these elements can effectively play their role as ecological connections in contexts that are often already heavily artificialized.
Dimensional	These criteria are related to the "size" of the different elements that agricultural landscapes are made of. As highlighted by several scholars, a better integration of APV in agricultural landscapes requires that the size of the APV is consistent with the average size of the landscape elements, and namely of the agricultural plots, avoiding the so called out-of-scale effect, also relevant from a perceptual point of view. To this aim, metrics extremely common in landscape analyses, such as the average size of agricultural plots in the area affected by the APV, are suggested. Dimensional criteria can be also used to define buffers to be respected in the areas contiguous to the APV, useful to interrupt the continuity of the PV modules, especially in the selected “warning” areas.
Geometric	These criteria refer to the consistency between the orientation of PV modules and that one of agricultural crops, taking into account the possibility of using modules with such "mobility" characteristics as to maximize their sun exposure.
Visual relationship	These criteria are the most widely used in scientific literature, with reference to the visibility of both APV from surrounding areas and surrounding areas from APV. The key objective is to avoid that PV modules obstruct relevant views (e.g. landmarks) or alter the view of agricultural landscapes from viewpoints located in protected areas, along routes with high historical and landscape value or from centres or artifacts of historical-architectural importance.

Again, due to the heterogeneity of agricultural landscapes, it is not appropriate to provide unambiguous rules for all of them: while for some landscapes it is essential to avoid the "sprawl" effect, in fact, for others, a widespread presence of APV can be relevant to counteract settlement pressures and the increasing phenomena of land take and soil sealing, currently affecting numerous agricultural areas. These are two extreme cases: between them, some intermediate cases can be identified. For example, in agricultural landscapes falling into the “warning” areas or in areas with low settlement pressure and high presence of natural vegetation, it is essential to provide limits on the maximum extension of the total agricultural area that can be devoted to APV, as well as on the mutual distance between new APV and pre-existing or authorized ones, with particular attention to the portions of landscape perceptible from viewpoints located in areas and/or along roads of particular historical and landscape significance. Conversely, in peri-urban and enclosed agricultural landscapes, it seems relevant to maximize the presence of APV even as replacements for existing greenhouses.

The methodological path here briefly outlined was tested on the Campania Region, which to date has a Preliminary Landscape Plan, approved in 2019.

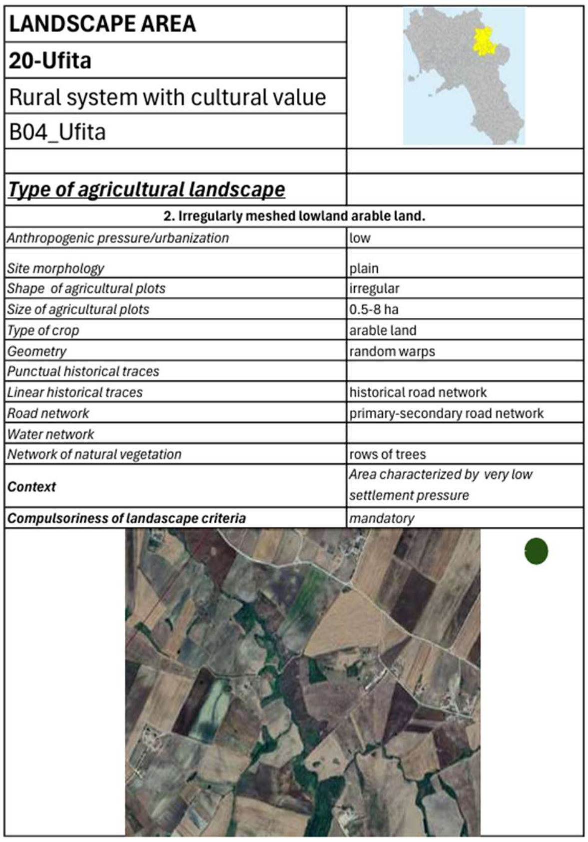
Specifically, from the 51 Landscape Areas identified by the Preliminary Plan, an Abacus of the agricultural landscapes in the Campania region was outlined. For each of the identified agricultural landscape types, a sheet describing their structuring elements (geometry and size of agricultural plots, crop type, etc.) and relationships with settlements (Figures 3a, 3b) was drawn up. These sheets also indicate the different levels of compulsoriness of the landscape criteria for the design of APVs. Finally, with reference to each type of agricultural landscape, a matrix of criteria to be adopted for guiding the design of APVs and for assessing the cumulative impacts has been developed (Figures 4, 5).

