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Landscape unit as an element of digital cultural heritage: theory and concepts on the example of Czułów

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Summary

The article presents the role of the landscape unit in the context of digital cultural heritage, analysing the theoretical foundations and concepts on the example of Czułów, a village with a traditional agricultural landscape. In an era of rapid socio-economic change, which often leads to the degradation of traditional landscapes, digital technology is becoming a key instrument in the documentation, analysis and protection of cultural heritage. Modern technologies such as geographic information systems (GIS), 3D modelling, photogrammetry and remote sensing enable precise mapping and the reconstruction of historical land use. This enables a more detailed and comprehensive study of landscape structures and their dynamics, supporting conservation measures and sustainable development planning.

The study of cultural landscapes, involving the analysis of structure, function and change over time, is crucial to understanding the complex relationship between humans and the environment. In particular, landscape units, such as the agricultural terraces at Czułów, reflect historical forms of land use and ways of adapting to natural conditions, thus being important elements of cultural heritage. Their protection and documentation with new technologies is essential to preserve these unique values for future generations.

A multi-criteria approach, which combines different perspectives – geomorphological, use, ecological and cultural – is crucial in landscape analysis as it enables a more comprehensive recognition and understanding of the value of rural space. In this way, a more complete picture of landscape structure and function can be obtained, which is particularly important in terms of protecting agricultural landscapes such as Czułów. The traditional landscape of the village with elements of agricultural terraces and a mosaic of land uses represents not only a natural value but also a cultural one, reflecting the enduring interactions between man and nature. Rural landscapes here are not only a testimony to the historical use of the land, but also a place where the past meets the pre-

sent, influencing the identity of local communities and shaping their future. Digital technologies allow for the documentation of both material and immaterial aspects of the landscape, fostering a better understanding of past land uses and cultural values that may not be apparent to the naked eye. This approach provides a more accurate assessment of historical and cultural values and leads to the planning of effective conservation strategies. The need to adapt conservation efforts to local environmental and social conditions and the challenges of digital archiving of heritage, such as authenticity and accuracy of historical reconstructions, should also be made clear.

Keywords

landscape unit • digital cultural heritage • cultural landscape • sustainable development

1. Introduction

Digital cultural heritage is playing an increasingly important role in the protection, documentation and popularisation of historical and landscape values. As digital technologies become more and more important, their application in landscape research becomes not only possible, but also necessary in order to effectively record and protect various aspects of cultural heritage. One of the key concepts in landscape research is the landscape unit, understood as a spatially distinct whole with specific environmental, natural and cultural characteristics. In the context of digital documentation, this concept takes on a new meaning, enabling more accurate mapping and analysis of landscape structure and functioning.

In the face of rapid socio-economic change that leads to the modification and often degradation of traditional agricultural landscapes, there is an emerging need to protect them effectively. These landscapes are not only natural elements, but also carriers of historical, aesthetic and cultural values, reflecting the way of life of past generations and their relationship with the natural environment. Digital documentation of such landscapes using modern technologies, is becoming a key tool in conservation and popularisation practices. The use of technologies such as photogrammetry, remote sensing or 3D modelling allows for a more precise and multifaceted capture of landscape features and their dynamic changes. Photogrammetric methods are primarily applied to reconstruct and analyse structural surfaces, i.e. those whose imaging contains separable elements in the image, corresponding to physical spatial objects with the possibility to locate them unambiguously.

One of the main research problems is determining how best to delineate landscape units in rural areas to reflect their cultural value and ecological functions.

This paper will present the theoretical basis for the delineation and analysis of landscape units in rural areas, with a particular focus on their role in digital cultural heritage.

2. Characteristics of the study area

Czułów is a village located in the municipality of Liszki, in the Małopolskie Voivodeship, near Krakow. It is characterised by a traditional agricultural landscape with elements of agricultural terraces, stream valleys and a mosaic of land use. It will serve as an

illustration for theoretical considerations on delimitation and description of landscape units within the framework of cultural heritage studies. The village is located on the border of Tenczyński Ridge and Cholerzyński Depression, being part of the Tenczyński Landscape Park. It is distinguished by a picturesque scenery combining hills, valleys and open agricultural spaces. There are two nature reserves in the immediate vicinity of Czułów – the Mnikowska Valley and the Zimny Dół, which further emphasises its high natural values.

The village is predominantly agricultural, with cereal crops such as wheat, barley and corn, which grow thanks to the fertile brown, lessive and alluvial soils. The area of Czułów is characterised by a favourable warm temperate climate, which is suitable for agriculture. At the same time, the village encounters threats such as soil erosion and the risk of flooding due to the Sanka river that flows nearby, a left tributary of the Vistula. As an important element of the cultural landscape, the Sanka river plays an important role in shaping the local ecosystem and land use, which makes it an important object for documentation in digital cultural heritage research. During periods of heavy rainfall or snowmelt, water levels in the Sanka can rise, leading to local flooding, which also poses a challenge for landscape management.

