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Impacts of land cover change in a cultural landscape: Vulnerability assessment of the archaeological landscape of Alaca Höyük, Türkiye

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Abstract
Whether caused by human or natural drivers, land use and land cover change (LULCc, hereafter) affect the landscape's vulnerability and brings environmental consequences. Landscape change also affects cultural heritage. LULCc and vulnerability studies around archaeological landscapes become more critical with climate change. We aim to assess changes in land cover types in the last 30 years and to create a vulnerability map concerning areas with different landscape characteristics around Alaca Höyük. We use a mixed-method approach; (i) a quantitative method for the LULCc assessment, (ii) the Landscape Character Assessment (LCA) and evaluation of expert opinion surveys, and (iii) a qualitative method to assess climate change impacts on land cover types with expert opinions. The study has important implications for revealing how archaeological landscapes around Alaca Höyük have become vulnerable in the context of climate change through land cover transformation over the last 30 years. The study demonstrates that the extent of agricultural land in and around Alaca Höyük has been increasing over time, while the area of uncultivated natural lands has been decreasing. This transition has resulted in an increase in the vulnerability of land uses and cover types. Thus, the unique historic landscapes of the area are under pressure and that policies for landscape management are needed. The vulnerability map underlines the immediate need for more holistic future studies to inform the management of cultural landscapes, in this case with an explicit focus on the archaeological site at Alaca Höyük and the gardens near Gölpınar Hittite Reservoir.

Keywords
Climate change, Cultural landscapes, Expert opinion, Landscape character assessment, Land cover change.

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1. Introduction

Landscapes are dynamic and change constantly as a result of natural and human factors. Many landscape changes that accelerated from the 18th century can be attributed to anthropogenic factors including population growth, urbanization, disruption of the urban-rural equilibrium, and increased mobility facilitating the spread of technological innovations (Antrop 2005).

LULCc is generally caused by human activities that alter the physical components of landscapes. Coupled with the impacts of climate change (e.g., changes in precipitation patterns and drought), it may lead to various negative impacts on the environment, for example fragmentation in landscape patterns, loss of biodiversity, and soil erosion. Pressure from population growth, urbanisation, industrial development, mineral extraction, energy infrastructure, and agriculture often cause ecologically diverse landscapes to shrink, disappear or change land cover types. For instance, the world's forests shrank from 32.5% to 31.2% of land area between 1990 and 2020 (The World Bank, 2020b); on a longer timescale, much pasture was converted to intensely cultivated agricultural land between the 1700s to the 1990s (Goldewijk, 2001).

The environmental impacts of LULCc may be accelerating due to the consequences of climate change. Such changes also put pressure on cultural heritage in threatened landscapes. One notable impact includes potential harm to buildings or structures at heritage sites, as they may experience deterioration of building materials, increased humidity, corrosion, salt crystallization, frost damage, and black crusts on stone (Carroll & Aarrevaara, 2018). According to IPCC (Intergovernmental Panel on Climate Change), the increasing pace of climate change exacerbates the effects of land cover change and increases the vulnerability of landscapes and their constituent elements (2018). The United Nations Educational, Scientific and Cultural Organization (UNESCO) has recognized the threats of climate change and its destructive impacts on World Heritage sites since 2006 (UNESCO, 2007). Increasing desertification and severe weather events such as flooding caused by climate change present substantial risks for cultural heritage sites (Gruber, 2008). As Plieninger et al. (2006) has noted, the abandonment of cultural landscapes, which may be partly or wholly driven by climate change, can lead to succession and an increase in the woodlands. While progress has been made in recognizing climate change as a threat to World Heritage properties, its integration into the monitoring system is still insufficient (Guzman et al., 2020). Such changes can directly endanger the distinctive character of landscapes and cultural elements including archaeological sites, with negative impacts on cultural values such as sense of place (De Noronha Vaz et al., 2012). Consequently, researchers studying climate change and cultural heritage sites have argued that site-specific approaches are essential, with each heritage site requiring evaluation and conservation actions tailored to its unique characteristics (Cartalis et al., 2022). This approach can also be extended to the historic landscapes around archaeological sites.

In this context, monitoring LULCc in cultural landscapes and understanding their vulnerabilities to climate change becomes crucial in protecting the natural and cultural environment. This research focuses on the archaeological site of Alaca Höyük in Çorum (Türkiye) over the last 30 years and the fragility of its landscape. Shaped by different societies in various periods, Alaca Höyük and its surroundings have a unique archaeological landscape character that has been evolving for at least 3500 years. The main research questions of the study are to examine: (i) which land cover types have changed in and around Alaca Höyük, (ii) to what extent fragility has increased, and (iii) whether the sensitive areas that have emerged affect the local landscape character of the region. Studies that focus on measuring the vulnerability to climate change generally employ one method, but rarely integrate multiple methods in physical and social sciences (Orr et al., 2021). This study uses a combination of various approaches: 1) a period-based land cover analysis by using CORINE land cover data to map landscape change, 2) expert opinion surveys to understand the climate change impacts on land cover types of Alaca Höyük, and 3) a landscape character assessment (LCA) both to identify individual landscape character areas and to present vulnerability in landscape character areas. Aerial photographs taken from the Republic of Türkiye-Ministry of National Defense General Directorate of Mapping (HGM) show that, as of 1990, there has been a significant increase in the agricultural lands in and around Alaca Höyük. In addition to the intensification of agricultural production, there may have been changes in other land use types. The CORINE maps examined within the scope of the study also support this change. In this sense, the time limit of the CORINE maps was sufficient for the study.

2. Materials and methods

2.1. The site and historical background

Alaca Höyük is located in Alaca district, 45 km southwest of the city of Çorum, Türkiye (Figure 1). The site was a key Hittite settlement, lying 36 km to the northeast of the capital of the Hittite Empire at Hattusa (Boğazköy). The mound at Alaca Höyük formed an essential node in the settlement network of Central Anatolia for millennia. Archaeologists have identified four principal epochs of activity from the Chalcolithic Period (ca. 4000 BC), Early Bronze Age (ca. 2500 BC-2000BC), Late Bronze Age/ Hittite Empire (ca. 1500 BC-1200 BC), and from the Hellenistic Period onwards (ca. 300 BC).

During the Hittite Empire (ca. 1400 BC), an ancient reservoir at Gölpınar, supplied water for arable land (Apaydın et al., 2020). At this time, dams were constructed by creating a triangular section on a surface to take advantage of the groundwater (Schachner, 2019; Wittenberg & Schachner, 2013). Landscape change is evidently not specific to modern times; indeed, progressive aridity in north-central Anatolia during the Bronze Age (ca. 3000-1200 BC; Arıkan & Yılmaz, 2018) may have contributed to the collapse of the Hittite Empire by causing long-term drought and food shortages (Manning et al., 2023). Coupled with changing precipitation regimes and intensive anthropogenic impacts on the landscape during the Hittite period, the rate of erosion-deposition increased and badlands developed (Arıkan & Yılmaz, 2018). Such events were exacerbated by intensive deforestation for a variety of purposes. Consequently, the climate and related ecological (e.g., surface processes and biodiversity) changes were influential factors in the fate of the Hittite Empire. Until the first archaeological excavations started in 1935, the village of Alaca Höyük was located on the mound itself. Since then, the village has been moved to the north and east of the mound. Excavations at the site continue to the present day. Alaca Höyük includes the archaeological site (Figure 2) and a museum, both open to the public. The modern village is surrounded by fields, orchards, and gardens (*bağ-bahçe* in Turkish). Following the excavation and restoration of Gölpınar in the early 2000s, the reservoir operates once again. Despite a modern irrigation dam built close to Alaca Höyük, farmers continue to use

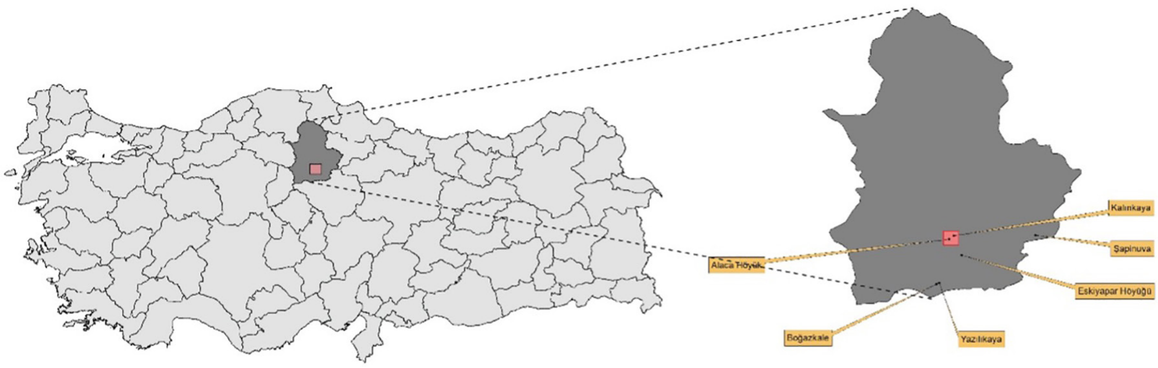

Figure 1. *Study area.*

the ancient dam during the dry summer days. Agricultural production in the region is based on wheat, rice, chickpeas, barley, and walnuts.

