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Practicing Critical Zone Observation in Agricultural Landscapes: Communities, Technology, Environment and Archaeology

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Abstract: The aims of agricultural land management change continuously, reflecting shifts in wider societal priorities. Currently, these include addressing the climate crisis, promoting environmental sustainability, and supporting the livelihoods of rural communities while ensuring food security. Working toward these aims requires information on the character of agricultural land and how dynamic processes influence it. Remote and near-surface sensing data are important sources of information on the characteristics of soils, plants, water, topography, and related processes. Sensing data are collected, analysed, and used in decision-making by specialists in multiple domains connected to land management. While progress has been made to connect the use of sensing data across agricultural and environmental applications under the umbrella of integrated sustainable land management, archaeological and heritage uses of these data remain largely disconnected. This creates barriers to accounting for the impacts of past human activities on contemporary agricultural landscapes through the alteration of soils, topography, and plant communities. In parallel, it hinders the creation of knowledge about the archaeological features which form an essential part of the heritage of agricultural landscapes. The *ipaast-czo* project explores the potential of a coordinated approach across all these domains, which would reduce these barriers and provide benefits by better integrating information generated using sensing. To do so, both conceptual and practical barriers to developing shared practices and how these might be overcome were considered. In this study, a conceptual framework designed to create a shared understanding of how agricultural landscapes work and enable collaboration around their management was proposed. This framework treats present-day rural agricultural landscapes as Critical Zones: complex entities shaped by long-term human–environment interactions including contemporary farming. Practitioners in precision agriculture and archaeological remote and near-surface sensing, as well as users of these data, were engaged using workshops and interviews. The relationships between practitioners' objectives, data requirements for their applications, and their perceptions of the benefits and disadvantages of changing working practices were interrogated. The conceptual framework and assessment of practical benefits and challenges emerging from this work provide a foundation for leveraging shared sensing data and methods for long-term integrated sustainable land management.

Keywords: Critical Zone; precision agriculture; remote sensing; near-surface geophysics; proximal soil sensing; archaeology; sustainability; land management; interoperability

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1. Introduction

1.1. Research Aims and Questions

In principle, contemporary agricultural land management brings together a broad network to address objectives across food production, environmental sustainability, soil health, and natural and cultural heritage [1–4]. Farmers and landowners consult with technical specialists and service providers and engage with officers of administrative, regulatory, and government organisations, and their activities are informed by the efforts of researchers [5–7]. While each has its own specific remit, and debates over how best to manage agricultural land continue [8–12], there is a broadly shared interest in understanding the characteristics of the land and changes in its characteristics over time to inform future work. The use of remote and near-surface sensing technologies, including multi- and hyper-spectral imaging, lidar, and ground-based electrical conductivity mapping or magnetometry, to provide basic data to characterise the biophysical properties of the land and trace changes in them is well established [13–16]. In addition to being increasingly important as a data source for each domain, remote and near-surface sensing provide a critical point of connection between them. However, while different actors in this network often use the same sensing technologies to study the same land, coordinated data collection is rare, analyses are carried out separately, and data sharing is limited [17–20].

The general problems posed by data silos are widely recognised, as are the potential benefits of coordinated data collection and interoperability [18,21]. The domain of land management is no exception, and the push to make land management more sustainable has motivated projects to bring together agricultural and environmental data, including sensing data [21–24]. This closer connection is an important step toward integrated sustainable land management. However, the connections to the objectives, sensing methods, and data used to study archaeological features in agricultural land are not well established [25]. This gap inhibits efforts to understand and account for the effects of past human activities through the alteration of soils, topography, and plant communities on the state of today's agricultural landscapes. In parallel, it complicates efforts to improve knowledge about the presence and character of sub-surface archaeology and to manage agricultural land's long-term heritage.

The *ipaast-czo project* aims to help bridge this gap by exploring the basis for a more coordinated approach to the collection, analysis, and exchange of sensing data between actors and organisations working in archaeological, heritage, agricultural, and environmental domains. To do so, the project analyses the relationships between the current objectives of these domains, investigating what sensing data practitioners believe they need for their applications, and assessing perceptions of benefits and disadvantages of coordination.

To clarify the relationship between the broad objectives of these domains, the project undertook a review of the key concepts of anthropogenic landscape change and ecosystems used in agricultural, agri-environmental, and archaeological literature. Building on concepts identified in this review, the project team established a framework for studying landscapes which bridges approaches used in these domains. This conceptual work is essential because a shared understanding of how landscapes work is needed so that practitioners can identify connections between their own models and sensing datasets and those used by colleagues in other land management domains. The outcomes are summarised in Section 2.

To assess the potential for developing interoperable workflows for the acquisition and analysis of sensing data that are compatible with the objectives of agri-environment and heritage land management, the *ipaast-czo project* (https://ipaast-czo.glasgow.ac.uk/, accessed on 17 September 2022) team gathered information on sensing data users' needs, current working practices, and perceptions of benefits and disbenefits to changes in practice (Section 3). This practice-focussed assessment was designed around three high-level questions:

1. How can information on buried archaeological remains, largely invisible when viewed from the ground, support the aims of sustainable agricultural land management?

2. How can contemporary archaeologists work at an extensive scale, commensurate with that of current landscape change, while maintaining the level of detail needed to tease out specific human impacts?
3. How can land managers and farmers benefit from the use of archaeological methods and insights when working to develop more sustainable practices?

The user needs that were identified in this study are summarised in Section 4. Key aspects of current practice are set out in Section 5, which are discussed in relation to sensor choice, data collection, and analytical practices (Sections 5.1 and 5.2) and to data governance paradigms (Section 5.3). Based on the barriers identified, suggestions for potential changes in practice are made in Section 5. Building on these suggestions, we argue that a coordinated and collaborative cross-domain approach to the use of sensing technologies on agricultural land has the potential to improve processes in and enhance the outcomes of sustainable agricultural land management, heritage management, and research on changing agricultural landscapes in multiple domains.

1.2. Research Context and Motivations

1.2.1. Changing Values

Recent legislation in the UK (Agriculture Act 2020 and Environment Act 2021) and the latest CAP reforms in Europe [26] are asking farmers, agricultural land managers, and regional bodies to significantly change how they manage their land. They insist that practices ensuring food production are balanced with practices that promote environmental sustainability, contribute to addressing the climate crisis, safeguard natural and cultural heritage, and enhance rural communities [27–30]. This reflects a growing broader societal concern in the UK and EU with these issues and a rebalancing of what is considered valuable.

A growing cohort of farmers and land managers are pursuing more sustainable farming strategies, motivated by their own changing ideas of what it means to be a ‘good farmer’ [31–34], going beyond what is required by the regulations. Here, we are using ‘sustainable agricultural land management’ and ‘sustainable farming’ as umbrella terms, encompassing diverse economic, social, cultural, and environmental aims and approaches, including agroecology, regenerative agriculture, the pursuit of nature-based solutions in farming, and other land management strategies in which environmental sustainability is given substantive value comparable to that of productivity [35]. The broader move toward sustainable farming reflects a new understanding of what defines ‘good farming’, including the value of being perceived as financially savvy, conscious of environmental sustainability, and engaged with local community issues. An important aspect of this transformation is a heightened awareness amongst farmers and the wider public of the effects of agricultural interventions on the physical environment and the role of people in shaping agricultural landscapes, maintaining healthy soils, and promoting biodiversity.

Archaeologists and cultural heritage managers, engaged in diverse activities through research, development-led, agency and charity-based projects addressing landscape archaeology and management of heritage in the landscape [36–38], have been prompted to rethink their professional aims by changes in regulatory frameworks, economics, and their own values. There is a new emphasis on archaeology’s public benefits, including informing and inspiring ways to pursue more sustainable practices [39–43] by providing information on the long-term effects of human interactions with the environment.

1.2.2. Changing Sensing Applications to Reflect Changing Values and Aims

The changes in the wider values and aims of both sectors described above lead to a convergence in objectives. Agriculturalists and archaeologists are now incentivised to better understand: the properties of the biophysical landscape; how land management activities transform soils and topography; how these changes alter insect, plant, and animal communities; how these changes accumulate and play out over time; and the impacts of past human actions on present-day sustainability. Data are needed to characterise the diverse aspects of the biophysical landscape and socio-environmental processes operating within it to meet these mutual objectives.

Remote and near-surface sensing methods have been used in both domains for several decades to provide data on the physical, chemical, and biological characteristics of soils and plants, which are major components of agricultural land, and to monitor the changes in them. The traditional objective of archaeological applications of these methods is to detect and characterise archaeological features and, in the context of heritage management, to monitor their condition to avoid their degradation and loss [44–46]. Precision agriculture (PA), a term referring to strongly digitalised approaches to farming that make use of sensing technologies and digital data to inform management, traditionally used sensing technologies to maximise food production and profitability and to comply with regulations [47]. This included undertaking activities such as implementing location-specific interventions, monitoring impacts and reporting and verification (MRV) exercises, as well as collecting data on a substantively overlapping set of properties of soils and their effects on crop development [48].

In both domains, the rapid proliferation of digital technologies and tools over the past decade, accelerated by the COVID-19 pandemic, is promoting experimentation with the use of digital methods including the expanded use of sensing technologies [19,49,50]. Some of these experimental applications are designed to serve the traditional aims of each domain, introducing new instrumentation capable of informing on a broader range of characteristics of the landscape or of collecting and analysing more detailed data over extensive areas, the latter often enabled using machine learning. Other applications are proposed to meet the emerging needs of sustainable land management. In precision agriculture, this includes the use of sensing technologies to inform practices that support healthy soils and crops, reduction of erosion, carbon sequestration, and related objectives [51,52]. In archaeological prospection, this encompasses the use of sensing technologies to detect and characterise a wider range of targets, including technosols and anthrosols, and to characterise past environments [53–56].

Practitioners of precision agriculture deploy sensing technologies such as electromagnetic induction (EMI), electrical resistance survey, and gamma-ray spectroscopy (GRS), which are focused on characterising soils, and narrowband multispectral sensors, fluorescence instruments, and lidar, which are used to assess Leaf Area Index (LAI) and biomass, on UAV, tractor, and cart platforms and collect further data from in situ instruments for local monitoring of weather and soil moisture [57]. The Aspexit tools directory, which aims to provide an updated resource on available technologies to the precision agricultural community, lists over 1200 tools of which approximately 400 are sensors or imagery sources (https://www.lesoutilsnumeriquesdesagriculteurs.com/, accessed on 4 May 2022).