Czułów has also cultural and traditional values, preserving the rural character of its buildings and local customs. Thanks to its proximity to Krakow, the village is gaining importance as a residential and recreational area, attracting new residents and tourists. Contemporary development challenges for Czułów focus on a harmonious combination of protection of natural heritage with modernisation of infrastructure and support for sustainable agriculture.

3. Theoretical framework for the analysis of landscape units

A landscape unit is a fundamental element of landscape analysis, defined as a spatially distinct part of the geographical environment, distinguished by specific natural, cultural and ecological features. They are understood as distinct structural and functional units, visually coherent, whose most important natural and cultural features should form the basis for sustainable landscape management throughout the area [Nague and Sala 2006]. The principles for the designation of units stipulate that they should be uniform in terms of altitude, slope, geological substrate, soil types, vegetation cover and use [Sowińska and Chmielewski 2011].

This concept has evolved across different research approaches to better understand landscape structure, function and dynamics. In the context of Czułów, the agricultural landscape of the region provides an excellent example of the application of these theories.

The concept of the landscape unit has changed considerably over the years, reflecting developments in landscape geography and other disciplines. In early landscape studies, such as the work of Leszczycki [1976], the approach to separating units was mainly geomorphological, focusing on physical land forms such as valleys, hills or plains. This division was based on the classification of topographic and hydrological features, which allowed the identification of units with clearly defined boundaries.

With the development of landscape ecology, the concept of landscape unit has been extended to include habitat diversity, ecological processes and flows of energy and matter. As Chmielewski [2012] points out, landscape units are now conceived as 'modules of the landscape system', which can be analysed in the context of the wider landscape mosaic and with the consideration of the flow of resources. In landscape ecology, it is not only the form of the units that is important, but also their function in the landscape system, which is reflected in the mosaic approach to landscape analysis.

The mosaic landscape introduced by Forman [1995] is one of the key concepts for analysing landscape units. It is a concept based on the analysis of the landscape as a structure consisting of a matrix, patches and corridors, where the matrix is the dominant landscape element and the patches and corridors are smaller units that contribute to the ecological diversity and functionality of the whole system. In the context of Czułów, the mosaic nature of the agricultural landscape allows for the identification of specific forms of land use, such as agricultural terraces, which serve a variety of ecological and cultural functions.

In the framework of cultural landscape analysis, the mosaic nature of the landscape plays a key role, as it allows for the consideration of spatial diversity resulting from historical forms of land use. This approach identifies both dominant landscape forms and minor elements that may be culturally significant, such as former spatial arrangements or traditional agricultural structures. The mosaic approach makes it possible to analyse the landscape at different levels of detail from elementary units, such as single agricultural parcels, to more complex systems spanning entire valleys or fragments of ecological networks.

The literature points to the need for a multi-criteria approach that combines geomorphological, ecological and cultural criteria to better understand landscape structure and function. Such an approach not only takes into account the physical characteristics of the terrain, but also socio-cultural aspects such as traditional forms of land use, monuments or historical spatial arrangements. Antrop and Van Eetvelde [2017] emphasise that the analysis of cultural landscapes should recognise the complexity of the relationship between natural elements and human activities, enabling a more holistic approach to the study and conservation of these landscapes.

Introducing digital technologies such as GIS, photogrammetry or 3D modelling allows a more precise delimitation of landscape units, by accounting for their physical, ecological and cultural features. By digitising spatial resources, it is possible to create detailed maps and models that integrate a variety of data, such as geomorphology, land cover, historical land use or cultural documentation. The use of these technologies facilitates the analysis of changes in the landscape over the centuries, which is crucial for assessing its cultural value and planning conservation measures.

Digital technologies also support a multi-criteria approach, allowing data from different sources to be integrated and analysed in a spatial context. Thanks to geographic information systems (GIS), it is possible to generate data layers that take into account a variety of criteria, leading to a more comprehensive study of the landscape. In the

context of digital cultural heritage research, this technology enables not only the precise delimitation of landscape units, but also the analysis of their dynamics and the identification of threats resulting from human activity and climate change. GIS also aids the visualisation of data, which facilitates the interpretation of results and decision-making in cultural heritage conservation and management.

4. Multi-criteria approach in landscape analysis

The multi-criteria approach integrates a variety of geomorphological, ecological and cultural criteria, allowing for a comprehensive recognition of the structure, function and value of the landscape. This approach can assist in the rational use of the landscape, the identification of protective measures, as well as the identification of the most valuable landscapes. The analysis of the agricultural landscape of Czułów needs to consider various spatial and temporal aspects that influence its complexity and dynamic character [Chmielewski 2012, Antrop and Van Eetvelde 2017].