2.2. Materials

The methodological flow chart (Figure 3) shows the systematic processes applied in this study. The research adopted a mixed-method approach: a quantitative method for the LULCc assessment with CORINE maps, a qualitative evaluation of experts in adapting climate change impacts to the field, a quantitative evaluation of the survey of expert opinion, and a quantitative method using LCA to assess climate change impacts on land cover types in the light of expert opinions. The graph outlines the approaches used, as well as the inputs and outputs of each technique.

2.2.1. Method 1: LULCc analysis

LULCc refers to a transition between land use/cover types and spatial alterations in specific cover types. It is widely acknowledged that LULCc can result from a combination of anthropogenic and non-anthropogenic factors (Kleemann et al., 2017). The CORINE land use/land cover data set (CLC, hereafter) is essential in providing quantitative and accessible data for researchers studying landscape change. CLC, produced in 1985, presents data relating to biodiversity, water resources, land cover, and soil structure and to create a platform to monitor the changes in the landscape within a period (Ljuša et al., 2013). Today, data are available for 1990, 2000, 2006, 2012, and 2018. CLC products are frequently used for landscape character

Figure 2. *Alaca Höyük archaeological area (by Arzu Türk, October 2022).*

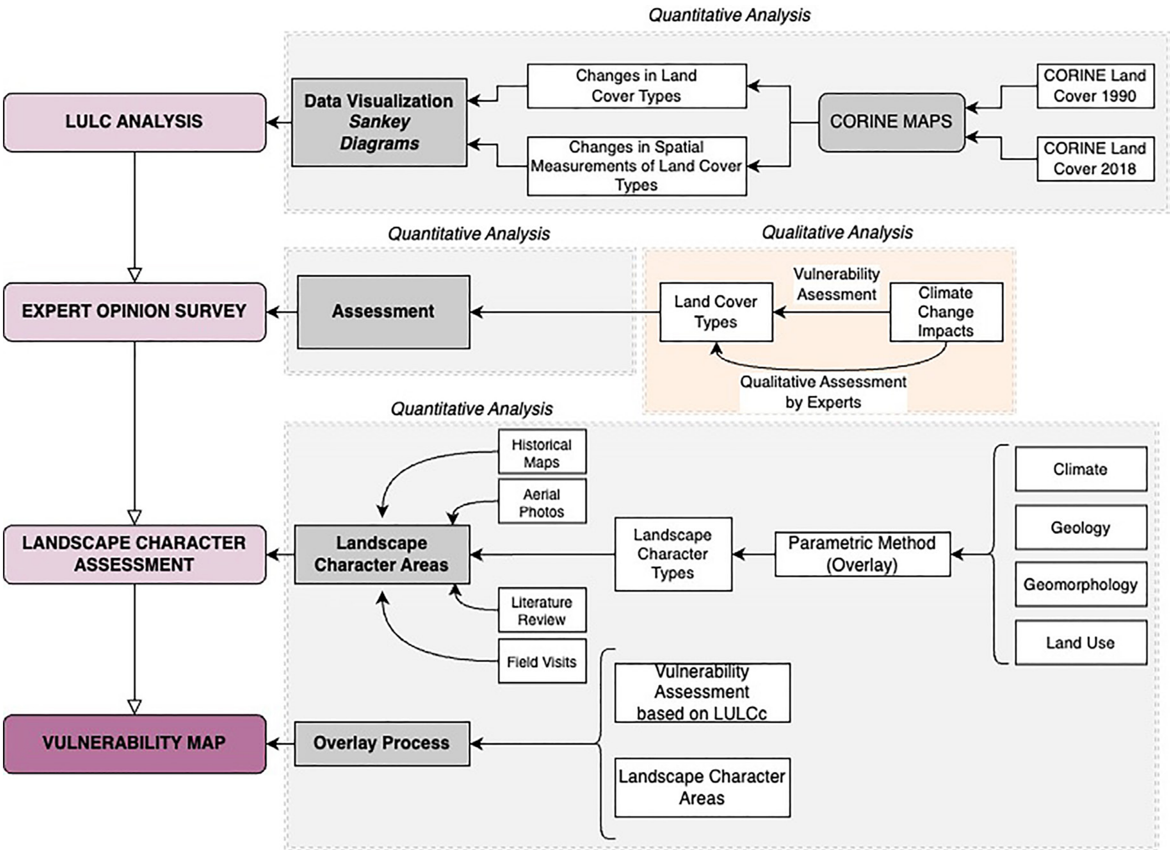

Figure 3. *Methodological flow chart.*

analysis (Uzun et al., 2015; Van Eetvelde & Antrop, 2009; Wascher, 2005), as well as to monitor change and urbanisation around archaeological sites (Agapiou, 2021; De Noronha Vaz et al., 2012; Florea, 2015) and to reconstruct past landscapes by combining land cover change and archaeological data such as pollen analysis (Abraham et al., 2014). On the other hand, current maps of CORINE can provide essential data for climate change-based LULCc studies. Cook and others (2021) advocate for the importance of near-future climate projections derived from current data in shaping archaeological heritage management decisions, highlighting their relevance over historical climate information.

The relatively low resolution of CORINE data (100 m) may prompt concern about its accuracy and usability. Nevertheless, examining aerial photos of the study area yielded results comparable to those of the CORINE data. For this reason, CORINE maps were preferred as land cover / use base within the scope of the study.

In this study, 1990 and 2018 CORINE land cover data was obtained from the Copernicus Land Monitoring Service for 5644 hectares (Figure 4).

To make the graphical representation more understandable, the explanation of code 243 has been altered to "mosaic landscapes" in the figures and tables below. Additionally, codes 332 and 333 have been combined into one and re-named "Sparsely vegetated bare rocks" since they have a similar landscape character.

Landscape change between 1990 and 2018 was assessed in two ways. First, the area of all land cover types was measured. Second, the flow of land cover types was visualized using the Sankey diagram method. Sankey diagrams display energy, material, and cost flows and major shifts in a system more efficiently, with arrows representing the power of the transfer. They may also be used to visualize the changes in land cover over time (Cuba, 2015; Zhang et al., 2017), for example, the conversion of forest to arable land or urbanization. Sankey diagrams are beneficial for communicating the impacts of land use change to stakeholders and decision-makers.

2.2.2. Method 2: Expert opinion survey to assess vulnerability to climate change

Expert-based surveys are important as participants possess comprehensive knowledge about the research subject derived from their expertise or professional background. They may be used in different ways to obtain perspectives on landscape change, for example by drawing on locally-produced oral histories (Bürgi et al., 2017), by asking experts to assess causes of change (Jacobs et al., 2015), or by generating models of possible future scenarios (Herring et al., 2022). Studies based on expert opinion are critical in forming consensus, as in the case of climate change (Anderegg et al., 2010). On the other hand, some structured expert opinion studies reveal the diversity of judgments on climate systems and factors (Morgan & Keith, 1995). It is of particular significance to consider the role of expert opinion studies in research on climate change. Studies indicate that surveys based on the opinions of experts create a positive opinion and motivation especially among policy makers and decision makers on climate change (Javeline et al., 2013). Such multiple exchanges can especially broaden communication networks between different actors and increase attention to the issue. Information gathered from different actors can be a driving force for future climate change agendas and strategies in different areas. In this context, expert opinion survey approach has been also used in cultural heritage sites and archaeological areas to assess national adaptation plans. The studies demonstrated how such methodologies can uncover innovative sources of data not readily available in the literature (Daly et al., 2022).

Our study implements a participatory expert opinion survey designed to assess the vulnerability of each land cover type at Alaca Höyük and its surroundings likely to be affected by climate change impacts, for example temperature rise, drought, floods, biodiversity, soils, and inland water. Direct impacts on coastal areas, such as sea level rise, were excluded. The survey was implemented using Google

Forms (online) and shared in English, after receiving the approval of the Ethics Committee at Istanbul Technical University.