Precision agriculture also makes extensive use of centrally collected satellite and aerial imagery. In UK and European contexts, the ESA Sentinel-1 and Sentinel-2 missions produce widely used data. Commercial satellite imagery is also used where higher spatial resolution is considered valuable. These data are increasingly supplemented by local calibration data, collected using a range of means including UAV or terrestrial vehicle-based surveys and input of images collected on the ground using a sensor or a smartphone [58,59]. These calibration data are used to improve the predictions and models created using satellite conditions, with the aim of increasing their accuracy for the local area [60]. Based on their representation in the Aspexit directory and literature reviews, the use of IoT sensors providing data on soil moisture, soil temperature, and local weather conditions is likewise increasing [61,62]. These data also play a role in the calibration of models and predictions created using sensing and imaging data.

Archaeologists using sensing data typically deploy technologies including narrowband and broadband multispectral imaging, ground penetrating radar (GPR), and magnetometry and electrical resistance surveys, whereas EMI and magnetic susceptibility are used to a lesser extent. Long-running aerial photographic survey projects and, more recently, projects that process and interpret airborne lidar, are also key data sources both for identifying anomalies and for tracking changes over time, as some aerial surveys have collected data intermittently for several decades. Again, satellite imagery is widely used, with a greater emphasis on the use of commercial sensors because a higher spatial resolution is prioritised for many applications, though the use of the Sentinel-1 and Sentinel-2 imagery has increased [44,45,63,64].

The overlap in sensing technologies used in these domains is evident in the brief summaries given here. We argue that the continued separation between their work with sensing data is partly rooted in the absence of a shared model of the relationship between the character of the land in the past and its changing character in the present, and how this relationship might impact data interpretation.

2. Method: Developing a Conceptual Framework to Bridge Models of Landscape Change Used in Archaeology and Agriculture

2.1. Why a New Conceptual Framework Is Necessary

Ecosystem services are the dominant conceptual framework underpinning agri-environmental land management today. They are actively promoted as a key to the encouragement of ecologically and socially sustainable practices by a range of actors, including farmers and land managers [65]. While there are varying definitions of ecosystem services [51,66–68], they share a core concept of describing ecosystem properties that benefit human wellbeing [69,70]. Simplistically, in this framework, humans make interventions in ecosystems to obtain more benefits from them. Attention to environmental (non-human) actors and processes is tightly focused on what enables and detracts from their capacity to deliver ecosystem services—to produce things that are valuable to humans.

The implicit placement of humans outside ecosystems and the 'inputs and outputs' framing of ecosystem services are counterproductive to developing an understanding of humans as participants in ecosystems and to modelling human activities as long-term processes. Understanding this is necessary to create a connection to contemporary archaeological ideas of landscape, in which these concepts are central, which provide the context for many archaeological applications of sensing data. To provide an alternative framework, we combine anthropogenic Critical Zone modelling and Latour's 'terrestrial' concept [71].

2.2. The Critical Zone as a Unifying Framework

The argument that agricultural land is the product of anthropogenic as well as environmental processes is now familiar [72–75]. The scientific concept of the 'Critical Zone' provides a well-developed framework for thinking about and modelling these processes. The Critical Zone is characterised as, "the region above and below the Earth surface, extending from the tops of the trees down through the subsurface to the bottom of the groundwater. It is a living, breathing, constantly evolving boundary layer where rock, soil, water, air, and living organisms interact." [76] The concept covers processes on multiple timescales [76] and provides a model for thinking about the diverse dynamics involved in shaping life on the earth's surface [77,78]. It promotes a range of computationally or analytically implementable models which can be used to investigate these systems [79–82]. The importance of soils, central to agricultural land management, in Critical Zone dynamics has been argued forcefully, highlighting their role in water systems, food systems, biological networks, and carbon cycling [83–85].

While the inclusion of human factors in early formal Critical Zone models was limited in practice [86], accounting for them is now widely recognised as necessary both scientifically, to support sustainability by understanding how people and environments operate together, and politically, to engage people with the process of sustainability-oriented land management. Current Critical Zone modelling and observation projects are designed to observe anthropic and environmental processes together [80,87,88] and are described as studying the 'Anthropogenic Critical Zone'. Anthropogenic Critical Zone modelling places explicit emphasis on transdisciplinary research, including social sciences and humanities [72,86,89]. Thus, it shares aspects of human ecodynamics [90,91], environmental humanities [92,93], and landscape ecology [94–96], providing a clear link to frameworks currently used in archaeology and heritage management [97,98].

Latour has drawn extensively on this concept in his writing on the Critical Zone [72,86] and arguments for what he terms a 'terrestrial' [71,99–102] orientation in policy and practice. He calls for "a critical, participatory relationship to our living world." His 'terrestrial project' framework provides a critical link between the scientific Critical Zone model and the aims and practices of land management [101,102] through its call to action. Putting these concepts into practice enables us to move beyond the framework provided by ecosystem services and encourages the development of methods and practices that better account for long-term anthropogenic impacts on the land.

2.3. Benefits of the Proposed Conceptual Framework

The Critical Zone framework provides a model in which archaeological prospection data on present-day agricultural land can be integrated with precision agricultural sensing data. Archaeological prospection contributes information on past human activities and the cumulative outcomes of past human–environment interactions [103,104], while data from precision agriculture adds information on present-day human activities and the outcomes of contemporary human–environment interactions. Brought together, these data can form a rich information resource for farmers, land managers, and researchers. Further information may be generated by interpreting precision agricultural data on soils using archaeological methods and vice versa.

Combining these data improves our capacity to account for the persistent impacts of past human actions that are widely distributed, accumulate over an extended period, and may affect future agricultural soil systems. This can contribute to land management decision-making in concrete, local terms. It can also draw further attention to the long-term role of people in agricultural soil formation. The combination of these data in a Critical Zone framework can shift thinking about the spatial and temporal dynamics of the processes and materials which make up agricultural landscapes, leading to the development of more robust and nuanced models, supporting research on landscape dynamics.

3. Method: Assessing Stakeholder Needs, Current Practice, and Barriers to Change

The community involved in creating and using sensing data for land management is diverse. To assess their needs and working practices, individuals were assigned to stakeholder groups, broadly composed of (1) farmers and landowners, (2) academics working on topics across archaeology, environment, agriculture, and remote sensing, (3) development-led archaeology professionals, and (4) professionals in organisations with land management remits or organisations which use aggregated data on land management practices. Organisations and individuals acting as specialist data providers or data brokers serving these groups form a further group of stakeholders, whose needs are strongly informed by those of the other groups. These stakeholders collect, exchange, analyse, and make decisions based on data on soils, crops, weather, and other variables related to landscape, land cover, and land use (Figure 1). Many members of these stakeholder groups are engaged in more than one activity, for example, both producing data and using data produced by others in an analysis, or both analysing data and making decisions on land management.

Individuals from across these groups were invited by the *ipaast* project team to participate in semi-structured interviews, workshops, or both. Some individuals were identified using the literature review, some using participation at conferences, and others using the network of the project team. Invitations were issued aiming to achieve representation across the stakeholder groups relevant to the project and technical expertise.

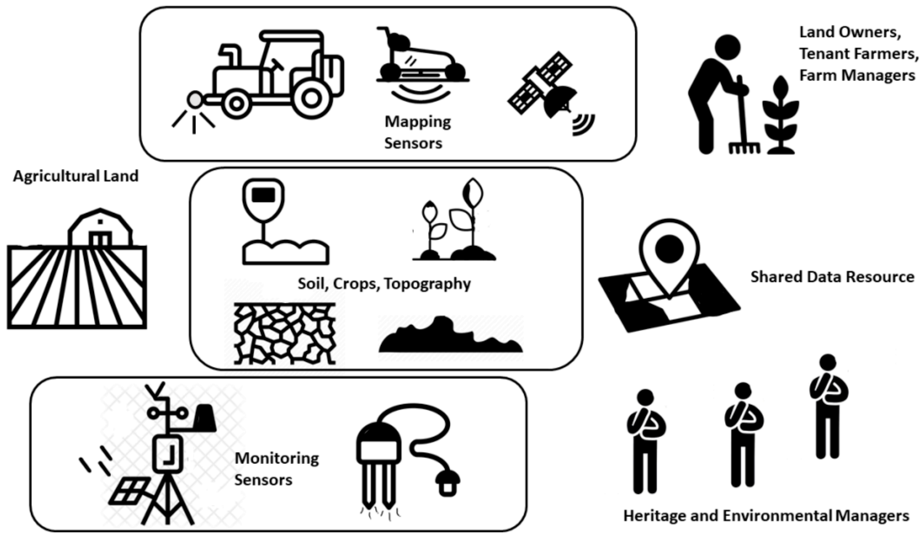

Figure 1. This schematic representation of sensors (**top** and **bottom**), targets of mapping and monitoring projects (**centre**), data, and stakeholders who employ these technologies (**right**) provides an overview of the key socio-technical components of an integrated approach to sensing for sustainable agricultural land management.

In the first year of the project, interviews and workshops comprised engagement with seventy-six individuals representing this broad stakeholder community using one-on-one semi-structured interviews, participant observation during workshops, and group discussions during six workshops. Further workshops and interviews took place during the second year of the project. Most interview participants had 20 or more years of professional experience, and sessions ran for c. 50 min, totalling access to c. 1573 years of experience and c. 61 hours of interviews. The practitioners participating in semi-structured interviews were asked about their aims, data requirements, and working practices, as well as their willingness to change practices, share data, and significant barriers. Specific questions were tailored to the expertise and role of each participant.

Workshops were used to engage further with professionals interviewed and to gather input from a wider group (Figure 2). Workshops ranged in length from three hours for virtual workshops to eight hours for in-person workshops. Some workshops focussed on the applications of specific sensing technology suites, with separate meetings on aerial and satellite remote sensing and near-surface geophysical prospection. Further workshops explored potential approaches to integrated sensing-led planning for agricultural land management on a specific estate or farm. One workshop focussed specifically on sensing and monitoring data to characterise soil systems.

Reports on workshops are published on the *ipaast* project website, as are themed bibliographies resulting from the literature review. A full formal analysis of the interviews and workshops from both years of the project, using thematic analysis, is ongoing. The preliminary study presented here relies on points that interviewers raised in multiple interviews and on paper-based exercises in workshops where participants were asked to summarise group discussions and identify potential future collaborative directions. It also draws on discussions within the *ipaast project* team, who are practitioners of archaeological and precision agricultural sensing.