The multi-criteria approach not only combines the physical features of the landscape, but also takes into account the historical and social context. In the case of Czułów, where the agricultural landscape is the result of long-term interactions between humans and nature, the analysis of historical forms of land use, such as agricultural terraces, makes it possible to include changes over the centuries [Plieninger and Bieling 2012]. By taking social aspects into account, it is possible to analyse how the cultural significance of a landscape shapes the identity of local communities and influences their relationship with the environment. Historic forms of land use, such as agricultural terraces, not only have use value, but also constitute an important element of local cultural memory and identity [Taylor and Lennon 2011].

A multi-criteria approach requires the integration of different types of data to create multi-layered spatial models. Geographical information systems (GIS) play a key role here, allowing geomorphological, ecological, historical and cultural data to be combined to provide a more comprehensive picture of the Czułów landscape [Wheatley and Gillings 2002]. GIS enables the creation of maps that incorporate different layers of data, such as land cover, vegetation structure, land use history, as well as the location of monuments and other significant cultural features [Conolly and Lake 2006]. This approach allows a more precise analysis of the landscape at different levels of detail, from microstructural local features, such as small landscape elements (e.g. baulks, roads), to macrostructural aspects of the whole region. The multi-layered analysis also enables the study of changes in the landscape over time, which is essential for understanding the dynamics of environmental and historical transformations [Gillings et al. 2020].

A multi-criteria landscape analysis should take into account not only the current features of a terrain, but also its potential to adapt to socio-economic and environmental changes. In the case of Czułów, it is important to assess the value of landscape units in terms of both their current state and their potential for future use and adaptability to changing conditions [Plieninger and Bieling 2012]. For example, agricultural terraces

can be analysed for their potential role in water retention, soil protection against erosion and the promotion of biodiversity. Such an approach recognises both their cultural and ecological importance, allowing for the development of conservation strategies tailored to local environmental and social conditions [Antrop and Van Eetvelde 2017].

The multi-criteria approach provides flexibility in the choice of scale of analysis, which is particularly important in the study of cultural landscapes. At the local level, the analysis can focus on specific micro-structural features, such as parcel layouts, local forms of development or former transport routes [Richling 1999]. Whereas at the regional scale, the analysis covers broader spatial patterns and interactions between larger landscape units, allowing the identification of key elements that influence the functioning of the entire landscape system. The use of different scales within a multi-criteria analysis also allows us to understand how local interventions can influence wider environmental and social processes. For example, the protection of small landscape units, such as baulks or traditional orchards, can have a significant impact on regional patterns of biodiversity and water conservation [Forman 1995].

The basis of the multi-criteria approach is the integration of different perspectives, providing a holistic assessment of the landscape. This approach assumes that the landscape cannot be understood on the basis of single features alone, but requires consideration of the complex interactions between physical, biological and cultural elements [Chmielewski 2012]. A holistic landscape assessment allows for the identification of both tangible and intangible values, such as aesthetics, symbolism or historical significance, which leads to a more sustainable approach to its protection and management [Taylor and Lennon 2011]. A multi-criteria approach to landscape analysis allows for a more comprehensive and flexible assessment of landscape values and the planning of conservation and management measures. This integration of a variety of geomorphological, ecological, cultural, historical and social criteria enables a better understanding of the complexity of the landscape and the dynamic processes that shape it. Through the use of modern digital tools, such as GIS and 3D modelling, it is possible to accurately map and analyse changes in the landscape, which promotes effective heritage protection and sustainable development [Goodchild and Janelle 2004, Gillings et al. 2020].

5. Digital cultural heritage and landscape units

Digital cultural heritage refers to cultural resources that first have been digitised or created in digital form, and then stored and shared using modern technologies. In the context of cultural landscapes, digitisation makes it possible to accurately document, analyse and archive landscape elements, thus contributing to the preservation of heritage for future generations. The significance of digital cultural heritage is growing with the development of digital technologies, such as 3D modelling, geographic information systems (GIS) and virtual reality (VR), which enable more detailed and comprehensive studies of landscapes.

Digital cultural heritage includes a variety of resources such as digital document archives, scans of historical maps, virtual reconstructions and 3D models of monu-

ments. With their digitisation, cultural resources can be archived and made accessible to the general public and researchers [Klamer 1996]. Digital technologies such as virtual reality and 3D modelling are becoming increasingly important in the maintenance of cultural heritage, especially where traditional documentation methods are not sufficient. Champion and Rahaman [2020] point out that these techniques allow for interactive recreation of cultural spaces, enriching the documentation process and enabling a better understanding of cultural values that may not be obvious at first glance.