In the study, experts working exclusively on climate change were not solely relied upon; instead, preference was given to researchers conducting work across a broad range of disciplines. The goal was to build consensus, enhance the reliability of results, and inspire decision-makers by incorporating diverse perspectives from various fields of study. In this sense, there are examples where experts are selected from different fields of study and thus a consensus is achieved in studies on climate change that use expert opinion in their research (Myers et al., 2021; Nordhaus, 1994). Our survey was conducted among thirty-three experts researching landscape ecology, landscape change, climate change, and vulnerability. Two survey results were excluded from the evaluation because of unrelated research areas. Out of the

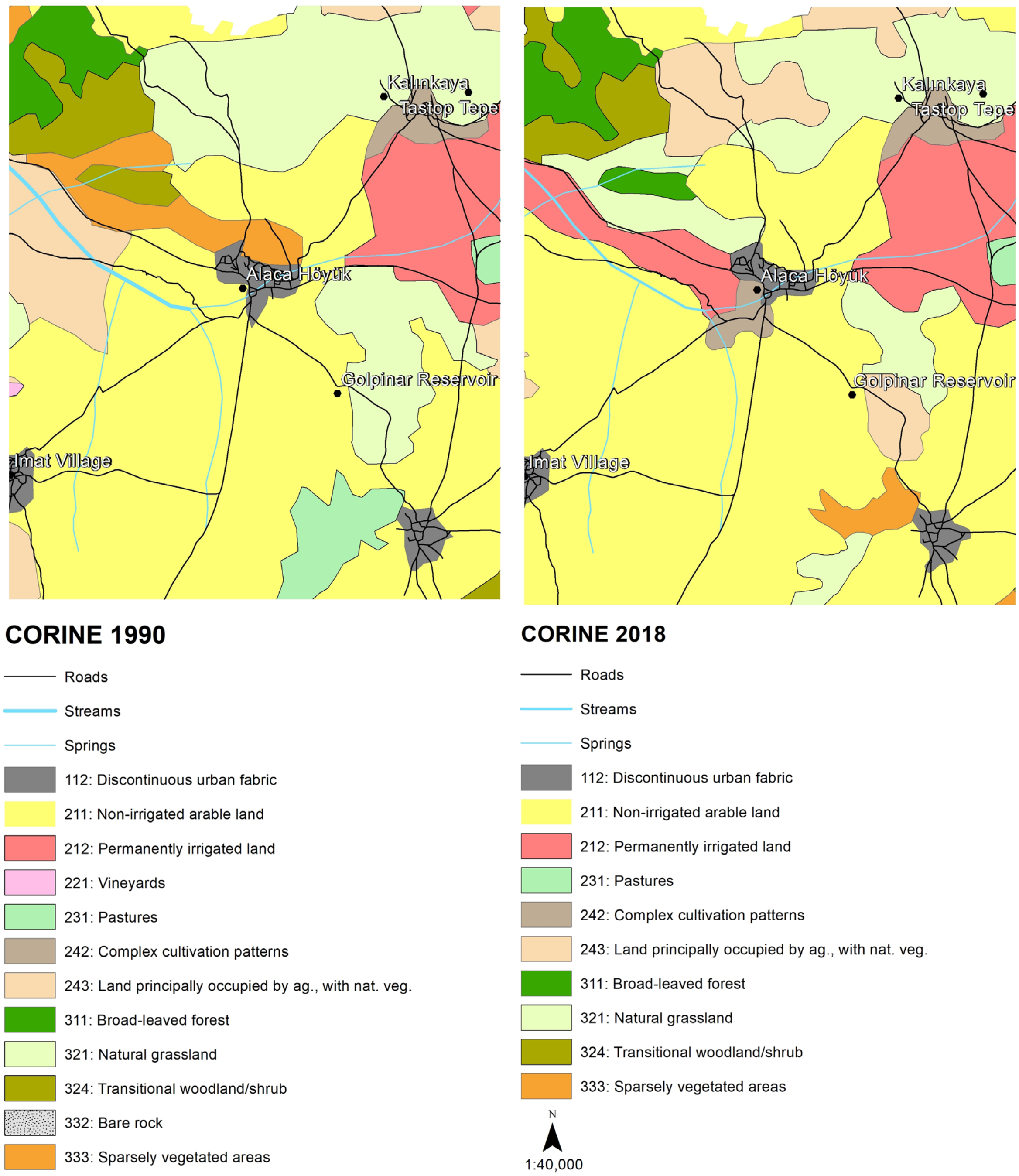

Figure 4. *CORINE land cover change between 1990 and 2018 (© European Union, Copernicus Land Monitoring Service 1990 and 2018, European Environment Agency (EEA)).*

Table 1. Classification of the vulnerability scores and their assessments.

Vulnerability Score (VS)	Vulnerability Assessment of Climate Change Impacts on Each Land Use Type
1-5	Minimum Vulnerability
5-10	Low Vulnerability
10-20	Medium
20-25	High Vulnerability
25-30	Highest Vulnerability

33 survey participants, 25 belong to university institutions, five are affiliated with the private sector, and three are associated with public institutions. Nonetheless, all survey participants have either completed their doctorates or are currently doctoral candidates.

In the first phase of the expert survey, participants were asked how each possible impact of climate change would affect the vulnerability of each land cover type. Responses were given based on the Likert Scale, ranging from 1 (low) to 5 (high) that desginate the vulnerability score. For example, a score of 1-5 is given for how biodiversity reduction affects transitional woodland-shrub areas. Expert opinions were averaged for each of the six climate change impacts: temperature rise, drought, floods, biodiversity, soils, and inland water. Each answer has a maximum of 5 points on the Likert scale and there are six climate change parameters, so the vulnerability score of a land cover type may be a maximum of 30 points. Table 1 shows how the vulnerability assessment was made for all land types based on the total points.

In the second step, the area covered by each land type in 1990 and 2018 was measured in hectares, and the ratio of each area to the total land size was used as a coefficient. The coefficient of each terrain type was multiplied by 100 to obtain a meaningful value in the first step and multiplied by the vulnerability score obtained. With the help of the equation given below (1), vulnerabilities of land cover types may be calculated for the years 1990 and 2018. In this equation, x and y express the area of land covers (in hectares) in 1990 and 2018, and VS represents the sum of the vulnerability scores given by experts for each land cover type. The Z value indicates the total area of each land cover type.

The spatial fragility measurement was then classified with a maximum value of 3000, the highest vulnerability between 2500-3000, high vulnerability between 2000-2500, medium vulnerability between 1000-2000, low vulnerability between 500-1000, and most minor vulnerability between 100-500 in both 1990 and 2018. As a final step, the spatial fragility was assessed and compared for 1990 and 2018.

2.2.3. Method 3: Landscape character assessment

The visible consequences of landscape change, especially in historic landscapes, suggest that the LCA initiatives have become increasingly necessary.

These studies are essential for identifying the characteristics that make a landscape unique, for mapping landscape character areas, for informing planning, design, and management with reference to the characteristics of place as well as monitoring the changes in the landscape. LCA was initially used in the UK and subsequently in Estonia, Germany, Hungary, and the Czech Republic (Tudor, 2014); with

$$\left(\frac{x}{z} \times 100\right) x\,VS = V_{1990}$$

$$\left(\frac{y}{z} \times 100\right) x\,VS = V_{2018} \quad (1)$$

Equation 1. Classification of the vulnerability scores and their assessments.

the signing of the European Landscape Convention in Turkey, it has become a necessity to classify, determine types, and assess landscapes on a national scale. Research in Turkey has facilitated the expansion of LCA studies to encompass basin-scale and wide-ranging readings (Uzun et al., 2015). Such initiatives are crucial in revealing the landscape characteristics of the natural, historical, and built environment (Atik et al., 2015) and underpinning sustainable management of natural and cultural resources through the identification of landscape character areas (Koç & Yılmaz, 2020).

The LCA used here consists of data collection, identification of landscape character types, and mapping of landscape character areas with the help of field visits. LCA is a structured process that determines how each element contributes to landscape character (Sarlöv Herlin, 2016) using the 'parametric method' (Van Eetvelde & Antrop, 2009). First, data relating to geology, climate, and geomorphology of the research were collated and a land-use map was prepared at a 1/10.000 scale. Following data integration, the parametric method was followed with the help of Intersect Analysis in ArcGIS. Four main spatial datasets were used for Climate, Geology, Geomorphology, and Land Use. Fifty-seven different landscape character types were identified through this method. Each type has common micro-climatic, geological, geomorphological, and land use aspects. In the GIS, each character type was given a name that contains codes for specific types of data. For instance, the Landscape Character Type (LCT) of Alaca Höyük was coded "s_as_SDSH_FA," (Sedimentary, defined as an Archaeological Site, Semi-Dry Low Humidity 1st Degree Mesothermal climate, and fill area); the LCT of Gölpınar Reservoir was defined as "s_as_SDSH_PVB" (Sedimentary, defined as Archaeological area, Semi-Dry Low Humidity 1st Degree Mesothermal climate and plain and valley base). Finally, the character types were used alongside additional information from historical maps and aerial photos, literature reviews, and field visits to identify and tag character areas based on their unique characteristics.

