

Perceiving Landscape Change Driven by Digital Agriculture: Findings from Expert Survey

Feiran Huang^{1,*}, Claudia Cassatella¹

¹ Interuniversity Department of Regional and Urban Studies and Planning, Politecnico di Torino, Viale Pier Andrea Mattioli, 39, 10125 Torino, Italy; feiran.huang@polito.it; claudia.cassatella@polito.it

* corresponding author

Parole chiave

digital agriculture,
landscape change,
expert survey,
perception and
anticipation, driving
force

Abstract

Amid the ongoing wave of digitalisation in agriculture, questions arise regarding the extent to which digital agriculture (DA) may influence landscape change. While the socio-economic and environmental impacts of DA have been extensively examined, its implications for landscape remain underexplored. This study investigates how scholars from the fields of landscape and agriculture perceive and anticipate DA-driven landscape change, drawing on data from an expert survey. The results demonstrate that DA affects both material and immaterial aspects of landscape, with its impact likely to intensify in the future. In particular, experts identified notable effects on cultural-social and bio-physical dimensions, while highlighting disciplinary divergences in perceiving perceptual-aesthetic change. These insights underscore the complexity of future landscape transformations and the need for interdisciplinary dialogue in shaping sustainable future for agri-digital transition and landscape.

1. Introduction

The important role of landscape in sustainability and societal well-being has been widely acknowledged (Antrop, 1997; Bastian et al., 2014; Termorshuizen & Opdam, 2009). Hence, considerable efforts have been devoted to understanding landscape change in order to support its sustainable management, planning and protection (Brandt et al., 1999; Bürgi et al., 2005; Plieninger et al., 2016; Wu et al., 2012). Conceptualized as a continuously evolving natural-social-cultural process, landscape is shaped by a range of drivers, such as policy interventions and natural processes—among which technological forces stand out as one of the most significant. The issue of technology-driven landscape change has been extensively discussed in landscape studies, focusing on a variety of topics such as land cover/use change and driving forces (Antrop, 2005; Plieninger et al., 2016; Stahlschmidt et al., 2017; Wu et al., 2012). In particular, advancements in farming technology have had profound impacts on landscape, as agricultural activities directly interact with land and landscape. Mechanization, for example, has enabled both intensification and extensification, resulting in landscape homogenization, increased farm size, and environmental degradation (Medley et al., 1995; Pinto-Correia et al., 2018).

Concurrently, the agricultural sector has been undergoing a new wave of technological transformation characterised by digitalisation (Del Río Castro et al., 2021; ElMassah & Mohieldin,

2020; European Commission, 2023; McKinsey Global Institute, 2014; Sachs et al., 2019). A broad range of digital technologies has been progressively incorporated into the farming process and the broader food system. These practices, which make use of digital tools across different stages of agricultural production and management, are commonly referred to as 'digital agriculture' (Basso & Antle, 2020; Klerkx et al., 2019; Rotz et al., 2019; Tang et al., 2002; Zhao, 2019), which will be referred to as DA in this article. Faced with increasing challenges such as population growth and climate change, DA has been promoted as a promising solution, offering improved resource efficiency, enhanced productivity and reduced environmental impact (Basso & Antle, 2020; Bellon-Maurel et al., 2022; Dörr & Nachtmann, 2022; El Bilali & Allahyari, 2018; Leveau et al., 2019; Rose & Chilvers, 2018). In light of these benefits, increasing numbers of countries and regions have been actively integrating DA into their agricultural and rural development agendas (European Commission, 2021; Ministry of Agriculture and Rural Affairs of China, 2022). Several major international organizations have also published reports and policy documents to endorse the digital transformation of the agricultural sector (Lajoie-O'Malley et al., 2020; OECD, 2019; Schroeder et al., 2021; Trendov et al., 2019). These policy-driven initiatives have led to a series of actions, including increased investments in technological innovation, training programmes to equip farmers with digital skills, and building new infrastructures to support the use of digital tools.

As the digital transformation of the agricultural sector accelerates, increasing attention has been directed toward understanding its influence from various disciplinary perspectives such as environmental (Basso & Antle, 2020; Bellon-Maurel & Huyghe, 2017; Clapp & Ruder, 2020; El Bilali & Allahyari, 2018; Leveau et al., 2019) and social considerations (Cavallo et al., 2014; Kernecker et al., 2020; Pfeiffer et al., 2021; Rotz et al., 2019). However, its implication for landscape remains largely overlooked in academia—an omission that stands in contrast to the widely acknowledged role of farming technology as major drivers of landscape change. Existing studies on this topic are relatively scarce, and the limited available knowledge tends to be uneven, focusing primarily on specific dimensions of landscape such as the bio-physical, while neglecting other, such as visual experience and social perception (Huang & Cassatella, 2024).

The gap between the limited awareness of DA-driven landscape change and the accelerating digitalisation of agriculture may pose challenges for future landscape policy and planning. Policymakers and planners may be insufficiently prepared to make landscape decisions and interventions in an increasingly digitalizing context. It is therefore essential to improve our understanding of the types of landscape changes that may be expected in more digitalised future. Against this background, the objective of this article is to explore the relationship between DA and landscape change. To this end, a survey was conducted to gather insights from scholars in relevant fields, investigating their perceptions of the issue and anticipation of future developments. The paper begins by briefly introducing the concept of DA, providing illustrative examples and outlining its relevance to landscape change. Section 3 presents the research methodology, introducing the analytical framework and explaining the design and implementation of the survey. Section 4 details and analyses the survey findings, followed by a critical discussion. Finally, the conclusion summarises the main results and suggests directions for future research.

2. Digital-Agriculture-Driven Landscape Change: A New Area Worthy for Attention?

DA has introduced substantial transformations in how agriculture activities are conducted and how farms are managed. The technologies involved are highly diverse, ranging from well-established tools such as remote sensing to more recent innovations such as robotics and unmanned aerial vehicles (UAVs). In practice, these technologies are often applied in combination, enabling integrated data-driven approach to farming. Two typical examples illustrate the integration of digital tools in agricultural operations: (1) the use of digital sensors to collect and analyse soil-climatic data, which supports farm decision-making process such as irrigation and fertilization (Figure 1); (2) the deployment of smart farming machinery such as robots, to carry out farm tasks autonomously. DA are being applied across a wide spectrum of agricultural

productions, ranging from grain cultivation, orchard and vineyard management to animal husbandry—each of which may be associated with different types of landscape. By enabling more efficient and precise agricultural practices, DA is reshaping farm management approaches, potentially resulting in changes to landscape.



Figure 1. Gigantic smart greenhouse equipped with different digital devices for intensive tomato cultivation (Source: Xinhua News).

Although the topic of DA-driven landscape change has been relatively overlooked in the current research about landscape change, a number of emerging studies have started to discuss this issue—either explicitly or subtly (Huang & Cassatella, 2024). For instance, Legun and Burch (2021) observed a transformation in the physical structure of apple orchards in New Zealand: from individual trees with full canopies to trees pruned flat against the trellis and aligned in straight rows. This standardization facilitates the use of agricultural robots, which typically operate along straight paths to perform tasks such as spraying and harvesting autonomously. As a result, not only have the spatial patterns and visual characteristics of the landscape changed, but the memories closely associated to the traditional orchard management has been changed. This case clearly exemplifies how the adoption of robotics can reshape landscape. Other studies have demonstrated how DA-informed farm decision making can lead to modifications in land use and vegetation cover (McConnell, 2019; Moreno et al., 2022; Nguyen et al., 2022). Huang (2025), for example, identified multiple evidence of changes by examining the real-world applications of the representative projects from the EU and China. Among the most common interventions are newly introduced built elements, ranging from small in-field sensors to large-scale smart greenhouses equipped with different digital devices. These newly added elements have been shown to affect various landscape aspects including visual openness, diversity and complexity, patterns and cyclical change over the seasons (Figure 2).

As illustrated by in the preceding examples, existing scholarly works on DA-driven landscape change have predominately focused on the past events, with some studies addressing ongoing developments. While such retrospective and contemporaneous approaches are common in landscape change research, they often lack a forward-looking perspective (Bürgi et al., 2022)—a limitation that becomes particularly evident in the context of rapidly evolving DA. To address this gap, the present study employed an expert survey targeting scholars in agriculture- and landscape-related fields. This method serves as a valuable complement to existing research, as it not only captures expert reflections based on past and present experiences, but also actively elicits their anticipations regarding future landscape change. In light of two concurrent trends which are the accelerating digitalisation of farming and the increasing emphasis on sustainable landscape management, it is essential to adopt an interdisciplinary approach. Integrating the knowledge of experts from both agricultural (particularly agri-tech) and landscape disciplines is crucial for developing more informed and future-oriented strategies.

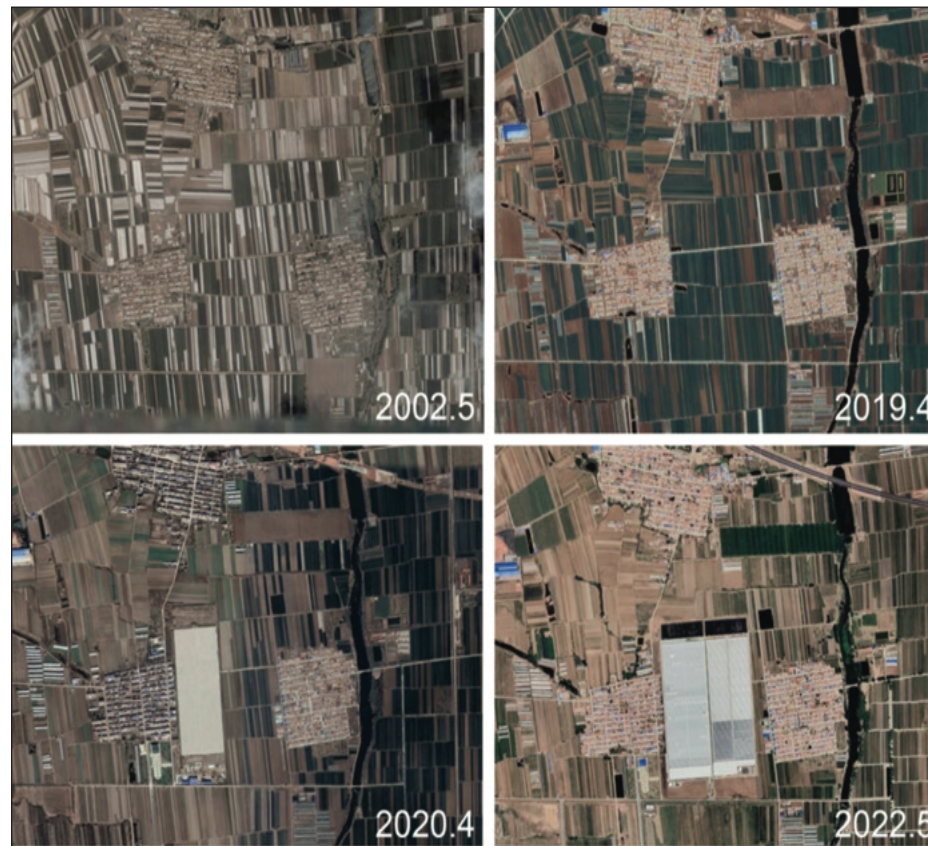


Figure 2. Satellite image showing the fast-changing landscape due to the implementation of smart green-houses (Source: elaboration based on Google Earth image).

3. Research Methodology: Landscape Change Checklist and Expert Survey

This methodology section first introduces the proposed analytical framework—namely, the landscape change checklist—which was used to examine changes across different aspects of the landscape. This is followed by description of the survey design and implementation.

Given the inherent complexity of landscape, one of the most widely accepted approaches for systematic analysis involves breaking it down into multiple dimensions and aspects, while at the same time acknowledging its undividable and holistic nature (Cassatella & Peano, 2011). In line with this approach, the landscape change checklist was developed as a conceptual framework to facilitate more comprehensive understanding of landscape change. It draws on the well-established methodology of the landscape character assessment (Swanwick, 2002; Tudor, 2014). The checklist divides landscape into three dimensions: cultural-social, bio-physical, and perceptual-aesthetic, each comprising a set of specific aspects as outlined in Table 1. It is important to note that the checklist is not intended to be exhaustive; rather, it serves as a guiding structure. Therefore, survey participants were explicitly invited to suggest additional landscape aspects that they believed were influenced by not captured by the predefined categories. The checklist was used to design the survey questions.

As explained at the end of Section 2, an online expert survey was selected as the method for data collection. The participating experts participating were drawn from disciplines related to agriculture technology and landscape studies. The survey consisted of three main sections. The first section gathered background information about the experts, including their geographical location and research field(s). The second section explored the perceived influence of DA on landscape. Experts were asked to evaluate the influence of some widely used farming technologies, using a unipolar scale ranging from 'no influence' (coded with 0) to 'great influence' (coded with 5) (Figure 3). In addition, a number of potential ways by which DA might affect the landscape

were presented, and respondents were invited to indicate which they consider the more prevalent. The third section focused on the impact of DA on specific landscape aspects. Again, a unipolar scale (0-5) was used to assess the extent of influence, where 0 indicates 'not affected by DA' and 5 indicates 'greatly influenced by DA' (Figure 4). Furthermore, the survey also included some open questions, inviting experts to identify additional aspects that are not included in the list. The full survey is available in Appendix 1. To ensure the clarity and relevance, the survey was first piloted among colleagues within the department who had relevant research experience. Their feedback was used to refine both the structure and wording of the final version.

Tabella 1. Il quadro analitico proposto, la checklist del cambiamento paesaggistico (Fonte: gli autori)

Cultural-social dimension	Bio-physical dimension	Perceptual-aesthetic dimension
Whether to cultivate	Vegetation cover	Openness of view
Type of cultivated crops	Land cover	Visual diversity/complexity
Way of managing crops	Soils	Colour and texture
Farm size	Water	Smell and sound
Pattern and type of field enclosure	Flora and fauna diversity	Seasonality (cyclical change over the year)
Preservation of traditional features	-	Sense of place
Abandonment of traditional features	-	-
Material of built elements	-	-
New built elements	-	-

There are some technologies currently adopted in the agricultural production and some examples are listed below. Do you think or can you imagine whether the implementation of these technology in the field will lead to landscape change? If your answer is 'yes', please indicate the extent of their influence using the provided scale.

0 refers to 'this digital technology has no influence on rural landscape', 1 refers 'little influence', 5 refers to 'great influence'.

	0	1	2	3	4	5
Unmanned aerial vehicle (UAV)	☐	☐	☐	☐	☐	☐
Internet of Things (IoT)	☐	☐	☐	☐	☐	☐
Robotics	☐	☐	☐	☐	☐	☐
Smart farming machineries	☐	☐	☐	☐	☐	☐
Remote sensing	☐	☐	☐	☐	☐	☐

Figure 3. The second part of the survey focuses on the topics related to digital technology (Source: the authors)

In this session, the concept of landscape is broken down into three dimensions and each dimension is divided into several aspects for analytical purpose. You will be asked if you can anticipate changes to the following aspects of landscape due to the implementation of the digital agriculture. Please indicate the extent of the impact using the provided scale (0 means this aspect is not affected by DA, 1 refers to 'slightly influenced' while 5 refers to 'greatly influenced'). If you can think of any other aspects maybe affected by the digitalisation of agriculture, you can add them at the bottom. It will be really appreciated if you can also provide an example.

Impact of the digital agriculture on the natural aspects of landscape

	0	1	2	3	4	5
Vegetation cover	☐	☐	☐	☐	☐	☐
Land cover	☐	☐	☐	☐	☐	☐
Soils	☐	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐	☐
Flora and fauna diversity	☐	☐	☐	☐	☐	☐

Figure 4. The third part of the survey focuses on the influences on landscape. Here is an example of evaluating the impact of DA on the bio-physical dimension of landscape (Source: the authors).

The survey was distributed to 41 experts working in the fields of agricultural and landscape studies, in particular, landscape assessment and rural planning, and farming technology related topic. They were identified based on their professional experience and academic contributions, such as published scholarly works, and/or membership in thematic networks such as the International Association of Landscape Ecology. Some recipients had already demonstrated familiarity with the research topic, as identified through the literature review (Huang & Cassatella, 2024). The survey was distributed to researchers in different geographic contexts, with the EU and China prioritised for the following reason. On the one hand, the literature review has shown that very few research is from the EU and China, suggesting a relatively low awareness on this issue. On the other hand, we can clearly see strong push in policymaking to facilitate the digital transformation of the farming sector, and proliferation of DA projects across these two regions. Therefore, such contrast makes understanding how researchers in the EU and China perceive this issue particularly interesting and urgent. It is important to note that the aim of this expert survey was not to conduct a large-scale quantitative analysis, but rather to gather insights from experts with a specific interest and knowledge in the topic. As such, the survey was deliberately designed to prioritise depth over breadth. Its goal was to gather qualitative input that could shed light on this emerging issue rather than to achieve statistical generalisability, given the current low level of awareness within academia. To encourage participation, the survey was kept concise and conducted online. It was open between April 2023 and February 2024, during which a total of 16 completed responses and one partially completed response. All participating experts responded to the unipolar-scale questions, although three experts did not provide answers to the open-ended questions.

4. Expert Survey Results

4.1 Analysing the General Trend

This section reports the results of the unipolar-scale questions, focusing on the perceived impact of various digital technologies on rural landscape and the extent to which specific landscape aspects are affected. Experts' ratings are presented as mean values in a radar chart, supplemented by a bar chart showing response distributions to mitigate potential mean distortion. Scores of four or five are interpreted as indicating high impact.

4.1.1 General Results

In terms of technology use, 'smart farming machine' was chosen as the most influential technology on the landscape, with a score of 3.63 and 11 experts giving it a high score. This was followed by 'robotics', which received a score of 3.44, with 10 experts giving it a high score (Figure 5). 'Supporting decision making by providing more data' was seen as the more prevalent way which DA affects the landscape.

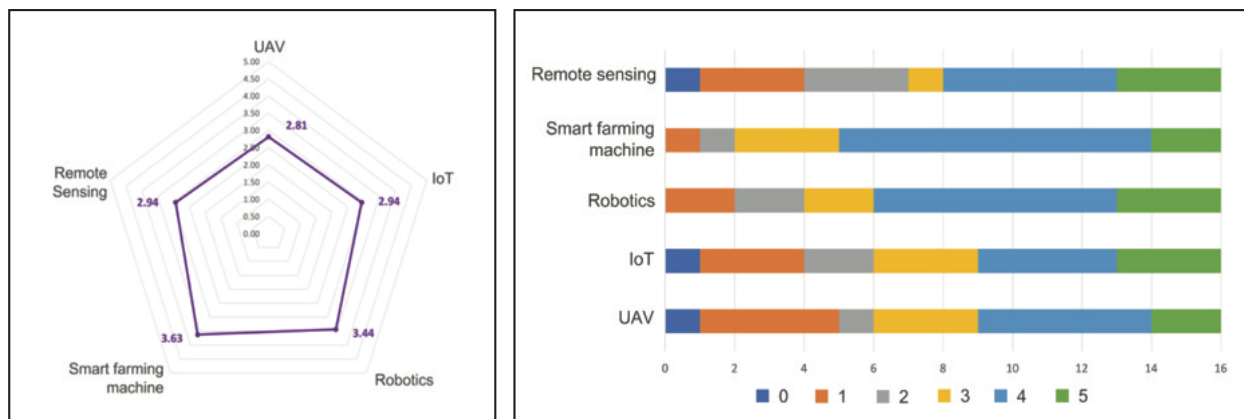


Figure 5. Impact of different digital technologies on rural landscape and number of experts for each rating (Source: the authors).

Among the cultural-social aspects, 'way of managing', 'decision on whether to cultivate' and 'pattern and enclosure' received the highest average scores—3.94, 3.50 and 3.44, respectively. In terms of consensus, 'way of managing', 'whether to cultivate' and 'new built elements' were most frequently rated as high impact, with twelve, nine and nine experts assigning scores of four or five, respectively. These results indicate at least a moderate level of landscape change, as five aspects scored above three on average. 'Preservation of the traditional feature' had the lowest score and, while 'farm size' received the fewest high ratings (Figure 6).

Most experts have acknowledged the impact of DA on the bio-physical dimension, with all surveyed aspects scoring three. 'Flora and fauna diversity' and 'water' received the highest number of high scores (Figure 7). In contrast, the perception-aesthetics dimension appeared least affected, with only 'sense of place' and 'visual complexity/diversity', exceeding a mean score of three (3.06) (Figure 8).