Figure 2. Participants in *ipaast* project workshops provided information on their needs as data users, current practices in their work, and their views on the challenges and potential of working together.

4. Results: What Sensing Data Is Needed?

4.1. For Farmers and Landowners

Three key objectives of farmers and landowners when using sensing technologies were reflected in the summary reporting on the uptake of precision agricultural methods. The first was to improve yields, either in quality or quantity, by using sensing data to plan actions such as variable rate fertiliser application. The second was to maintain soil, viewed as an important resource, by planning management actions such as adjusting tillage depth. The third was to benefit financially and socially from participation in agri-environment schemes, by using data to inform management decisions and to demonstrate that actions are being taken and having the desired effect [105,106]. We note that many farmers commission companies specialising in agricultural surveys to collect, analyse, and report on sensing data.

Variable rate application technologies allow farmers to adjust fertiliser and irrigation applications, track the effectiveness of treatments, improve yields, and maintain soils. To inform them, data on soil property variations are needed. Typical properties measured using sensing technologies include soil electric conductivity, measured using an EMI instrument, and soil colour, assessed using multispectral or hyperspectral imaging. These data are typically calibrated using lab analysis of soil samples for properties including pH, bulk density, and SOC levels. Farmers require these calibration data to connect sensor data to soil physical properties and soil type [107].

To assess the impacts of variable rate treatments during the growing season, the spectral properties of crops at different stages of their development are measured, typically using narrowband multispectral or hyperspectral instruments. Such sensors are typically mounted on agricultural vehicles or UAVs when farmers are collecting their own data. Publicly available Sentinel-2 data products are another common source of spectral data [108].

Mirroring what is reported in national and EU-level studies, participants in the interviews and workshops discussions noted current interest in the measurement of soil carbon and soil carbon storage capacity [109,110] as well as overall soil health and environmental stewardship [111,112]. Interest in gamma-ray spectroscopy as a sensing technique is notable for its potential to provide information on multiple soil properties, including properties related to soil carbon. Increasing interest in the development of sensors that provide detailed assessments of crop development and crop health was noted in interviews and workshops, as variations in crop conditions can be used to infer local differences in soil conditions including those caused by the presence of buried archaeological remains. High-resolution data were of particular interest to the growers of high-value crops, providing improved local baselines for the use of satellite image-based monitoring systems [113–115]. These include plant-contact spectral sensors and narrowband spectral sensors with tuneable spectral bands mounted on agricultural vehicles and UAVs.

When asked about the spatial resolution required for their sensing data, most landowners and farmers noted this was constrained by the size of the agricultural vehicles used to undertake management actions. In practice, sensing data at a 10–20 m sampling distance between lines and 1–3 m along lines is considered suitable for the creation of management zones for typical applications such as applying variable rate fertiliser, whereas more detail is needed for some applications, e.g., targeted weeding. Very high-resolution data was rarely perceived as useful by the *ipaast* project participants, except for those working with high-value crops, who are a minority within this stakeholder group.

More frequently collected sensing data is a priority for these users, especially for applications where the impacts of a management intervention are being reported or where crop development is being actively monitored. The temporal resolution required ranges from weekly (e.g., crop greenness during development) to multi-year (e.g., changes in soil acidity).

Farmers and land managers continue to be required to steward known archaeological remains within their land, particularly scheduled monuments [116], and the need for data to facilitate this was expressed by some, but not all, participants. Some noted that there is no agreed or established practice for the use of sensing data in the condition monitoring processes.

In summary, farmers and landowners emphasise the need for sensing data on a range of soil properties and conditions, on crop development as it progresses, on yield, and on the impacts of treatments, interventions, and management strategies. The increasingly varied incentives and tasks for farmers working within ecosystem services frameworks are driving the emergence of a diverse range of precision agricultural technologies to produce relevant data and information. The uptake of this wider range of technologies reported by participants in the *ipaast* project activities was limited, suggesting the need for them is not yet compelling. The technology requirements and uses reported by the *ipaast* interview and workshop participants broadly reflect those reported in the literature.

4.2. For Development-Led Archaeologists and Archaeological Researchers

Most archaeological projects that use sensing data in the UK and Europe are embedded within the planning process, taking place in advance of development. A smaller set of projects are carried out for heritage management and research (While no specific assessment of the distribution of geophysical projects has been carried out, this is extrapolated from the overall distribution of Archaeological labour. A 2019 survey by Landward for ALGAO showed that approximately 5000 of 6800 archaeologists in England, Wales, and Scotland work in development-led archaeology [117].). For development-led sensing data users, the primary aim is the efficient detection of areas of 'high archaeological potential' to inform the planning process. Consequently, these users prioritised sensors that could be deployed rapidly in a range of conditions and analysed quickly, and which matched in-house expertise. Magnetic gradiometry sensors (a commonly used type of magnetometry setup) are the most used instruments to meet these objectives, whereas ground penetrating radar data are used secondarily, particularly in urban contexts. Existing sensing data from airborne lidar, multispectral satellite imagery, and conventional colour aerial photography are also regularly used. Because of the need to characterise features and assess their potential significance, very high spatial resolution is widely perceived to be a key requirement by these users. Temporal resolution, in contrast, is unimportant, as data is collected once.

Some development-led users saw a secondary need for sensing data that could support their community engagement work within larger infrastructure schemes. The type of sensor data used was not expressed as important, but again very high spatial resolution was prioritised because this was deemed necessary to produce compelling visual representations of buried features. While the *ipaast* project team envisaged a wider set of potential uses for more diverse types of sensing data in development-led archaeology, these did not match with the needs most expressed by practitioners.

Research users noted a wider range of sensing data needs, contingent on their specific research focus, in addition to sharing the need to detect and characterise potential archaeological features. Notably, there was greater interest from this group in the availability of data from sensors that could inform on a wider range of buried soil properties, including EMI and magnetic susceptibility data, to refine characterisation without excavating.

Most archaeological researchers emphasised the need for very high spatial resolution data to identify and characterise archaeological anomalies [64,118], reflecting the scale of conventional objects of study: physical features produced by human activities, which are observed at a micro-scale from sub-meter to 10 s of meters [53,119,120]. Improved sampling and coverage of sensing data were also listed as key needs across this group. While development-led work has generated a substantive data resource, for researchers aiming to create robust information on landscape-scale patterns of past land use, settlement and human–environment interactions, the need for data on areas not under consideration for development was noted by the *ipaast* project participants. This requirement was related to the objective of avoiding sampling biases which could create a misleading picture of past patterns. These users, when asked about the potential for data from precision agriculture to meet their need for improved coverage and sampling, expressed interest but also reservations because of their perceived need for high spatial resolution data, paralleling the concerns of development-led archaeologists.

4.3. For Managers in Organisations with a Land Management Remit

Organisations and agencies with land management remits operate in the agricultural, environmental, and heritage management domains, and their remits may cross over them. The bulk of their work that uses sensing data falls under three broad objectives. First, ensuring compliance with regulatory schemes and assessing individual applications to undertake activities affecting the land [121–123]. Second, planning and monitoring to meet regional targets related to the land, such as increasing biodiversity, and planning of land use change, such as selection of appropriate areas for the transition from arable to woodland [17,124]. Third, collating and maintaining authoritative datasets on the character of various aspects of the land and monitoring their changing conditions. As learned in discussions with farmers and landowners, most of these users commission specialists to collect sensing data and rely on their advice. They are typically working with reports and information derived from sensing data, as non-specialist users.

Local government archaeology officers and national organisation staff who use sensing data regularly in compliance and application-driven work suggested that any data that can help to inform decision-making and planning was needed, including data at a lower spatial resolution than needed for characterisation and significance assessments. Some heritage managers within government organisations have stated that circa 10 m spatial resolution would be useful to support decision-making on scheme applications and in planning land use change if translated into an assessment of archaeological potential, while others pointed to the need to assess significance and the requirement for high-resolution data for this work (*ipaast-czo* project interviews). They further noted that data was assembled on a per-application basis, so consistent coverage or availability was less important.

The need for interpreted outputs of ‘raw’ sensor data that are easily understood by non-technical staff was strongly expressed by this group, as was the need for mapped data rather than reports. Management users stated the specific need for agreed indicators of environmental or archaeological potential, of higher local variability in soils, or of change over time in management strategies or conditions. The mowing and ploughing event layers generated using Sentinel-1 and Sentinel-2 multispectral satellite imagery are a good example of the kind of indicator data which matches these needs, and interest in their use was indicated by these practitioners when it was presented.

The need for training and guidance in the use of new data sources and indicators was emphasized by practitioners interviewed within government organisations, a sentiment shared by farmers and landowners (*ipaast-czo* project interviews). Given the high number of applications to review, simplicity and clarity of information provided were expressed as a priority. The increasing complexity of the different incentives to be balanced within an ecosystem services framework and emphasis on integrated land management underlines the importance of pre-digested indicators, rather than 'raw' sensor data, for organisational sensing data consumers.

In balance with this, some organisations also have a research remit, and for these data consumers, 'raw' data that can be integrated into research programmes is also valuable. The Scottish and English Forestry Services, NatureScot, and Natural England all conduct research programmes, for example. When asked, the *ipaast* project participants expressed openness to the idea that precision agricultural sensing data could provide a useful source of data on the characteristics of soils and plants and on landscape change. The potential incorporation of precision agricultural data into the research work of these organisations is significant, as the research outcomes may influence future practice and future data requirements.

4.4. For Service Providers

Service providers, such as professionals carrying out soil surveys, supplying monitoring equipment, and hosting data exchange platforms, benefit from consistency in the kinds of sensing data and derivatives produced. Shared 'good practice' and standardisation in data types, formats, and metadata enable their work. For data brokers, the increasing use of cloud platforms and APIs for data exchange creates an increased need for technical interoperability of data and metadata. These needs were expressed by the *ipaast* project participants and are reflected in multiple parallel industry–research partnership projects focused on improving agricultural data interoperability [125–127].