Twenty-four landscape character areas were determined around Alaca Höyük, including 'Alaca Höyük Fields', 'Gölpınar Gardens', 'İmat Village Woodlands and Vineyards', 'Kalınkaya Grassland and Archaeological Area' (Figure 5). The majority of the landscape is arable with fields, orchards, and small areas of vineyards. The other examples of the character areas include historic vineyards and ancient quarries, as well as the archaeological sites of Alaca Höyük itself and the ancient Hittite reservoir.

The final step is to identify areas vulnerable to climate change impacts by mapping the landscape character areas against vulnerable land cover types that emerged in 1990 and 2018 based on data gathered in each previous research stage.

3. Results

3.1. LULCc analysis

CORINE maps, which were given in the second part, produced in 1990 and 2018 were used in the research, and these production dates played a significant role in establishing their temporal scope. The analysis of field patterns in aerial photos from 1957 revealed a notable increase in new fields by 1990, indicative of expanded agricultural land and field division. However, parallel with these changes, Alaca Höyük, like other rural settlements in Central Anatolia, witnessed a substantial decline in population (Yılmaz, 2015). Our diagram (Figure 6) displays the quantitative transition of classification results and the observed land cover change dynamics between 1990 and 2018. The graph additionally provides the quantitative alterations in land cover sizes measured in hectares. For instance, it is evident that "non-irrigated arable land" comprised of 2,267 hectares in 1990 and it increased to 2,961 by 2018.

Based on our results, it is clear that in 1990, non-irrigated arable lands, natural grasslands, and mosaic landscapes had covered the largest area in the region. By 2018, natural grasslands and mosaic landscapes decreased, while non-irrigated arable lands and permanently irrigated lands increased. It is also clear that less intensively used land was transformed into arable land. Finally, vineyards were almost entirely replaced by mosaic landscapes. However, viticulture and grape consumption have been influential in Anatolia for millennia. Endemic grape species supported wine production during the Hittite Empire and the production of table grapes during the Ottoman period, and historical descriptions by travelers indicate that there were extensive vineyards in the research area.

3.2. Expert opinion survey to assess vulnerability to climate change

The vulnerability assessment based on expert opinion is given in Figure 7, depending on each climate change parameter. Expert opinion indicates that sparsely vegetated lands have a medium vulnerability, while other land cover types are interpreted to be highly vulnerable. Thus, an increase or decrease in the latter land cover types will inevitably affect the vulnerability of the landscapes around Alaca Höyük. When land-cover changes between 1990-2018 were analyzed, the spatial

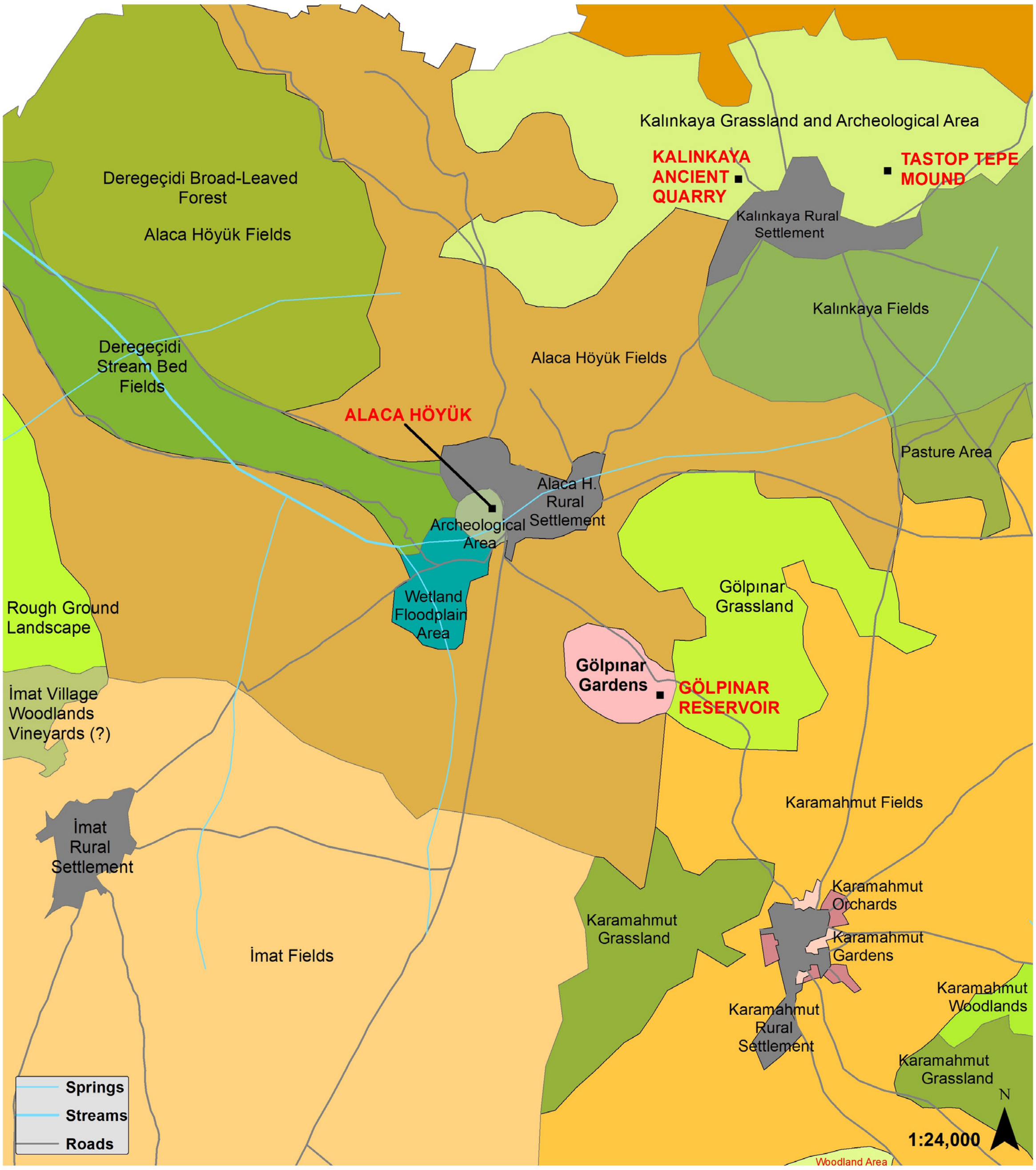

Figure 5. Landscape character assessment of Alaca Höyük.

vulnerability of non-irrigated arable lands appeared to increase, that of natural grasslands decreased, and the other areas seemed stable.

Alaca Höyük and its surroundings are suitable for dry farming with precipitation values varying between 400-500 mm/year: in response to economic drivers, the area of non-irrigated agricultural land increased substantially between 1990 and 2018. However, precipitation became more irregular in the same period, especially after 2000. The increase in non-irrigated lands is consequently becoming more vulnerable to climate change impacts under drought (Lu et al., 2020). Even though the region is suitable for dry farming, permanently irrigated arable lands are also increasing. This indicates that changes in the rainfall regime are likely visible and perceivable among local people and landowners. It suggests that rainwater has become insufficient, and water management strategies have become increasingly crucial for agriculture around Alaca Höyük. In the future, there may be a shift from non-irrigated arable land to more permanently irrigated land. Indeed, a similar shift has already been identified at the national level (The World Bank, 2020a). Water management for arable agriculture is likely to become increasingly crucial on both the regional and national scales.

Other fundamental changes are seen in mosaic landscapes and natural grasslands. The mosaic landscapes of the area include woodland-shrub, mixed with small fields. Between 1990 and 2018 much natural grassland and pasture land was converted into permanently irrigated land, with a consequent reduction in the carbon-hold capability of the soil (IPCC, 2003).