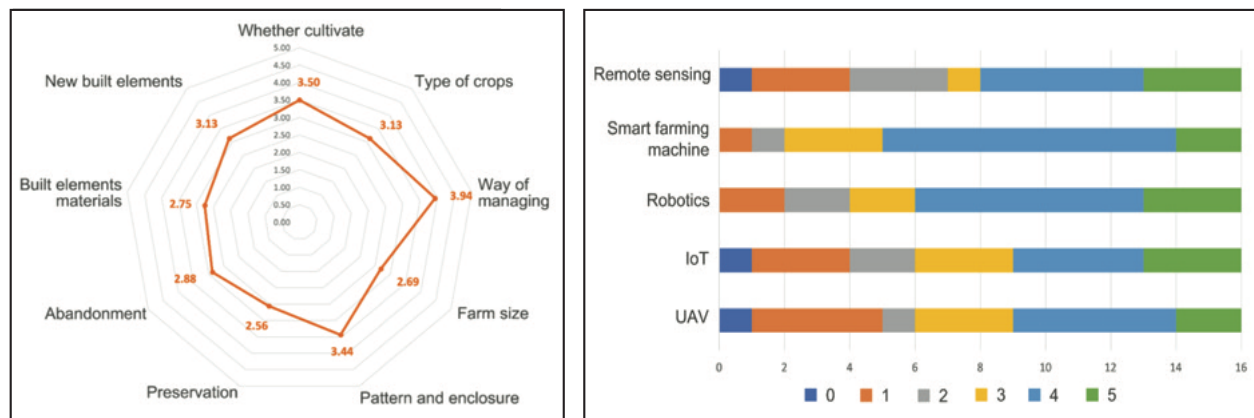


Figure 6. Expert assessment of the impact of digital agriculture on various cultural-social landscape aspects: (a) average scores; (b) distribution of expert ratings (Source: the authors).

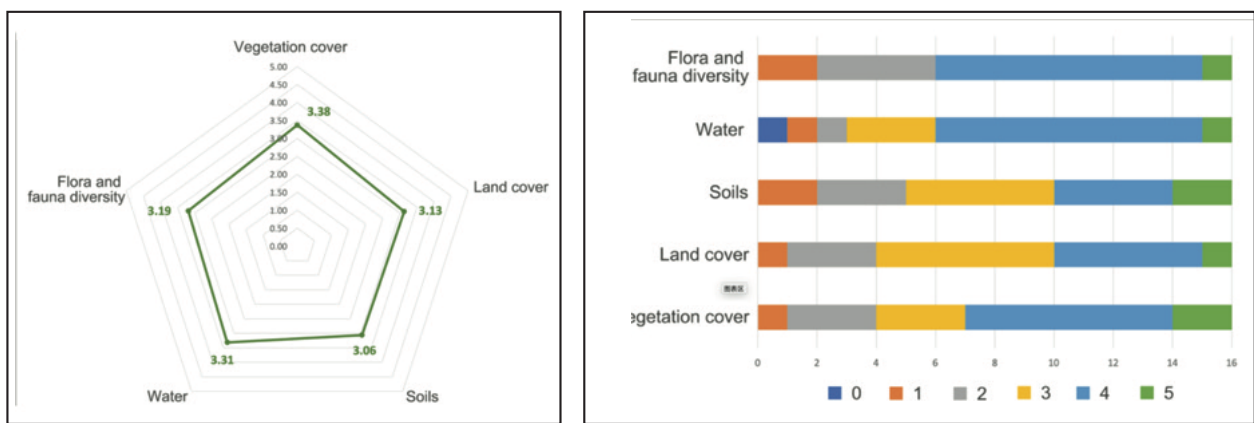


Figure 7. Expert assessment of the impact of digital agriculture on various bio-physical landscape aspects: (a) average scores; (b) distribution of expert ratings (Source: the authors).

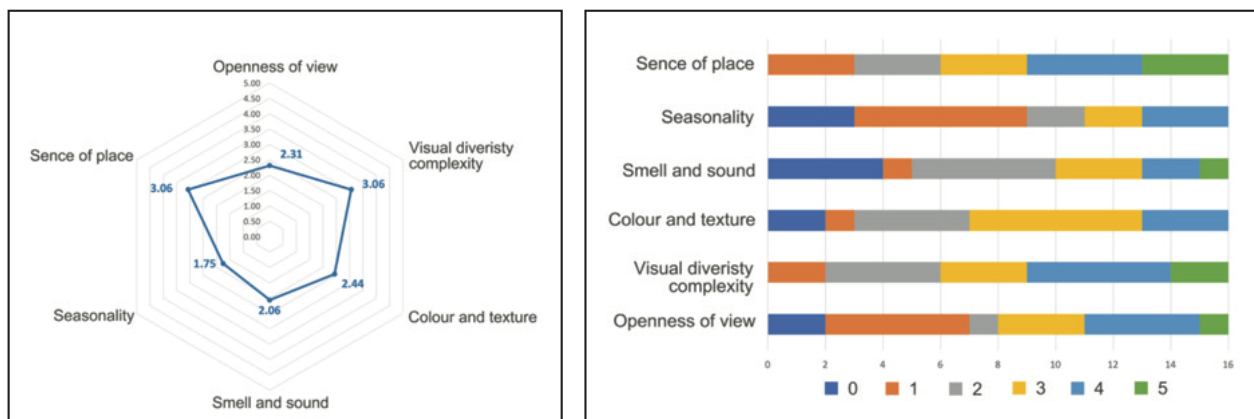


Figure 8. Expert assessment of the impact of digital agriculture on various perceptual-aesthetic landscape aspects: (a) average scores; (b) distribution of expert ratings (Source: the authors).

4.1.2. Different Understandings between Disciplines?

A key objective of the survey is to compare experts' perspectives across research domains. Respondents were grouped based on their self-identified research — 'landscape related', 'agriculture related', or 'both' — with each expert selecting only one category. Each group includes a

comparable number of experts, with no overlap among them; notably, the 'both' group is not a combination of the other two. The respondents were numbered from 0 to 16 (Figure 9). It should be noted that there is *no* overlap between the three groups, and that the 'both' group is *not* the sum of the experts in the other two groups. Besides self-identification of research fields, participants were also invited to provide up to three keywords about their research areas, which offers us more insights about their expertise showing their relevance to our survey. Table 2 synthesizes the keywords provided by experts about their research fields. The same analytical approach was applied across groups, and results are presented in consistent radar chart formats for comparison.

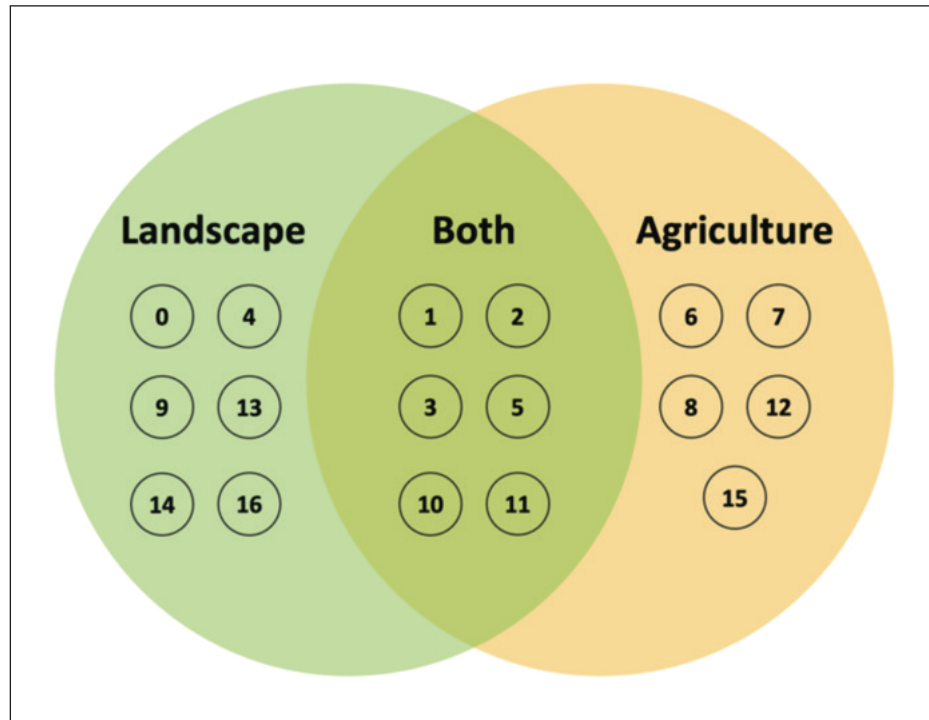


Figure 9. Experts in each research area (Source: the authors).

Table 2. Keywords about the research areas of the participating scholars (Source: the authors)

Landscape	Both	Agriculture
Landscape change, Biodiversity conservation, Landscape ecology, Landscape planning and governance, Farmers landscape management, Policy analysis, Landscape, Geography, Rural heritage, Landscape analysis	Precision farming, Technology adoption, Farmland biodiversity, Agroforestry, Landscape scale ecosystem service evaluation, Biological pest control, Pollination, Landscape ecology, AI robotics in food and agriculture, Sustainable techno-future Rural landscape, Agroforestry system, Digital agriculture, Land use change, Climate change impact on value chain	Soil and water conservation in agriculture, Innovation of vineyard management, Internet of Things (IoT) for agriculture, Sociology of agriculture, Science and technology studies, Machinery for agriculture, Digital technologies for agriculture, logistics

According to the results on the perceived influence of digital technologies on landscape, experts from agricultural and agricultural-landscape domains viewed DA as a significant driver of change, whereas while landscape scholars its impact less (Figure 10). Across all groups, ‘smart farming machine’ was identified as the most influential technology, and agricultural experts additionally rated ‘robotics’ equally high.

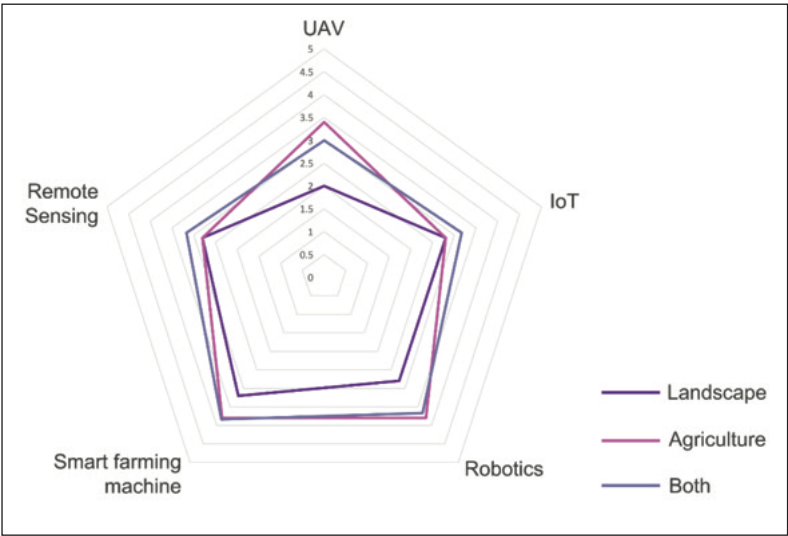


Figure 10. Disciplinary differences in expert assessments of the impact of digital technologies on landscapes (Source: the authors).

A review of the results on the impact of DA across landscape dimensions reveals marked disciplinary differences. In the cultural-social dimension, ‘way of managing’ emerged as the most influenced landscape aspect, with the majority of experts agreed (Figure 11). However, the second most highly rated aspect differs according to the group. For landscape experts, this was ‘new built elements’; for agricultural experts, ‘pattern and enclosure’; and for experts from both fields, ‘whether to cultivate’ (Table 3).

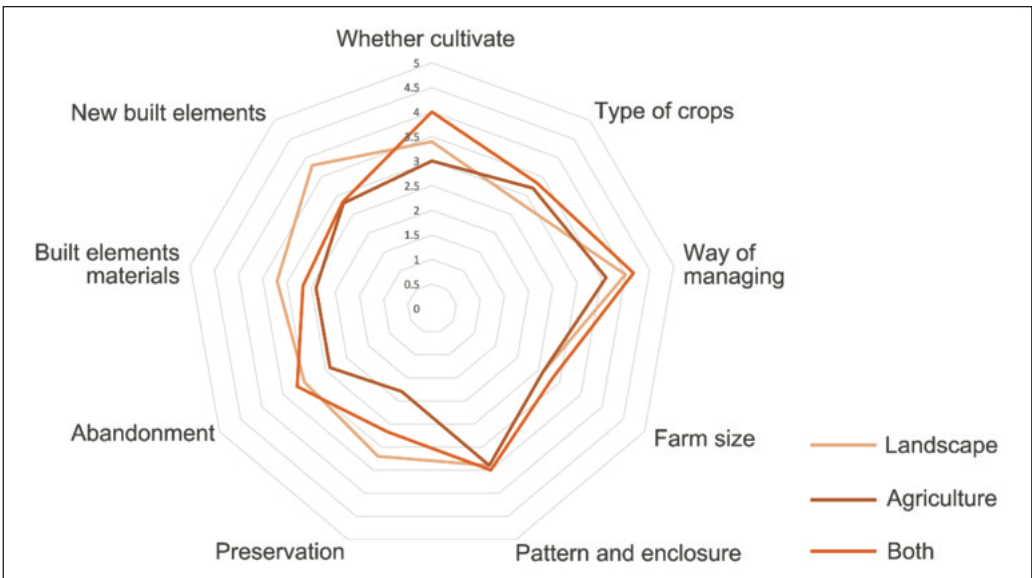


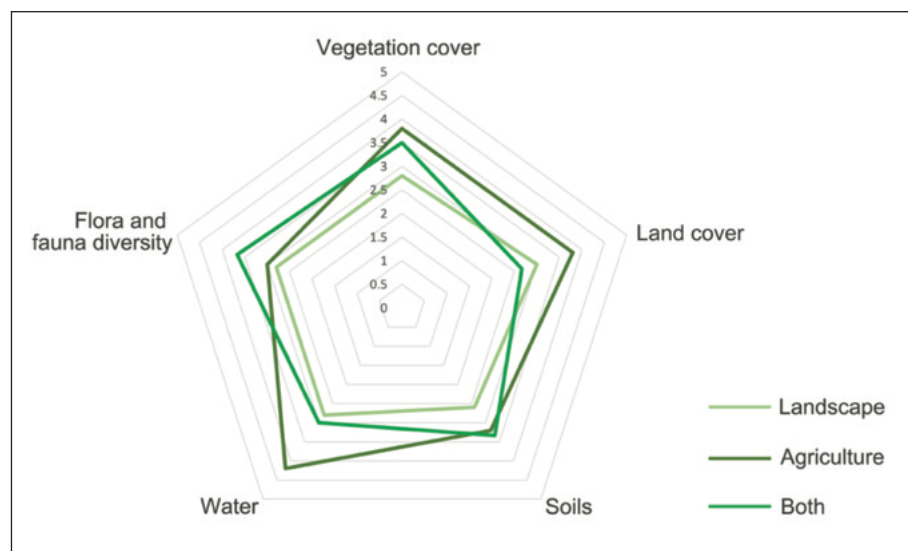
Figure 11. Perceived influence of DA on landscape aspects of the cultural-social dimension by experts from different research fields (Source: the authors).

Tabella 3. Top two ranked influenced aspects and the least affected aspect of the cultural-social dimension (Source: the authors)

Field of expertise	Least affected landscape aspect	Most affected top two landscape aspects			
Landscape	2.6 Farm size	4.0	Way of managing	3.8	New built elements
Agriculture	1.9 Preservation*	3.6	Way of managing	3.4	Pattern and enclosure
Landscape and agriculture	2.7 New built elements Preservation*	4.1	Way of managing	4.0	Whether to cultivate

* Preservation of traditional features

Landscape experts perceived the bio-physical dimension as less impacted, with only 'land cover' scoring 3 (all other aspects scoring below 3; Figure 12). In contrast, agricultural experts rated the bio-physical dimension as the most affected by DA implementation, with all aspects scoring above three and 'water' scored 4.2. Agriculture-landscape experts expressed different opinions that 'flora and fauna diversity' was the most affected aspect, while 'land cover' is the least (Table 4).

**Figure 12.** Perceived influence of DA on landscape aspects of the bio-physical dimension by experts from different research fields (Source: the authors).**Table 4.** Top two ranked influenced aspects and the least affected aspect of the bio-physical dimension (Source: the authors)

Field of expertise	Least affected landscape aspect	Most affected top two landscape aspects			
Landscape	2.6 Soil	3.0	Land cover	2.8	The other three*
Agriculture	3.0 Flora and fauna diversity	4.2	Water	3.8	Vegetation cover
Landscape and agriculture	2.7 Land cover	3.7	Flora and fauna diversity	3.5	Vegetation cover

* Water, Flora and fauna diversity, and vegetation cover

The perceptual-aesthetic dimension was the least affected, with all aspects scoring relatively low (Figure 13). Landscape experts perceived the greatest impact, particularly on ‘sense of place’, whereas agricultural scholars rated all aspects below 3. Landscape-agriculture experts identified ‘visual complexity/diversity’ as the most influenced aspect, with ‘seasonality’ scoring lowest (Table 5).

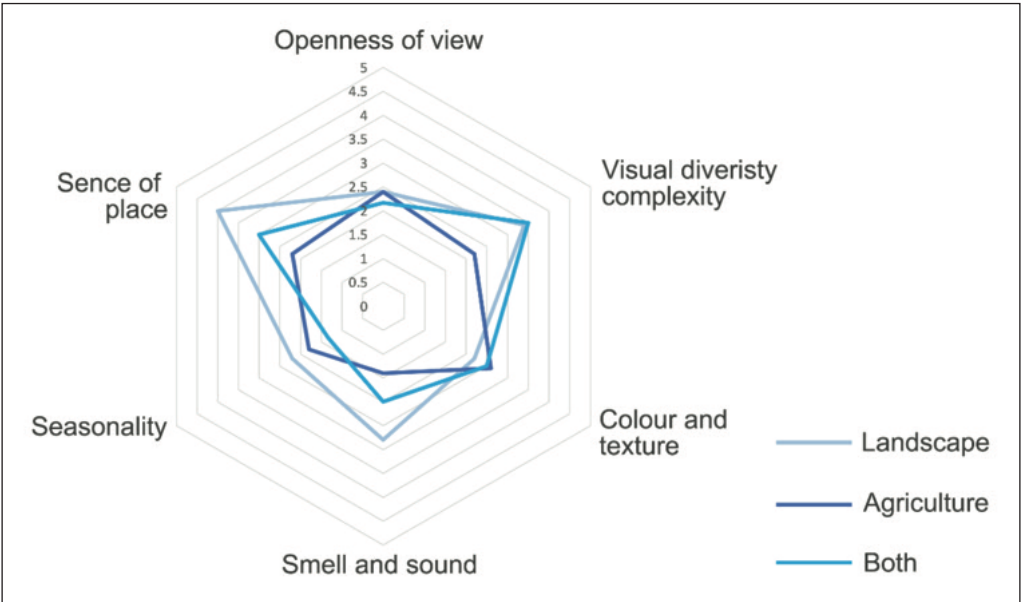


Figure 13. Perceived influence of DA on landscape aspects of the perceptual-aesthetic dimension by experts from different research fields (Source: the authors).

Table 5. Top two ranked influenced aspects and the least affected aspect of the perceptual-aesthetic dimension (Source: the authors)

Field of expertise	Least affected landscape aspect	Most affected top two landscape aspects			
Landscape	2.2 Colour and texture Seasonality	4.0	Sense of place	3.4	Visual complexity diversity
Agriculture	1.4 Smell and sound	2.6	Colour and texture	2.4	Openness of view
Landscape and agriculture	1.3 Seasonality	3.5	Visual complexity diversity	3.0	Sense of place

4.2. Analysing the Open Questions - Thematic Analysis

Experts also responded to open-ended questions, offering additional explanations for their scale ratings and sharing further insights. Using thematic analysis with an inductive coding approach was used (Joffe & Yardley, 2003), we identified six emergent themes: five concerning landscape changes one addressing the way DA affects landscape. These included environmental benefits, farm size divergence, field organisation, landscape experience and social perception, societal and work organisation, and indirect influence.

4.2.1. *Environmental Benefits*

This theme highlights the environmental benefits derived from DA implementation. Among these, resource efficiency—a core characteristic of precision farming (Clapp & Ruder, 2020) —emerged as a recurring concept. Experts emphasised that DA can reduce the leaching of nitrogen and use of pesticides, thereby mitigating environmental pollution and improving water and soil quality. As one participant observed, DA supports ‘... an environment with optimised use of resources, with less use of chemical to maintain the agricultural landscape (expert 6)’.

DA also supports climate change mitigation and adaptation. Experts (1, 9, 11) noted that digital tools enable more precision control of carbon emissions from practices such as soil tillage. Beyond human-centred benefits, these outcomes positively influence the agricultural ecosystem, representing shifts in the bio-physical dimension. As expert 6 noted, ‘precision farming and GPS navigation could help in strip farming to avoid erosion in hilly areas’, addressing terrain-specific environmental changes.

4.2.2. *Farm Size Divergence*

The second theme concerns farm size, encompassing both size changes and differentiated management strategies. Experts suggested that DA may encourage either expansion or fragmentation of fields, depending on the technology adopted. As expert 0 noted, ‘robots may allow cultivation of new types of crops and can result in more small fields ... whereas bulk production improved by big machines and precision agriculture may result in bigger fields.’ While large farms are often better technically, economically, and culturally equipped to adopt innovation (expert 1), small farms face the challenges in awareness, skills, and investment. Expert 6 emphasised that these challenges may limit DA adoption, potentially reinforcing trends towards larger-scale farming, which is consistent with Lajoie-O’Malley et al. (2020)’s argument that DA merely represents a continuation of industrial mass farming driven by mechanisation.