Introducing digital technologies into cultural landscape research allows detailed mapping and analysis of changes in spatial structure and land use dynamics over the centuries. The use of tools such as GIS, photogrammetry and remote sensing makes it possible to integrate spatial data with historical and cultural information, which is a key element in the process of landscape value assessment and protection [Gillings et al. 2020].

Landscape units, distinguished on the basis of natural and cultural criteria, are a key element of digital cultural heritage, as they allow for the systematisation and analysis of the spatial and historical values of the site. The integration of geomorphology, land use history and cultural documentation data using GIS tools enables a comprehensive approach to landscape assessment [Gillings et al. 2020]. In Czułów, where agricultural terraces are part of a landscape with a long agricultural tradition, digital mapping and virtual reconstruction of these spatial forms can support the study of historical land use changes and the identification of landscape elements in need of protection [Chmielewski 2012, Klamer 1996].

Digital heritage represents a new form of cultural memory that can store not only material aspects of heritage, such as buildings or historical spatial arrangements, but also intangible values related to the identity of local communities, memories and traditions. Digitisation makes it possible to preserve and popularise cultural resources that would otherwise be difficult to access or vulnerable to destruction [Champion and Rahaman 2020]. For example, digital reconstructions of historic landscape forms enable an understanding of what rural areas used to look like, which is not only important for researchers, but also for local communities and education. Technologies such as GIS and photogrammetry also support multi-layered landscape analysis, integrating different spatial, historical and ecological data in order to reconstruct a dynamic picture of past landscape forms. This makes it possible to study not only current but also decayed spatial systems, such as former agricultural fields, road networks or hydrological systems [Forman 1995]. Thanks to digital tools, changes in the landscape over the centuries can be analysed, thus fostering a better understanding of the processes of environmental transformation under the impact of human activities and natural factors. The digitisation and archiving of cultural resources is not limited to documentation, but also includes the management and protection of cultural landscapes with virtual tools. An example is the project carried out at Stonehenge in the UK, where the extent of settlement and land use over the centuries was mapped using GIS and 3D models. Such projects demonstrate that digital technologies can significantly support

the study of landscape transformation and cultural heritage conservation [Gillings et al. 2020, Champion and Rahaman 2020]. A similar approach can be applied in Czułów, where digital documentation of historical land use forms, such as terraces, can support research on landscape evolution and planning of conservation measures in the context of cultural heritage [Chmielewski 2012, Klamer 1996].

Digital cultural heritage also has a major role to play in educating and creating public awareness about the preservation of cultural landscapes. Virtual reconstructions and interactive apps can be used to popularise knowledge of a region's history, engaging users in exploring the past in a more accessible and interactive way than traditional teaching methods [Champion and Rahaman 2020]. For example, mobile applications using augmented reality (AR) let users view historical landscape forms over contemporary views, enhancing their understanding of the complexity of spatial transformations and cultural values.

The management of digital cultural heritage also raises challenges for the long-term archiving and preservation of digital assets. This requires the use of appropriate storage standards to ensure the permanence and availability of data for future generations. International organisations such as UNESCO are developing guidelines for the management of digital heritage to support digitisation and preservation efforts globally [UNESCO 2003].

In the context of cultural landscapes, the digitisation of spatial and historical resources is not only a research tool, but also an instrument to support sustainability measures. It makes it possible to monitor changes in the landscape, identify threats to heritage and support spatial planning processes. Digital maps, models and analyses can be used to develop conservation strategies that take into account both natural and cultural values, as well as the need for adaptation to contemporary social and economic needs [Goodchild and Janelle 2004].

In summary, digital cultural heritage offers extensive opportunities for the analysis and documentation of cultural landscapes. Through the use of digital technologies, changes in the landscape can be more fully appreciated and its historical and cultural value assessed. In the context of digital cultural heritage, the integration of different data sources (such as archives, museums, GIS databases, as well as social and environmental data), within digital cultural heritage allows for a more complete picture of landscape units. This multifaceted analysis enables a better understanding of their cultural and historical value.

6. Protection of cultural heritage in the rural landscape

The preservation of historic landscapes, such as agricultural terraces, is essential for future generations to pass on knowledge of traditional land uses and long-term environmental changes. As pointed out by Antrop [2005], landscapes of the past can provide important insights for future land management, especially in the face of global challenges such as climate change and urbanisation pressures. The history of land use, preserved in the form of landscape units, is a valuable source of information that can

support decision-making in conservation and spatial planning. Digital technologies (GIS, remote sensing, photogrammetry), play a key role in the documentation and conservation of rural landscapes. They enable the precise identification and documentation of historical landscape elements such as field layouts, terraced structures, former roads or settlements. In the context of digital cultural heritage, digitisation makes it possible to archive these elements, analyse them and share with the general public, which helps to popularise knowledge about the historic landscape and its protection [Wojciechowski 2010].