An area with small intermixed parcels for various crops and pastures identified as 'complex cultivation patterns' forms part of a small floodplain, which retains rainwater and therefore provides a valuable resource during drought seasons (Ebert et al., 2019). While the total area may be relatively small, replacing such complex ecosystems with agricultural land may create areas that are more vulnerable to climate change. Whilst it was used mainly for grazing in the past, the area has been used increasingly as agricultural

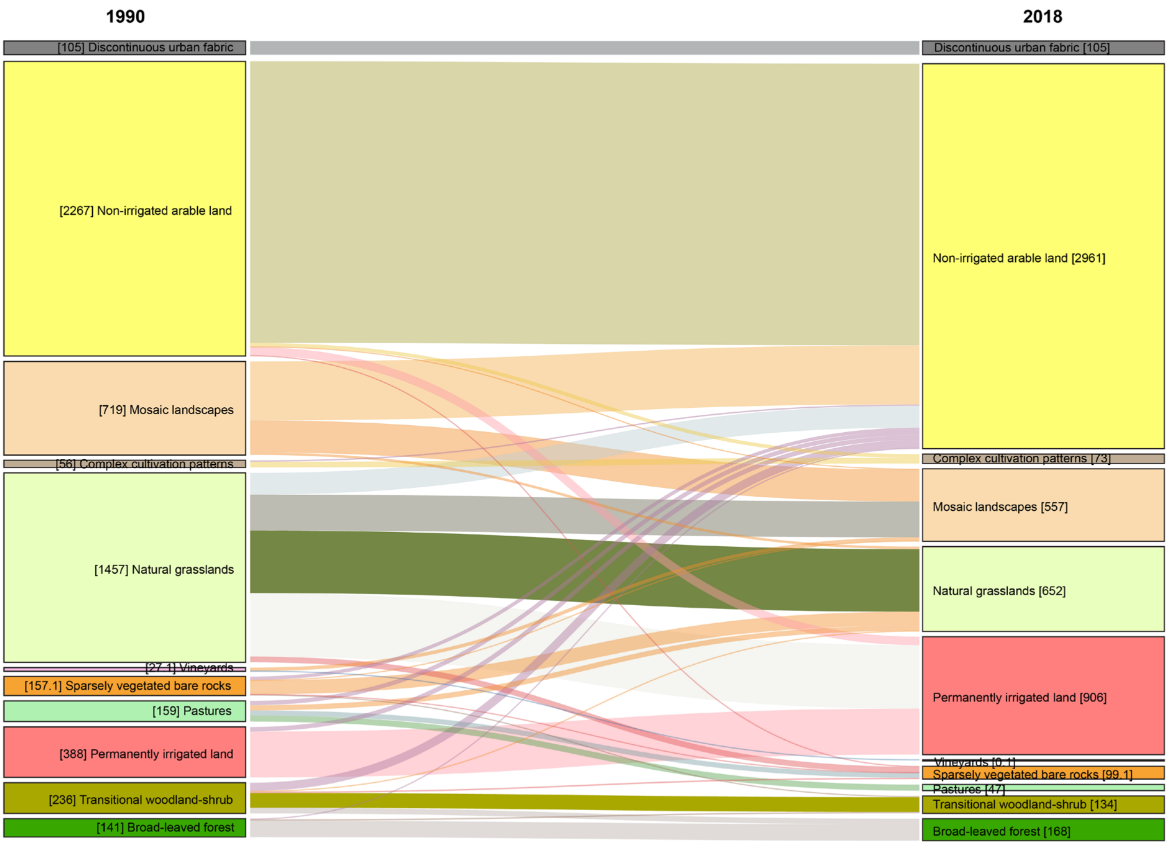

Figure 6. *Transition among different land cover types, between 1990 and 2018.*

land in the last 20 years. This change in landscape character is therefore likely to increase sensitivity to drought.

The replacement of woodland/shrub areas, which are important for local flora with arable land, is also likely to increase vulnerability to climate change. On the other hand, natural or human-induced ecological succession has increased in other parts of the study area, notably areas characterised by sparsely vegetated bare rocks which have tended to move towards transitional woodland/shrub. This change

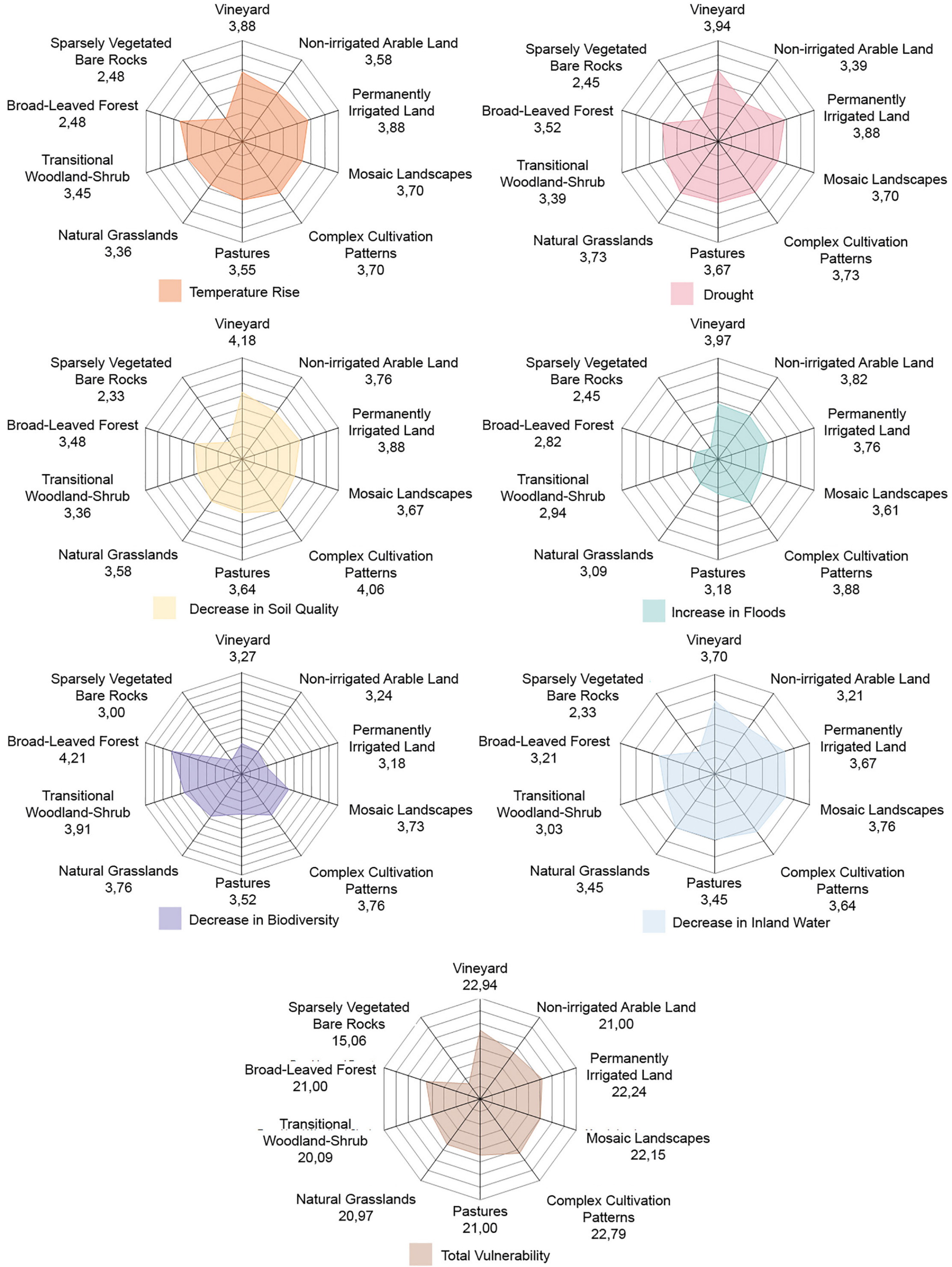

Figure 7. *Radar (or web) chart of expert opinion survey about the vulnerability assessment of different LULC types and climate change parameters.*

may be beneficial to prevent erosion resulting from weak soil medium and temperature changes and to create resistance patches in the vegetational layer. Some natural grasslands have also changed into coniferous forests, with benefits for carbon capture, preventing erosion, increasing soil quality, and enriching biodiversity.

The descriptions of land cover types, the direction of land cover change and its causes, and an assessment of vulnerability are given in Table 2. LULCc is affected by economic drivers, as shown by the demand for arable land, as well as climate change, extreme grazing, and ecological succession. However, the lack of management strategies for landscapes in and around Alaca Höyük will inevitably create ecological impacts in the coming years since temperatures are rising, precipitation patterns are changing, and extreme weather events are happening more frequently (IPCC, 2018). Indeed, rainfall data in Çorum show significant increases and decreases in various years. Changing rainfall patterns also make cultivation more difficult; besides the adverse effects of droughts, unstable precipitation patterns can cause crop damage in fields and orchards (Çevre Yönetimi ve Denetimi Şube Müdürlüğü, 2023). Significant drops in water levels have been observed in local dams over recent years, and research indicates that drought also played a pivotal role in the decline of the Hittite Empire (Manning et al., 2023). Fluctuations in rainfall patterns and drought are likely to have been experienced by past inhabitants of the region.

Between 1990-2021 the average temperature in Çorum has already increased by as much as 2 degrees. Climate change in agricultural areas will negatively affect soil quality and crops. According to the latest report by the IPCC, although crop productivity and quality have increased with the help of agricultural techniques on a global scale, the development speed has slowed down due to climate change in the last 50 years (IPCC, 2023). Given projected population growth and the need for food, climate change is therefore likely to create further instability in terms of food security.