4.2.3. *Field Organization*

Several experts discussed changes in the field organisation, reflecting divergent trends. Addressing Klerkx et al. (2019) question on how new information flows between farmers and their environment reshape structural change. Some experts suggested DA enables more intricate landscape design. For instance, expert 9 mentioned the potential of the artificial intelligence to optimise field structures, while expert 15 noted that precision data may prompt adjustments in field size, shapes, and irrigation system. Expert 6 referred to GPS-supported design like corn maze in the U.S., which can reduce maintenance cost and promote rural tourism. Similarly, expert 7 observed that plant organisation might be adjusted to suit automation and sensor use, which aligns with the observation in the beforementioned apple orchard example (Legun & Burch, 2021). Expert 7 also added that DA might potentially impact crop varieties rather than types. By contrast, expert 11 anticipated increased landscape uniformity, suggesting DA could also lead to homogenisation.

4.2.4. *Landscape Experience and Social Perception*

The fourth theme concerns changes in landscape experience and social perception brought about by DA. Several experts noted that visible technologies, such as drones or electric fences, may alter public perceptions of agricultural landscapes, with some viewing them as aesthetic disturbances (experts 0, 13). Sound was also raised as a concern—certain machines can be loud enough to provoke complaints (expert 3). Beyond sensory impacts, DA introduces new forms of landscape knowledge, encouraging more ‘precise and scientific’ understandings. As expert 13 observed, tools like UAV and GPS tracker can shift pastoralists’ perceptions of grazing intensity and livestock impact. While such tools may enhance decision-making and socio-ecological resilience, several experts expressed concern that automation could weaken place-based

relationships. Expert 3 warned that ‘people might lose connection to place through leaving things to robotics,’ and that this could disrupt indigenous knowledge systems. Expert 14 similarly noted that a depopulated countryside undermines the sense of place—a theme developed further below.

4.2.5. Societal Organisation and Work Arrangement

Unipolar-scale responses identified ‘way of managing’ as the most affected cultural-social aspect, pointing to significant shifts in societal organization and labour dynamics. Expert 0 and 9 have anticipated increased collaboration among the farmers, particularly as smaller farms may need to share costly technologies. However, other highlighted risk of the divergences between the farmers due to the digital divide (Salemink et al., 2017). Expert 1 warned that ‘DA may create a significant divide ... between front-runners and laggards.’ Expert 3 further cautioned that agri-tech reinforce colonial power dynamics, with uneven access to land and technologies exacerbating existing inequalities. Expert 14 linked increase of labour efficiency to demographic decline, noting that ‘less people [are] needed to work the land,’ potentially leading to rural depopulation and the collapse of rural society.’

In parallel, expert 10 and 11 observed that DA may enable new combinations of on- and off-farm work. Expert 6 pointed to possible changes in farm management rules, such as permitting vineyard irrigation if sensor data supports it, which demonstrates how DA might drive regulatory adaptation.

4.2.6. Indirect Influence

The final theme concerns the indirect influence of DA on landscape, a point of particular interest among experts with backgrounds in both agriculture and landscape studies. Expert 3 stressed the need to better articulate this dimension, noting that data-driven decisions may reshape both landscape and labour. Expert 14 described a chain of effects in which automation-induced labour-efficiency might lead to rural depopulation, and, eventually, changes in sense of place. Meanwhile, expert 1 viewed DA as an enabler of different practices, such as precision agriculture, climate smart agriculture, agroecology, which in turn drive landscape change. In this view, DA was interpreted as a tool to achieve certain types of farming practices, and these practices are the direct cause of landscape change.

Beyond the six core themes, three additional expert perspectives merit attention. First, expert 10 highlighted the importance of timescale, suggesting that in the short term, data availability will shape farming, while in the longer run (>10 years), robotics may begin to influence practices. Second, experts 7 and 12 raised contrasting possibilities: the abandonment of the areas unsuitable for new technologies, and the potential for innovations such as saltwater greenhouse systems to enable cultivation in previously unproductive regions—both with significant landscape implications. Finally, Expert 0, who did not complete the full survey, cautioned against generalising DA’s effects without specify the type of technology, noting that ‘directions of changes depend very much on the technology introduced’. This underscores the conditional and context-specific nature of landscape change under DA.

5. Discussion

The expert survey results reveal considerable diversity and richness, demonstrating that DA does exert influences on different aspects of landscape to various degrees, despite the relatively low number of responses. In addition to identifying the most and the least affected landscape aspects, the findings highlight three interesting points that deserve further discussion.

The first point is about the changing way of how landscapes are affected by DA, shifting from primarily indirect influence today to potentially more direct impacts in the future. The unipolar-scale responses identified ‘providing data to support farm decisions’ as the most dominant way of influencing, echoing previous research (McConnell, 2019; Moreno et al., 2022). These studies

similarly describe DA as a decision support system (DSS), aiding farm management decisions such as field design, land covers, irrigation and fertilization. The theme of 'indirect influence' also emerged from the thematic analysis, reinforcing this interpretation. By contrast, technologies like smart farming machines and robotics which were viewed by the expert as the most influential act directly on farm operations and, by extension, landscape itself. The seemingly contradictory results can be explained by considering the temporal dimension. Given current technological limitations and high cost, DSS remains the dominate form of DA today. However, in the longer term, we can reasonably foresee wider implementation of more advanced, cost-effective automation tools. These technologies would exert more direct influence on landscape, underscoring the value of the expert survey in anticipating future landscape changes.

The second notable finding is the identification of the disciplinary gap in how landscape change driven by DA is perceived. This is particularly evident when analysing the affected landscape dimensions, where both convergence and divergence emerge. The convergence is reflected in the consensus across expert groups on the impacts on the cultural-social dimension. 'Way of managing', 'new built elements', 'whether to cultivate' and 'pattern and enclosure' were consistently perceived as highly influenced, especially by agriculture-landscape scholars, who generally gave higher scores than the other two groups. The divergence appears in responses regarding the bio-physical and the perceptual-aesthetic dimensions. Agricultural experts considered DA to have substantial impact on the bio-physical dimension, whereas the landscape experts thought less so. Conversely, landscape experts gave significantly higher scores for the perceptual-aesthetic dimension, while agricultural scholars were less convinced. Agriculture-landscape experts offered more moderate assessments across both dimensions. This discrepancy likely stems from disciplinary familiarity: agricultural experts, well-versed in environmental aspects of farming, may be less attuned to landscape perception concepts, while the opposite holds for landscape experts. These patterns highlight a disciplinary divide in how landscape change is interpreted. Such gaps may pose challenges for future agricultural and landscape policymaking, especially amid accelerating farming digitalisation and increasing emphasis on landscape sustainability.

Finally, there is a seemingly paradoxical pattern in how changes to the perceptual-aesthetic dimension are perceived. Compared to the other two dimensions, it appears least influenced according to unipolar-scale questions results. Yet, a considerable number of experts discussed landscape perception in their responses to the open-end questions, leading to its emergence as a theme in the thematic analysis. One possible explanation lies in the temporal lag associated with perceptual change. Experts may find easier to recognise or anticipate in the cultural-social and bio-physical dimensions on the basis of their past experiences. These changes—such as land use, vegetation cover, or field structure—are more readily measured and observed. By contrast, as Bieling (2013) notes, 'perception of incremental landscape change does not correspond with a survey on biophysical features of landscape change, but rather focuses on visible effects and exhibits considerable time lags'. This observation may help explain the apparent mismatch in how the perceptual-aesthetic dimension is assessed. Furthermore, it may be inherently difficult to anticipate or imagine changes in landscape perception without directly experiencing them. While changes to the physical structures are often measured in a quantitative approach, aesthetic and sensory dimensions are more subjective, unfolding over time and in context.

6. Conclusion

The expert survey revealed a broad consensus among participants on the growing impact of DA on rural landscape change, particularly in the long term. Overall, the experts agreed that DA exerts pronounced impacts on the cultural-social and bio-physical dimensions, while also noting some signs of changes in the perceptual-aesthetic dimension, with disciplinary differences in interpretation. In addition to reflecting on the current changes, respondents offered anticipations of future developments, such as a shift from indirect to direct influence on landscapes, and the cascading effects of DA-enabled automation on local identity and rural depopulation. These highly

diverse changes range from proximate effects on the physical structure to underlying changes to the deeper societal restructuring. The fact that all items in the landscape change checklist were referenced suggests it provides a robust framework for analyzing DA-driven change, with potential for broader application in future research.

Instead of focusing on the influence of a single type of technology on landscape, our research intended to identify the general direction of landscape change driven by farming digitalization, helping to put forward a new direction for future studies by providing an interpretative framework. Indeed, what change a specific technology can bring will need specific investigation, also considering that the same technology can lead to different results depending on how it is implemented in the field. For instance, remote sensing can enable the smart farming machineries for mass production leading to potential landscape homogenization, while it can also provide data to support decision making on the restoration of landscape features in the field. First, future studies on DA-driven landscape change could benefit from case-based research, where digital technologies, landscape characteristics, and stakeholder roles (e.g. farmers, agri-tech companies) are more clearly defined. Second, the absence of a timeframe in this survey made expert projections relatively generic; incorporating clearer time horizon—such as five or ten years—could help produce more actionable insights. Finally, broadening participation to include experts from different fields such as digital agriculture technology could strengthen interdisciplinary dialogue and help bridge knowledge gaps across fields.

Central to this research is the recognition of landscape multifunctionality, yet current policy frameworks remain fragmented. While digital agriculture is predominantly governed by production-oriented agricultural policies, the ecological, cultural, and aesthetic dimensions of the landscape are managed through separate planning tools. This research seeks to bridge these sectoral gaps by advocating for a more holistic governance approach. A key step in this integration is the formal incorporation of agri-tech actors as relevant stakeholders in landscape governance and planning, ensuring that technological drivers are aligned with landscape values. It can also contribute to the achievement of the “dual-win” situation which optimise limited financial resources to simultaneously advance digitalization and landscape sustainability. Ultimately, bridging the sectoral gap between technology and landscape allows for a more ethical digitalization, one that safeguards the ecological, cultural, and aesthetic dimensions of the landscape while fostering technological innovation.

Acknowledgement

We would like to express our gratitude to the experts who participated in the survey.

We would like to express our sincere gratitude to the editor for their invaluable assistance in refining this manuscript. We are also deeply grateful to the reviewers for their constructive feedback and critical comments, which greatly contributed to the improvement of this paper.

Authors' contribution

Conceptualization: F.H., C.C.; Methodology: F.H., C.C.; Data collection: F.H.; Formal analysis: F.H.; Original draft: F.H.; Review and editing: F.H., C.C.; Supervision: C.C.

Bibliography

- Antrop M. (1997). The concept of traditional landscapes as a base for landscape evaluation and planning. The example of Flanders Region. *Landscape and urban planning*, 38(1-2), 105-117. [https://doi.org/https://doi.org/10.1016/S0169-2046\(97\)00027-3](https://doi.org/https://doi.org/10.1016/S0169-2046(97)00027-3)
- Antrop M. (2005). Why landscapes of the past are important for the future. *Landscape and urban planning*, 70(1-2), 21-34. <https://doi.org/https://doi.org/10.1016/j.landurbplan.2003.10.002>
- Basso B. & Antle J. (2020). Digital agriculture to design sustainable agricultural systems. *Nature Sustainability*, 3(4), 254-256. <https://doi.org/https://doi.org/10.1038/s41893-020-0510-0>

- Bastian O., Grunewald K., Syrbe R.-U., Walz U. & Wende W. (2014). Landscape services: the concept and its practical relevance. *Landscape ecology*, 29(9), 1463-1479. <https://doi.org/https://doi.org/10.1007/s10980-014-0064-5>
- Bellon-Maurel V. & Huyghe C. (2017). Putting agricultural equipment and digital technologies at the cutting edge of agroecology. *Oléagineux, Corps Gras, Lipides*, 24(3), 1-7. <https://doi.org/https://doi.org/10.1051/ocl/2017028>
- Bellon-Maurel V., Lutton E., Bisquert P., Brossard L., Chambaron-Ginhac S., Labarthe P., Lagacherie P., Martignac F., Molenat J. & Parisey N. (2022). Digital revolution for the agroecological transition of food systems: A responsible research and innovation perspective. *Agricultural systems*, 203, 103524. <https://doi.org/https://doi.org/10.1016/j.agry.2022.10352>
- Bieling C. (2013). Perceiving and Responding to Gradual Landscape Change at the Community Level: Insights from a Case Study on Agricultural Abandonment in the Black Forest, Germany. *Ecology and Society*, 18(2). <https://doi.org/http://dx.doi.org/10.5751/ES-05590-180236>
- Brandt J., Primdahl J. & Reenberg A. (1999). Rural land-use and landscape dynamics-analysis of 'driving forces' in space and time. *Man and the Biosphere Series*, 24, 81-102. https://forskning.ruc.dk/files/34926652/Rural_land_use_and_landscape_dynamics.pdf
- Bürge M., Celio E., Diogo V., Hersperger A.M., Kizos T., Lieskovsky J., Pazur R., Plieninger T., Prishchepov A.V. & Verburg P.H. (2022). Advancing the study of driving forces of landscape change. *Journal of Land Use Science*, 1-16. <https://doi.org/https://doi.org/10.1080/1747423X.2022.2029599>
- Bürge M., Hersperger A.M. & Schneeberger N. (2005). Driving forces of landscape change-current and new directions. *Landscape ecology*, 19(8), 857-868. <https://doi.org/https://doi.org/10.1007/s10980-005-0245-3>
- Cassatella C. & Peano A. (2011). *Landscape Indicators: Assessing and Monitoring Landscape Quality*. Springer.
- Cavallo E., Ferrari E., Bollani L. & Coccia M. (2014). Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system. *Agricultural systems*, 130, 44-54. <https://doi.org/https://doi.org/10.1016/j.agry.2014.05.012>
- Clapp J. & Ruder S.-L. (2020). Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. *Global Environmental Politics*, 20(3), 49-69. https://doi.org/https://doi.org/10.1162/glep_a_00566
- Del Río Castro G., González Fernández M. C. & Uruburu Colsa, Á. (2021). Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. *Journal of Cleaner Production*, 280, 122204. <https://doi.org/https://doi.org/10.1016/j.jclepro.2020.122204>
- Dörr J. & Nachtmann M. (2022). *Handbook Digital Farming: Digital Transformation for Sustainable Agriculture*. Springer.
- El Bilali H. & Allahyari M.S. (2018). Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Information Processing in Agriculture*, 5(4), 456-464. <https://doi.org/https://doi.org/10.1016/j.inpa.2018.06.006>
- ElMassah S. & Mohieldin M. (2020). Digital transformation and localizing the Sustainable Development Goals (SDGs). *Ecological economics*, 169, 106490. <https://doi.org/https://doi.org/10.1016/j.ecolecon.2019.106490>
- European Commission. (2021). *The new common agricultural policy: 2023-27*. Retrieved 14 February 2024 from https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27_en
- European Commission. (2023). *2030 Digital Decade: Report on the state of the digital decade 2023*. <https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade>
- Huang F. (2025). *Examining Rural Landscape Change Driven by the Digitalisation of Agriculture* [Doctoral Thesis, Politecnico di Torino]. Torino. <https://iris.polito.it/handle/11583/2999502>
- Huang F. & Cassatella C. (2024). Examining Rural Landscape Change in the Context of Agriculture Digitalisation: A Review. *Landscape Research*, 50(1), 250-268. <https://doi.org/10.1080/01426397.2024.2391387>

- Joffe H. & Yardley L. (2003). Chapter four: content and thematic analysis. *Research Methods for Clinical and Health Psychology*. Marks D, Yardley L (ed): Sage Publications, London, 56-68.
- Kernecker M., Knierim A., Wurbs A., Kraus T. & Borges F. (2020). Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precision Agriculture*, 21(1), 34-50. <https://doi.org/https://doi.org/10.1007/s11119-019-09651-z>
- Klerkx L., Jakku E. & Labarthe P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS-Wageningen Journal of Life Sciences*, 90, 100315. <https://doi.org/https://doi.org/10.1016/j.njas.2019.100315>
- Lajoie-O'Malley A., Bronson K., van der Burg S. & Klerkx L. (2020). The future (s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services*, 45, 101183. <https://doi.org/https://doi.org/10.1016/j.ecoser.2020.101183>
- Legun K. & Burch K. (2021). Robot-ready: How apple producers are assembling in anticipation of new AI robotics. *Journal of Rural Studies*, 82, 380-390. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2021.01.032>
- Leveau L., Bénel A., Cahier J.-P., Pinet F., Salembier P., Soullignac V. & Bergez J.-E. (2019). Information and communication technology (ICT) and the agroecological transition. In *Agroecological transitions: from theory to practice in local participatory design* (pp. 263-287). Springer, Cham.
- McConnell M.D. (2019). Bridging the gap between conservation delivery and economics with precision agriculture. *Wildlife Society Bulletin*, 43(3), 391-397. <https://doi.org/https://doi.org/10.1002/wsb.995>
- Mckinsey Global Institute. (2014). *China's digital transformation: The internet's impact on productivity and growth*. M. Company. <https://www.mckinsey.com/~media/mckinsey/industries/technology%20media%20and%20telecommunications/high%20tech/our%20insights/chinas%20digital%20transformation/mgi%20china%20digital%20full%20report.pdf>
- Medley K.E., Okey B.W., Barrett G.W., Lucas M.F. & Renwick W.H. (1995). Landscape change with agricultural intensification in a rural watershed, southwestern Ohio, USA. *Landscape ecology*, 10(3), 161-176.
- Ministry of Agriculture and Rural Affairs of China. (2022). *Quanguo nongye nongcun xinxihua fazhan guihua [National Development Plan for Informationisation of Agriculture and Rural Area]*. Retrieved from http://www.moa.gov.cn/govpublic/SCYJJXXS/202203/t20220309_6391175.htm
- Moreno A., Rescia A.J., Pascual S. & Ortega M. (2022). Methodological approach to spatial analysis of agricultural pest dispersal in olive landscapes. *Environmental Monitoring and Assessment*, 194(6), 411. <https://doi.org/https://doi.org/10.1007/s10661-022-10068-x>
- Nguyen L.H., Robinson S.V. & Galpern P. (2022). Effects of landscape complexity on crop productivity: an assessment from space. *Agriculture, ecosystems & environment*, 328, 107849. <https://doi.org/https://doi.org/10.1016/j.agee.2021.107849>
- OECD. (2019). *Digital Opportunities for Better Agricultural Policies*. <https://doi.org/doi:https://doi.org/10.1787/571a0812-en>
- Pfeiffer J., Gabriel A. & Gandorfer M. (2021). Understanding the public attitudinal acceptance of digital farming technologies: a nationwide survey in Germany. *Agriculture and Human Values*, 38(1), 107-128. <https://doi.org/https://doi.org/10.1007/s10460-020-10145-2>
- Pinto-Correia T., Primdahl J., Pedroli B. & Pedroli G.B.M. (2018). *European landscapes in transition*. Cambridge University Press.
- Plieninger T., Draux H., Fagerholm N., Bieling C., Bürgi M., Kizos T., Kuemmerle T., Primdahl J. & Verburg P.H. (2016). The driving forces of landscape change in Europe: A systematic review of the evidence. *Land Use Policy*, 57, 204-214. <https://doi.org/https://doi.org/10.1016/j.landusepol.2016.04.040>
- Rose D.C. & Chilvers J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems*, 2, 87. <https://doi.org/https://doi.org/10.3389/fsufs.2018.00087>
- Rotz S., Gravely E., Mosby I., Duncan E., Finnis E., Horgan M., LeBlanc J., Martin R., Neufeld H.T. &

- Nixon A. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, 68, 112-122. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2019.01.023>
- Sachs J.D., Schmidt-Traub G., Mazzucato M., Messner D., Nakicenovic N. & Rockström J. (2019). Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, 2(9), 805-814. <https://doi.org/10.1038/s41893-019-0352-9>
- Salemink K., Strijker D. & Bosworth G. (2017). Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies*, 54, 360-371. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2015.09.001>
- Schroeder K., Lampietti J. & Elabed G. (2021). *What's cooking: Digital transformation of the Agrifood system*. World Bank Publications. <http://hdl.handle.net/10986/35216>
- Stahlschmidt P., Swaffield S., Primdahl J. & Nellesmann V. (2017). *Landscape Analysis: Investigating the potentials of space and place*. Routledge.
- Swanwick C. (2002). *Landscape Character Assessment: Guidance for England and Scotland*. Countryside Agency Retrieved from <https://digital.nls.uk/pubs/e-monographs/2020/216649977.23.pdf>
- Tang S., Zhu Q., Zhou X., Liu S. & Wu M. (2002). A conception of digital agriculture. IEEE international geoscience and remote sensing symposium,
- Termorshuizen J.W. & Opdam P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape ecology*, 24(8), 1037-1052. <https://doi.org/https://doi.org/10.1007/s10980-008-9314-8>
- Trendov N.M., Varas S. & Zeng M. (2019). *Digital technologies in agriculture and rural areas status report*. Food and Agriculture Organisation. <https://www.fao.org/documents/card/en/c/ca4985en>
- Tudor C. (2014). *An approach to landscape character assessment*. Natural England Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/691184/landscape-character-assessment.pdf
- Wu J., Wang Z., Zhang L. & Song J. (2012). Jingguan geju bianhua qudongli yanjiu jinzhan [Research progresses on driving forces of the changes of landscape pattern]. *Progress in Geography*, 31(12), 1739-1746. <https://doi.org/https://doi.org/10.11820/dlkxjz.2012.12.021>
- Zhao C. (2019). Zhihui nongye fazhan xianzhuang ji zhanlve mubiao yanjiu [State-of-the-art and recommended development strategy objectives of smart agriculture]. *Smart Agriculture*, 1(1), 1-7. <https://doi.org/https://doi.org/10.12133/j.smartag.2019.1.1.201812-SA005>

Appendix

Appendice 1. Expert survey

Survey on Experts' Opinions on the Relationship between the Digital Agriculture and the Rural Landscape Change

I. BASIC INFORMATION

In this session, you will be asked some questions related to your academic background the research interests. All the information collected in this session, except the part about your research area and the geographical location of your affiliated institute, will remain anonymous, unless you feel OK to reveal it.