While digital technologies offer great opportunities for the preservation and management of cultural landscapes, they also come up against some challenges. One of the main issues is the question of authenticity and fidelity of digital reconstructions of historic landscapes. The diversity of data sources and their quality can affect the accuracy of reconstructed 3D models and historical maps. It is therefore crucial that digital archiving and reconstruction is supported by extensive historical research and interdisciplinary collaboration [Champion and Rahaman 2020]. Another challenge is the integration of different approaches to landscape conservation at local, regional and national levels. Landscape conservation policies often differ between countries and regions, making it harder to manage digital cultural heritage in a coherent way. Hence, it is important to develop standards and guidelines that can facilitate the implementation of best practices in digital landscape conservation [Wheatley and Gillings 2002]. Land-use planning and the protection of cultural landscapes in rural areas present significant challenges, particularly in the context of preserving historic landscape units. Digital technologies enable the accurate mapping and documentation of historic landscape elements, which supports their conservation and sustainable management. However, it is important that these tools are used in an informed manner, taking into account the diversity of approaches to landscape conservation and local cultural context.

7. Cultural landscape – conservation theory and practice

Cultural landscapes are a unique type of space in which nature and culture coexist and interact. Researchers such as Taylor and Lennon [2011] stress that these landscapes provide a kind of bridge between natural and cultural heritage, thus rendering them an important object of protection in the context of preserving cultural as well as biological diversity. In this view, the protection of cultural landscapes requires consideration of both environmental and historical aspects, thus it is an interdisciplinary and multifaceted task. These landscapes also bear witness to human activity, showing changes in land use patterns, agricultural technologies, as well as the influence of different cultural traditions. Consequently, the study and protection of cultural landscapes requires an analysis not only of their physical structure, but also an understanding of the historical and social contexts that have contributed to their formation. For example, in the case of rural areas such as Czułów, it is critical to understand how agricultural traditions and social development have influenced the formation of the contemporary landscape.

The conservation of cultural landscapes in Europe faces numerous challenges that are tied to the historical and geographical diversity of the region. Hofmeister and Walz [2021] indicate that one of the main problems is the maintenance of traditional agricultural practices and forms of land use, which in many places are being displaced by intensive agriculture or construction. In addition, globalisation and economic change are contributing to the homogenisation of landscapes, leading to the loss of unique cultural features of individual regions.

Digital technologies can address these challenges by enabling the detailed documentation and archiving of landscapes, as well as the creation of spatial models that can support spatial planning and conservation efforts. In this context, GIS technologies, remote sensing and virtual reconstruction tools allow for detailed spatial analysis of cultural landscapes, which assists their management and integration into heritage conservation policies. Digital technologies are becoming increasingly important in the management of cultural landscapes, particularly through their use in documentation, analysis and presentation processes. They make it possible not only to archive landscape elements, but also to present them dynamically and interpret them in an educational and tourism perspective. According to [Champion and Rahaman 2020], these technologies also support virtual historical reconstructions that allow the restoration of destroyed or disappearing landscape elements.

In the case of Czułów and similar rural areas, the application of digital technologies can help to document traditional features, such as agricultural terraces that reflect a long history of land use and local economic practices. Such documentation is crucial not only for conservation purposes, but also for public education and promotion of local cultural heritage. Effective cultural landscape conservation requires the integration of natural and cultural approaches, which means taking into account both natural and cultural values. Taylor and Lennon [2011] emphasise that such an orientation allows for a fuller understanding of the complexity of the landscape and its long-term management. For example, the conservation of agricultural terraces should consider their importance not only as historic landscape features, but also as natural habitats that can support biodiversity. An integrated approach also allows for better management of conflicts that may arise between the protection of cultural heritage and the needs of modern agriculture or urbanisation. Through the implementation of tools such as Landscape Impact Assessment and adaptive management strategies, a balance between the protection of cultural values and development aspirations can be achieved.

The conservation of cultural landscapes is a task that requires an interdisciplinary approach and the inclusion of digital technologies as a tool to support heritage management. It is crucial to develop methodologies that enable not only the documentation and spatial analysis of landscapes, but also their active conservation and adaptation to contemporary needs. Digital technologies can support spatial planning and conservation processes by enabling the identification of valuable landscape elements and the monitoring of change. However, it is central that these technologies are applied with consideration of local cultural and natural contexts to preserve the uniqueness of landscapes and their heritage values.

8. Sustainable management of the cultural landscape

Sustainable development plays a key role in the protection of cultural landscapes, combining the preservation of heritage with the needs of modern society. In the context of agricultural landscapes, such as the landscape of Czułów in the municipality of Liszki, the concepts of sustainability can be applied by integrating adaptive approaches and considering the sustainability and resilience of the cultural landscape.