3.3. Landscape character assesment

LCA of Alaca Höyük and its environs demonstrate that the existing landscape exhibits a heterogeneous structure in terms of both modern and historic landscape patterns. The study area has unique microclimate structures and topographic characteristics. Moreover, the region displays notable variations in geology and land cover, which have given rise to a diverse range of land uses. While the monotonous of the brownish color steppe landscape is disrupted by diverse modern and ancient settlement and structures, the region also builds a landscape seasonally blossomed.

As noted in relation to individual land cover types above, LULCc is likely to create landscapes that are more vulnerable to climate change (Riebsame et al., 1994). Monitoring changes in land cover is therefore essential to provide a basis for future planning and management. From this perspective, Figure 8 presents the relationship between vulnerable areas and landscape character areas, identifying areas that were sensitive in and before 1990, and new sensitive areas identified in 2018.

Based on the vulnerability assessment, vineyards, non-irrigated arable lands, and permanently irrigated lands exhibit a high score. The major factor influencing these assessments is the reduction in 'inland water' surfaces for vineyards and permanently irrigated lands. Unlike non-irrigated arable lands that rely on rainfall, vineyards, and permanently irrigated arable lands depend heavily on inland water and irrigation systems for sustainability.

Mosaic landscapes and complex plantations also have a high vulnerability. These areas are diverse landscapes comprising wetlands, water resources, corridor areas, and agricultural areas. Such diverse landscapes are affected by a wide range of climate change events at different rates. Additionally, pastures, natural grasslands, transitional woodland shrubs, and broad-leaved forests also demonstrate a high level of vulnerability. The cover type that is the least vulnerable to climate change is "sparsely vegetated bare rocks".

In Figure 8, dotted areas represent fragile land use areas in 1990, and hatched areas represent fragile land use in 2018. The map is the result of two CORINE maps (1990 and 2018, Figure 4) and vulnerability assessment of expert opinions and shows the land use types with vulnerability values greater than 21 are shown. As a consequence, İmat Village woodlands and vineyards, Alaca Höyük, İmat and Kalınkaya Fields, Alaca Höyük site and wetland, Gölpınar Hittite Reservoir Gardens, Dere Geçidi Stream and fields have strong vulnerability, especially coming from the land use types from and before 1990. On the other hand, new land use changes starting from 2018 created new vulnerable areas. Thus, Gölpınar Grassland, Deregeçidi Broad-Leaved Forests, and Kalınkaya Grassland and Archaeological Area are facing pressure. Future studies should consider how to protect these areas from this new pressure.

4. Discussion

In this research, we assess the LULCc and vulnerabilities that these changes bring in and around Alaca Höyük in relation to climate change. The results suggest that the most significant change in Alaca Höyük and its surroundings is in agricultural areas (i.e., non-irrigated arable land and permanently irrigated land categories in Tables 2). Both land character types tend to increase,

Table 2. *Changes in land cover, reasons, and expert opinion results on their vulnerability.*

CLC Types	Description	LULCc	Driver(s)	Vulnerability Assessment
Vineyard	Vineyard for viticulture	Decrease	Economic Reasons, Climate	22,93
Non-irrigated Arable Land	Cereals, legumes, fodder crops, root crops, fruit trees, and flowers	Increase	Demand for arable land	21,03
Permanently Irrigated Land	Crops irrigated with irrigation channels, drainage networks	Increase	Demand for arable land	22,24
Mosaic Areas	Land Occupied by Significant Areas of Agriculture, Natural Vegetation, Water Bodies	Decrease	Demand for arable land	22,15
Complex Cultivation Patterns	Small parcels of diverse annual crops, pasture, or permanent crops	Increase	Demand for arable land	22,78
Pastures	Dense grass cover	Decrease	Extreme Grazing, Demand for arable land	21,00
Natural Grasslands	Low productivity grassland	Decrease	Demand for arable land	20,96
Transitional Woodland-Shrub	Bush vegetation with scattered trees	Decrease	Ecological succession	20,09
Broad-leaved forest	Vegetation formation composed with trees	Increase	Ecological succession	21,00
Sparsely Vegetated Bare Rocks	Cliffs sparsely vegetated lands where rocks cover %75 of the land	Decrease	Ecological succession	15.06

this agriculture-driven change has resulted in a return to areas with more natural character. This pattern fits Plieninger's (2006) statement that land use, particularly agriculture, is the fundamental motivation to shape the rural landscape. According to Antrop (2005) agricultural intensification may destroy the landscape characteristics and spirit of traditional landscapes. Indeed, the landscape, which has gradually become an agricultural area in Alaca Höyük, has begun to lose its unique parts. The vulnerability assessment reveals that agricultural areas are generally more sensitive to climate change. Therefore, transforming natural areas into agricultural areas has led to the increase of fragile areas in Alaca Höyük and its surroundings. Kurukulasuriya and Rosenthal (2013) underscore the vulnerability of agricultural lands (e.g., variations in temperature, rainfall, and extreme weather events) all of which bring significant repercussions on food production and security.

Our research highlights how some landscape character types risk disappearing altogether from the region.

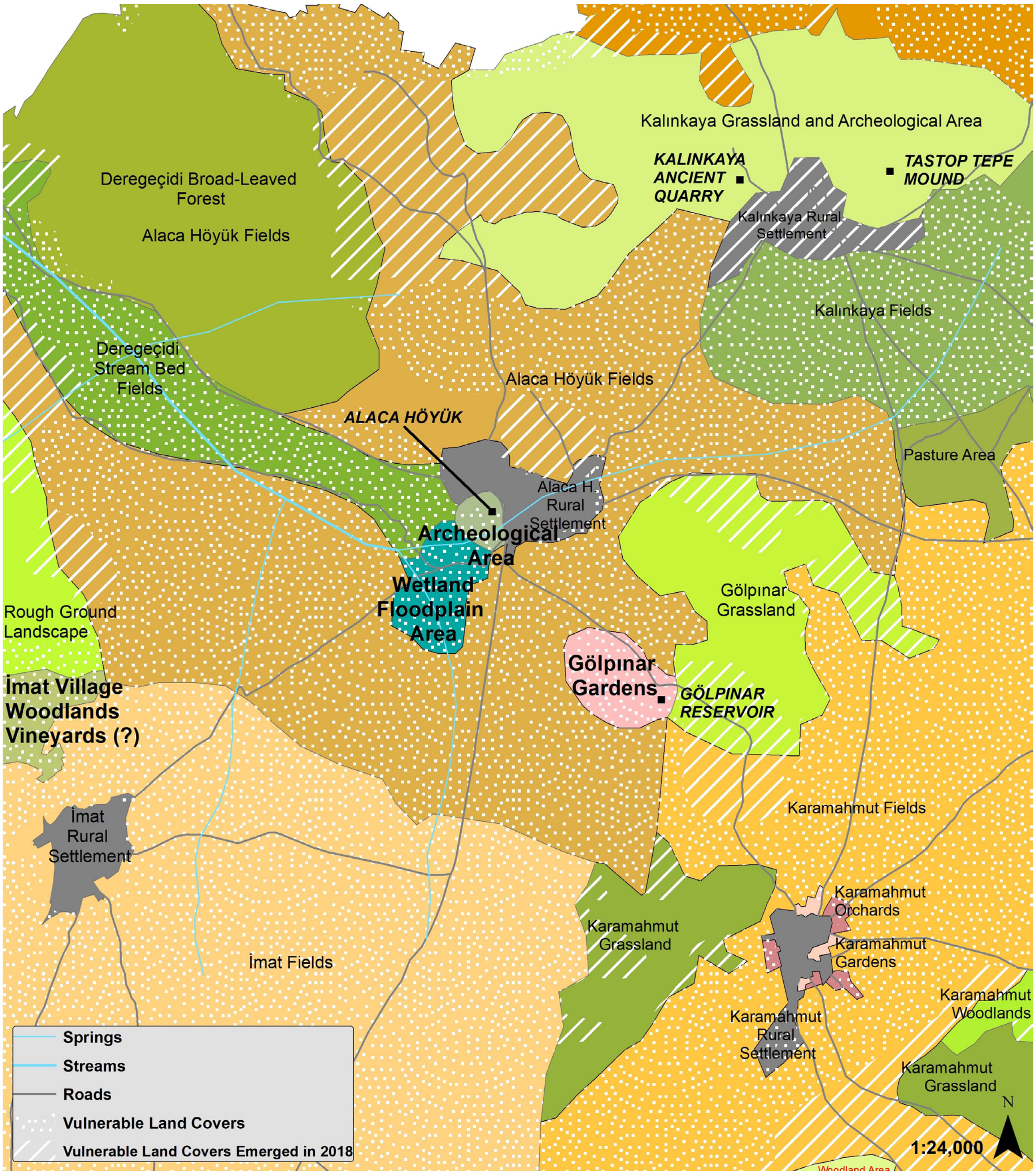

Figure 8. *Vulnerability maps and unique landscape character areas around Alaca Höyük.*

Notably, vineyards were once typical in the districts of Alaca and Boğazkale (the capital of the Hittite Empire), but today they have decreased significantly. Studies show that the effects of climate change put pressure on viticulture due to the increasing temperature and drought (Cardell et al., 2019; Webb et al., 2008). All the vineyards in the village of İmat were lost by 2018; it is possible that climate change affected crop yields and increased the vulnerability of this land cover type. Climate change brings significant challenges not only in the distribution and conservation of viticulture globally but also in the economic sense (Hannah et al., 2013). The loss of suitable land for this commercially important produce means a significant economic loss for the rural population.