5. Discussion: Perceived Potential Benefits of and Barriers to Coordination

In addition to asking about their sensing data needs, participants in the *ipaast* workshops and interviews were explicitly asked about their views on the issues connected to coordinated data practices. Topics discussed included potential coordination around: adopting sensing methods and technologies from another domain, planning and executing joint data collection, collaborative analysis and interpretation, and archiving and dissemination to improve data discoverability, covering much of the digital data lifecycle. The individuals who agreed to commit time and effort by engaging voluntarily with the *ipaast* project team are, almost by definition, a self-selecting group with a tendency toward openness to seeing what benefits coordination might bring. The perceptions of benefits and barriers reported reflect this openness, but they also show a good degree of pragmatism, with varying views on the likelihood that the benefits could be realised, particularly in light of regulatory and economic barriers, as discussed below.

5.1. Adopting Sensing Methods and Technologies

The potential to adopt new technologies that proved useful in related applications in another domain was, unsurprisingly, perceived as a potential benefit by many *ipaast* participants. Overall, the range of types of sensors employed in precision agriculture to collect information on soils and crops covers and extends beyond the sensors used in archaeology and heritage management, and the greatest benefits of technology transfer were perceived by archaeologists in the group. In contrast, participants using sensing in agriculture perceived fewer potential benefits from adopting instrumentation used in archaeology. The deluge of new technologies on offer to farmers and landowners working with precision agricultural methods may explain this overarching difference in attitudes. Tempering any perceived benefits, as alluded to above, all domains have strong norms around the types of data needed for different applications. The perception by some participants that it would be necessary to benchmark any new instrument against existing methods creates a disincentive to adopt new technologies, limiting the potential for coordinated data collection. Reviewing perceptions of the potential benefits of the adoption of a few technologies and methods illustrates the mixed views expressed.

The Internet of Things (IOT) monitoring sensors are used in precision agriculture to provide monitoring of state variables including soil moisture and temperature, alongside local weather conditions. They were perceived as having the potential to meet the need for extensive ongoing monitoring of soil conditions at heritage sites by some participants from organisations with land management remits. This represents a significant change in archaeological sensing practice, traditionally focussed on feature detection rather than condition monitoring. While there was interest in potential gains in the efficiency of monitoring, in this case, uncertainty around how the data from the IOT sensing instruments could be benchmarked against traditional condition monitoring methods was perceived as a barrier.

Calibration of sensing data with lab analysis of physical samples is more common amongst agricultural than archaeological practitioners because agricultural applications have a greater need to compare between surveys. Increased acquisition and use of calibration data by archaeological surveyors could make archaeological data more interoperable between projects and more reusable by agricultural practitioners. The benefits of making sensing data more comparable were presented and discussed as good practice for archaeologists. However, in this case, the costs involved in calibration were perceived as a barrier that might outweigh potential benefits in the present context.

Magnetic gradiometry is extensively used in archaeological applications to map soils, as noted above, and magnetic susceptibility data are sometimes also used to refine soil maps and interpretations. Magnetic data are frequently collected during EMI surveys by agricultural practitioners, but these data are not analysed or used to generate outputs for farmers and landowners. Changing practice to retain the magnetic component in agricultural analyses of EMI data could meet multiple stakeholders' need for improved soils maps and create a potential for data reuse across domains. In this case, the benefits of making better use of data already being collected was perceived as a clear benefit, but the need for additional training in the analysis and interpretation of these data by agricultural practitioners was seen by some as a barrier.

5.2. Coordinating Data Collection and Analysis

The spatial resolution at which data are collected emerged in workshops and interviews as the critical area where changes might have significant benefits, but this was also the area where there are the most substantial barriers. In summary, as noted above, most development-led and research-oriented archaeologists using sensing data prioritise very high spatial resolution, on the order of 0.2–1 m, and even more extensive surveys executed in this domain cover modest areas compared with typical agricultural surveys. Most agri-environment data users prioritise efficient coverage of large areas and see little benefit in collecting data at a resolution higher than that at which they can change the management of the soil. Data is typically collected at 10–20 m between lines and 1–3 m along lines using tractor-mounted instruments, and 5–10 m resolution data is commonly used in vegetation monitoring. The collection of higher spatial resolution data by agricultural practitioners would benefit archaeologists, who could reuse these data, and agriculturalists, who profit from a new application for their data. However, the initial costs of data collection would increase, and this is perceived to be a major barrier in the current context.

The benefits of and barriers to analysis at different spatial scales are more nuanced. This divergence in analytical scales is partly rooted in how the domains approach the temporal and spatial modelling of the processes and phenomena of interest to them. Many models of environmental processes, including those related to soil formation, water–soil interactions, and soil–plant–insect communities, are designed based on assumptions that the main drivers operate at a relatively extensive scale. Consequently, environmental features and phenomena are documented and studied at an extensive scale and relatively coarse spatial resolution, following a sampling scheme [128–130].

Attention to more local processes and phenomena in agri-environmental studies, which would make use of higher spatial resolution data, could be beneficial as anthropogenic drivers for environmental change become the subject of more research [131–133]. In parallel, as environmental archaeology, geoarchaeology and landscape archaeology, and human modifications of the physical landscape in a broader sense become central, analysis of coarser resolution data covering larger areas could be beneficial to archaeological work. In both cases, the potential benefits are new insights and models, and the barrier is the investment required to develop them.

5.3. Data Management Governance and Infrastructures

Two key barriers to the coordinated use of sensing data between land management communities are differences in governance related to data management and the prevalence of domain-specific data infrastructures. While research data in all domains are increasingly made available on a FAIR basis [134], much data is generated by commercial and private organisations, and access to them is the focus of this section.

In the UK and Europe, the policies and guidance about data management in cultural heritage and archaeology are influenced by the Malta (Valletta) convention, which framed archaeology as something to be managed to benefit the public. Consequently, creating social value by providing public access to information is a core principle underlying the governance of data management. How this principle is translated into regulations and common practice varies nationally and regionally, as reflected in the work of the SEADDA-COST project [135].

The principles underlying data management in agriculture are rather different. The EU Code of Conduct for data sharing in Agriculture, a benchmark regulatory document developed by a coalition led by Copa-Cogeca and CEJA (2018), recognises the commercial value of agricultural data but aims to promote (and comply with EU regulations around) free flow of information and data sharing. The core principles underlying governance of data management attempt to balance commercial and public interests. While, again, regulation and common practice vary nationally and regionally, they reflect that the current primary value of these data is commercial.

Increasing requirements to demonstrate outcomes of land management practices in EU and UK agri-environment funding schemes, together with interest in environmental research domains in these data, create some incentives for making these data FAIR as they are used or reused in the public sphere. This is particularly the case for precision agricultural data on soil conditions, as the soil has been argued to be a communal or national resource [136]. Increasing the deposit of these data under licences permitting non-commercial use would constitute an impactful first step toward realising the potential for cross-domain data sharing.

These different principles are reflected in each sector's dominant data infrastructures. Archives designed to preserve data, such as the Archaeological Data Service (ADS) [137,138] in the UK, are common in archaeology and cultural heritage management, while platforms designed to exchange data, such as Agrimetrics [125], are typical in precision agriculture. This difference in remit constitutes a barrier.

Further technical barriers are created through domain-specific vocabularies and ontologies used in these infrastructures. In both communities, geospatial metadata standards such as INSPIRE [139] and standard data formats such as HDF are widely used [140]. This enables the discovery of sensing data for a given location using spatial search. However, the recognition of data as relevant requires the alignment of the keywords and summaries used to describe datasets. The use of domain-specific language to describe and document data is a barrier to effective data exchange and reuse [140].

The lack of connections between archives and exchanges serving archaeologists, ecologists, geologists, and precision agriculturalists reinforces silos between domains [22,141,142]. Cross-mapping between vocabularies and ontologies, e.g., AGROVOC, BONARES [126,143], FISH, and the CIDOC CRM [144], and the tagging of data with keywords from both domains would improve technical interoperability and constitute another impactful change in practice which could realise benefits of data sharing.

6. Conclusions

The development of a coordinated approach to working with sensing data used to characterise and monitor agricultural land has significant potential to benefit farmers and landowners, managers, researchers, and professionals working in related domains. Discussions with participants in the *ipaast-czo* project's workshops and interviews highlighted community-wide recognition of the potential of new tools, methods, outputs, and applications for sensing data and, in equal measure, underscored their strong consciousness of the barriers and of the disbenefits of changing embedded working practices. These conversations also highlighted that more research is needed to satisfactorily address the project's original high-level questions. Information on buried archaeological remains may be able to support the aims of sustainable agricultural land management by providing new insights into local soil conditions if the relationship between the presence of diverse buried archaeological deposits and current soil properties related to soil health is better understood. The confidence with which impacts of past human activities could be recognised by archaeologists in coarse-scale data equally requires further investigation, as do the cross-scale effects of these activities. The benefits to land managers and farmers of archaeological methods and insights require demonstration with case studies.

While the practical benefits and drawbacks seem finely balanced at present and further research is needed, the wider benefits in terms of developing a shared understanding of the diverse anthropogenic and environmental processes which interact over the long term in agricultural critical zones may tip the balance in favour of change. Collaboration around technical sensing work can provide a mechanism for better communication and understanding of different groups' needs and perspectives, which are important to the success of efforts to promote integrated sustainable land management. Initiatives such as the "Towards Integrated Cultural/Natural Heritage Decision Making" project have highlighted the need for new strategies to respond and engage proactively, rather than reactively, to planning for the future of the landscape and call for a rethinking of the aims of integrated land management [145,146].

Tully et al. [147] note that "Heritage, agricultural, ecological and community interests interweave within the complex process of 'shaping' cultural landscapes, and yet these elements are rarely addressed through a holistic framework in research or policy making." Collaboration and coordination around shared sensing data and methods is an opportunity to bring thinking from archaeological and heritage domains further into this contemporary discourse, joining it with thinking in agricultural and environmental domains. At the same time, it allows us to raise fundamental questions about the kinds of data we need, the questions we are using these data to answer, and the connection between the long-term past and future of agricultural land.