Sustainable development in the context of agricultural landscapes refers to an approach that balances the protection of heritage with the demands of contemporary land use. Adaptive approaches, such as those presented by Plieninger and Bieling [2012], emphasise the importance of cultural landscape resilience, which applies to the ability of a landscape system to survive and adapt in the face of social, economic and ecological change. The resilience of a cultural landscape entails the maintenance of its historical, aesthetic and cultural values in the long term, despite the influence of various external factors [Costanza 1992, Folke 2006].

One of the key challenges in the sustainable management of the agricultural landscape of Czułów is addressing conflicts between heritage conservation and the needs of economic and social development. Landscape management theory underlines the need to combine conservation objectives with local development. This approach requires the involvement of all stakeholders from local communities to local governments to international organisations in the landscape planning and management process [Plieninger and Bieling 2012, Selman 2006].

Adaptive approaches in the management of the Czułów agricultural landscape rely on responding flexibly to changing conditions and implementing strategies that preserve key landscape values. One example is the adaptation of traditional land uses, such as agricultural terraces, to the contemporary needs of organic farming. The approach of cultural landscape resilience, on the other hand, holds that the landscape may be dynamic and changing, but its core values remain intact [Holling 1973]. In the context of managing the agricultural landscape of Czułów, it is worth mentioning examples of strategies such as the protection and restoration of traditional spatial arrangements, the promotion of sustainable tourism or the introduction of educational programmes to raise public awareness of the importance of cultural heritage. In practice, this may mean, for example, the introduction of integrated landscape management plans that combine nature conservation objectives with the socio-economic development needs of the region [Selman 2006].

Sustainable management of the agricultural landscape in Czułów requires a multifaceted approach that takes into account both the needs of heritage protection and dynamic socio-economic development. By integrating sustainability theory and the model of value conflict management, a balance between conservation and development can be achieved, ensuring the sustainability and resilience of the cultural landscape to future challenges [Plieninger and Bieling 2012, Folke 2006, Selman 2006].

The rural landscape is subject to constant transformations that result from dynamic socio-economic processes, such as changes in agriculture, infrastructure development or

population migration. These transformations affect the structure of the landscape, often leading to the loss of traditional forms of land use, which consequently poses a threat to cultural heritage. Wojciechowski [2010] notes that the modernisation and mechanisation of agriculture cause the simplification of landscape structures, the elimination of minor forms of use, such as baulks, homesteads or traditional orchards. This phenomenon is observed in many regions of Europe, including rural areas in Poland. At the same time, demographic changes and urbanisation processes are influencing the transformation of the countryside, which oftentimes loses its traditional character in favour of a more urban lifestyle and development. Antrop [2005] points out that historic landscapes, although still present in rural space, are becoming increasingly difficult to recognise and preserve due to the lack of traditional forms of use and the fragmentation of space.

In the context of heritage protection in rural areas, the concept of sustainability acquires particular significance. It includes not only nature conservation, but also the preservation of traditional forms of land use and landscape structures. Pietrzak [2010] draws attention to the fact that the rural landscape is an important resource in local development, which requires the integration of conservation activities with economic activities such as cultural tourism, agrotourism and ecological production.

However, the protection of the cultural landscape is not an easy task, especially amidst dynamic change. Taylor and Lennon [2011] point to the need for an adaptive approach that combines the protection of historic values with flexibility to contemporary needs and challenges. In the context of sustainable development, this implies the need to consider not only environmental but also social and economic aspects in order to effectively protect the rural landscape.

Digital technologies are taking on an increasingly important role in the documentation and protection of landscape heritage in rural areas. Tools such as geographic information systems (GIS), 3D modelling and virtual reality (VR) allow for the precise documentation of changes in the landscape and the identification of features at risk of degradation. Research by Wheatley and Gillings [2002] demonstrates that digital tools can be used to analyse historic maps and field documentation, making it easier to reconstruct the former layout of the landscape and plan conservation measures. Champion and Rahaman [2020] point out that the digitisation of landscape heritage not only supports conservation efforts, but also makes heritage knowledge widely available to local communities and tourists. An example is the creation of virtual reconstructions of traditional villages or agricultural areas, which not only increases public awareness of cultural values, but can also serve as an educational and promotional tool. Examples of successful conservation efforts show that effective protection of cultural landscapes requires cooperation between different actors: local governments, heritage protection institutions, NGOs and residents. In Spain, in the region of La Alpujarra, a programme for the protection of traditional agricultural terraces was implemented, which included not only the restoration of structures but also support for farmers to continue traditional farming methods. As a result, both the physical appearance of the landscape and the traditions associated with land use have been preserved [Selman 2006]. Similar activities were undertaken in Poland, where a project to protect traditional field layouts

and rural architecture was undertaken in Roztocze. The programme integrated conservation activities with the promotion of cultural tourism, which contributed to increased interest in the region and the development of the local economy [Wojciechowski 2010].