1. You identify yourself as a scholar working in the field of:

A. Agriculture related research;

B. Landscape related research;

C. Both;

D. Other _____

2. Please write down your main research area (up to 3)

3. Please write down your position and affiliation (please indicate the country of your institution):

4. Do you want to remain anonymous in this survey?

A. YES

B. It's OK to share the above information

N.B. information regarding to your position and affiliation will be kept confidential, if you prefer to stay anonymous. Only the answer of Q1, Q2, and the geographical location of your affiliation in Q3 will be used for the research. For the use of information, your response in this survey may be quoted in the following works such as articles and my thesis when I write about the result of this survey.

II. DIGITAL AGRICULTURE

In this session, you will be asked questions related to digital technologies in agriculture focusing on if you think these technologies will have an influence, the extent of their influence and how they influence.

5. There are some technologies currently adopted to agriculture, if you can think or imagine whether the implementation of these technologies in the field will lead to landscape change. If your answer is 'yes', please indicate the extent of their influence using the provided scale. 0 refers to "this digital technology has no influence on rural landscape", 1 refers "little influence", 5 refers to "great influence"

	0	1	2	3	4	5
Unmanned aerial vehicle (UAV)	☐	☐	☐	☐	☐	☐
Internet of Things (IoT)	☐	☐	☐	☐	☐	☐
Robotics	☐	☐	☐	☐	☐	☐
Smart farming machineries	☐	☐	☐	☐	☐	☐
Remote sensing	☐	☐	☐	☐	☐	☐

Appendix

6. If you know any other technological applications, please write them down (max. 3) and indicate if you think their application in the field will influence the rural landscape and the extent of their influence as well using the scale from 1 to 5. e.g. (name of the technology) – 4
-

7. Some brief descriptions on how digital agriculture may influence the rural landscape are listed below. Do you think these descriptions below are the way that rural landscape gets affected by the digital agriculture? If your answer is 'yes', please indicate the extent of its dominance using the provided scale

0 refers to "digital agriculture does not influence rural landscape in such way", 1 refers "the least dominant way that the digital agriculture affects the rural landscape", 5 refers to "the most dominant way that the digital agriculture affects the rural landscape"

	0	1	2	3	4	5
Directly changing the farming practices and the way that farm organised. A more direct influence.	☐	☐	☐	☐	☐	☐
Providing more data and information to inform decision making in the farm choices, leading to change. A more indirect influence.	☐	☐	☐	☐	☐	☐

8. If you can think of more, please add them below and indicate the extent of its dominance using the scale from 1 to 5.
e.g. (the description of the way how digital agriculture influence landscape) – 4
-

III. INFLUENCES ON LANDSCAPE

In this session, the concept of landscape will be broken down into three dimensions with multiple aspects. You will be asked if you can anticipate changes to the following aspects of landscape related to the implementation of the digital agriculture. Please indicate the extent of the impact using the provided scale.

0 refers to "not affected by the adoption of digital agriculture"; 1 refers "little influence"; 5 refers to "great influence"

9. Impact of the digital agriculture on cultural-social aspects

	0	1	2	3	4	5
Decision on whether to cultivate	☐	☐	☐	☐	☐	☐
Type of cultivated crops	☐	☐	☐	☐	☐	☐
Way of managing crops	☐	☐	☐	☐	☐	☐
Farm size	☐	☐	☐	☐	☐	☐
Pattern and type of field enclosure	☐	☐	☐	☐	☐	☐
Preservation of traditional features	☐	☐	☐	☐	☐	☐
Abandonment of traditional features	☐	☐	☐	☐	☐	☐
Material of built elements	☐	☐	☐	☐	☐	☐
Insertion of new built elements	☐	☐	☐	☐	☐	☐

Appendix

10. If you can think of more cultural-social aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (cultural-social aspect) – 3.

If you can think of an example of how landscape socio-cultural factors get influence, you can write it down briefly here.

11. Impact of the digital agriculture on bio-physical aspects

Vegetation cover	☐	☐	☐	☐	☐	☐
Land cover	☐	☐	☐	☐	☐	☐
Soils	☐	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐	☐
Flora and fauna diversity	☐	☐	☐	☐	☐	☐

12. If you can think of more natural aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (bio-physical aspect) – 4.

If you can think of an example of how landscape natural factors get influence, you can write it down briefly here.

13. Impact of the digital agriculture on perceptual-aesthetic aspects

	0	1	2	3	4	5
Openness of view	☐	☐	☐	☐	☐	☐
Visual diversity/complexity	☐	☐	☐	☐	☐	☐
Colour and texture	☐	☐	☐	☐	☐	☐
Smells or sounds	☐	☐	☐	☐	☐	☐
Seasonality	☐	☐	☐	☐	☐	☐
Sense of place	☐	☐	☐	☐	☐	☐

14. If you can think of more perceptual-aesthetic aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (perceptual-aesthetic aspect) – 2.

If you can think of an example of how landscape perceptual-aesthetic factors get influence, you can write it down briefly here.

Appendix

Appendice 2. Experts' answers to open-end questions

Expert 0 – Landscape

Precision fertilization and pest management based on high-tech agricultural machinery and data from satellites and sensors may reduce the leaching of nitrogen from the soil as well as limit the pollution from pesticides

Collaboration between farmers - new technology is expensive, so smaller farms may need to collaborate and own machinery jointly

Depending on the technology introduced it may result either in bigger fields or small fields-robots may allow cultivation of new types of crops (vegetables likes) and can result in more small fields and more field structures, whereas bulk production improved by big machines and precision agriculture may result in bigger fields.

it is difficult to answer question 8a - it will have an influence on all natural factors; however the effects can be positive, negative or neutral

also here I find it difficult to make an answer to 9a as it depends on the technology introduced. However the introduction of more visible technology in agriculture will change our perception of agriculture and the landscape - the use of drones - can be seen as a kind of disturbance

Expert 1 – both

The technologies listed above are all digital technologies and have, in my view, mostly an indirect impact on landscape (e.g. because they can support precision agriculture, climate smart agriculture, agro-ecology, etc.). Other agriculture technologies (not necessarily digital) may have a stronger influence. For instance, protected agriculture, genomics, low carbon agricultural practices

Providing data and information for decision making at landscape (aggregated) and higher level

Digital agriculture may create a significant divide (technical and then economic, social) between farmers between front-runners and laggards. A factor 5

There are studies which show that adopters of digital innovation, especially precision farming related, are and will be in the future large farms, well equipped technically, economically, culturally towards innovation. To have small scale producers adopting such innovations strong investments are needed in terms of awareness creation, digital skills, and assets (e.g. IoT enabled sensors and machinery, farm management information systems, use of UAV and remote sensing data)

soil carbon emission and fixation (if we can consider these as natural factors): factor 3

digital agriculture can help assessing the impact of soil carbon emissions caused by farming practices (e.g. tillage)

Expert 3 – both

I think that the point about indirect influences needs to be fleshed out a bit. They may be collecting data and using it to influence landscapes and work, but that does not mean that is the best way to reorganize things. But, as Bronson 2022 argues, data is often considered a political (immaculately conceived) which is a huge issue.

Some of the machines can be really loud. So much so that neighbors might complain. Regarding sense of place, I think people might lose connection to place through leaving things to robotics. The Legun et al 2022 paper Can a Robot Be an Expert? addresses these dimensions, alongside the kinds of knowledges that are valued. Taiuru et al 2022 paper on agricultural big data also discusses how assumed access to land via agtech can perpetuate colonial power dynamics

Appendix

which interferes in Indigenous peoples' knowledges and sense of place, particularly in settler colonial contexts

(<https://www.tandfonline.com/doi/abs/10.1080/00779954.2022.2147861?journalCode=rnzp20>).

Expert 5 – both:

Manned aerial vehicles - YES – 3

Expert 6 – Agriculture:

I think the areas you suggested cover the topics. Especially robots for agriculture they can help in the future to maintain the landscape. Also all these digital technologies will provide an environment with optimised use of resources, with less use of chemical to maintain the agricultural landscape.

the adoption of digital agriculture is influenced negatively by the age of farmers, increasing, and for Italy, by the small, cultivated area for each farm, that hinder the implementation of digital/smart farming;

Precision farming and GPS navigation could help to provide stripes cultivation to avoid erosion in hilly areas

possibility to make mazes visited by citizens, to maintain with low costs the landscape around cultivation, to promote waking patterns inside /around agricultural fields.

Expert 7 – Agriculture:

Digital greenhouse technologies - yes – 4

influencing what kinds of farming systems are economically viable - yes - 2 now, likely more in the future

A quick clarifying note - I would say digital agriculture would impact the variety of crop that is cultivated, but probably not the type of crop (I variety of apples rather than apples or oranges, if that makes sense)

I think the organization of plants may be changed on the landscape to support their incorporation into automatic systems or sensor technologies. They may also shape things like irrigation patterns through sensors and tech automation, or for example, the use of frost deterrents through sensors. This would mediate the effects of natural processes on crop production.

New saltwater technologies for greenhouses may allow for cultivation in areas that have not been able to produce food before (ie deserts). This would potentially have significant influences on landscapes.

Expert 8 – Agriculture:

Artificial Intelligence

Expert 9 – landscape:

Artificial intelligence as instruments for advice and problem solutions - will contribute to new farming practices and 'optimization' of landscape and field structures, water resource optimization, climate mitigation practices etc

Farmers collaboration concerning landscape practices (spreading of manure, integrated pest management, ecological network etc)

Pest management through support of living conditions for natural enemies of pests
landscape pattern, hydrology patterns

Appendix

Expert 10 – both

I think that the time scale matters. On the shorter run, it will be more “data availability” that influences farming (e.g. in the coming 10 years). On the longer run (>10 years) maybe actual robots will be available and may start to affect farming practices.

(I would probably not consider “type of cultivated crops” as a cultural/social factor. This is an agronomic and economic decision.) Similar for the other factors listed.)

A cultural /social factor that may be influenced could be the possibility to combine farm work and off-farm work. It could become easier due to information technology. Rating 2

Arable weeds - 4 (precision spray applications)

Insect pests - 2 (monitoring)

Plant diseases - 3 (prediction models)

it will be an indirect influence E.g. by the effect on field size.

Expert 11 – both:

variable-rate technology - yes - 5

on-farm and off-farm work proportion - 4; labor - 5

more homogeneous landscape

greenhouse gas emission - 5

Expert 12 - agriculture

abandonment of areas not suitable for new technologies - YES - 4

new guidelines for making wine: e.g. now it is not allowed to irrigate vineyards, they are thinking about change these rules to allow irrigation if sensor demonstrate the necessity.

the slope of the hill in order to let tractors to work on the hill (during our conversation at the OPP poster event)

change of the soil gestion: bare land or covered by grass

as said before if the soil is covered with grass and before it was kept bare change the color of the hill.

Expert 13 -landscape:

electricity fences - YES - 4; Realtime GPS livestock tracker - YES - 3

providing path-dependence breaking solutions which leads to more agricultural innovation of practices and institutions - YES - 4

perception change of agricultural socio-ecological system resilience - 4 (for example pastoralists may have a different perception of grazing intensity when they use UAV images to detect standing biomass)

not in a direct way but from the feedback of land use change

perception change of agricultural socio-ecological system resilience - 4 (for example pastoralists may have a different perception of grazing intensity when they use UAV images to detect standing biomass)

the same perception change can also be related to land use intensity, for example using GPS tracker they may have a different understanding of livestock trampling/grazing disturbance on pastures.

the application of technology may change the aesthetic aspect of “cultural landscape” E.g., when electricity fences are installed in summer pastures to replace shepherd.

Appendix

Expert 14 -landscape:

Make changes to the environment so that can be equipped with digital devices – 4 (this one is added by me later after I did the example review)

Less people needed to work the land, leading to rural depopulation and potentially in the end the collapse of rural society – 4

Robots can work day and night I.e. leading to all day disturbance for animals.

a depopulated countryside certainly does not provide the same sense of place – 3

Expert 15 - agriculture

Make changes to the environment so that can be equipped with digital devices – 3

Organization of work for farmers 4

DA gives more detailed information (soil, status of crops, timing) about fields and their needing (water, fertilization, adequate crop), so a more complex and detailed organization of fields and work is needed, that can be reflected in field size and shapes, irrigation system, use of agricultural machinery.

Quality of water and soil can be positively affected by a more detailed knowledge and management of soil and water (nature-based solution, detailed fertilization)

La percezione dei cambiamenti del paesaggio causati dall'agricoltura digitale: risultati da un'indagine sul parere degli esperti

Feiran Huang^{1,*}, Claudia Cassatella¹

¹ Dipartimento Interateneo di Scienze, Progetto e Politiche del Territorio, Politecnico di Torino, Viale Pier Andrea Mattioli, 39, 10125 Torino, Italia; feiran.huang@polito.it; claudia.cassatella@polito.it

* autore corrispondente

Parole chiave

agricoltura digitale, cambiamento del paesaggio, sondaggio tra esperti, percezione e anticipazione, *driving force*

Abstract

Il paesaggio è plasmato dalle interazioni dinamiche tra processi naturali, sociali e culturali, e la tecnologia agricola svolge un ruolo chiave nella sua trasformazione. Nell'attuale ondata di digitalizzazione in agricoltura, sorgono interrogativi riguardo a quanto l'agricoltura digitale (DA) possa influenzare il cambiamento del paesaggio. Sebbene gli impatti socio-economici e ambientali della DA siano stati ampiamente studiati, le sue implicazioni per il paesaggio restano ancora poco esplorate. Questo articolo, basandosi sui dati di un'indagine condotta tra esperti, indaga come studiosi dei campi del paesaggio e dell'agricoltura percepiscano e anticipino il cambiamento paesaggistico guidato dalla DA. I risultati mostrano che la DA influisce sia sugli aspetti materiali che immateriali del paesaggio, e che il suo impatto è destinato ad intensificarsi in futuro. In particolare, gli esperti hanno identificato effetti significativi sulle dimensioni socio-culturale e bio-fisica, sottolineando al contempo divergenze disciplinari nella percezione del cambiamento estetico-percettivo. Questi risultati evidenziano la complessità delle future trasformazioni paesaggistiche e la necessità di un dialogo interdisciplinare per plasmare un futuro sostenibile per la transizione agro-digitale e per il paesaggio.

1. Introduzione

Il ruolo cruciale del paesaggio nella sostenibilità e nel benessere sociale è stato ampiamente riconosciuto (Antrop, 1997; Bastian et al., 2014; Termorshuizen & Opdam, 2009). Di conseguenza, notevoli sforzi sono stati dedicati a comprendere il cambiamento del paesaggio per supportarne una gestione, pianificazione e protezione sostenibili (Brandt et al., 1999; Bürgi et al., 2005; Plieninger et al., 2016; Wu et al., 2012). Concettualizzato come un processo naturale-sociale-culturale in continua evoluzione, il paesaggio è plasmato da una serie di forze trainanti, dai processi naturali alle politiche, tra le quali le spinte tecnologiche si distinguono come una delle più significative. La questione del cambiamento paesaggistico guidato dalla tecnologia è stata ampiamente discussa negli studi sul paesaggio, concentrandosi su una varietà di temi quali le trasformazioni della copertura/uso del suolo e le relative *driving forces* (Antrop, 2005; Plieninger et al., 2016; Stahlschmidt et al., 2017; Wu et al., 2012). In particolare, i progressi nella tecnologia agricola hanno avuto impatti profondi sul paesaggio, poiché le attività agricole interagiscono direttamente con il territorio e il paesaggio. La meccanizzazione, ad esempio, ha consentito sia l'intensificazione che l'estensivizza-

zione, portando all'omogeneizzazione del paesaggio, all'aumento delle dimensioni delle aziende agricole e al degrado ambientale (Medley et al., 1995; Pinto-Correia et al., 2018).

Attualmente, il settore agricolo sta attraversando una nuova ondata di trasformazione tecnologica caratterizzata dalla digitalizzazione (Del Río Castro et al., 2021; ElMassah & Mohieldin, 2020; European Commission, 2023; McKinsey Global Institute, 2014; Sachs et al., 2019). Un'ampia gamma di tecnologie digitali è stata progressivamente incorporata nel processo agricolo e nel più ampio sistema alimentare. Queste pratiche, che fanno uso di strumenti digitali nelle diverse fasi della produzione e della gestione agricola, sono comunemente indicate come "agricoltura digitale" (Basso & Antle, 2020; Klerkx et al., 2019; Rotz et al., 2019; Tang et al., 2002; Zhao, 2019), che in questo articolo sarà denominata con l'acronimo "DA". Di fronte a sfide crescenti come l'aumento della popolazione e il cambiamento climatico, la DA è stata promossa come una soluzione promettente, in grado di offrire una maggiore efficienza nell'uso delle risorse, una produttività migliorata e un ridotto impatto ambientale (Basso & Antle, 2020; Bellon-Maurel et al., 2022; Dörr & Nachtmann, 2022; El Bilali & Allahyari, 2018; Leveau et al., 2019; Rose & Chilvers, 2018). Alla luce di questi benefici, un numero crescente di Paesi e regioni sta integrando attivamente la DA nei propri programmi di sviluppo agricolo e rurale (European Commission, 2021; Ministero dell'Agricoltura e degli Affari Rurali della Cina, 2022). Anche diverse importanti organizzazioni internazionali hanno pubblicato rapporti e documenti politici per sostenere la trasformazione digitale del settore agricolo (Lajoie-O'Malley et al., 2020; OECD, 2019; Schroeder et al., 2021; Trendov et al., 2019). Queste iniziative politiche hanno portato ad azioni quali maggiori investimenti nell'innovazione tecnologica, programmi di formazione per fornire agli agricoltori competenze digitali e la costruzione di nuove infrastrutture per supportare l'uso di strumenti digitali.

Mentre la trasformazione digitale del settore agricolo accelera, crescente attenzione è stata rivolta a comprendere i suoi effetti da varie prospettive disciplinari, quali quelle ambientali (Basso & Antle, 2020; Bellon-Maurel & Huyghe, 2017; Clapp & Ruder, 2020; El Bilali & Allahyari, 2018; Leveau et al., 2019) e sociali (Cavallo et al., 2014; Kernecker et al., 2020; Pfeiffer et al., 2021; Rotz et al., 2019). Tuttavia, le sue implicazioni per il paesaggio rimangono in gran parte trascurate in ambito accademico, un'omissione che contrasta con il ruolo ampiamente riconosciuto della tecnologia agricola quale principale forza trainante del cambiamento paesaggistico. Gli studi esistenti su questo argomento sono relativamente scarsi e la limitata conoscenza disponibile tende ad essere disomogenea, concentrandosi principalmente su dimensioni specifiche del paesaggio, come quella bio-fisiche, ma trascurandone altre, quali l'esperienza visiva e la percezione sociale (Huang & Casatella, 2024).

Il divario tra la limitata consapevolezza del cambiamento paesaggistico guidato dalla DA e l'accelerazione della digitalizzazione dell'agricoltura potrebbe porre sfide per le future politiche. I decisori e i pianificatori potrebbero non essere sufficientemente preparati a prendere decisioni e a intervenire sul paesaggio in un contesto sempre più digitalizzato. È quindi essenziale migliorare la nostra comprensione dei tipi di cambiamenti paesaggistici che ci si può aspettare. In questo contesto, l'obiettivo di questo articolo è esplorare la relazione tra la DA e il cambiamento del paesaggio. A tal fine, è stata condotta un'indagine per raccogliere le opinioni di studiosi in campi pertinenti, investigando la loro percezione del problema e le loro aspettative sugli sviluppi futuri. L'articolo inizia introducendo brevemente il concetto di DA, fornendo esempi illustrativi e delineando la sua rilevanza per il cambiamento del paesaggio. La Sezione 3 presenta la metodologia di ricerca, introducendo il quadro analitico e spiegando la progettazione e l'implementazione dell'indagine. La Sezione 4 analizza i risultati dell'indagine, seguiti da una discussione critica. Infine, la conclusione riassume i principali risultati e suggerisce direzioni per la ricerca futura.