Concluding Remarks

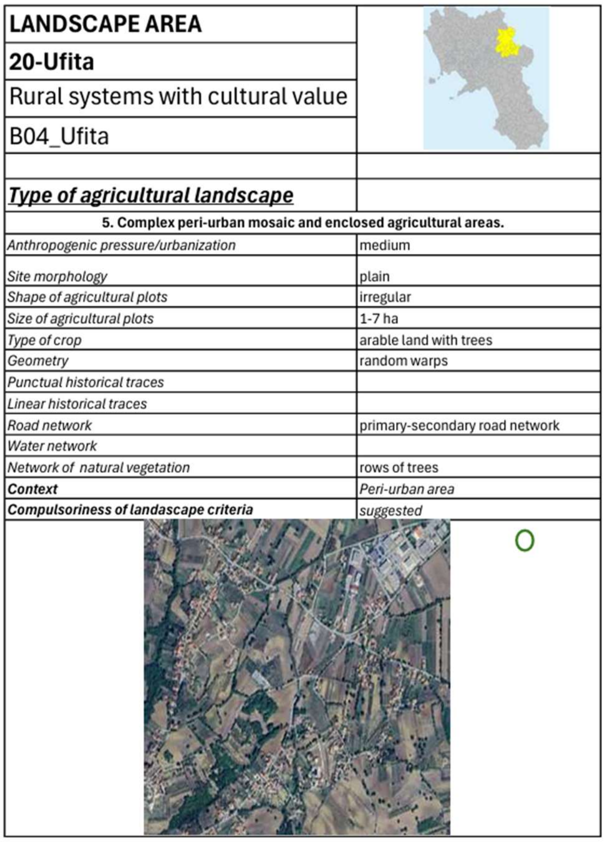
The definition of criteria for improving the compatibility of APVs with agricultural landscapes represents a complex and meanwhile an unavoidable challenge to ensure a proper balance between the needs related to the sustainable energy transition and the equally relevant needs related to the protection and enhancement of landscape heritage.

APV represents, nowadays, an important innovation in renewable energy generation, enabling the coexistence of energy and agricultural production and, in many cases, allowing an increased agricultural productivity; nevertheless, the spread of APV, if not carefully planned and in the lack of landscape criteria guiding their design, could induce uncontrolled landscape transformations, with negative consequences both for the quality of agricultural landscapes and for the social acceptability of APV.

Therefore, landscape planning tools have been here identified as the most suitable tool to achieve a better balance between landscape quality and the spread of APV: these plans are, in fact, endowed with binding and prevalent effectiveness compared to other planning tools and they might guide both the location and design of APV through guidelines, tailored to the peculiarities of the heterogeneous regional landscapes.



LANDSCAPE AREA	
20-Ufita	
Rural system with cultural value	
B04_Ufita	
Type of agricultural landscape	
2. Irregularly meshed lowland arable land.	
Anthropogenic pressure/urbanization	low
Site morphology	plain
Shape of agricultural plots	irregular
Size of agricultural plots	0.5-8 ha
Type of crop	arable land
Geometry	random warps
Punctual historical traces	
Linear historical traces	historical road network
Road network	primary-secondary road network
Water network	
Network of natural vegetation	rows of trees
Context	*Area characterized by very low settlement pressure*
Compulsoriness of landascape criteria	*mandatory*



LANDSCAPE AREA	
20-Ufita	
Rural systems with cultural value	
B04_Ufita	
Type of agricultural landscape	
5. Complex peri-urban mosaic and enclosed agricultural areas.	
Anthropogenic pressure/urbanization	medium
Site morphology	plain
Shape of agricultural plots	irregular
Size of agricultural plots	1-7 ha
Type of crop	arable land with trees
Geometry	random warps
Punctual historical traces	
Linear historical traces	
Road network	primary-secondary road network
Water network	
Network of natural vegetation	rows of trees
Context	*Peri-urban area*
Compulsoriness of landascape criteria	*suggested*

Figures 3a, 3b – Examples of agricultural landscapes: descriptive sheets. Source: Authors' elaboration

Thus, based on the national and regional regulatory framework for the location of energy generation plants from RES, the state of the art of regional landscape planning in relation to energy and agricultural landscapes, and the scientific literature on the relationship between APV and landscape, this paper has outlined a methodological path to guide landscape planning tools in guiding:

- the location of APV through criteria for identifying unsuitable and warning areas;
- the design of APV, through morphological, dimensional, geometric and visual criteria tailored to different agricultural landscapes;
- the compulsoriness of these criteria, depending on the degree of urbanization of the context;
- the assessment of cumulative impacts.

The methodological path, tested on the Campania region, has led to outline specific Guidelines, useful to support the dissemination and application of the proposed methodology at national level. The Guidelines are addressed to different categories of end-users (regional and local administrators, landscape planners and people in charge of the authorization procedures of individual APV system) and are user-friendly, including numerous explanatory examples of the different steps of the methodology.