Climate change poses a major challenge to the conservation of rural landscapes, especially for agriculture, which is directly dependent on weather conditions. These changes can lead to soil degradation, increased erosion and reduced water availability, threatening traditional land uses such as agricultural terraces and orchards [Antrop 2005]. Rural landscape conservation must therefore include adaptation strategies that take these changing conditions into account. Digital technologies can prove beneficial here, enabling the monitoring of environmental change and the prediction of its effects; they can provide data on the state of the landscape and support decision-making on conservation measures such as the restoration of degraded land or the protection of water resources [Conolly and Lake 2006].

The protection of the cultural landscape in rural areas requires a sustainable approach that combines conservation measures with local development and the use of modern technologies. An integrated approach, taking into account both cultural and environmental aspects, allows for better landscape management and adaptation to dynamic socio-economic and climatic changes.

9. Significance for heritage conservation and sustainable development

Cultural landscapes play an important role in preserving heritage and shaping the identity of local communities. These spaces reflect a centuries-long history of human interaction with nature, and their protection is a key element in maintaining cultural identity. As pointed out by Taylor and Lennon [2011], cultural landscapes are a bridge between nature and culture, standing as evidence of historic land use and cultural traditions that are meaningful to local communities. The preservation of these landscapes encourages social bonding and raises awareness of the significance of heritage for present and future generations. An example of this is the preservation of agricultural terraces such as those in Czułów. They are material evidence of long-standing agricultural practices that formed the basis of the local way of life. Their preservation not only perpetuates traditional forms of land use, but also strengthens the community's identity and sense of belonging to a place. Both cultural heritage and rural landscapes can take on a significant role in sustainable local development. For rural landscapes this means using their cultural and natural values for economic development activities while respecting traditions and protecting the environment [Pietrzak 2010]. In practice, this means integrating the conservation of cultural heritage with economic activities such as tourism, organic farming or the production of regional products. The preservation of traditional landscape forms, including field layouts, baulks or orchards, can support biodiversity and foster the development of sustainable agriculture.

The protection of cultural heritage within the landscape should not be limited to conservation measures alone. As noted by Hofmeister and Walz [2021], social and economic aspects must also be taken into account if the landscape is to fulfil its function

as a development resource. This implies supporting local communities in maintaining traditional forms of farming and promoting sustainable practices that are compatible with heritage conservation.

Digital technologies and virtual reality software are increasingly important in the protection of cultural landscapes and planning for sustainable development. They aid the documentation and spatial analysis of landscape units, enabling the precise definition of cultural values and the identification of threats. According to Goodchild and Janelle [2004], the integration of spatial data with socio-economic analysis can significantly improve the quality of planning and decision-making for sustainable development. Digitisation of landscape heritage also enables better education of the public on heritage conservation and promotion of cultural values. Champion and Rahaman [2020] emphasise that these technologies can improve accessibility to knowledge about heritage, e.g. by creating virtual museums or historical reconstructions, which not only protects heritage but also popularises knowledge about it and inspires active preservation.

The integration of cultural landscape protection with sustainable development also poses some challenges. Wojciechowski [2010] points out that conflicts of interest between the need for development and the protection of cultural values can lead to difficulties in managing rural landscapes. These problems often arise from urbanisation pressures, changes in agriculture or the lack of coherent heritage conservation policies at local and regional levels. Another challenge is the continuation of traditional practices of land use, which may not be viable in today's market economy. As highlighted by Taylor and Lennon [2011], the conservation of cultural landscapes requires innovative solutions that address both cultural and economic aspects, as well as financial support mechanisms for landowners and farmers committed to preserving traditional farming practices.

The preservation of the cultural landscape is vital not only for contemporary communities, but also for future generations. The protection of historic landscapes, including field layouts, rural architectural monuments and traditional agricultural practices, contributes to the transmission of knowledge about the past and the construction of cultural identity. As pointed out by Anthrop [2005], landscapes are carriers of collective memory and are important for shaping the cultural consciousness of future generations. Landscape heritage conservation efforts are also part of global efforts towards sustainable development, which is in line with the goals set by UNESCO and the International Council for the Conservation of Monuments and Sites (ICOMOS). In the context of climate change and the global transformation of rural landscapes, the preservation of cultural heritage becomes even more relevant as a form of protection of intangible values and biodiversity. The conservation of cultural landscapes in sustainable development requires a holistic approach that combines cultural traditions with modern technological tools and responsible resource management. The importance of landscape heritage is not only limited to aesthetic or historical values, but also encompasses social, educational and economic aspects, making it a key element of sustainable development strategies.