The disappearance of vineyards that distinguish Alaca Höyük's steppe landscape from others marks a shift in the rural landscape's identity. Although changing agricultural farmlands to natural areas may sound ideal, this change may cause problems. For instance, the traditional cultural landscapes of Europe were cultivated by moderate human intervention, and if the land were abandoned, ecological succession would ensue, resulting in the loss of cultural landscapes (Plieninger et al., 2006).

Moreover, the vulnerability assessment here indicates extinction in other areas as well. The final vulnerability map (Figure 7) shows that the unique character areas such as Gölpınar Gardens and the Alaca Höyük Natural Pasture area (wetland/floodplain) are under tremendous pressure today. The character of both these pastures and the vineyards and gardens of Gölpınar result from their historical development; they are likely to represent surviving elements of the historic character of past landscapes. In this context, decision-makers need to have a concrete planning and management strategy in order to preserve their cultural characteristics. Moreover, the vulnerability of land-use types in 1990 continued in 2018; new fragile areas were added in 2018, which means there is a lack of management strategies in Alaca Höyük. In this context, robust landscape management strategies are needed in and around Alaca Höyük so that other unique landscape areas will not be destroyed, as in the case of the historic vineyards of İmat. Alaca Höyük and its surroundings have a land use strategy under the Master Plan covering Samsun-Çorum-Tokat provinces. However, this 1/100.000 scale plan does not reflect the unique and site-specific characteristics of the landscapes in the region due to its scale. Therefore, in such historic landscapes, it is important to identify small-scale approaches and strategies that work with the whole.

Planning and management policies may help protect cultural landscapes and local identity. After the European Landscape Convention, which was put forward for the protection, management and planning of landscapes, the Council of Europe carried out a new study –Landscape Mosaics– to ensure the applicability of these objectives, to understand the landscapes and to make the strategies put forward more tangible (Council of Europe, 2023). The ratification of the European Landscape Convention in Turkey supports efforts to monitor and record landscape changes, while government agencies have initiated planning and management strategies (Uzun et al., 2018).

In this context, it is essential for planners to work across scales and collaborate with various stakeholders. A network of actors—including agricultural engineers and botanists to understand site-specific cultural and natural landscapes, archaeologists to emphasize cultural heritage and archaeological value, and climate experts to address climatic vulnerability—is of great significance. However, it is crucial that landscape architects, as well as urban and regional planners, play an active role in ensuring a strong link between these experts and decision-makers. The engagement of local communities and administrative units should also be considered to facilitate the transfer of knowledge and strategies between local and broader scales (or vice versa). Thus, the significance of multi-actor, site-specific studies in such archaeological landscapes becomes evident. As the LCA reveals, even in Alaca Höyük and its immediate surroundings alone, different landscape characters have been identified, and more localized solutions are needed to protect the vulnerability of these areas, especially against to climate change. This is also important for the protection of cultural fragility. This is why a multi-spectral action scheme comprising experts, public officials, cultural and ecological conservation actors and local communities is crucial for such historic sites.

Employing mixed-method approaches in a case like this may facilitate the implementation of site-specific strategies for landscape planning and management. These methods go beyond purely quantitative research and enable the inclusion of different actors (in this case, experts) in the research. The study also has the potential to draw multi-disciplinary attention to the landscape of Alaca Höyük and its vulnerability. In this sense, it can potentially attract the attention of a broader audience to the research subject, method, and location. Although countries currently have risk prevention strategies against natural disasters such as climate change, these strategies and plans fail because stakeholder participation is interrupted or not considered at all (Shirvani Dastgerdi & Kheyroddin, 2022). Future approaches may expand the scope of research on the socio-ecological resilience of historical landscapes in response to the challenges posed by climate change. Future studies with the local community are of especially great importance. Many solutions to global problems in local regions are likely to be hidden at the local scale with local actors (Vos & Meekes, 1999). In this sense, it will be essential to include locals and local decision-makers in the planning, strategy, and management stages.

5. Conclusion

Landscapes are constantly changing due to anthropogenic and natural drivers. The critical distinction between traditional/historical and contemporary landscapes lies in their dynamic nature, characterized by rapid and extensive changes driven by shifting perceptions, which, although accompanied by an exceptional volume of data, often exceed the capacity for data documentation and study (Antrop, 2005). However, managing and monitoring these changes and preserving diversity in landscape patterns is necessary for effective adaptation to global changes. In our study, CORINE land cover maps helped us to understand the changes in Alaca Höyük in the last 30 years. The interpretive score-based approach contributed to assessing the multi-variables of climate change effects on different land cover types and revealing the vulnerability of each land cover type. These different approaches were synthesized into a final vulnerability assessment map based on the unique landscape character areas in and around Alaca Höyük. In this context, the superposed map provides a valuable synthesis with the potential to underpin landscape management strategies for the Alaca Höyük landscape.

The study has two kinds of limitations. The first is that the oldest CORINE data for land cover change is from 1990. In a future similar study with a longer time span, a manual land cover classification method using historical satellite imagery could be chosen, which would also reveal changes in the landscape, especially before the mechanization of agriculture. However, since the study involves a methodological approach based on CORINE maps, a manual classification was not used. Moreover, it is a fact that high-resolution satellite images are needed for such manual classification. Another limitation was the inability to interview local people due to time constraints and transportation problems. As mentioned in the results section in the meaning of landscape management, an open-ended interview and workshop bringing together different actors would be important to adopt a common ground approach.

The study reveals that the agricultural areas in and around Alaca Höyük have been gradually increasing whilst uncultivated areas have been shrinking, with the result that more vulnerable land uses and land cover types have become more widespread. The disappearance of vineyards, the gradual shrinkage of wetland areas and their transformation into agricultural areas, and the decrease in natural pastures negatively impact rural character. Moreover, LULCc puts pressure on characteristics that underpin the sense of place in Alaca Höyük, for example the historic Gölpınar Gardens. In this context, the study highlights the need to increase awareness regarding the preservation of this unique landscape character around the archaeological site of Alaca Höyük. Preparing holistic planning and management strategies that include both local people and experts will be an essential step toward addressing this issue.

This article synthesizes qualitative and quantitative approaches to assessing land cover changes in cultural landscapes and measures their vulnerability to climate change. The research provides valuable insights into the vulnerability of Alaca Höyük and its surroundings to climate change, shedding light on the specific factors and land cover types most susceptible to climate impacts. Mixed method approaches can enable the development of site-specific landscape planning and management approaches, which are especially valuable for cultural landscapes with a strong sense of place identity. Future studies could also extend the research to understand the socio-ecological resilience of such historic landscapes to climate change. In this context, the views of local people could be integrated into the study to better understand the social, economic, and cultural impacts of climate and land cover changes on them. In this way, more inclusive and location-specific planning and management strategies could be designed that involve local people, decision-makers and planners. Such actions will be vital in raising awareness of the risks that climate change poses to the natural and cultural heritage of landscapes.

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References

Abraham, V., Oušková, V., & Kuneš, P. (2014). Present-day vegetation helps quantifying past land cover in selected regions of the Czech Republic. *PLoS ONE*, *9*(6), e100117. https://doi.org/10.1371/journal.pone.0100117

Agapiou, A. (2021). UNESCO World Heritage properties in changing and dynamic environments: change detection methods using optical and radar satellite data. *Heritage Science*, *9*(1). https://doi.org/10.1186/s40494-021-00542-z

Anderegg, W. R. L., Prall, J. W., Harold, J., & Schneider, S. H. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(27), 12107–12109. https://doi.org/10.1073/pnas.1003187107

Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning*, *70*(1–2), 21–34. https://doi.org/10.1016/j.landurbplan.2003.10.002

Apaydın, A., Çınaroğlu, A., İnal, İ., Dilektaşlı, C., & Çelik, D. (2020). Çorum-Alaca Höyük'te 3260 yıl öncesine dönüş: antik hitit barajının iyileştirilmesi ve Hitit yaşamının canlandırılması. *DSİ Teknik Bülteni*, *135*(Ocak), 18-35.