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References

1. Power, A.G. Ecosystem Services and Agriculture: Tradeoffs and Synergies. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 2959–2971. [CrossRef]
2. Huang, J.; Tichit, M.; Poulot, M.; Darly, S.; Li, S.; Petit, C.; Aubry, C. Comparative Review of Multifunctionality and Ecosystem Services in Sustainable Agriculture. *J. Environ. Manag.* **2015**, *149*, 138–147. [CrossRef] [PubMed]
3. Schaller, L.; Targetti, S.; Villanueva, A.J.; Zasada, I.; Kantelhardt, J.; Arriaza, M.; Bal, T.; Fedrigotti, V.B.; Giray, F.H.; Häfner, K.; et al. Agricultural Landscapes, Ecosystem Services and Regional Competitiveness—Assessing Drivers and Mechanisms in Nine European Case Study Areas. *Land Use Policy* **2018**, *76*, 735–745. [CrossRef]
4. Henle, K.; Alard, D.; Clitherow, J.; Cobb, P.; Firbank, L.; Kull, T.; McCracken, D.; Moritz, R.F.A.; Niemelä, J.; Rebane, M.; et al. Identifying and Managing the Conflicts between Agriculture and Biodiversity Conservation in Europe–A Review. *Agric. Ecosyst. Environ.* **2008**, *124*, 60–71. [CrossRef]
5. Hauck, J.; Schmidt, J.; Werner, A. Using Social Network Analysis to Identify Key Stakeholders in Agricultural Biodiversity Governance and Related Land-Use Decisions at Regional and Local Level. *Ecol. Soc.* **2016**, *21*, 49. [CrossRef]
6. Šūmane, S.; Kunda, I.; Knickel, K.; Strauss, A.; Tisenkopfs, T.; Rios, I.d.I.; Rivera, M.; Chebach, T.; Ashkenazy, A. Local and Farmers' Knowledge Matters! How Integrating Informal and Formal Knowledge Enhances Sustainable and Resilient Agriculture. *J. Rural Stud.* **2018**, *59*, 232–241. [CrossRef]
7. Klerkx, L.; Jakku, E.; Labarthe, P. A Review of Social Science on Digital Agriculture, Smart Farming and Agriculture 4.0: New Contributions and a Future Research Agenda. *NJAS Wagening. J. Life Sci.* **2019**, *90–91*, 100315. [CrossRef]
8. Feliciano, D. Factors Influencing the Adoption of Sustainable Agricultural Practices: The Case of Seven Horticultural Farms in the United Kingdom. *Scott. Geogr. J.* **2022**, *138*, 291–320. [CrossRef]
9. Karimi, A.; Yazdandad, H.; Fagerholm, N. Evaluating Social Perceptions of Ecosystem Services, Biodiversity, and Land Management: Trade-Offs, Synergies and Implications for Landscape Planning and Management. *Ecosyst. Serv.* **2020**, *45*, 101188. [CrossRef]
10. Nelson, E.; Mendoza, G.; Regetz, J.; Polasky, S.; Tallis, H.; Cameron, D.; Chan, K.M.; Daily, G.C.; Goldstein, J.; Kareiva, P.M.; et al. Modeling Multiple Ecosystem Services, Biodiversity Conservation, Commodity Production, and Tradeoffs at Landscape Scales. *Front. Ecol. Environ.* **2009**, *7*, 4–11. [CrossRef]
11. Plieninger, T.; Torralba, M.; Hartel, T.; Fagerholm, N. Perceived Ecosystem Services Synergies, Trade-Offs, and Bundles in European High Nature Value Farming Landscapes. *Landsc. Ecol.* **2019**, *34*, 1565–1581. [CrossRef]
12. Zwetsloot, M.J.; van Leeuwen, J.; Hemerik, L.; Martens, H.; Simó Josa, I.; Van de Broek, M.; Debeljak, M.; Rutgers, M.; Sandén, T.; Wall, D.P.; et al. Soil Multifunctionality: Synergies and Trade-Offs across European Climatic Zones and Land Uses. *Eur. J. Soil Sci.* **2021**, *72*, 1640–1654. [CrossRef]
13. Nellis, M.D.; Lulla, K.; Jensen, J. Interfacing Geographic Information Systems and Remote Sensing for Rural Land-Use Analysis. *Photogramm. Eng. Remote Sens.* **1990**, *56*, 329–331.
14. Steven, M.; Clark, J.A. *Applications of Remote Sensing in Agriculture*; Elsevier: Amsterdam, The Netherlands, 2013.
15. Mulla, D.J. Twenty Five Years of Remote Sensing in Precision Agriculture: Key Advances and Remaining Knowledge Gaps. *Biosyst. Eng.* **2013**, *114*, 358–371. [CrossRef]
16. Weiss, M.; Jacob, F.; Duveiller, G. Remote Sensing for Agricultural Applications: A Meta-Review. *Remote Sens. Environ.* **2020**, *236*, 111402. [CrossRef]
17. Coble, K.H.; Mishra, A.K.; Ferrell, S.; Griffin, T. Big Data in Agriculture: A Challenge for the Future. *Appl. Econ. Perspect. Policy* **2018**, *40*, 79–96. [CrossRef]
18. Ali, B.; Dahlhaus, P. The Role of FAIR Data towards Sustainable Agricultural Performance: A Systematic Literature Review. *Agriculture* **2022**, *12*, 309. [CrossRef]
19. Araújo, S.O.; Peres, R.S.; Barata, J.; Lidon, F.; Ramalho, J.C. Characterising the Agriculture 4.0 Landscape—Emerging Trends, Challenges and Opportunities. *Agronomy* **2021**, *11*, 667. [CrossRef]
20. Durrant, A.; Markovic, M.; Matthews, D.; May, D.; Leontidis, G.; Enright, J. How Might Technology Rise to the Challenge of Data Sharing in Agri-Food? *Glob. Food Secur.* **2021**, *28*, 100493. [CrossRef]

21. Roussaki, I.; Doolin, K.; Skarmeta, A.; Routis, G.; Lopez-Morales, J.A.; Claffey, E.; Mora, M.; Martinez, J.A. Building an Interoperable Space for Smart Agriculture. *Digit. Commun. Netw.* 2022, *in press*. [CrossRef]
22. Delgado, J.; Short, N.; Roberts, D.; Vandenberg, B. Big Data Analysis for Sustainable Agriculture on a Geospatial Cloud Framework. *Front. Sustain. Food Syst.* **2019**, *3*, 54. [CrossRef]
23. Whitcraft, A.K.; Becker-Reshef, I.; Justice, C.O.; Gifford, L.; Kavvada, A.; Jarvis, I. No Pixel Left behind: Toward Integrating Earth Observations for Agriculture into the United Nations Sustainable Development Goals Framework. *Remote Sens. Environ.* **2019**, *235*, 111470. [CrossRef]
24. Shen, Y. Transdisciplinary Convergence: Intelligent Infrastructure for Sustainable Development. *Data Intell.* **2021**, *3*, 261–273. [CrossRef]
25. Moore, T.; Guichard, V.; Sanchís, J.Á. The Place of Archaeology in Integrated Cultural Landscape Management. *J. Eur. Landsc.* **2020**, *1*, 9–28. [CrossRef]
26. European Union. The New Common Agricultural Policy: 2023-27. Available online: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27_en (accessed on 12 February 2022).
27. Dempsey, B. Understanding Conflicting Views in Conservation: An Analysis of England. *Land Use Policy* **2021**, *104*, 105362. [CrossRef]
28. Dessart, F.J.; Barreiro-Hurlé, J.; van Bavel, R. Behavioural Factors Affecting the Adoption of Sustainable Farming Practices: A Policy-Oriented Review. *Eur. Rev. Agric. Econ.* **2021**, *46*, 417–471. [CrossRef]
29. Hasler, B.; Termansen, M.; Nielsen, H.Ø.; Daugbjerg, C.; Wunder, S.; Latacz-Lohmann, U. European Agri-Environmental Policy: Evolution, Effectiveness, and Challenges. *Rev. Environ. Econ. Policy* **2022**, *16*, 105–125. [CrossRef]
30. Heyl, K.; Döring, T.; Garske, B.; Stubenrauch, J.; Ekardt, F. The Common Agricultural Policy beyond 2020: A Critical Review in Light of Global Environmental Goals. *Rev. Eur. Comp. Int. Environ. Law* **2021**, *30*, 95–106. [CrossRef]
31. Brown, C.; Kovács, E.; Herzon, I.; Villamayor-Tomas, S.; Albizua, A.; Galanaki, A.; Grammatikopoulou, I.; McCracken, D.; Olsson, J.A.; Zinngrebe, Y. Simplistic Understandings of Farmer Motivations Could Undermine the Environmental Potential of the Common Agricultural Policy. *Land Use Policy* **2021**, *101*, 105136. [CrossRef]
32. Cusworth, G. Falling Short of Being the 'Good Farmer': Losses of Social and Cultural Capital Incurred through Environmental Mismanagement, and the Long-Term Impacts Agri-Environment Scheme Participation. *J. Rural Stud.* **2020**, *75*, 164–173. [CrossRef]
33. Cusworth, G.; Dodsworth, J. Using the 'Good Farmer' Concept to Explore Agricultural Attitudes to the Provision of Public Goods. A Case Study of Participants in an English Agri-Environment Scheme. *Agric. Hum. Values* **2021**, *38*, 929–941. [CrossRef]
34. de Krom, M.P.M.M. Farmer Participation in Agri-Environmental Schemes: Regionalisation and the Role of Bridging Social Capital. *Land Use Policy* **2017**, *60*, 352–361. [CrossRef]
35. Weith, T.; Barkmann, T.; Gaasch, N.; Rogga, S.; Strauß, C.; Zscheischler, J. (Eds.) *Sustainable Land Management in a European Context: A Co-Design Approach*; Springer Nature: Berlin/Heidelberg, Germany, 2021; Available online: https://library.oapen.org/handle/20.500.12657/41734 (accessed on 10 October 2022).
36. David, B.; Thomas, J. *Handbook of Landscape Archaeology*; Routledge: London, UK, 2016; ISBN 9781315427737.
37. Bloemers, T.; Kars, H.; der Valk, A.V. *The Cultural Landscape & Heritage Paradox: Protection and Development of the Dutch Archaeological-Historical Landscape and Its European Dimension*; Amsterdam University Press: Amsterdam, The Netherlands, 2010; ISBN 978-90-8964-155-7.
38. Hicks, D.; McAtackney, L.; Fairclough, G. (Eds.) *Envisioning Landscape: Situations and Standpoints in Archaeology and Heritage*; Routledge: New York, NY, USA, 2016; ISBN 978-1-315-42953-3.
39. Belford, P. Ensuring Archaeology in the Planning System Delivers Public Benefit. *Public Archaeol.* **2019**, *18*, 191–216. [CrossRef]
40. DeSilvey, C.; Fredheim, H.; Fluck, H.; Hails, R.; Harrison, R.; Samuel, I.; Blundell, A. When Loss Is More: From Managed Decline to Adaptive Release. *Hist. Environ. Policy Pract.* **2021**, *12*, 418–433. [CrossRef]
41. Orr, S.A.; Richards, J.; Fatorić, S. Climate Change and Cultural Heritage: A Systematic Literature Review (2016–2020). *Hist. Environ. Policy Pract.* **2021**, *12*, 434–477. [CrossRef]
42. Richards, J.; Orr, S.A.; Viles, H. Reconceptualising the Relationships between Heritage and Environment within an Earth System Science Framework. *J. Cult. Herit. Manag. Sustain. Dev.* **2020**, *10*, 122–129. [CrossRef]
43. Watson, S. Public Benefit: The Challenge for Development-Led Archaeology in the UK. *Internet Archaeol.* **2021**, *57*. [CrossRef]
44. Tapete, D. Earth Observation, Remote Sensing, and Geoscientific Ground Investigations for Archaeological and Heritage Research. *Geosciences* **2019**, *9*, 161. [CrossRef]
45. Opitz, R.; Herrmann, J. Recent Trends and Long-Standing Problems in Archaeological Remote Sensing. *J. Comput. Appl. Archaeol.* **2018**, *1*, 19–42. [CrossRef]
46. Agapiou, A.; Lysandrou, V. Remote Sensing Archaeology: Tracking and Mapping Evolution in European Scientific Literature from 1999 to 2015. *J. Archaeol. Sci. Rep.* **2015**, *4*, 192–200. [CrossRef]
47. Clapp, J.; Ruder, S.-L. Precision Technologies for Agriculture: Digital Farming, Gene-Edited Crops, and the Politics of Sustainability. *Glob. Environ. Polit.* **2020**, *20*, 49–69. [CrossRef]
48. Sishodia, R.P.; Ray, R.L.; Singh, S.K. Applications of Remote Sensing in Precision Agriculture: A Review. *Remote Sens.* **2020**, *12*, 3136. [CrossRef]
49. Ehlers, M.-H.; Huber, R.; Finger, R. Agricultural Policy in the Era of Digitalisation. *Food Policy* **2021**, *100*, 102019. [CrossRef]