2. Il cambiamento paesaggistico dovuto all'agricoltura digitale: un nuovo campo di ricerca?

L'Agricoltura Digitale (DA) ha introdotto trasformazioni sostanziali nel modo in cui le attività agricole sono condotte e le aziende sono gestite. Le tecnologie coinvolte sono estremamente diversificate, spaziando da strumenti consolidati come il telerilevamento a innovazioni più recenti

come la robotica e i veicoli aerei senza pilota (UAV). Nella pratica, queste tecnologie sono spesso applicate in combinazione, consentendo un approccio agricolo integrato e guidato dai dati. Due esempi tipici illustrano l'integrazione degli strumenti digitali nelle operazioni agricole: (1) l'uso di sensori digitali per raccogliere e analizzare dati pedo-climatici, a supporto del processo decisionale aziendale come nell'irrigazione e nella fertilizzazione (Figura 1); (2) l'impiego di macchinari agricoli intelligenti, come i robot, per eseguire compiti in azienda in modo autonomo. La DA viene applicata in un'ampia gamma di produzioni agricole, dalla coltivazione cerealicola, alla gestione di frutteti e vigneti, fino all'allevamento animale – ciascuna delle quali può essere associata a diversi tipi di paesaggio. Consentendo pratiche agricole più efficienti e precise, la DA sta rimodellando gli approcci di gestione aziendale, potenzialmente determinando cambiamenti nel paesaggio.



Figura 1. Serra intelligente di grandi dimensioni, equipaggiata con diversi dispositivi digitali per la coltivazione intensiva del pomodoro (Fonte: Xinhua News).

Sebbene il tema del cambiamento paesaggistico guidato dalla DA sia stato relativamente trascurato nella ricerca attuale sul cambiamento del paesaggio, diversi studi emergenti hanno iniziato a discutere questa questione, in modo sia esplicito che implicito (Huang & Cassatella, 2024). Ad esempio, Legun e Burch (2021) hanno osservato una trasformazione nella struttura fisica dei meleti in Nuova Zelanda, nella quale si è passati da alberi singoli con chiome complete a alberi potati in modo piatto contro il traliccio e allineati in file rettilinee. Questa standardizzazione facilita l'uso di robot agricoli, che tipicamente operano lungo percorsi rettilinei per eseguire compiti come la spruzzatura e la raccolta in modo autonomo. Di conseguenza, non solo sono cambiati i modelli spaziali e le caratteristiche visive del paesaggio, ma sono cambiati anche i ricordi strettamente associati alla gestione tradizionale del frutteto. Questo caso esemplifica chiaramente come l'adozione della robotica possa rimodellare il paesaggio. Altri studi hanno dimostrato come il processo decisionale in azienda supportato dalla DA possa portare a modifiche nell'uso del suolo e nella copertura vegetale (McConnell, 2019; Moreno et al., 2022; Nguyen et al., 2022). Huang (2025), ad esempio, ha identificato molteplici evidenze di cambiamento esaminando le applicazioni reali di progetti rappresentativi provenienti dall'UE e dalla Cina. Tra gli interventi più comuni vi sono elementi costruiti di nuova introduzione, che vanno da piccoli sensori in campo a serre intelligenti su larga scala equipaggiate con diversi dispositivi digitali. È stato dimostrato che questi elementi aggiunti di recente influenzano vari aspetti del paesaggio, tra cui l'apertura visiva, la diversità e la complessità, i modelli e il cambiamento ciclico nel corso delle stagioni (Figura 2).

Come illustrato dagli esempi precedenti, i lavori accademici esistenti sul cambiamento paesaggistico guidato dalla DA si sono concentrati prevalentemente su eventi passati, con alcuni studi che affrontano sviluppi in corso. Sebbene questi approcci retrospettivi e contemporanei siano comuni nella ricerca sul cambiamento paesaggistico, spesso mancano di una prospettiva orientata al futuro (Bürgi et al., 2022), una limitazione che diventa particolarmente evidente nel contesto

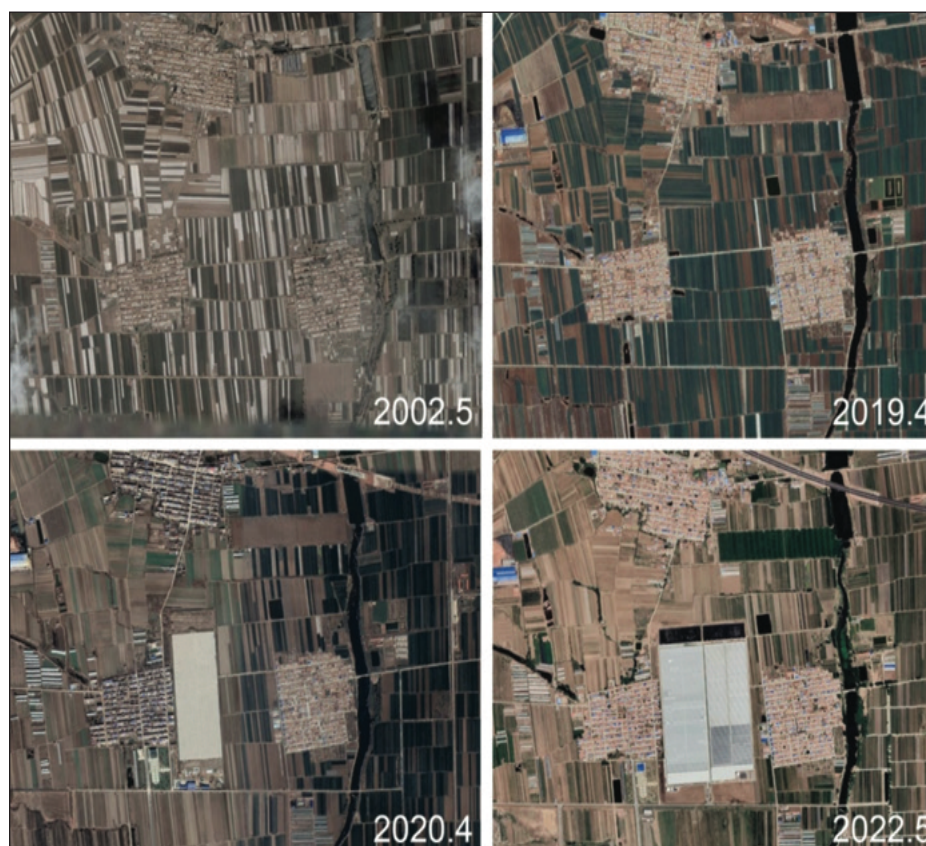


Figura 2. Immagine satellitare che mostra il paesaggio in rapida trasformazione a seguito dell'implementazione di serre intelligenti (Fonte: elaborazione sull'immagine di Google Earth).

della DA in rapida evoluzione. Per colmare questa lacuna, il presente studio ha impiegato un'indagine esperta rivolta a studiosi nei campi dell'agricoltura e del paesaggio. Questo metodo costituisce un prezioso complemento alla ricerca esistente, in quanto non solo cattura le riflessioni degli esperti basate su esperienze passate e presenti, ma sollecita attivamente le loro anticipazioni riguardo al futuro cambiamento del paesaggio. Alla luce di due tendenze concomitanti, ovvero l'accelerazione della digitalizzazione dell'agricoltura da un lato e la crescente enfasi sulla gestione sostenibile del paesaggio dall'altro, è essenziale adottare un approccio interdisciplinare. Integrare le conoscenze di esperti provenienti sia dalle discipline agricole (in particolare l'agri-tech) che da quelle paesaggistiche è fondamentale per sviluppare strategie più consapevoli e orientate al futuro.

3. Metodologia della ricerca: checklist del cambiamento paesaggistico e indagine tra esperti

Questa sezione metodologica introduce innanzitutto il quadro analitico proposto, ovvero la checklist del cambiamento paesaggistico, che è stato utilizzato per esaminare i cambiamenti attraverso i diversi aspetti del paesaggio. Segue la descrizione della progettazione e dell'implementazione dell'indagine.

Data l'intrinseca complessità del paesaggio, uno degli approcci più ampiamente accettati per l'analisi sistematica consiste nello scomporlo in molteplici dimensioni e aspetti, riconoscendo al contempo la sua natura indivisibile e olistica (Cassatella & Peano, 2011). In linea con questo approccio, è stata sviluppata come quadro concettuale la checklist del cambiamento paesaggistico. Essa si basa sulla metodologia consolidata del Landscape Character Assessment (Swanwick, 2002; Tudor, 2014). La checklist suddivide il paesaggio in tre dimensioni: socio-culturale, biofisica e estetico-percettiva. Ciascuna di esse comprende una serie di aspetti specifici, come delineato nella

Tabella 1. È importante sottolineare che la checklist non ha l'intenzione di essere esaustiva; piuttosto, serve come struttura di riferimento. Pertanto, ai partecipanti all'indagine è stato esplicitamente chiesto di suggerire ulteriori aspetti del paesaggio che, a loro avviso, fossero influenzati dalla DA ma non catturati dalle categorie predefinite. La checklist è stata utilizzata per progettare le domande del sondaggio.

Tabella 1. Il quadro analitico proposto, la checklist del cambiamento paesaggistico (Fonte: gli autori)

Dimensione socio-culturale	Dimensione biofisica	Dimensione estetico-percettiva
Decisione di coltivare o meno	Copertura vegetale	Apertura visiva (ampiezza del campo visivo)
Tipologia di colture coltivate	Copertura del suolo	Diversità/Complessità visiva
Modalità di gestione	Suolo	Colore e tessitura
Dimensione dell'azienda agricola	Acqua	Odori e suoni
Pattern and enclosure	Diversità della flora e della fauna	Stagionalità (cambiamento ciclico durante l'anno)
Conservazione degli elementi tradizionali	-	Senso del luogo
Abbandono d egli elementi tradizionali	-	-
Materiale degli elementi costruiti	-	-
Elementi costruiti nuovi	-	-

Come spiegato alla fine della Sezione 2, è stata selezionata un'indagine esperta online come metodo per la raccolta dei dati. Gli esperti partecipanti sono stati selezionati tra discipline relative all'agronomia agli studi sul paesaggio. L'indagine era composta da tre sezioni principali. La prima sezione raccoglieva informazioni di base sugli esperti, inclusa la loro collocazione geografica e il/i loro campo/i di ricerca. La seconda sezione esplorava la percezione dell'influenza della DA sul paesaggio. Agli esperti è stato chiesto di valutare l'influenza di alcune tecnologie agricole ampiamente utilizzate, utilizzando una scala unipolare che andava da "nessuna influenza" (codificata con 0) a "grande influenza" (codificata con 5) (Figura 3). Inoltre, sono stati presentati una serie di potenziali modi in cui la DA potrebbe influenzare il paesaggio, ed è stato chiesto ai rispondenti di indicare quelli che ritenevano più prevalenti. La terza sezione si concentrava sull'impatto della DA su aspetti specifici del paesaggio. Anche in questo caso è stata utilizzata una scala unipolare (0-5) per valutare l'entità dell'influenza, dove 0 indica "non influenzato dalla DA" e 5 indica "fortemente influenzato dalla DA" (Figura 4). Inoltre, l'indagine includeva anche alcune domande aperte, invitando gli esperti a identificare ulteriori aspetti non inclusi nell'elenco. Il questionario è stato inizialmente testato tra colleghi del dipartimento con esperienza di ricerca pertinente. Il loro feedback è stato utilizzato per affinare sia la struttura che la formulazione della versione finale.

L'indagine è stata distribuita a 41 esperti operanti in studi agronomici e paesaggistici, nella valutazione del paesaggio e pianificazione rurale, e in tematiche relative alla tecnologia agricola. Essi sono stati individuati in base alla loro esperienza professionale e ai contributi accademici, come opere scientifiche pubblicate, e/o all'appartenenza a network tematici quali l'International Association of Landscape Ecology. Alcuni destinatari avevano già dimostrato familiarità con l'argomento di ricerca, come emerso dalla revisione della letteratura (Huang & Cassatella, 2024). L'indagine è stata distribuita a ricercatori in diversi contesti geografici, privilegiando l'UE e la Cina per i seguenti motivi. Da un lato, la revisione della letteratura ha mostrato che pochissime ricerche provengono dall'UE e dalla Cina, suggerendo una consapevolezza relativamente bassa su questo tema. Dall'altro, in entrambe le aree possiamo osservare chiaramente una forte spinta nelle politiche per facilitare la trasformazione digitale del settore agricolo e una proliferazione di progetti

Alcune tecnologie sono attualmente adottate nella produzione agricola e di seguito sono riportati alcuni esempi. Ritieni o riesci a immaginare se l'implementazione di queste tecnologie in campo porterà a un cambiamento del paesaggio? Se la tua risposta è "sì", indica l'entità della loro influenza utilizzando la scala fornita.

0 corrisponde a "questa tecnologia digitale non ha alcuna influenza sul paesaggio rurale", 1 corrisponde a "influenza lieve", 5 corrisponde a "influenza elevata".

	0	1	2	3	4	5
Aeromobile a pilotaggio remoto (APR)	☐	☐	☐	☐	☐	☐
Internet of Things (IoT)	☐	☐	☐	☐	☐	☐
Robotica	☐	☐	☐	☐	☐	☐
Macchina agricola intelligente	☐	☐	☐	☐	☐	☐
Remote sensing	☐	☐	☐	☐	☐	☐

Figura 3. La seconda parte dell'indagine si concentra sulle tecnologie digitali (Fonte: gli autori).

In questa sezione, il concetto di paesaggio viene scomposto in tre dimensioni, ciascuna delle quali è suddivisa in diversi aspetti a scopo analitico. Ti verrà chiesto se puoi anticipare cambiamenti nei seguenti aspetti del paesaggio a causa dell'implementazione dell'agricoltura digitale. Indica l'entità dell'impatto utilizzando la scala fornita (0 significa che questo aspetto non è influenzato dalla DA, 1 corrisponde a "leggermente influenzato", mentre 5 corrisponde a "fortemente influenzato"). Se riesci a pensare a qualsiasi altro aspetto che potrebbe essere influenzato dalla digitalizzazione dell'agricoltura, puoi aggiungerlo in fondo. Sarà molto apprezzato se potrai fornire anche un esempio.

Impatto dell'agricoltura digitale sugli aspetti naturali del paesaggio

	0	1	2	3	4	5
Copertura vegetale	☐	☐	☐	☐	☐	☐
Copertura del suolo	☐	☐	☐	☐	☐	☐
Suolo	☐	☐	☐	☐	☐	☐
Acqua	☐	☐	☐	☐	☐	☐
Diversità della flora e della fauna	☐	☐	☐	☐	☐	☐

Figura 4. La terza parte dell'indagine si concentra sull'influenza della AD sul paesaggio. Di seguito è riportato un esempio di valutazione dell'impatto della AD sulla dimensione bio-fisica del paesaggio (Fonte: gli autori).

DA. Pertanto, tale contrasto rende particolarmente interessante e urgente comprendere come i ricercatori nell'UE e in Cina percepiscono questa problematica. È importante sottolineare che l'obiettivo di questa indagine esperta non era condurre un'analisi quantitativa su larga scala, ma piuttosto raccogliere approfondimenti da esperti con un interesse specifico e una conoscenza dell'argomento. In quanto tale, l'indagine è stata deliberatamente progettata per privilegiare la profondità rispetto all'ampiezza. Il suo scopo era raccogliere input qualitativi che potessero far luce su questa questione emergente, piuttosto che raggiungere una generalizzabilità statistica, dato

l'attuale basso livello di consapevolezza in ambito accademico. Per incoraggiare la partecipazione, l'indagine è stata mantenuta concisa e condotta online. È rimasta aperta tra aprile 2023 e febbraio 2024, periodo durante il quale sono pervenute un totale di 16 risposte completate e una parzialmente completata. Tutti gli esperti partecipanti hanno risposto alle domande a scala unipolare, sebbene tre esperti non abbiano fornito risposte alle domande aperte.

4. Risultati dell'Indagine tra esperti

4.1 Analisi della tendenza generale

Questa sezione presenta i risultati delle domande a scala unipolare, concentrandosi sulla percezione dell'impatto di varie tecnologie digitali sul paesaggio rurale e sulla misura in cui specifici aspetti del paesaggio ne sono influenzati. Le valutazioni degli esperti sono presentate come valori medi in un grafico radar, integrato da un grafico a barre che mostra la distribuzione delle risposte per mitigare possibili distorsioni della media. Un punteggio di quattro o cinque è interpretato come indicativo di un impatto elevato.

4.1.1 Risultati generali

Per quanto riguarda l'uso della tecnologia, la "macchina agricola intelligente" è stata indicata come la tecnologia più influente sul paesaggio, con un punteggio di 3,63 e 11 esperti che le hanno attribuito un punteggio elevato. Segue la "robotica", che ha ricevuto un punteggio di 3,44, con 10 esperti che le hanno attribuito un punteggio elevato (Figura 5). "Supportare il processo decisionale fornendo maggiori dati" è stato considerato il modo prevalente con cui la DA influisce sul paesaggio.

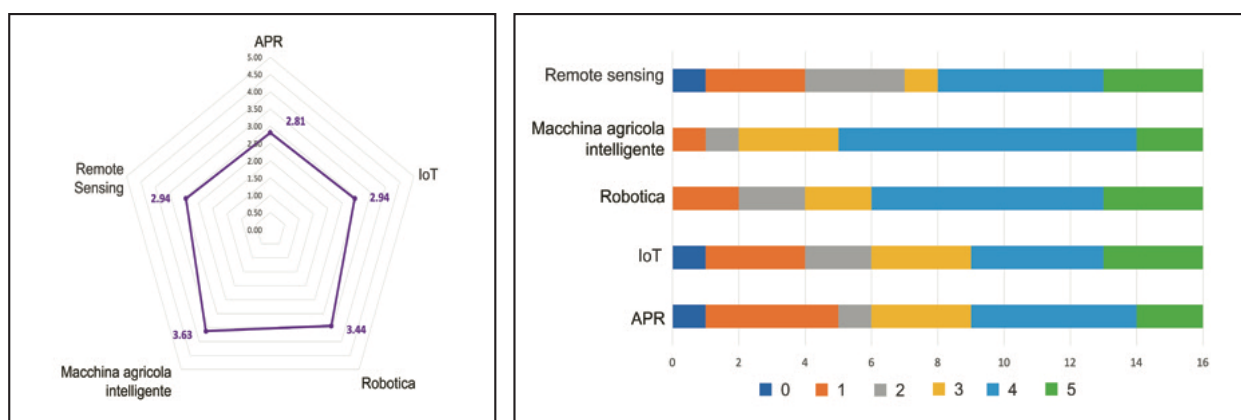


Figura 5. Impatto delle diverse tecnologie digitali sul paesaggio rurale e numero di esperti per ciascuna valutazione (Fonte: gli autori).

Tra gli aspetti socio-culturali, "modalità di gestione", "decisione di coltivare o meno" e "modelli e recinzioni" hanno ottenuto i punteggi medi più elevati: rispettivamente 3,94, 3,50 e 3,44. Per quanto riguarda il consenso, "modalità di gestione", "decisione di coltivare o meno" ed "elementi costruiti nuovi" sono stati più frequentemente valutati come ad alto impatto, con dodici, nove e nove esperti che hanno assegnato rispettivamente punteggi di quattro o cinque. Questi risultati indicano almeno un livello moderato di cambiamento del paesaggio, dato che cinque aspetti hanno ottenuto un punteggio medio superiore a tre. "Preservazione delle caratteristiche tradizionali" ha ricevuto il punteggio più basso, mentre "dimensione dell'azienda agricola" ha ottenuto il minor numero di valutazioni elevate (Figura 6).

La maggior parte degli esperti ha riconosciuto l'impatto della DA sulla dimensione bio-fisica, con tutti gli aspetti indagati che hanno ottenuto un punteggio medio pari o superiore a tre. "Diversità della flora e della fauna" e "acqua" hanno ricevuto il maggior numero di punteggi elevati

(Figura 7). Al contrario, la dimensione estetico-percettiva è apparsa la meno influenzata, con solo “senso del luogo” e “complessità/diversità visiva” che hanno superato un punteggio medio di tre (3,06) (Figura 8).