10. Conclusions

Protecting cultural landscapes in the digital age requires not only the use of modern technologies, but also calls for an integrated approach that combines ecological, cultural and social perspectives. Digital technologies play a key role in the documentation and analysis of the landscape, providing a more precise mapping and survey of its dynamic transformations. This enables the identification of landscape elements in need of protection and the planning of measures to preserve cultural heritage values.

A multi-criteria approach, which integrates various aspects of landscape analysis, allows for a more comprehensive understanding of landscape structure and function. This type of analysis is particularly important in rural areas, where the cultural landscape reflects long-lasting forms of land use and agricultural traditions, as in the case of Czułów. Landscape units, identified on the basis of natural and cultural criteria, constitute the foundation of a digital heritage that can be used to popularise knowledge of the region's history and to plan conservation measures.

However, digital technologies also present challenges, including the question of authenticity of reconstructions and the integration of data from different sources. For digital archiving to be effective, interdisciplinary collaboration and extensive historical research are necessary. Moreover, landscape heritage management requires consideration of both the protection of traditional land uses and adaptation to contemporary social and economic needs.

In a view of sustainable development, the preservation of cultural landscapes should be closely linked to economic activities such as tourism, organic farming and the promotion of regional traditions. Integrating digital technologies with different approaches of sustainable management can contribute to the lasting preservation of cultural heritage and support local development in a way that respects both the history and future needs of communities.

Theoretical discussions of the cultural landscape provide the groundwork for future empirical studies that can provide concrete data on landscape transformations in Czułów and other villages. Future research should combine geomorphological, historical and digital aspects to fully understand and protect the rural landscape as an essential element of cultural heritage.

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References

Antrop M. 2005. Why landscapes of the past are important for the future. Landscape and Urban Planning, 70(1–2), 21–34.

Antrop M., Van Eetvelde V. 2017. Landscape Perspectives: The Holistic Nature of Landscape. Springer.

Champion E., Rahaman H. 2020. Virtual Heritage: A Guide. Ubiquity Press.

Chmielewski T.J. 2012. Ekologiczne podstawy planowania krajobrazu. Wydawnictwo SGGW.

Chmielewski T.J. 2012. Systemy krajobrazowe: struktura, funkcjonowanie, planowanie. Wydawnictwo Naukowe PWN.
Conolly J., Lake M. 2006. Geographical Information Systems in Archaeology. Cambridge University Press.
Costanza R. 1992. Toward an operational definition of ecosystem health. In: Ecosystem health: New goals for environmental management, ed. R. Costanza, B.G. Norton, B.D. Haskell. Island Press.
Folke C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change, 16(3), 253–267.
Forman R.T.T. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press.
Gillings M., Hacıgüzeller P., Lock G. (eds.). 2020. Re-Mapping Archaeology: Critical Perspectives, Alternative Mappings. Routledge.
Goodchild M.F., Janelle D.G. (eds.). 2004. Spatially Integrated Social Science. Oxford University Press.
Hofmeister B., Walz U. 2021. European Cultural Landscapes: Insights into the Current State and Challenges for their Future Conservation. Springer.
Holling C.S. 1973. Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics, 4, 1–23.
Klamer A. (ed.). 1996. The Value of Culture: On the Relationship between Economics and Arts. Amsterdam University Press.
Leszczycki S. 1976. Krajobraz geograficzny: badania i klasyfikacja. Wydawnictwo Naukowe PWN.
Nague J., Sala P. 2006. Prototype landscape catalogue. Conceptual, methodological and procedural bases for the preparation of the Catalan Landscape Catalogues. Observatori del Paisatge, Olot and Barcelona, 13–18.
Pietrzak M. 2010. Krajobraz wiejski jako zasób rozwoju lokalnego. Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu.
Plieninger T., Bieling C. 2012. Resilience and the Cultural Landscape: Understanding and Managing Change in Human-Shaped Environments. Cambridge University Press.
Richling A. 1999. Geografia fizyczna Polski. Wydawnictwo Naukowe PWN.
Selman P. 2006. Planning at the Landscape Scale. Routledge.
Sowińska B., Chmielewski T.J. 2011. Research on historical agricultural landscape for the design and management of a biosphere reserve. In: Ekologia, 30, 2, 171–186.
Taylor K., Lennon J. 2011. Cultural landscapes: A bridge between culture and nature? International Journal of Heritage Studies, 17(6), 537–554.
UNESCO. 2003. Charter on the Preservation of the Digital Heritage.
Wheatley D., Gillings M. 2002. Spatial Technology and Archaeology: The Archaeological Applications of GIS. CRC Press.
Wojciechowski K.H. 2010. Krajobraz kulturowy w planowaniu przestrzennym i ochronie środowiska. Wydawnictwo Politechniki Śląskiej.