50. Huvila, I. Management of Archaeological Information and Knowledge in Digital Environment. In *Knowledge Management, Arts, and Humanities: Interdisciplinary Approaches and the Benefits of Collaboration*; Handzic, M., Carlucci, D., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 147–169. ISBN 978-3-030-10922-6.
51. Baveye, P.C.; Baveye, J.; Gowdy, J. Soil "Ecosystem" Services and Natural Capital: Critical Appraisal of Research on Uncertain Ground. *Front. Environ. Sci.* **2016**, *4*, 41. [CrossRef]
52. Greiner, L.; Keller, A.; Grêt-Regamey, A.; Papritz, A. Soil Function Assessment: Review of Methods for Quantifying the Contributions of Soils to Ecosystem Services. *Land Use Policy* **2017**, *69*, 224–237. [CrossRef]
53. Lambers, K. Airborne and Spaceborne Remote Sensing and Digital Image Analysis in Archaeology. In *Digital Geoarchaeology: New Techniques for Interdisciplinary Human-Environmental Research*; Siart, C., Forbriger, M., Bubenzer, O., Eds.; Natural Science in Archaeology; Springer International Publishing: Cham, Swizerland, 2018; pp. 109–122, ISBN 978-3-319-25316-9.
54. Siart, C.; Forbriger, M.; Bubenzer, O. *Digital Geoarchaeology: New Techniques for Interdisciplinary Human-Environmental Research*; Springer: Berlin/Heidelberg, Germany, 2017. [CrossRef]
55. Donoghue, D.; Shennan, I. The Application of Remote Sensing to Environmental Archaeology. *Geoarchaeology* **1988**, *3*, 275–285. [CrossRef]
56. Pricope, N.G.; Mapes, K.L.; Woodward, K.D. Remote Sensing of Human–Environment Interactions in Global Change Research: A Review of Advances, Challenges and Future Directions. *Remote Sens.* **2019**, *11*, 2783. [CrossRef]
57. Ahmadi, A.; Emami, M.; Daccache, A.; He, L. Soil Properties Prediction for Precision Agriculture Using Visible and Near-Infrared Spectroscopy: A Systematic Review and Meta-Analysis. *Agronomy* **2021**, *11*, 433. [CrossRef]
58. Emilien, A.-V.; Thomas, C.; Thomas, H. UAV & Satellite Synergies for Optical Remote Sensing Applications: A Literature Review. *Sci. Remote Sens.* **2021**, *3*, 100019. [CrossRef]
59. Revill, A.; Florence, A.; MacArthur, A.; Hoad, S.; Rees, R.; Williams, M. Quantifying Uncertainty and Bridging the Scaling Gap in the Retrieval of Leaf Area Index by Coupling Sentinel-2 and UAV Observations. *Remote Sens.* **2020**, *12*, 1843. [CrossRef]
60. Kerry, R.; Escolà, A. (Eds.) *Sensing Approaches for Precision Agriculture*; Progress in Precision Agriculture; Springer International Publishing: Cham, Swizerland, 2021; ISBN 978-3-030-78430-0.
61. Monteleone, S.; de Moraes, E.A.; Tondato de Faria, B.; Aquino Junior, P.T.; Maia, R.F.; Neto, A.T.; Toscano, A. Exploring the Adoption of Precision Agriculture for Irrigation in the Context of Agriculture 4.0: The Key Role of Internet of Things. *Sensors* **2020**, *20*, 7091. [CrossRef] [PubMed]
62. Nowak, B. Precision Agriculture: Where Do We Stand? A Review of the Adoption of Precision Agriculture Technologies on Field Crops Farms in Developed Countries. *Agric. Res.* **2021**, *10*, 515–522. [CrossRef]
63. Deiana, R.; Leucci, G.; Martorana, R. New Perspectives on Geophysics for Archaeology: A Special Issue. *Surv. Geophys.* **2018**, *39*, 1035–1038. [CrossRef]
64. Schmidt, A.R.; Linford, P.; Linford, N.; David, A.; Gaffney, C.F.; Sarris, A.; Fassbinder, J. *EAC Guidelines for the Use of Geophysics in Archaeology: Questions to Ask and Points to Consider*; EAC Guidelines 2; Europae Archaeologia Consilium (EAC), Association Internationale sans But Lucratif (AISBL): Namur, Belgium, 2015; ISBN 978-963-9911-73-4.
65. Angelstam, P.; Munoz-Rojas, J.; Pinto-Correia, T. Landscape Concepts and Approaches Foster Learning about Ecosystem Services. *Landsc. Ecol.* **2019**, *34*, 1445–1460. [CrossRef]
66. Kadykalo, A.N.; López-Rodriguez, M.D.; Ainscough, J.; Droste, N.; Ryu, H.; Ávila-Flores, G.; Le Clec'h, S.; Muñoz, M.C.; Nilsson, L.; Rana, S.; et al. Disentangling 'Ecosystem Services' and 'Nature's Contributions to People'. *Ecosyst. People* **2020**, *16*, 269–287. [CrossRef]
67. Braat, L.C.; de Groot, R. The Ecosystem Services Agenda:Bridging the Worlds of Natural Science and Economics, Conservation and Development, and Public and Private Policy. *Ecosyst. Serv.* **2012**, *1*, 4–15. [CrossRef]
68. Gray, M. The Confused Position of the Geosciences within the "Natural Capital" and "Ecosystem Services" Approaches. *Ecosyst. Serv.* **2018**, *34*, 106–112. [CrossRef]
69. Leviston, Z.; Walker, I.; Green, M.; Price, J. Linkages between Ecosystem Services and Human Wellbeing: A Nexus Webs Approach. *Ecol. Indic.* **2018**, *93*, 658–668. [CrossRef]
70. Costanza, R. Valuing Natural Capital and Ecosystem Services toward the Goals of Efficiency, Fairness, and Sustainability. *Ecosyst. Serv.* **2020**, *43*, 101096. [CrossRef]
71. Latour, B. *Down to Earth: Politics in the New Climatic Regime*; John Wiley & Sons: Hoboken, NJ, USA, 2018; ISBN 978-1-5095-3059-5.
72. Aguilar, R.G.; Owens, R.; Giardino, J.R. The Expanding Role of Anthropogeomorphology in Critical Zone Studies in the Anthropocene. *Geomorphology* **2020**, *366*, 107165. [CrossRef]
73. Kuzyakov, Y.; Zamanian, K. Reviews and Syntheses: Agropedogenesis—Humankind as the Sixth Soil-Forming Factor and Attractors of Agricultural Soil Degradation. *Biogeosciences* **2019**, *16*, 4783–4803. [CrossRef]
74. Adderley, W.P.; Wilson, C.A.; Simpson, I.A.; Davidson, D.A. Chapter 26—Anthropogenic Features. In *Interpretation of Micromorphological Features of Soils and Regoliths*, 2nd ed.; Stoops, G., Marcelino, V., Mees, F., Eds.; Elsevier: Amsterdam, The Netherlands, 2018; pp. 753–777. ISBN 978-0-444-63522-8.
75. Vanwalleghem, T.; Gómez, J.A.; Infante Amate, J.; González de Molina, M.; Vanderlinden, K.; Guzmán, G.; Laguna, A.; Giráldez, J.V. Impact of Historical Land Use and Soil Management Change on Soil Erosion and Agricultural Sustainability during the Anthropocene. *Anthropocene* **2017**, *17*, 13–29. [CrossRef]