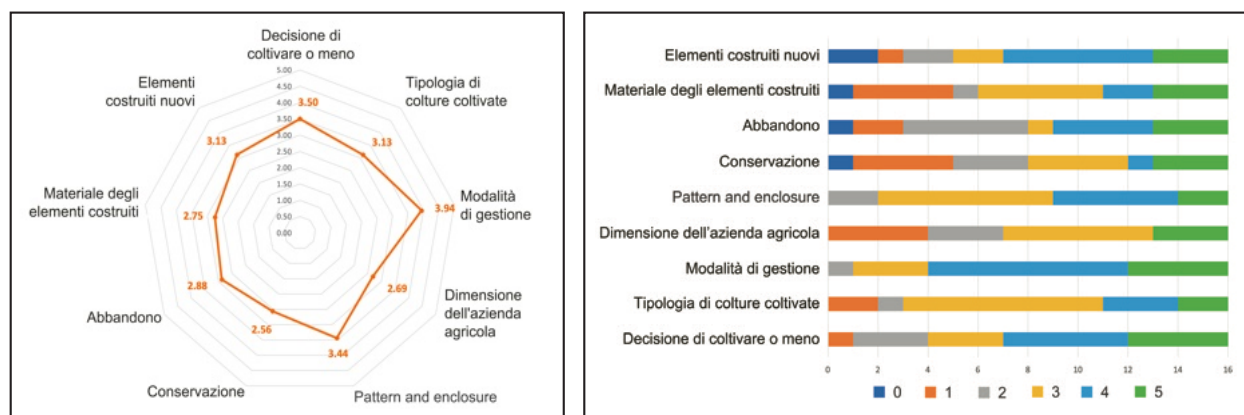


Figura 6. Valutazione esperta dell'impatto dell'agricoltura digitale su vari aspetti del paesaggio socio-culturale: (a) punteggi medi; (b) distribuzione delle valutazioni degli esperti (Fonte: gli autori).

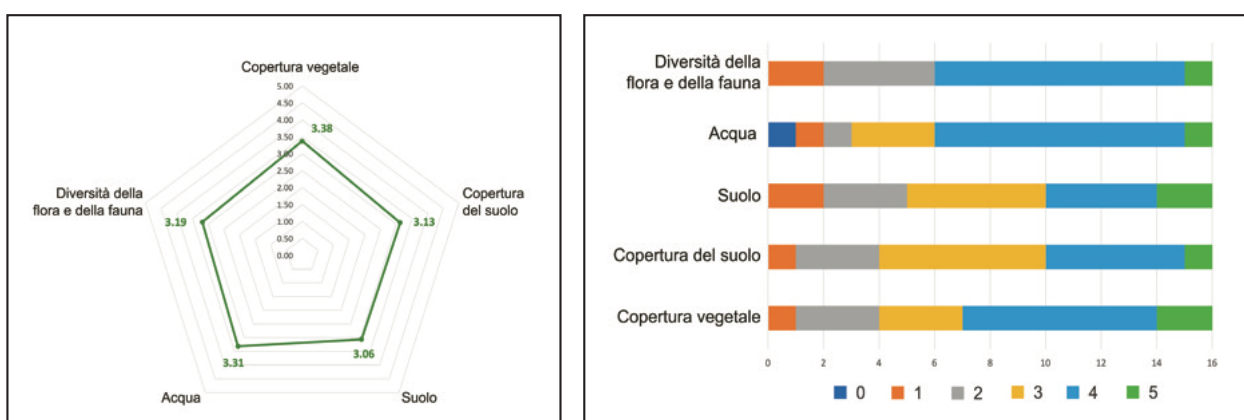


Figura 7. Valutazione esperta dell'impatto dell'agricoltura digitale su vari aspetti del paesaggio bio-fisico: (a) punteggi medi; (b) distribuzione delle valutazioni degli esperti (Fonte: gli autori).

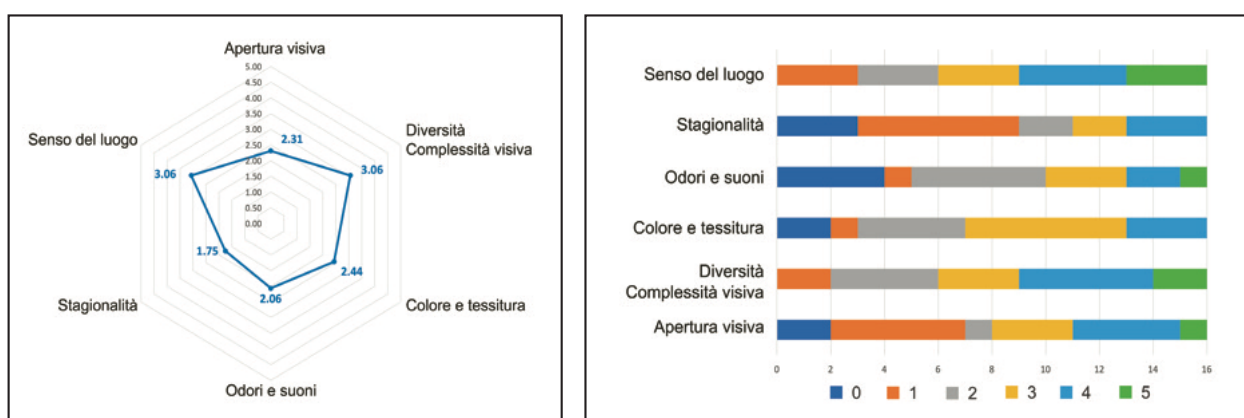


Figura 8. Valutazione esperta dell'impatto dell'agricoltura digitale su vari aspetti del paesaggio estetico-percettivo: (a) punteggi medi; (b) distribuzione delle valutazioni degli esperti (Fonte: gli autori).

4.1.2. Divergenze disciplinari?

Un obiettivo chiave dell'indagine è confrontare le prospettive degli esperti tra diversi domini di ricerca. I rispondenti sono stati raggruppati in base al loro campo di ricerca auto-dichiarato

(definito come 'relativo al paesaggio', 'relativo all'agricoltura' o 'entrambi'), con ogni esperto che ha selezionato una sola categoria. Ciascun gruppo include un numero comparabile di esperti, senza sovrapposizioni tra loro; è importante notare che il gruppo 'entrambi' non è una combinazione degli altri due, perciò non vi è alcuna sovrapposizione tra i tre gruppi. Ai rispondenti è stato assegnato un numero da 0 a 16 (Figura 9). Oltre all'auto-identificazione del campo di ricerca, ai partecipanti è stato anche chiesto di fornire fino a tre parole chiave relative alle loro aree di ricerca, il che ci offre ulteriori approfondimenti sulla loro competenza, mostrandone la rilevanza per la nostra indagine. La Tabella 2 sintetizza le parole chiave fornite dagli esperti riguardo ai loro campi di ricerca. Lo stesso approccio analitico è stato applicato a tutti i gruppi, e i risultati sono presentati in formati consistenti di grafico radar per il confronto.

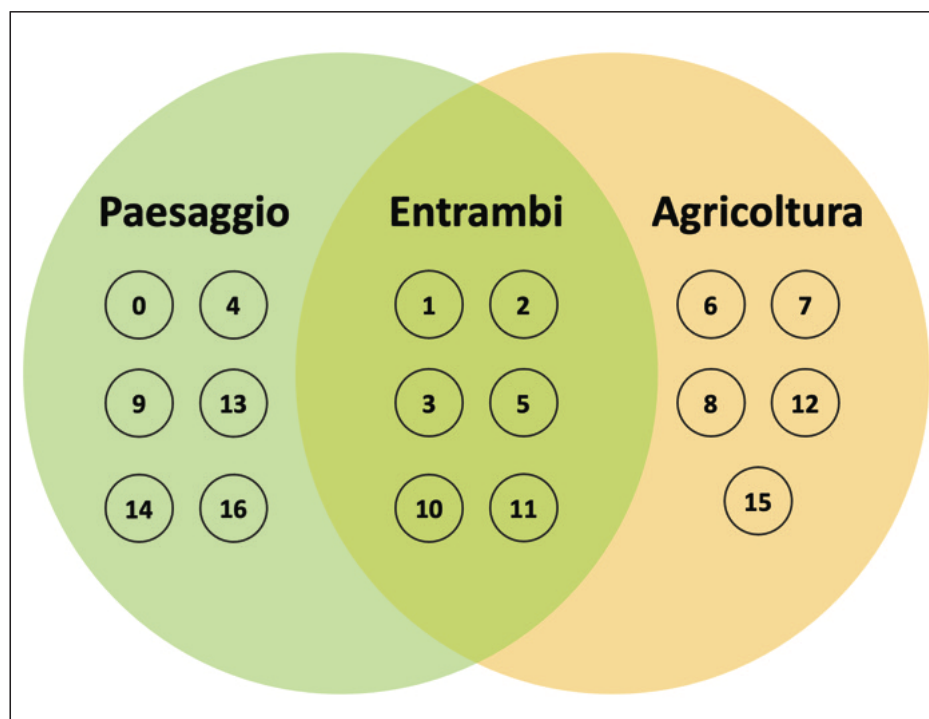


Figura 9. Esperti in ciascuna area di ricerca (Fonte: gli autori).

Tabella 2. Parole chiave relative alle aree di ricerca degli studiosi partecipanti (Fonte: gli autori)

Paesaggio	Entrambi	Agricoltura
Landscape change, Biodiversity conservation, Landscape ecology, Landscape planning and governance, Farmers landscape management, Policy analysis, Landscape, Geography, Rural heritage, Landscape analysis	Precision farming, Technology adoption, Farmland biodiversity, Agroforestry, Landscape scale ecosystem service evaluation, Biological pest control, Pollination, Landscape ecology, AI robotics in food and agriculture, Sustainable techno-future Rural landscape, Agroforestry system, Digital agriculture, Land use change, Climate change impact on value chain	Soil and water conservation in agriculture, Innovation of vineyard management, Internet of Things (IoT) for agriculture, Sociology of agriculture, Science and technology studies, Machinery for agriculture, Digital technologies for agriculture, logistics

Secondo i risultati sulla percezione dell'influenza delle tecnologie digitali sul paesaggio, gli esperti in ambito agricolo e agro-paesaggistico hanno considerato la DA come un motore significativo del cambiamento, mentre gli studiosi del paesaggio ne hanno valutato l'impatto in misura minore (Figura 10). In tutti i gruppi, la “macchina agricola intelligente” è stata identificata come la tecnologia più influente, e gli esperti agricoli hanno inoltre valutato la “robotica” allo stesso alto livello.

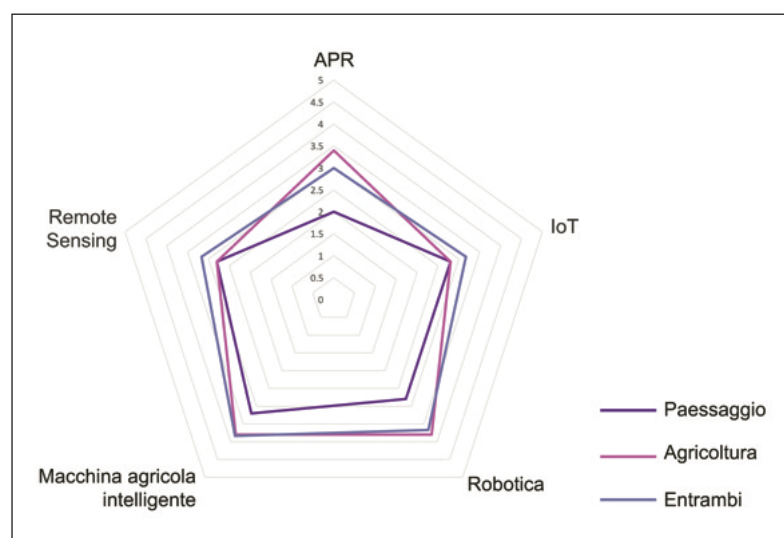


Figura 10. Differenze disciplinari nelle valutazioni esperte dell'impatto delle tecnologie digitali sui paesaggi (Fonte: gli autori).

Una revisione dei risultati sull'impatto della DA attraverso le dimensioni del paesaggio rivela marcate differenze disciplinari. Nella dimensione socio-culturale, la “modalità di gestione” è emersa come l'aspetto paesaggistico più influenzato, con il consenso della maggioranza degli esperti (Figura 11). Tuttavia, il secondo aspetto più altamente valutato differisce in base al gruppo. Per gli esperti di paesaggio, si tratta di “elementi costruiti nuovi”; per gli esperti di agricoltura, “pattern and enclosure”; e per gli esperti di entrambi i campi, “decisione di coltivare o meno” (Tabella 3).

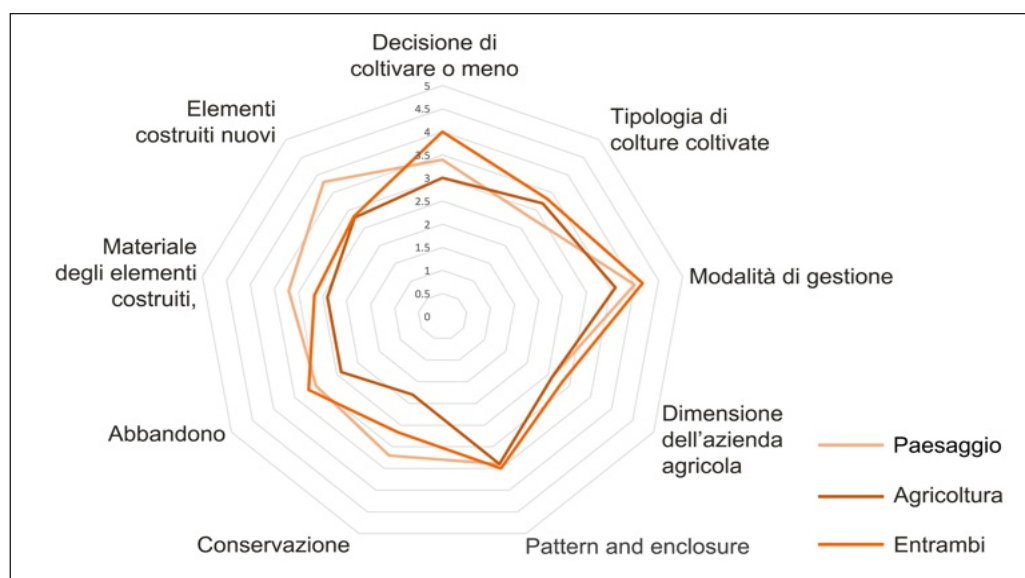


Figura 11. Influenza percepita della AD su aspetti socio-culturale del paesaggio, da parte di esperti appartenenti a diversi ambiti disciplinari (Fonte: gli autori).

Tabella 3. I due aspetti maggiormente influenzati e l'aspetto meno influenzato della dimensione socio-culturale (Fonte: gli autori)

Campo di ricerca	Aspetto paesaggistico meno interessato		I due aspetti paesaggistici più colpiti			
Paesaggio	2.6	Dimensione dell'azienda agricola	4.0	Modalità di gestione	3.8	Elementi costruiti nuovi
Agricoltura	1.9	Conservazione*	3.6	Modalità di gestione	3.4	Pattern and enclosure
Entrambi	2.7	Elementi costruiti nuovi Conservazione*	4.1	Modalità di gestione	4.0	Decisione di coltivare o meno

* Conservazione degli elementi tradizionali

Gli esperti di paesaggio hanno percepito la dimensione bio-fisica come meno influenzata, con solo la "copertura del suolo" che ha ottenuto un punteggio di 3 (tutti gli altri aspetti hanno ottenuto un punteggio inferiore a 3; Figura 12). Al contrario, gli esperti di agricoltura hanno valutato la dimensione bio-fisica come la più colpita dall'implementazione della DA, con tutti gli aspetti che hanno ottenuto un punteggio superiore a tre e l'"acqua" che ha ottenuto un punteggio di 4,2. Gli esperti di agricoltura-paesaggio hanno espresso opinioni diverse, indicando la "diversità della flora e della fauna" come l'aspetto più influenzato, mentre la "copertura del suolo" è risultata la meno influenzata (Tabella 4).

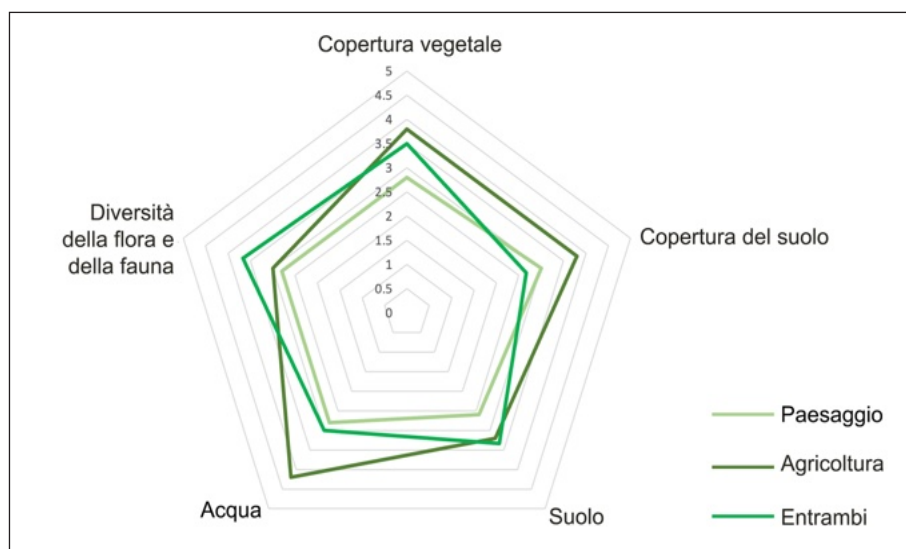


Figura 12. Percezione dell'influenza della AD sugli aspetti del paesaggio della dimensione bio-fisica da parte di esperti di diversi campi di ricerca (Fonte: gli autori).

Tabella 4. I due aspetti maggiormente influenzati e l'aspetto meno influenzato della dimensione bio-fisica (Fonte: gli autori)

Campo di ricerca	Aspetto paesaggistico meno interessato		I due aspetti paesaggistici più colpiti			
Paesaggio	2.6	Suolo	3.0	Copertura del suolo	2.8	Gli altri tre*
Agricoltura Entrambi	3.0	Diversità della flora e della fauna	4.2	Acqua	3.8	Copertura vegetale
Entrambi	2.7	Copertura del suolo	3.7	Diversità della flora e della fauna	3.5	Copertura vegetale

* Acqua, diversità della flora e della fauna, and copertura vegetale

Dimensione	Paesaggio	Agricoltura	Entrambi
Apertura visiva	2.5	2.0	2.2
Diversità Complessità visiva	2.2	2.0	2.5
Colore e tessitura	2.5	1.5	2.0
Odori e suoni	2.0	1.5	1.8
Stagionalità	1.5	2.5	2.0
Senso del luogo	2.0	2.5	2.2

Tabella 5. I due aspetti maggiormente influenzati e l'aspetto meno influenzato della dimensione estetico-percettiva (Fonte: gli autori)

Campo di ricerca	Aspetto paesaggistico meno interessato	Most affected top two landscape aspects			
Paesaggio	2.2 Colore e tessitura Stagionalità	4.0	Senso del luogo	3.4	Diversità Complessità visiva
Agricoltura	1.4 Odori e suoni	2.6	Colore e tessitura	2.4	Apertura visiva
Entrambi	1.3 Stagionalità	3.5	Diversità Complessità visiva	3.0	Senso del luogo

Gli esperti hanno anche risposto alle domande aperte, fornendo spiegazioni aggiuntive per le loro valutazioni in scala e condividendo ulteriori approfondimenti. Utilizzando un'analisi tematica con un approccio di codifica induttiva (Joffe & Yardley, 2003), sono stati identificati sei temi emergenti: cinque riguardanti i cambiamenti del paesaggio e uno relativo al modo in cui la DA influenza il paesaggio. Questi includevano: benefici ambientali, divergenza nella dimensione delle aziende agricole, organizzazione del campo, esperienza del paesaggio e percezione sociale, organizzazione sociale e del lavoro, e influenza indiretta. La trascrizione completa delle risposte degli esperti è consultabile nell'Appendice 2.

4.2.1. Benefici Ambientali

Questo tema evidenzia i benefici ambientali derivanti dall'implementazione della DA. Tra questi, l'efficienza delle risorse, caratteristica fondamentale dell'agricoltura di precisione (Clapp & Ruder, 2020), è emersa come un concetto ricorrente. Gli esperti hanno sottolineato che la DA può ridurre la lisciviazione dell'azoto e l'uso di pesticidi, mitigando così l'inquinamento ambientale e migliorando la qualità dell'acqua e del suolo. Come ha osservato un partecipante, la DA sostiene "... un ambiente con un uso ottimizzato delle risorse, con un minor uso di prodotti chimici per mantenere il paesaggio agricolo (esperto 6)". La DA supporta anche la mitigazione e l'adattamento al cambiamento climatico. Gli esperti (1, 9, 11) hanno notato che gli strumenti digitali consentono un controllo più preciso delle emissioni di carbonio derivanti da pratiche come la lavorazione del suolo. Oltre ai benefici incentrati sull'uomo, questi risultati influenzano positivamente l'ecosistema agricolo, rappresentando cambiamenti nella dimensione bio-fisica. Come ha notato l'esperto 6, "l'agricoltura di precisione e la navigazione GPS potrebbero aiutare nella coltivazione a strisce per evitare l'erosione nelle aree collinari", affrontando cambiamenti ambientali specifici del territorio.