	2. Irregularly meshed lowland arable land.	Dimensional	Morphological	Geometric	Visual relationships
LANDSCAPE ELEMENTS	***Site morphology***				APV must avoid obstructing relevant views
	Shape and size of agricultural plots	APV must occupy an area ranging from 0.5 ha (minimum lot size) to 4.5 ha (average parcels' size). The area covered by the APV must have a buffer on each side equal to, at least, the largest dimension of the area occupied by the APV,	APV can fully or partially cover the agricultural parcel, preserving the recognizability of its shape.		In the first level visibility bands (500 mt), calculated from relevant viewpoints located in unsuitable or in warning areas, APVs are not allowed; in the second-level visibility bands (1200 mt), calculated from the same viewpoints, APVs are allowed on a maximum area of two hectares.
	Type of crop			The warping of PV modules should be consistent with the warping of different types of crops.	The different elements of the APV system should be shielded with hedges or tree rows along the sides visible from roads, including inter-farm roads. The colors of the PV modules should harmonize with the predominant colors of the surrounding landscape.
	Punctual historical traces				In case of presence of artifacts of historical-artistic-architectural value, the non-visibility, also through natural screens, of the different elements that make up the APV system for at least 100 m, from all accessible observation points, inside or outside the artifact, must be ensured.
	Linear historical traces		In the presence of historical traces (e.g., Roman centuriatio), APV must ensure the legibility of these traces, respecting their geometries and proportions.		In case of presence of roads (vehicular or pedestrian) of historical significance, the non-visibility of the different elements that make up the APV system must be ensured, also through natural screens, for at least 100 m, from all accessible viewpoints, along the entire route.
	Road network		In the presence of road networks (including inter-farm tracks), APV must ensure the legibility of these networks, respecting their geometries and proportions.		In case of presence of road routes of landscape significance, the non-visibility of the different elements that make up the APV system should be ensured, also through natural screens, along the entire route.
	Water network		In the presence of water networks (canals, rivers, etc.), APV must ensure the legibility of these networks, respecting their geometries and proportions.		
	Network of natural vegetation		In the presence of networks of natural vegetation (hedges, rows od trees, strips of spontaneous vegetation, wooded patches, etc.), APV must avoid the alteration or the loss of continuity of these elements, since these networks have a key ecological role		
	CUMULATIVE IMPACTS	**1. In the second-level visibility bands (1200 mt) calculated from relevant viewpoints located in unsuitable or warning area, new are allowed up to a maximum cumulative limit of the 40% of the agricultural area visible from the viewpoint, taking into account any existing, authorized or pending permit energy production systems.** **2. In case of existing, authorized or pending permit energy production systems, new APVs must be located at a distance equal to at least twice a buffer zone established, on each side, according to the largest size of the area occupied by the APV.** **3. An adequate number of viewpoints must be identified along the routes crossing the first and second level visibility bands in order to evaluate the cumulative impact due to the simultaneous perception of the new APV with other energy generation systems located in the same area. Viewpoints must be even more numerous along elevated routes that have a wider view field**			

Figure 4 - The criteria matrix for the landscape type shown in Fig. 3a. Source: Authors' elaboration

	5. Complex peri-urban mosaic and enclosed agricultural areas.	Dimensional	Morphological	Geometric	Visual relationships
LANDSCAPE ELEMENTS	***Site morphology***				
	Shape and size of agricultural plots	The size of APV must be compatible with the maximum size of agricultural parcels in the area.	APV can fully or partially cover the agricultural parcel, preserving the recognizability of its shape.		
	Type of crop			The warping of PV modules should be consistent with the warping of different types of crops.	Where APV affects areas characterized by low-lying crops (e.g., vegetables, flowers, etc.), the presence of its elements should be screened with hedges or tree rows along the sides visible from roads, including inter-farm roads.
	Punctual historical traces				In case of presence of artifacts of historical-artistic-architectural value, the non-visibility, also through natural screens, of the different elements of the APV for at least 100 m, from all accessible observation points, inside or outside the artifact, must be ensured.
	Linear historical traces		In the presence of historical traces (e.g., Roman centuriatio), APV must ensure the legibility of these traces, respecting their geometries and proportions.		In case of presence of roads (vehicular or pedestrian) of historical significance, the non-visibility of the different elements of the APV must be ensured, also through natural screens, for at least 100 m, from all accessible viewpoints, along the entire route.
	Road network		In the presence of road networks (including inter-farm tracks), APV must ensure the legibility of these networks, respecting their geometries and proportions.		In case of presence of road routes of landscape significance, the non-visibility of the different elements of the APV should be ensured, also through natural screens, along the entire route.
	Water network		In the presence of water networks (canals, rivers, etc.), APV must ensure the legibility of these networks, respecting their geometries and proportions.		
	Network of natural vegetation		In the presence of networks of natural vegetation (hedges, rows od trees, strips of spontaneous vegetation, wooded patches, etc.), APV must avoid the alteration or the loss of continuity of these elements, since these networks have a key ecological role		
	CUMULATIVE IMPACTS	**In case of existing, authorized or pending permit energy generation systems, greenhouses and other landscape detractors, new APVs should be preferably located adjacent to such elements.**			

Figure 5 - The criteria matrix for the landscape type shown in Fig. 3b. Source: Authors' elaboration

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