76. The Critical Zone | National Critical Zone Observatory. Available online: https://czo-archive.criticalzone.org/national/research/the-critical-zone-1national/ (accessed on 13 February 2022).
77. Alcántara-Ayala, I.; Berhe, A.A.; Derry, L.; Ganti, V.; Horton, A.A.; Sim, M.S. Reflections on Earth Surface Research. *Nat. Rev. Earth Environ.* **2021**, *2*, 15–20. [CrossRef]
78. Giardino, J.R.; Houser, C. Chapter 1—Introduction to the Critical Zone. In *Developments in Earth Surface Processes*; Giardino, J.R., Houser, C., Eds.; Elsevier: Amsterdam, The Netherlands, 2015; Volume 19, pp. 1–13.
79. Anders, A.M.; Bettis, E.A.; Grimley, D.A.; Stumpf, A.J.; Kumar, P. Impacts of Quaternary History on Critical Zone Structure and Processes: Examples and a Conceptual Model From the Intensively Managed Landscapes Critical Zone Observatory. *Front. Earth Sci.* **2018**, *6*, 24. [CrossRef]
80. Baatz, R.; Sullivan, P.L.; Li, L.; Weintraub, S.R.; Loescher, H.W.; Mirtl, M.; Groffman, P.M.; Wall, D.H.; Young, M.; White, T.; et al. Steering Operational Synergies in Terrestrial Observation Networks: Opportunity for Advancing Earth System Dynamics Modelling. *Earth Syst. Dyn.* **2018**, *9*, 593–609. [CrossRef]
81. Brantley, S.L.; Goldhaber, M.B.; Ragnarsdottir, K.V. Crossing Disciplines and Scales to Understand the Critical Zone. *Elements* **2007**, *3*, 307–314. [CrossRef]
82. Duffy, C.; Shi, Y.; Davis, K.; Slingerland, R.; Li, L.; Sullivan, P.L.; Goddéris, Y.; Brantley, S.L. Designing a Suite of Models to Explore Critical Zone Function. *Procedia Earth Planet. Sci.* **2014**, *10*, 7–15. [CrossRef]
83. Krzywoszynska, A. Caring for Soil Life in the Anthropocene: The Role of Attentiveness in More-than-Human Ethics. *Trans. Inst. Br. Geogr.* **2019**, *44*, 661–675. [CrossRef]
84. Krzywoszynska, A. Nonhuman Labor and the Making of Resources: Making Soils a Resource through Microbial Labor. *Environ. Humanit.* **2020**, *12*, 227–249. [CrossRef]
85. Salazar, J.F.; Granjou, C.; Kearnes, M.; Krzywoszynska, A.; Tironi, M. *Thinking with Soils: Material Politics and Social Theory*; Bloomsbury Publishing: London, UK, 2020; ISBN 978-1-350-10958-2.
86. Minor, J.; Pearl, J.K.; Barnes, M.L.; Colella, T.R.; Murphy, P.C.; Mann, S.; Barron-Gafford, G.A. Critical Zone Science in the Anthropocene: Opportunities for Biogeographic and Ecological Theory and Praxis to Drive Earth Science Integration. *Prog. Phys. Geogr. Earth Environ.* **2020**, *44*, 50–69. [CrossRef]
87. Brantley, S.L.; McDowell, W.H.; Dietrich, W.E.; White, T.S.; Kumar, P.; Anderson, S.P.; Chorover, J.; Lohse, K.A.; Bales, R.C.; Richter, D.D.; et al. Designing a Network of Critical Zone Observatories to Explore the Living Skin of the Terrestrial Earth. *Earth Surf. Dyn.* **2017**, *5*, 841–860. [CrossRef]
88. Gaillardet, J.; Braud, I.; Hankard, F.; Anquetin, S.; Bour, O.; Dorfliger, N.; de Dreuzy, J.r.; Galle, S.; Galy, C.; Gogo, S.; et al. OZCAR: The French Network of Critical Zone Observatories. *Vadose Zone J.* **2018**, *17*, 180067. [CrossRef]
89. Ferraro, J.V.; Hoggarth, J.A.; Zori, D.; Binetti, K.M.; Stinchcomb, G. Integrating Human Activities, Archeology, and the Paleo-Critical Zone Paradigm. *Front. Earth Sci.* **2018**, *6*, 84. [CrossRef]
90. Fitzhugh, B.; Butler, V.L.; Bovy, K.M.; Etnier, M.A. Human Ecodynamics: A Perspective for the Study of Long-Term Change in Socioecological Systems. *J. Archaeol. Sci. Rep.* **2019**, *23*, 1077–1094. [CrossRef]
91. McGlade, J. Archaeology and the Ecodynamics of Human-Modified Landscapes. *Antiquity* **1995**, *69*, 113–132. [CrossRef]
92. Emmett, R.S.; Nye, D.E. *The Environmental Humanities: A Critical Introduction*; MIT Press: Cambridge, MA, USA, 2017; ISBN 978-0-262-03676-4.
93. Heise, U.K.; Christensen, J.; Niemann, M. *The Routledge Companion to the Environmental Humanities*; Taylor & Francis: New York, NY, USA, 2017; ISBN 978-1-317-66019-4.
94. Naveh, Z. Ten Major Premises for a Holistic Conception of Multifunctional Landscapes. *Landsc. Urban Plan.* **2001**, *57*, 269–284. [CrossRef]
95. Naveh, Z.; Lieberman, A.S. *Landscape Ecology: Theory and Application*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2013; ISBN 978-1-4757-2331-1.
96. Sanderson, J. *Landscape Ecology: A Top Down Approach*; CRC Press: Boca Raton, FL, USA, 2020; ISBN 978-1-4200-4867-4.
97. Edgeworth, M. More than Just a Record: Active Ecological Effects of Archaeological Strata. In *Historical Archaeology and Environment*; de Souza, M.A.T., Costa, D.M., Eds.; Springer International Publishing: Cham, Swizerland, 2018; pp. 19–40; ISBN 978-3-319-90857-1.
98. Edgeworth, M. Transgressing Time: Archaeological Evidence in/of the Anthropocene. *Annu. Rev. Anthropol.* **2021**, *50*, 93–108. [CrossRef]
99. Arènes, A.; Latour, B.; Gaillardet, J. Giving Depth to the Surface: An Exercise in the Gaia-Graphy of Critical Zones. *Anthr. Rev.* **2018**, *5*, 120–135. [CrossRef]
100. Latour, B. Some Advantages of the Notion of "Critical Zone" for Geopolitics. *Procedia Earth Planet. Sci.* **2014**, *10*, 3–6. [CrossRef]
101. Latour, B. Is Geo-Logy the New Umbrella for All the Sciences? Hints for a Neo-Humboldtian University. In *The PhD at the End of the World: Provocations for the Doctorate and a Future Contested*; Barnacle, R., Cuthbert, D., Eds.; Debating Higher Education: Philosophical Perspectives; Springer International Publishing: Cham, Switzerland, 2021; pp. 9–23; ISBN 978-3-030-62219-0.
102. Latour, B.; Weibel, P. *Critical Zones: The Science and Politics of Landing on Earth*; MIT Press: Cambridge, MA, USA, 2020; ISBN 978-0-262-04445-5.
103. Gras, C.; Cáceres, D.M. Technology, Nature's Appropriation and Capital Accumulation in Modern Agriculture. *Curr. Opin. Environ. Sustain.* **2020**, *45*, 1–9. [CrossRef]