4.2.2. Divergenza nella Dimensione delle Aziende Agricole

Il secondo tema riguarda la dimensione delle aziende agricole, comprendendo sia i cambiamenti di dimensione sia le strategie di gestione differenziate. Gli esperti hanno suggerito che la DA può incoraggiare sia l'espansione che la frammentazione dei campi, a seconda della tecnologia adottata. Come ha osservato l'esperto 0, "i robot potrebbero permettere la coltivazione di nuovi tipi di colture e possono risultare in più piccoli campi ... mentre la produzione di massa migliorata da grandi macchine e agricoltura di precisione può risultare in campi più grandi". Sebbene le grandi aziende agricole siano spesso meglio attrezzate tecnicamente, economicamente e culturalmente per adottare l'innovazione (esperto 1), le piccole aziende affrontano sfide nella consapevolezza, nelle competenze e negli investimenti. L'esperto 6 ha sottolineato che queste sfide possono limitare l'adozione della DA, potenzialmente rafforzando le tendenze verso un'agricoltura su larga scala, il che è coerente con l'argomentazione di Lajoie-O'Malley et al. (2020) secondo cui la DA rappresenta semplicemente una continuazione dell'agricoltura industriale di massa guidata dalla meccanizzazione.

4.2.3. Organizzazione del Campo

Diversi esperti hanno discusso i cambiamenti nell'organizzazione del campo, riflettendo tendenze divergenti, affrontando la questione sollevata da Klerkx et al. (2019) su come i nuovi flussi di informazioni tra agricoltori e il loro ambiente rimodellino il cambiamento strutturale. Alcuni esperti hanno suggerito che la DA consente una progettazione del paesaggio più articolata. Ad esempio, l'esperto 9 ha menzionato il potenziale dell'intelligenza artificiale per ottimizzare le strutture dei campi, mentre l'esperto 15 ha notato che i dati di precisione possono indurre aggiustamenti nelle dimensioni, nelle forme dei campi e nel sistema di irrigazione. L'esperto 6 ha fatto riferimento a progetti supportati da GPS come i labirinti di mais negli Stati Uniti, che possono ridurre i costi di manutenzione e promuovere il turismo rurale. Analogamente, l'esperto 7 ha osservato che l'organizzazione delle piante potrebbe essere modificata per adattarsi all'automazione e all'uso di sensori, il che è in linea con l'osservazione dell'esempio precedente del meleto (Legun & Burch, 2021). L'esperto 7 ha anche aggiunto che la DA potrebbe potenzialmente influenzare le varietà di colture piuttosto che i tipi. Al contrario, l'esperto 11 ha anticipato un aumento dell'uniformità del paesaggio, suggerendo che la DA potrebbe anche portare a un'omogeneizzazione.

4.2.4. Esperienza del Paesaggio e Percezione Sociale

Il quarto tema riguarda i cambiamenti nell'esperienza del paesaggio e nella percezione sociale provocati dalla DA. Diversi esperti hanno notato che tecnologie visibili, come droni o recinzioni

elettriche, possono alterare la percezione pubblica dei paesaggi agricoli, con alcuni che le considerano disturbi estetici (esperti 0, 13). Anche il rumore è stato sollevato come motivo di preoccupazione, in quanto certe macchine possono essere abbastanza rumorose da provocare lamentele (esperto 3). Oltre agli impatti sensoriali, la DA introduce nuove forme di conoscenza del paesaggio, incoraggiando comprensioni più “precise e scientifiche”. Come ha osservato l’esperto 13, strumenti come UAV e localizzatori GPS possono modificare la percezione dei pastori riguardo all’intensità del pascolo e all’impatto del bestiame. Sebbene tali strumenti possano migliorare il processo decisionale e la resilienza socio-ecologica, diversi esperti hanno espresso preoccupazione che l’automazione possa indebolire i legami basati sul luogo. L’esperto 3 ha avvertito che “le persone potrebbero perdere il legame con il luogo lasciando le cose alla robotica”, e che ciò potrebbe interrompere i sistemi di conoscenza indigeni. Analogamente, l’esperto 14 ha osservato che una campagna spopolata mina il senso del luogo, un tema che verrà approfondito ulteriormente di seguito.

4.2.5. Organizzazione Sociale e Assetto del Lavoro

Le risposte alla scala unipolare hanno identificato la “modalità di gestione” come l’aspetto socio-culturale più influenzato, indicando cambiamenti significativi nell’organizzazione sociale e nelle dinamiche del lavoro. Gli esperti 0 e 9 hanno previsto una maggiore collaborazione tra gli agricoltori, in particolare poiché le aziende più piccole potrebbero aver bisogno di condividere tecnologie costose. Tuttavia, altri hanno evidenziato il rischio di divergenze tra gli agricoltori a causa del divario digitale (Salemink et al., 2017). L’esperto 1 ha avvertito che “la DA potrebbe creare un divario significativo ... tra pionieri e ritardatari”. L’esperto 3 ha inoltre messo in guardia sul fatto che l’agri-tech rafforza le dinamiche di potere coloniali, con un accesso disuguale alla terra e alle tecnologie che esacerba le disuguaglianze esistenti. L’esperto 14 ha collegato l’aumento dell’efficienza del lavoro al declino demografico, notando che “servono meno persone per lavorare la terra”, il che potrebbe potenzialmente portare allo spopolamento rurale e al collasso della società rurale.

Parallelamente, gli esperti 10 e 11 hanno osservato che la DA potrebbe consentire nuove combinazioni di lavoro in azienda e fuori azienda. L’esperto 6 ha indicato possibili cambiamenti nelle regole di gestione aziendale, come il permettere l’irrigazione dei vigneti se supportata dai dati dei sensori, il che dimostra come la DA possa guidare l’adattamento normativo.

4.2.6. Influenza Indiretta

Il tema finale riguarda l’influenza indiretta della DA sul paesaggio, un punto di particolare interesse tra gli esperti con formazione sia in agricoltura che in studi sul paesaggio. L’esperto 3 ha sottolineato la necessità di articolare meglio questa dimensione, notando che le decisioni basate sui dati possono rimodellare sia il paesaggio che il lavoro. L’esperto 14 ha descritto una catena di effetti in cui l’efficienza del lavoro indotta dall’automazione potrebbe portare allo spopolamento rurale e, infine, a cambiamenti nel senso del luogo. Nel frattempo, l’esperto 1 ha visto la DA come un abilitatore di diverse pratiche, come l’agricoltura di precisione, l’agricoltura climaticamente intelligente e l’agroecologia, le quali a loro volta guidano il cambiamento del paesaggio. In questa prospettiva, la DA è stata interpretata come uno strumento per realizzare determinati tipi di pratiche agricole, e queste pratiche sono la causa diretta del cambiamento paesaggistico.

Oltre ai sei temi principali, meritano attenzione tre ulteriori prospettive esperte. In primo luogo, l’esperto 10 ha sottolineato l’importanza della scala temporale, suggerendo che nel breve termine la disponibilità di dati plasmerà l’agricoltura, mentre nel lungo periodo (oltre 10 anni) la robotica potrebbe iniziare a influenzare le pratiche. In secondo luogo, gli esperti 7 e 12 hanno sollevato possibilità contrastanti, vale a dire da un lato l’abbandono delle aree inadatte alle nuove tecnologie e dall’altro il potenziale di innovazioni come i sistemi di serre ad acqua salata per consentire la coltivazione in regioni precedentemente improduttive, entrambe con significative implicazioni paesaggistiche. Infine, l’Esperto 0, che non ha completato l’intero sondaggio, ha messo

in guardia dal generalizzare gli effetti della DA senza specificare il tipo di tecnologia, notando che "le direzioni dei cambiamenti dipendono fortemente dalla tecnologia introdotta". Ciò sottolinea la natura condizionale e specifica del contesto del cambiamento paesaggistico sotto la DA.

5. Discussione

I risultati dell'indagine esperta rivelano una notevole diversità e ricchezza, dimostrando che la DA esercita effettivamente influenze, in vari gradi, su diversi aspetti del paesaggio, nonostante il numero relativamente basso di risposte. Oltre a identificare gli aspetti del paesaggio più e meno influenzati, i risultati evidenziano tre punti interessanti che meritano un'ulteriore discussione.

Il primo punto riguarda il modo in cui i paesaggi sono influenzati dalla DA: da un'influenza prevalentemente indiretta a impatti potenzialmente più diretti in futuro. Le risposte alla scala unipolare hanno identificato "fornire dati per supportare le decisioni aziendali" come la modalità di influenza più dominante, riecheggiando ricerche precedenti (McConnell, 2019; Moreno et al., 2022). Questi studi descrivono similmente la DA come un sistema di supporto alle decisioni (DSS), che aiuta nelle scelte gestionali dell'azienda come la progettazione dei campi, la copertura del suolo, l'irrigazione e la fertilizzazione. Anche il tema dell'"influenza indiretta" è emerso dall'analisi tematica, rafforzando questa interpretazione. Al contrario, tecnologie come le macchine agricole intelligenti e la robotica, che dagli esperti sono state viste come le più influenti, agiscono direttamente sulle operazioni agricole e, per estensione, sul paesaggio stesso. I risultati apparentemente contraddittori possono essere spiegati considerando la dimensione temporale. Date le attuali limitazioni tecnologiche e gli alti costi, il DSS rimane oggi la forma dominante di DA. Tuttavia, nel lungo termine, possiamo ragionevolmente prevedere un'implementazione più ampia di strumenti di automazione più avanzati ed economicamente accessibili. Queste tecnologie eserciterebbero un'influenza più diretta sul paesaggio, sottolineando il valore dell'indagine esperta nell'anticipare i futuri cambiamenti paesaggistici.

Il secondo risultato degno di nota è l'identificazione di un divario disciplinare nella percezione del cambiamento paesaggistico guidato dalla DA. Questo è particolarmente evidente analizzando le dimensioni del paesaggio interessate, dove emergono sia convergenze che divergenze. La convergenza si riflette nel consenso tra i gruppi di esperti riguardo agli impatti sulla dimensione socio-culturale. "Modalità di gestione", "elementi costruiti nuovi", "decisione di coltivare o meno" e "modelli e recinzioni" sono stati percepiti in modo coerente come fortemente influenzati, in particolare dagli studiosi di agricoltura-paesaggio, che generalmente hanno assegnato punteggi più alti rispetto agli altri due gruppi. La divergenza appare nelle risposte riguardanti le dimensioni bio-fisical e estetico-percettiva. Gli esperti di agricoltura hanno ritenuto che la DA avesse un impatto sostanziale sulla dimensione bio-fisica, mentre gli esperti di paesaggio hanno pensato il contrario. Al contrario, gli esperti di paesaggio hanno dato punteggi significativamente più alti per la dimensione estetico-percettiva, mentre gli studiosi di agricoltura erano meno convinti. Gli esperti di agricoltura-paesaggio hanno fornito valutazioni più moderate per entrambe le dimensioni. Questa discrepanza probabilmente deriva dalla familiarità disciplinare: gli esperti di agricoltura, esperti negli aspetti ambientali della coltivazione, potrebbero essere meno sensibili ai concetti di percezione del paesaggio, mentre vale il contrario per gli esperti di paesaggio. Questi modelli evidenziano una divisione disciplinare nell'interpretazione del cambiamento paesaggistico. Tali divari potrebbero porre sfide per le future politiche agricole e paesaggistiche, specialmente in un contesto di accelerazione della digitalizzazione agricola e di crescente enfasi sulla sostenibilità del paesaggio.

Infine, esiste un modello apparentemente paradossale nella percezione dei cambiamenti della dimensione estetico-percettiva. Rispetto alle altre due dimensioni, essa appare la meno influenzata secondo i risultati delle domande a scala unipolare. Tuttavia, un numero considerevole di esperti ha discusso della percezione del paesaggio nelle loro risposte alle domande aperte, portando alla sua emersione come tema nell'analisi tematica. Una possibile spiegazione risiede nel ritardo temporale associato al cambiamento percettivo. Gli esperti potrebbero trovare più facile riconoscere o anticipare cambiamenti nelle dimensioni cultural-social e bio-fisica sulla base delle loro

esperienze passate. Tali cambiamenti, ad esempio l'uso del suolo, la copertura vegetale o la struttura dei campi, sono più facilmente misurabili e osservabili. Al contrario, come nota Bieling (2013), "la percezione del cambiamento paesaggistico incrementale non corrisponde a un'indagine sulle caratteristiche biofisiche del cambiamento del paesaggio, ma piuttosto si concentra sugli effetti visibili e presenta considerevoli ritardi temporali". Questa osservazione può aiutare a spiegare la apparente discrepanza nella valutazione della dimensione estetico-percettiva. Inoltre, potrebbe essere intrinsecamente difficile anticipare o immaginare cambiamenti nella percezione del paesaggio senza sperimentarli direttamente. Mentre i cambiamenti alle strutture fisiche sono spesso misurati con un approccio quantitativo, le dimensioni estetiche e sensoriali sono più soggettive, sviluppandosi nel tempo e nel contesto.

6. Conclusione

L'indagine esperta ha rivelato un ampio consenso tra i partecipanti riguardo al crescente impatto della DA sul cambiamento del paesaggio rurale, specialmente nel lungo termine. Nel complesso, gli esperti hanno concordato sul fatto che la DA eserciti impatti pronunciati sulle dimensioni cultural-social e bio-fisica, pur notando anche alcuni segni di cambiamento nella dimensione estetico-percettiva, con differenze disciplinari nell'interpretazione. Oltre a riflettere sui cambiamenti attuali, i rispondenti hanno offerto anticipazioni sugli sviluppi futuri, come un passaggio da un'influenza indiretta a una diretta sui paesaggi, e gli effetti a cascata dell'automazione abilitata dalla DA sull'identità locale e sullo spopolamento rurale. Questi cambiamenti altamente diversificati spaziano da effetti prossimi sulla struttura fisica a cambiamenti sottostanti nella più profonda ristrutturazione sociale. Il fatto che tutti gli elementi della checklist del cambiamento paesaggistico siano stati menzionati suggerisce che essa fornisca un quadro solido per analizzare il cambiamento guidato dalla DA, con un potenziale per un'applicazione più ampia nella ricerca futura.

Invece di concentrarsi sull'influenza di un singolo tipo di tecnologia sul paesaggio, la nostra ricerca ha inteso identificare la direzione generale del cambiamento paesaggistico guidato dalla digitalizzazione agricola, contribuendo a proporre una nuova direzione per gli studi futuri fornendo un quadro interpretativo. Infatti, quale cambiamento le specifiche tecnologie specifica possano portare richiederà indagini ad hoc, considerando anche che la stessa tecnologia può portare a risultati diversi a seconda di come viene utilizzata. Ad esempio, il telerilevamento può abilitare macchinari agricoli intelligenti per la produzione di massa, portando a una potenziale omogeneizzazione del paesaggio, ma può anche fornire dati per supportare il processo decisionale sul ripristino delle caratteristiche del paesaggio in campo. In primo luogo, gli studi futuri sul cambiamento paesaggistico guidato dalla DA potrebbero beneficiare di ricerche basate su casi studio, in cui le tecnologie digitali, le caratteristiche del paesaggio e i ruoli degli stakeholder (ad esempio agricoltori, aziende agri-tech) siano definiti in modo più chiaro. In secondo luogo, l'assenza di un arco temporale in questa indagine ha reso le proiezioni degli esperti relativamente generiche; l'integrazione di un orizzonte temporale più definito, ad esempio di cinque o dieci anni, potrebbe aiutare a produrre approfondimenti più concreti e applicabili. Infine, ampliare la partecipazione per includere esperti di diversi campi, come la tecnologia dell'agricoltura digitale, potrebbe rafforzare il dialogo interdisciplinare e contribuire a colmare le lacune di conoscenza tra i vari ambiti.

Al centro di questa ricerca vi è il riconoscimento della multifunzionalità del paesaggio, eppure gli attuali quadri politici rimangono frammentati. Sebbene l'agricoltura digitale sia governata principalmente da politiche agricole orientate alla produzione, le dimensioni ecologiche, culturali ed estetiche del paesaggio sono gestite attraverso strumenti di pianificazione separati. Questa ricerca cerca di colmare queste lacune settoriali sostenendo un approccio di governance più olistico. Un passo chiave in questa integrazione è l'incorporazione formale degli attori dell'agri-tech come portatori di interesse rilevanti nella governance e nella pianificazione del paesaggio, garantendo che i driver tecnologici siano allineati ai valori paesaggistici. Questo può anche contribuire al raggiungimento di una situazione di "doppia vittoria" che ottimizzi le risorse finanziarie limitate per

far avanzare simultaneamente la digitalizzazione e la sostenibilità del paesaggio. In definitiva, colmare il divario settoriale tra tecnologia e paesaggio consente una digitalizzazione più etica, che salvaguardi le dimensioni ecologiche, culturali ed estetiche del paesaggio promuovendo al contempo l'innovazione tecnologica.

Riconoscimenti

Desideriamo esprimere la nostra gratitudine agli esperti che hanno partecipato alla survey.

Desideriamo inoltre ringraziare l'editore per la sua assistenza nella revisione di questo manoscritto e i revisori per i loro feedback costruttivi, che hanno contribuito al miglioramento di questo articolo.

Contributo degli autori

Concettualizzazione: F.H., C.C.; Metodologia: F.H., C.C.; Raccolta dati: F.H.; Analisi dei risultati: F.H.; Redazione originale: F.H.; Revisione e editing: F.H., C.C.; Supervisione: C.C.

Bibliografia

- Antrop M. (1997). The concept of traditional landscapes as a base for landscape evaluation and planning. The example of Flanders Region. *Landscape and urban planning*, 38(1-2), 105-117. [https://doi.org/https://doi.org/10.1016/S0169-2046\(97\)00027-3](https://doi.org/https://doi.org/10.1016/S0169-2046(97)00027-3)
- Antrop M. (2005). Why landscapes of the past are important for the future. *Landscape and urban planning*, 70(1-2), 21-34. <https://doi.org/https://doi.org/10.1016/j.landurbplan.2003.10.002>
- Basso B. & Antle J. (2020). Digital agriculture to design sustainable agricultural systems. *Nature Sustainability*, 3(4), 254-256. <https://doi.org/https://doi.org/10.1038/s41893-020-0510-0>
- Bastian O., Grunewald K., Syrbe R.-U., Walz U. & Wende W. (2014). Landscape services: the concept and its practical relevance. *Landscape ecology*, 29(9), 1463-1479. <https://doi.org/https://doi.org/10.1007/s10980-014-0064-5>
- Bellon-Maurel V. & Huyghe C. (2017). Putting agricultural equipment and digital technologies at the cutting edge of agroecology. *Oléagineux, Corps Gras, Lipides*, 24(3), 1-7. <https://doi.org/https://doi.org/10.1051/ocl/2017028>
- Bellon-Maurel V., Lutton E., Bisquert P., Brossard L., Chambaron-Ginhac S., Labarthe P., Lagacherie P., Martignac F., Molenat J. & Parisey N. (2022). Digital revolution for the agroecological transition of food systems: A responsible research and innovation perspective. *Agricultural systems*, 203, 103524. <https://doi.org/https://doi.org/10.1016/j.agry.2022.10352>
- Bieling C. (2013). Perceiving and Responding to Gradual Landscape Change at the Community Level: Insights from a Case Study on Agricultural Abandonment in the Black Forest, Germany. *Ecology and Society*, 18(2). <https://doi.org/http://dx.doi.org/10.5751/ES-05590-180236>
- Brandt J., Primdahl J. & Reenberg A. (1999). Rural land-use and landscape dynamics-analysis of 'driving forces' in space and time. *Man and the Biosphere Series*, 24, 81-102. https://forskning.ruc.dk/files/34926652/Rural_land_use_and_landscape_dynamics.pdf
- Bürgi M., Celio E., Diogo V., Hersperger A.M., Kizos T., Lieskovsky J., Pazur R., Plieninger T., Prishchepov A.V. & Verburg P.H. (2022). Advancing the study of driving forces of landscape change. *Journal of Land Use Science*, 1-16. <https://doi.org/https://doi.org/10.1080/1747423X.2022.2029599>
- Bürgi M., Hersperger A.M. & Schneeberger N. (2005). Driving forces of landscape change-current and new directions. *Landscape ecology*, 19(8), 857-868. <https://doi.org/https://doi.org/10.1007/s10980-005-0245-3>
- Cassatella C. & Peano A. (2011). *Landscape Indicators: Assessing and Monitoring Landscape Quality*. Springer.
- Cavallo E., Ferrari E., Bollani L. & Coccia M. (2014). Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system.

- Agricultural systems*, 130, 44-54. <https://doi.org/https://doi.org/10.1016/j.agry.2014.05.012>
- Clapp J. & Ruder S.-L. (2020). Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. *Global Environmental Politics*, 20(3), 49-69. https://doi.org/https://doi.org/10.1162/glep_a_00566
- Del Río Castro G., González Fernández M. C. & Uruburu Colsa, Á. (2021). Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): A holistic review. *Journal of Cleaner Production*, 280, 122204. <https://doi.org/https://doi.org/10.1016/j.jclepro.2020.122204>
- Dörr J. & Nachtmann M. (2022). *Handbook Digital Farming: Digital Transformation for Sustainable Agriculture*. Springer.
- El Bilali H. & Allahyari M.S. (2018). Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. *Information Processing in Agriculture*, 5(4), 456-464. <https://doi.org/https://doi.org/10.1016/j.inpa.2018.06.006>
- ElMassah S. & Mohieldin M. (2020). Digital transformation and localizing the Sustainable Development Goals (SDGs). *Ecological economics*, 169, 106490. <https://doi.org/https://doi.org/10.1016/j.ecolecon.2019.106490>
- European Commission. (2021). *The new common agricultural policy: 2023-27*. Retrieved 14 February 2024 from https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/new-cap-2023-27_en
- European Commission. (2023). *2030 Digital Decade: Report on the state of the digital decade 2023*. <https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade>
- Huang F. (2025). *Examining Rural Landscape Change Driven by the Digitalisation of Agriculture* [Doctoral Thesis, Politecnico di Torino]. Torino. <https://iris.polito.it/handle/11583/2999502>
- Huang F. & Cassatella C. (2024). Examining Rural Landscape Change in the Context of Agriculture Digitalisation: A Review. *Landscape Research*, 50(1), 250-268. <https://doi.org/10.1080/01426397.2024.2391387>
- Joffe H. & Yardley L. (2003). Chapter four: content and thematic analysis. *Research Methods for Clinical and Health Psychology*. Marks D, Yardley L (ed): Sage Publications, London, 56-68.
- Kernecker M., Knierim A., Wurbs A., Kraus T. & Borges F. (2020). Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precision Agriculture*, 21(1), 34-50. <https://doi.org/https://doi.org/10.1007/s11119-019-09651-z>
- Klerkx L., Jakku E. & Labarthe P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS-Wageningen Journal of Life Sciences*, 90, 100315. <https://doi.org/https://doi.org/10.1016/j.njas.2019.100315>
- Lajoie-O'Malley A., Bronson K., van der Burg S. & Klerkx L. (2020). The future (s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services*, 45, 101183. <https://doi.org/https://doi.org/10.1016/j.ecoser.2020.101183>
- Legun K. & Burch K. (2021). Robot-ready: How apple producers are assembling in anticipation of new AI robotics. *Journal of Rural Studies*, 82, 380-390. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2021.01.032>
- Leveau L., Bénél A., Cahier J.-P., Pinet F., Salembier P., Soullignac V. & Bergez J.-E. (2019). Information and communication technology (ICT) and the agroecological transition. In *Agroecological transitions: from theory to practice in local participatory design* (pp. 263-287). Springer, Cham.
- McConnell M.D. (2019). Bridging the gap between conservation delivery and economics with precision agriculture. *Wildlife Society Bulletin*, 43(3), 391-397. <https://doi.org/https://doi.org/10.1002/wsb.995>
- Mckinsey Global Institute. (2014). *China's digital transformation: The internet's impact on productivity and growth*. M. Company. <https://www.mckinsey.com/~media/mckinsey/industries/technology%20media%20and%20telecommunications/high%20tech/our%20insights/chinas%20digital%20transformation/mgi%20china%20digital%20full%20report.pdf>
- Medley K.E., Okey B.W., Barrett G.W., Lucas M.F. & Renwick W.H. (1995). Landscape change with agricultural intensification in a rural watershed, southwestern Ohio, USA. *Landscape ecology*,

- 10(3), 161-176.
- Ministry of Agriculture and Rural Affairs of China. (2022). *Quanguo nongye nongcun xinxihua fazhan guihua [National Development Plan for Informationisation of Agriculture and Rural Area]*. Retrieved from http://www.moa.gov.cn/govpublic/SCYJJXXS/202203/t20220309_6391175.htm
- Moreno A., Rescia A.J., Pascual S. & Ortega M. (2022). Methodological approach to spatial analysis of agricultural pest dispersal in olive landscapes. *Environmental Monitoring and Assessment*, 194(6), 411. <https://doi.org/https://doi.org/10.1007/s10661-022-10068-x>
- Nguyen L.H., Robinson S.V. & Galpern P. (2022). Effects of landscape complexity on crop productivity: an assessment from space. *Agriculture, ecosystems & environment*, 328, 107849. <https://doi.org/https://doi.org/10.1016/j.agee.2021.107849>
- OECD. (2019). *Digital Opportunities for Better Agricultural Policies*. <https://doi.org/doi:https://doi.org/10.1787/571a0812-en>
- Pfeiffer J., Gabriel A. & Gandorfer M. (2021). Understanding the public attitudinal acceptance of digital farming technologies: a nationwide survey in Germany. *Agriculture and Human Values*, 38(1), 107-128. <https://doi.org/https://doi.org/10.1007/s10460-020-10145-2>
- Pinto-Correia T., Primdahl J., Pedrolí B. & Pedrolí G.B.M. (2018). *European landscapes in transition*. Cambridge University Press.
- Plieninger T., Draux H., Fagerholm N., Bieling C., Bürgi M., Kizos T., Kuemmerle T., Primdahl J. & Verburg P.H. (2016). The driving forces of landscape change in Europe: A systematic review of the evidence. *Land Use Policy*, 57, 204-214. <https://doi.org/https://doi.org/10.1016/j.landusepol.2016.04.040>
- Rose D.C. & Chilvers J. (2018). Agriculture 4.0: Broadening responsible innovation in an era of smart farming. *Frontiers in Sustainable Food Systems*, 2, 87. <https://doi.org/https://doi.org/10.3389/fsufs.2018.00087>
- Rotz S., Gravely E., Mosby I., Duncan E., Finnis E., Horgan M., LeBlanc J., Martin R., Neufeld H.T. & Nixon A. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, 68, 112-122. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2019.01.023>
- Sachs J.D., Schmidt-Traub G., Mazzucato M., Messner D., Nakicenovic N. & Rockström J. (2019). Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, 2(9), 805-814. <https://doi.org/10.1038/s41893-019-0352-9>
- Salemink K., Strijker D. & Bosworth G. (2017). Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies*, 54, 360-371. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2015.09.001>
- Schroeder K., Lampietti J. & Elabed G. (2021). *What's cooking: Digital transformation of the Agrifood system*. World Bank Publications. <http://hdl.handle.net/10986/35216>
- Stahlschmidt P., Swaffield S., Primdahl J. & Nellesmann V. (2017). *Landscape Analysis: Investigating the potentials of space and place*. Routledge.
- Swanwick C. (2002). *Landscape Character Assessment: Guidance for England and Scotland*. Countryside Agency Retrieved from <https://digital.nls.uk/pubs/e-monographs/2020/216649977.23.pdf>
- Tang S., Zhu Q., Zhou X., Liu S. & Wu M. (2002). A conception of digital agriculture. IEEE international geoscience and remote sensing symposium,
- Termorshuizen J.W. & Opdam P. (2009). Landscape services as a bridge between landscape ecology and sustainable development. *Landscape ecology*, 24(8), 1037-1052. <https://doi.org/https://doi.org/10.1007/s10980-008-9314-8>
- Trendov N.M., Varas S. & Zeng M. (2019). *Digital technologies in agriculture and rural areas status report*. Food and Agriculture Organisation. <https://www.fao.org/documents/card/en/c/ca4985en>
- Tudor C. (2014). *An approach to landscape character assessment*. Natural England Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/691184/landscape-character-assessment.pdf

- Wu J., Wang Z., Zhang L. & Song J. (2012). Jingguan geju bianhua qudongli yanjiu jinzhan [Research progresses on driving forces of the changes of landscape pattern]. *Progress in Geography*, 31(12), 1739-1746. <https://doi.org/https://doi.org/10.11820/dlkxjz.2012.12.021>
- Zhao C. (2019). Zhihui nongye fazhan xianzhuang ji zhanlve mubiao yanjiu [State-of-the-art and recommended development strategy objectives of smart agriculture]. *Smart Agriculture*, 1(1), 1-7. <https://doi.org/https://doi.org/10.12133/j.smartag.2019.1.1.201812-SA005>

Appendice

Appendice 1. Expert survey

Survey on Experts' Opinions on the Relationship between the Digital Agriculture and the Rural Landscape Change

I. BASIC INFORMATION

In this session, you will be asked some questions related to your academic background the research interests. All the information collected in this session, except the part about your research area and the geographical location of your affiliated institute, will remain anonymous, unless you feel OK to reveal it.

1. You identify yourself as a scholar working in the field of:

- A. Agriculture related research;
- B. Landscape related research;
- C. Both;
- D. Other _____

2. Please write down your main research area (up to 3)

3. Please write down your position and affiliation (please indicate the country of your institution):

4. Do you want to remain anonymous in this survey?

- A. YES
- B. It's OK to share the above information

N.B. information regarding to your position and affiliation will be kept confidential, if you prefer to stay anonymous. Only the answer of Q1, Q2, and the geographical location of your affiliation in Q3 will be used for the research. For the use of information, your response in this survey may be quoted in the following works such as articles and my thesis when I write about the result of this survey.

II. DIGITAL AGRICULTURE

In this session, you will be asked questions related to digital technologies in agriculture focusing on if you think these technologies will have an influence, the extent of their influence and how they influence.

5. There are some technologies currently adopted to agriculture, if you can think or imagine whether the implementation of these technologies in the field will lead to landscape change. If your answer is 'yes', please indicate the extent of their influence using the provided scale. 0 refers to "this digital technology has no influence on rural landscape", 1 refers "little influence", 5 refers to "great influence"

	0	1	2	3	4	5
Unmanned aerial vehicle (UAV)	☐	☐	☐	☐	☐	☐
Internet of Things (IoT)	☐	☐	☐	☐	☐	☐
Robotics	☐	☐	☐	☐	☐	☐
Smart farming machineries	☐	☐	☐	☐	☐	☐
Remote sensing	☐	☐	☐	☐	☐	☐

Appendice

6. If you know any other technological applications, please write them down (max. 3) and indicate if you think their application in the field will influence the rural landscape and the extent of their influence as well using the scale from 1 to 5. e.g. (name of the technology) – 4
-

7. Some brief descriptions on how digital agriculture may influence the rural landscape are listed below. Do you think these descriptions below are the way that rural landscape gets affected by the digital agriculture? If your answer is 'yes', please indicate the extent of its dominance using the provided scale

0 refers to "digital agriculture does not influence rural landscape in such way", 1 refers "the least dominant way that the digital agriculture affects the rural landscape", 5 refers to "the most dominant way that the digital agriculture affects the rural landscape"

	0	1	2	3	4	5
Directly changing the farming practices and the way that farm organised. A more direct influence.	☐	☐	☐	☐	☐	☐
Providing more data and information to inform decision making in the farm choices, leading to change. A more indirect influence.	☐	☐	☐	☐	☐	☐

8. If you can think of more, please add them below and indicate the extent of its dominance using the scale from 1 to 5.

e.g. (the description of the way how digital agriculture influence landscape) – 4

III. INFLUENCES ON LANDSCAPE

In this session, the concept of landscape will be broken down into three dimensions with multiple aspects. You will be asked if you can anticipate changes to the following aspects of landscape related to the implementation of the digital agriculture. Please indicate the extent of the impact using the provided scale.

0 refers to "not affected by the adoption of digital agriculture"; 1 refers "little influence"; 5 refers to "great influence"

9. Impact of the digital agriculture on cultural-social aspects

	0	1	2	3	4	5
Decision on whether to cultivate	☐	☐	☐	☐	☐	☐
Type of cultivated crops	☐	☐	☐	☐	☐	☐
Way of managing crops	☐	☐	☐	☐	☐	☐
Farm size	☐	☐	☐	☐	☐	☐
Pattern and type of field enclosure	☐	☐	☐	☐	☐	☐
Preservation of traditional features	☐	☐	☐	☐	☐	☐
Abandonment of traditional features	☐	☐	☐	☐	☐	☐
Material of built elements	☐	☐	☐	☐	☐	☐
Insertion of new built elements	☐	☐	☐	☐	☐	☐

Appendice

10. If you can think of more cultural-social aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (cultural-social aspect) – 3.

If you can think of an example of how landscape socio-cultural factors get influence, you can write it down briefly here.

11. Impact of the digital agriculture on bio-physical aspects

Vegetation cover	☐	☐	☐	☐	☐	☐
Land cover	☐	☐	☐	☐	☐	☐
Soils	☐	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐	☐
Flora and fauna diversity	☐	☐	☐	☐	☐	☐

12. If you can think of more natural aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (bio-physical aspect) – 4.

If you can think of an example of how landscape natural factors get influence, you can write it down briefly here.

13. Impact of the digital agriculture on perceptual-aesthetic aspects

	0	1	2	3	4	5
Openness of view	☐	☐	☐	☐	☐	☐
Visual diversity/complexity	☐	☐	☐	☐	☐	☐
Colour and texture	☐	☐	☐	☐	☐	☐
Smells or sounds	☐	☐	☐	☐	☐	☐
Seasonality	☐	☐	☐	☐	☐	☐
Sense of place	☐	☐	☐	☐	☐	☐

14. If you can think of more perceptual-aesthetic aspects which may be influenced by the implementation of digital agriculture, please add them below and indicate the extent of the impact using the scale from 1 to 5. E.g. (perceptual-aesthetic aspect) – 2.

If you can think of an example of how landscape perceptual-aesthetic factors get influence, you can write it down briefly here.

Appendice

Appendice 2. Experts' answers to open-end questions

Expert 0 – Landscape

Precision fertilization and pest management based on high-tech agricultural machinery and data from satellites and sensors may reduce the leaching of nitrogen from the soil as well as limit the pollution from pesticides

Collaboration between farmers - new technology is expensive, so smaller farms may need to collaborate and own machinery jointly

Depending on the technology introduced it may result either in bigger fields or small fields- robots may allow cultivation of new types of crops (vegetables likes) and can result in more small fields and more field structures, whereas bulk production improved by big machines and precision agriculture may result in bigger fields.

it is difficult to answer question 8a - it will have an influence on all natural factors; however the effects can be positive, negative or neutral

also here I find it difficult to make an answer to 9a as it depends on the technology introduced. However the introduction of more visible technology in agriculture will change our perception of agriculture and the landscape - the use of drones - can be seen as a kind of disturbance

Expert 1 – both

The technologies listed above are all digital technologies and have, in my view, mostly an indirect impact on landscape (e.g. because they can support precision agriculture, climate smart agriculture, agro-ecology, etc.). Other agriculture technologies (not necessarily digital) may have a stronger influence. For instance, protected agriculture, genomics, low carbon agricultural practices

Providing data and information for decision making at landscape (aggregated) and higher level

Digital agriculture may create a significant divide (technical and then economic, social) between farmers between front-runners and laggards. A factor 5

There are studies which show that adopters of digital innovation, especially precision farming related, are and will be in the future large farms, well equipped technically, economically, culturally towards innovation. To have small scale producers adopting such innovations strong investments are needed in terms of awareness creation, digital skills, and assets (e.g. IoT enabled sensors and machinery, farm management information systems, use of UAV and remote sensing data)

soil carbon emission and fixation (if we can consider these as natural factors): factor 3

digital agriculture can help assessing the impact of soil carbon emissions caused by farming practices (e.g. tillage)

Expert 3 – both

I think that the point about indirect influences needs to be fleshed out a bit. They may be collecting data and using it to influence landscapes and work, but that does not mean that is the best way to reorganize things. But, as Bronson 2022 argues, data is often considered a political (immaculately conceived) which is a huge issue.

Some of the machines can be really loud. So much so that neighbors might complain. Regarding sense of place, I think people might lose connection to place through leaving things to robotics. The Legun et al 2022 paper Can a Robot Be an Expert? addresses these dimensions, alongside the kinds of knowledges that are valued. Taiuru et al 2022 paper on agricultural big data also discusses how assumed access to land via agtech can perpetuate colonial power dynamics

Appendice

which interferes in Indigenous peoples' knowledges and sense of place, particularly in settler colonial contexts

(<https://www.tandfonline.com/doi/abs/10.1080/00779954.2022.2147861?journalCode=rnzp20>).

Expert 5 – both:

Manned aerial vehicles - YES – 3

Expert 6 – Agriculture:

I think the areas you suggested cover the topics. Especially robots for agriculture they can help in the future to maintain the landscape. Also all these digital technologies will provide an environment with optimised use of resources, with less use of chemical to maintain the agricultural landscape.

the adoption of digital agriculture is influenced negatively by the age of farmers, increasing, and for Italy, by the small, cultivated area for each farm, that hinder the implementation of digital/smart farming;

Precision farming and GPS navigation could help to provide stripes cultivation to avoid erosion in hilly areas

possibility to make mazes visited by citizens, to maintain with low costs the landscape around cultivation, to promote waking patterns inside /around agricultural fields.

Expert 7 – Agriculture:

Digital greenhouse technologies - yes – 4

influencing what kinds of farming systems are economically viable - yes - 2 now, likely more in the future

A quick clarifying note - I would say digital agriculture would impact the variety of crop that is cultivated, but probably not the type of crop (I variety of apples rather than apples or oranges, if that makes sense)

I think the organization of plants may be changed on the landscape to support their incorporation into automatic systems or sensor technologies. They may also shape things like irrigation patterns through sensors and tech automation, or for example, the use of frost deterrents through sensors. This would mediate the effects of natural processes on crop production.

New saltwater technologies for greenhouses may allow for cultivation in areas that have not been able to produce food before (ie deserts). This would potentially have significant influences on landscapes.

Expert 8 – Agriculture:

Artificial Intelligence

Expert 9 – landscape:

Artificial intelligence as instruments for advice and problem solutions - will contribute to new farming practices and 'optimization' of landscape and field structures, water resource optimization, climate mitigation practices etc

Farmers collaboration concerning landscape practices (spreading of manure, integrated pest management, ecological network etc)

Pest management through support of living conditions for natural enemies of pests

landscape pattern, hydrology patterns

Appendice

Expert 10 – both

I think that the time scale matters. On the shorter run, it will be more “data availability” that influences farming (e.g. in the coming 10 years). On the longer run (>10 years) maybe actual robots will be available and may start to affect farming practices.

(I would probably not consider “type of cultivated crops” as a cultural/social factor. This is an agronomic and economic decision.) Similar for the other factors listed.)

A cultural /social factor that may be influenced could be the possibility to combine farm work and off-farm work. It could become easier due to information technology. Rating 2

Arable weeds - 4 (precision spray applications)

Insect pests - 2 (monitoring)

Plant diseases - 3 (prediction models)

it will be an indirect influence E.g. by the effect on field size.

Expert 11 – both:

variable-rate technology - yes – 5

on-farm and off-farm work proportion - 4; labor – 5

more homogeneous landscape

greenhouse gas emission – 5

Expert 12 - agriculture

abandonment of areas not suitable for new technologies - YES – 4

new guidelines for making wine: e.g. now it is not allowed to irrigate vineyards, they are thinking about changing these rules to allow irrigation if sensors demonstrate the necessity.

the slope of the hill in order to let tractors to work on the hill (during our conversation at the OPP poster event)

change of the soil gestion: bare land or covered by grass

as said before if the soil is covered with grass and before it was kept bare change the color of the hill.

Expert 13 -landscape:

electricity fences - YES - 4; Realtime GPS livestock tracker - YES – 3

providing path-dependence breaking solutions which leads to more agricultural innovation of practices and institutions - YES – 4

perception change of agricultural socio-ecological system resilience - 4 (for example pastoralists may have a different perception of grazing intensity when they use UAV images to detect standing biomass)

not in a direct way but from the feedback of land use change

perception change of agricultural socio-ecological system resilience - 4 (for example pastoralists may have a different perception of grazing intensity when they use UAV images to detect standing biomass)

the same perception change can also be related to land use intensity, for example using GPS tracker they may have a different understanding of livestock trampling/grazing disturbance on pastures.

the application of technology may change the aesthetic aspect of “cultural landscape” E.g., when electricity fences are installed in summer pastures to replace shepherd.

Appendice

Expert 14 -landscape:

Make changes to the environment so that can be equipped with digital devices – 4 (this one is added by me later after I did the example review)

Less people needed to work the land, leading to rural depopulation and potentially in the end the collapse of rural society – 4

Robots can work day and night I.e. leading to all day disturbance for animals.

a depopulated countryside certainly does not provide the same sense of place – 3

Expert 15 - agriculture

Make changes to the environment so that can be equipped with digital devices – 3

Organization of work for farmers 4

DA gives more detailed information (soil, status of crops, timing) about fields and their needing (water, fertilization, adequate crop), so a more complex and detailed organization of fields and work is needed, that can be reflected in field size and shapes, irrigation system, use of agricultural machinery.

Quality of water and soil can be positively affected by a more detailed knowledge and management of soil and water (nature-based solution, detailed fertilization)



Juan Pedro Grammaldo
Francesco Mazziotti

DOWNLOAD

Esempio Atto costitutivo
e Statuto della CER
Check List

Comunità Energetiche Rinnovabili (CER) e AutoConsumo Collettivo (ACC)



Aggiornato al Decreto
CER MASE n. 414/2023

Esempi pratici di CER e ACC

dei
TIPOGRAFIA DEL GENIO CIVILE

www.build.it

dei
TIPOGRAFIA DEL GENIO CIVILE