104. Karlsson, L.; Naess, L.O.; Nightingale, A.; Thompson, J. 'Triple Wins' or 'Triple Faults'? Analysing the Equity Implications of Policy Discourses on Climate-Smart Agriculture (CSA). *J. Peasant Stud.* **2018**, *45*, 150–174. [CrossRef]
105. Khanna, M. Digital Transformation of the Agricultural Sector: Pathways, Drivers and Policy Implications. *Appl. Econ. Perspect. Policy* **2021**, *43*, 1221–1242. [CrossRef]
106. Birner, R.; Daum, T.; Pray, C. Who Drives the Digital Revolution in Agriculture? A Review of Supply-Side Trends, Players and Challenges. *Appl. Econ. Perspect. Policy* **2021**, *43*, 1260–1285. [CrossRef]
107. Nawar, S.; Corstanje, R.; Halcro, G.; Mulla, D.; Mouazen, A.M. Chapter Four—Delineation of Soil Management Zones for Variable-Rate Fertilization: A Review. In *Advances in Agronomy*; Sparks, D.L., Ed.; Academic Press: Cambridge, MA, USA, 2017; Volume 143, pp. 175–245. [CrossRef]
108. Basso, B.; Fiorentino, C.; Cammarano, D.; Schulthess, U. Variable Rate Nitrogen Fertilizer Response in Wheat Using Remote Sensing. *Precis. Agric.* **2016**, *17*, 168–182. [CrossRef]
109. Billings, S.A.; Lajtha, K.; Malhotra, A.; Berhe, A.A.; de Graaff, M.-A.; Earl, S.; Fraterrigo, J.; Georgiou, K.; Grandy, S.; Hobbie, S.E.; et al. Soil Organic Carbon Is Not Just for Soil Scientists: Measurement Recommendations for Diverse Practitioners. *Ecol. Appl.* **2021**, *31*, e02290. [CrossRef]
110. Mandal, A.; Majumder, A.; Dhaliwal, S.S.; Toor, A.S.; Mani, P.K.; Naresh, R.K.; Gupta, R.K.; Mitran, T. Impact of Agricultural Management Practices on Soil Carbon Sequestration and Its Monitoring through Simulation Models and Remote Sensing Techniques: A Review. *Crit. Rev. Environ. Sci. Technol.* **2022**, *52*, 1–49. [CrossRef]
111. Barnes, A.P.; Soto, I.; Eory, V.; Beck, B.; Balafoutis, A.; Sánchez, B.; Vangeyte, J.; Fountas, S.; van der Wal, T.; Gómez-Barbero, M. Exploring the Adoption of Precision Agricultural Technologies: A Cross Regional Study of EU Farmers. *Land Use Policy* **2019**, *80*, 163–174. [CrossRef]
112. Lowenberg-DeBoer, J.; Erickson, B. Setting the Record Straight on Precision Agriculture Adoption. *Agron. J.* **2019**, *111*, 1552–1569. [CrossRef]
113. Browning, D.M.; Russell, E.S.; Ponce-Campos, G.E.; Kaplan, N.; Richardson, A.D.; Seyednasrollah, B.; Spiegal, S.; Saliendra, N.; Alfieri, J.G.; Baker, J.; et al. Monitoring Agroecosystem Productivity and Phenology at a National Scale: A Metric Assessment Framework. *Ecol. Indic.* **2021**, *131*, 108147. [CrossRef]
114. Salinero-Delgado, M.; Estévez, J.; Pipia, L.; Belda, S.; Berger, K.; Paredes Gómez, V.; Verrelst, J. Monitoring Cropland Phenology on Google Earth Engine Using Gaussian Process Regression. *Remote Sens.* **2022**, *14*, 146. [CrossRef]
115. Singh, P.; Pandey, P.C.; Petropoulos, G.P.; Pavlides, A.; Srivastava, P.K.; Koutsias, N.; Deng, K.A.K.; Bao, Y. 8-Hyperspectral Remote Sensing in Precision Agriculture: Present Status, Challenges, and Future Trends. In *Hyperspectral Remote Sensing*; Pandey, P.C., Srivastava, P.K., Balzter, H., Bhattacharya, B., Petropoulos, G.P., Eds.; Earth Observation; Elsevier: Amsterdam, The Netherlands, 2020; pp. 121–146, ISBN 978-0-08-102894-0. [CrossRef]
116. Robertson, D. Outcomes for the Historic Environment. Archaeology East Anglia Report, 47. 2020. Available online: https://www.algao.org.uk/sites/default/files/documents/HEFERSHINE_report_v5.pdf (accessed on 4 January 2023).
117. Rocks-Macqueen, D.; Lewis, B. *Archaeology in Development Management: Its Contribution in England, Scotland & Wales*; Landward Research Ltd.: Sheffield, UK, 2019; ISBN 978-0-9572452-5-9.
118. Schmidt, A.; Marshall, A. The Impact of Resolution on the Interpretation of Archaeological Prospection Data. In *Archaeological Sciences 1995. Proceedings of a Conference on the Application of Scientific Techniques to the Study of Archaeology, Liverpool, UK, July 1995, OXBOW Monogr*; Sinclair, A., Slater, E., Gowlett, J., Eds.; Oxbow Books: Oxford, UK, 1997; pp. 343–348.
119. McGrath, C.N.; Scott, C.; Cowley, D.; Macdonald, M. Towards a Satellite System for Archaeology? Simulation of an Optical Satellite Mission with Ideal Spatial and Temporal Resolution, Illustrated by a Case Study in Scotland. *Remote Sens.* **2020**, *12*, 4100. [CrossRef]
120. Verdonck, L.; De Smedt, P.; Verhegge, J. Chapter 6—Making Sense of Anomalies: Practices and Challenges in the Archaeological Interpretation of Geophysical Data. In *Innovation in Near-Surface Geophysics*; Persico, R., Piro, S., Linford, N., Eds.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 151–194, ISBN 978-0-12-812429-1.
121. Cuca, B.; Hadjimitsis, D.G. Space Technology Meets Policy: An Overview of Earth Observation Sensors for Monitoring of Cultural Landscapes within Policy Framework for Cultural Heritage. *J. Archaeol. Sci. Rep.* **2017**, *14*, 727–733. [CrossRef]
122. Détang-Dessendre, C.; Guyomard, H.; Geerling-Eiff, F.; Poppe, K. EU Agriculture and Innovation: What Role for the CAP? 2018, INRA and WUR. Available online: https://hal.inrae.fr/hal-02789078. (accessed on 4 January 2023).
123. Pe'er, G.; Bonn, A.; Bruelheide, H.; Dieker, P.; Eisenhauer, N.; Feindt, P.H.; Hagedorn, G.; Hansjürgens, B.; Herzon, I.; Lomba, Â.; et al. Action Needed for the EU Common Agricultural Policy to Address Sustainability Challenges. *People Nat.* **2020**, *2*, 305–316. [CrossRef]
124. Movilla-Pateiro, L.; Mahou-Lago, X.M.; Doval, M.I.; Simal-Gandara, J. Toward a Sustainable Metric and Indicators for the Goal of Sustainability in Agricultural and Food Production. *Crit. Rev. Food Sci. Nutr.* **2021**, *61*, 1108–1129. [CrossRef]
125. Allemang, D.; Teegarden, B. A Global Data Ecosystem for Agriculture and Food. *F1000Research* **2017**, *6*, 1844. [CrossRef]
126. Mietzsch, E.; Martini, D.; Kolshus, K.; Turbati, A.; Subirats, I. How Agricultural Digital Innovation Can Benefit from Semantics: The Case of the AGROVOC Multilingual Thesaurus. *Eng. Proc.* **2021**, *9*, 17. [CrossRef]
127. Fulton, J.P.; Port, K. Precision Agriculture Data Management. In *Precision Agriculture Basics*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2018; pp. 169–187, ISBN 978-0-89118-367-9. [CrossRef]

128. Bramer, I.; Anderson, B.J.; Bennie, J.; Bladon, A.J.; De Frenne, P.; Hemming, D.; Hill, R.A.; Kearney, M.R.; Körner, C.; Korstjens, A.H.; et al. Chapter Three—Advances in Monitoring and Modelling Climate at Ecologically Relevant Scales. In *Advances in Ecological Research*; Bohan, D.A., Dumbrell, A.J., Woodward, G., Jackson, M., Eds.; Next Generation Biomonitoring: Part 1; Academic Press: Cambridge, MA, USA, 2018; Volume 58, pp. 101–161. [CrossRef]
129. Cavazzi, S.; Corstanje, R.; Mayr, T.; Hannam, J.; Fealy, R. Are Fine Resolution Digital Elevation Models Always the Best Choice in Digital Soil Mapping? *Geoderma* **2013**, *195–196*, 111–121. [CrossRef]
130. Pradervand, J.-N.; Dubuis, A.; Pellissier, L.; Guisan, A.; Randin, C. Very High Resolution Environmental Predictors in Species Distribution Models: Moving beyond Topography? *Prog. Phys. Geogr. Earth Environ.* **2014**, *38*, 79–96. [CrossRef]
131. Bazzato, E.; Rosati, L.; Canu, S.; Fiori, M.; Farris, E.; Marignani, M. High Spatial Resolution Bioclimatic Variables to Support Ecological Modelling in a Mediterranean Biodiversity Hotspot. *Ecol. Model.* **2021**, *441*, 109354. [CrossRef]
132. He, Y.; Weng, Q. *High Spatial Resolution Remote Sensing: Data, Analysis, and Applications*; CRC Press: Boca Raton, FL, USA, 2018; ISBN 978-0-429-89300-1.
133. McDowell, N.G.; Coops, N.C.; Beck, P.S.A.; Chambers, J.Q.; Gangodagamage, C.; Hicke, J.A.; Huang, C.; Kennedy, R.; Krofcheck, D.J.; Litvak, M.; et al. Global Satellite Monitoring of Climate-Induced Vegetation Disturbances. *Trends Plant Sci.* **2015**, *20*, 114–123. [CrossRef]
134. Wilkinson, M.D.; Dumontier, M.; Aalbersberg, I.J.; Appleton, G.; Axton, M.; Baak, A.; Blomberg, N.; Boiten, J.-W.; da Silva Santos, L.B.; Bourne, P.E.; et al. The FAIR Guiding Principles for Scientific Data Management and Stewardship. *Sci. Data* **2016**, *3*, 160018. [CrossRef] [PubMed]
135. Richards, J.D.; Jakobsson, U.; Novák, D.; Štular, B.; Wright, H. Digital Archiving in Archaeology: The State of the Art. Introduction. *Internet Archaeol.* **2021**. [CrossRef]
136. Brady, M.V.; Hristov, J.; Wilhelmsson, F.; Hedlund, K. Roadmap for Valuing Soil Ecosystem Services to Inform Multi-Level Decision-Making in Agriculture. *Sustainability* **2019**, *11*, 5285. [CrossRef]
137. Richards, J.D. Archiving Archaeological Data in the United Kingdom. *Internet Archaeol.* **2021**, *58*. [CrossRef]
138. Richards, J.D. Twenty Years Preserving Data: A View from the United Kingdom. *Adv. Archaeol. Pract.* **2017**, *5*, 227–237. [CrossRef]
139. Minghini, M.; Cetl, V.; Kotsev, A.; Tomas, R.; Lutz, M. INSPIRE: The Entry Point to Europe's Big Geospatial Data Infrastructure. In *Handbook of Big Geospatial Data*; Springer, Cham: Berlin/Heidelberg, Germany, 2021; pp. 619–641. [CrossRef]
140. Wang, S.; Wang, J.; Zhan, Q.; Zhang, L.; Yao, X.; Li, G. A Unified Representation Method for Interdisciplinary Spatial Earth Data. *Big Earth Data* **2022**, 1–20. [CrossRef]
141. McKeague, P.; Corns, A.; Larsson, Å.; Moreau, A.; Posluschny, A.; Van Daele, K.; Evans, T. One Archaeology: A Manifesto for the Systematic and Effective Use of Mapped Data from Archaeological Fieldwork and Research. *Information* **2020**, *11*, 222. [CrossRef]
142. Tamene, L.; Ali, A.; Tena, W.; Abera, W. *Report on Data Ecosystem Mapping: Mapping of Agricultural Data and Data Holding Institutions*; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Wageningen, The Netherlands, 2021.
143. Specka, X.; Gärtner, P.; Hoffmann, C.; Svoboda, N.; Stecker, M.; Einspanier, U.; Senkler, K.; Zoarder, M.A.M.; Heinrich, U. The BonaRes Metadata Schema for Geospatial Soil-Agricultural Research Data—Merging INSPIRE and DataCite Metadata Schemes. *Comput. Geosci.* **2019**, *132*, 33–41. [CrossRef]
144. Bruseker, G.; Carboni, N.; Guillem, A. Cultural Heritage Data Management: The Role of Formal Ontology and CIDOC CRM. In *Heritage and Archaeology in the Digital Age: Acquisition, Curation, and Dissemination of Spatial Cultural Heritage Data*; Vincent, M.L., López-Menchero Bendicho, V.M., Ioannides, M., Levy, T.E., Eds.; Quantitative Methods in the Humanities and Social Sciences; Springer International Publishing: Cham, Swizerland, 2017; pp. 93–131, ISBN 978-3-319-65370-9. [CrossRef]
145. Bartolini, N.; DeSilvey, C. Landscape Futures: Decision-Making in Uncertain Times, a Literature Review. *Landsc. Res.* **2021**, *46*, 8–24. [CrossRef]
146. Harrison, R.; DeSilvey, C.; Holtorf, C.; Macdonald, S.; Bartolini, N.; Breithoff, E.; Fredheim, H.; Lyons, A.; May, S.; Morgan, J.; et al. *Heritage Futures: Comparative Approaches to Natural and Cultural Heritage Practices*; UCL Press: London, UK, 2020; ISBN 9781787356016.
147. Tully, G.; Piai, C.; Rodríguez-Hernández, J.; Delhommeau, E. Understanding Perceptions of Cultural Landscapes in Europe: A Comparative Analysis Using 'Oppida' Landscapes. *Hist. Environ. Policy Pract.* **2019**, *10*, 198–223. [CrossRef]