Arıkan, B., & Yıldırım, T. (2018). Paleoclimate, geology, geomorphology, and middle holocene settlement systems in the Delice Valley of North-Central Anatolia. *Journal of Field Archaeology*, *43*(8), 570–590. https://doi.org/10.1080/00934690.2018.1535161

Atik, M., Işikli, R. C., Ortaçeşme, V., & Yildirim, E. (2015). Definition of landscape character areas and types in Side region, Antalya-Turkey with regard to land use planning. *Land Use Policy*, *44*, 90–100. https://doi.org/10.1016/j.landusepol.2014.11.019

Bürgi, M., Bieling, C., von Hackwitz, K., Kizos, T., Lieskovský, J., Martín, M. G., McCarthy, S., Müller, M., Palang, H., Plieninger, T., & Printsmann, A. (2017). Processes and driving forces in changing cultural landscapes across Europe. *Landscape Ecology*, *32*(11), 2097–2112. https://doi.org/10.1007/s10980-017-0513-z

Cardell, M. F., Amengual, A., & Romero, R. (2019). Future effects of climate change on the suitability of wine grape production across Europe. *Regional Environmental Change*, *19*(8), 2299–2310. https://doi.org/10.1007/s10113-019-01502-x

Carroll, P., & Aarrevaara, E. (2018). Review of potential risk factors of cultural heritage sites and initial modelling for adaptation to climate change. *Geosciences (Switzerland)*, *8*(9). https://doi.org/10.3390/geosciences8090322

Cartalis, C., Polydoros, A., Mavrakou, T., Philippopoulos, K., Asprogerakas, E., Pantazis, P., Samarina, A., Zoumpaki, S., & Karambinis, M. (2022). Assessing the risks of climate change for cultural heritage – The CLIMASCAPE project. *Proceedings of the 17th International Conference on Environmental Science and Technology*, *17*(September). https://doi.org/10.30955/gnc2021.00767

Cook, I., Johnston, R., & Selby, K. (2021). Climate change and cultural heritage: a landscape vulnerability framework. *Journal of Island and Coastal Archaeology*, *16*(2–4), 553–571. https://doi.org/10.1080/15564894.2019.1605430

Council of Europe. (2023). Landscape Mosaics: Thoughts and proposals for the implementation of the Council of Europe Landscape Convention. In M. Déjeant-Pons & S. Moller. (Eds.), *The Ecology of Landscape and Regions*. Council of Europe.

Cuba, N. (2015). Research note: Sankey diagrams for visualizing land cover dynamics. *Landscape and Urban Planning*, *139*, 163–167. https://doi.org/10.1016/j.landurbplan.2015.03.010

Çevre Yönetimi ve Denetimi Şube Müdürlüğü. (2023). *Çorum ili 2022 yılı durum raporu. https://webdosya.csb.gov.tr/db/ced/icerikler/corum-ilc-dr-2022-20230914130852.pdf*

Daly, C., Fatorić, S., Carmichael, B., Pittungnapoo, W., Adetunji, O., Hollesen, J., Nakhaei, M., & Diaz, A. H. (2022). Climate change adaptation policy and planning for cultural heritage in low- and middle-income countries. *Antiquity*, *96*(390), 1427–1442. https://doi.org/10.15184/aqy.2022.114

De Noronha Vaz, E., Cabral, P., Caetano, M., Nijkamp, P., & Painho, M. (2012). Urban heritage endangerment at the interface of future cities and past heritage: A spatial vulnerability assessment. *Habitat International*, *36*(2), 287–294. https://doi.org/10.1016/j.habitatint.2011.10.007

Ebert, S., Hulea, O., & Strobel, D. (2019). Floodplain restoration along the lower Danube: A climate change adaptation case study. *Climate and Development*, *1*(3), 212–219. https://doi.org/10.3763/cdev.2009.0022

Florea, M. Ştefan. (2015). Anthropic impact on the archaeological sites reflected in geospatial analysis. Study case: Ilfov County. *Studii de Preistorie* (12), 207-221.

Goldewijk, K. K. (2001). Estimating global land use change over the past 300 years: The HYDE database. *Global Biogeochemical Cycles*, *15*(2), 417–433. https://doi.org/10.1029/1999GB001232

Gruber, S. (2008). The impact of climate change on cultural heritage sites: environmental law and adaptation. *SEIN Corporate Governance & Accountability EJournal.*, *06*, 1-20.

Guzman, P., Fatorić, S., & Ishizawa, M. (2020). Monitoring climate change in world heritage properties: Evaluating landscape-based approach in the state of conservation system. *Climate*, *8*(3), 1-19. https://doi.org/10.3390/cli8030039

Hannah, L., Roehrdanz, P. R., Ikegami, M., Shepard, A. V., Shaw, M. R., Tabor, G., Zhi, L., Marquet, P. A., & Hijmans, R. J. (2013). Climate change, wine, and conservation. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(17), 6907–6912. https://doi.org/10.1073/pnas.1210127110

Herring, P., Turner, S., & Sevara, C. (2022). *The historic landscape: assessing opportunity for change. Historic England,* (69).

IPCC (Intergovernmental Panel on Climate Change). (2003). *Good practice guidance for land use, land-use change and forestry (J. Penman, M. Gytarsky, T.*

Hiraishi, T. Krug, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe, & F. Wagner (eds.)). Institute for Global Environmental Strategies (IGES) for the IPCC.

IPCC (Intergovernmental Panel on Climate Change). (2018). *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. P. Head, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.)). Cambridge University Press. https://doi.org/10.1017/9781009157940

IPCC (Intergovernmental Panel on Climate Change). (2023). *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Core Writing Team, H. Lee, & J. Romero (Eds.); Issue 2).

Jacobs, S., Burkhard, B., Van Daele, T., Staes, J., & Schneiders, A. (2015). 'The Matrix Reloaded': A review of expert knowledge use for mapping ecosystem services. *Ecological Modelling*, *295*, 21–30. https://doi.org/10.1016/J.ECOLMODEL.2014.08.024

Javeline, D., Hellmann, J. J., Cornejo, R. C., & Shufeldt, G. (2013). Expert opinion on climate change and threats to biodiversity. In *BioScience* (Vol. 63, Issue 8, pp. 666–673). https://doi.org/10.1525/bio.2013.63.8.9

Kleemann, J., Baysal, G., Bulley, H. N. N., & Fürst, C. (2017). Assessing driving forces of land use and land cover change by a mixed-method approach in north-eastern Ghana, West Africa. *Journal of Environmental Management*, *196*, 411–442. https://doi.org/10.1016/J.JENVMAN.2017.01.053

Koç, A., & Yılmaz, S. (2020). Landscape character analysis and assessment at the lower basin-scale. *Applied Geography*, *125*(June 2019), 102359. https://doi.org/10.1016/j.apgeog.2020.102359

Kurukulasuriya, P., & Rosenthal, S. (2013). Climate change and agriculture: a review of impacts and adaptations. *The World Bank Environment Department*, *6*(3), 101. https://doi.org/10.1016/0169-5347(91)90186-2

Ljuša, M., Čustović, H., Vojniković, S., Taletović, J., & Đuzo, F. (2013). The structure of land cover changes in Bosnia and Herzegovina during the period from 2000 to 2006. *23rd International Scientific-Experts Congress on Agriculture and Food Industry*.

Lu, J., Carbone, G. J., Huang, X., Lackstrom, K., & Gao, P. (2020). Mapping the sensitivity of agriculture to drought and estimating the effect of irrigation in the United States, 1950–2016. *Agricultural and Forest Meteorology*, *292–293*(July), 108124. https://doi.org/10.1016/j.agrformet.2020.108124

Manning, S. W., Kocik, C., Lorentzen, B., & Sparks, J. P. (2023). Severe multi-year drought coincident with Hittite collapse around 1198-1196 BC. *Nature*, *614*, 719. https://doi.org/10.1038/s41586-022-05693-y

Morgan, M. G., & Keith, D. W. (1995). Subjective judgments by climate experts. *Environmental Science & Technology*, *29*(10), 468-476.

Myers, K. F., Doran, P. T., Cook, J., Kotcher, J. E., & Myers, T. A. (2021). Consensus revisited: Quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later. *Environmental Research Letters*, *16*(10), 104030. https://doi.org/10.1088/1748-9326/ac2774

Nordhaus, W. D. (1994). Expert opinion on climatic change. *American Scientist*, *82*(1), 45–51.

Orr, S. A., Richards, J., & Fatorić, S. (2021). Climate change and cultural heritage: a systematic literature review (2016–2020). *Historic Environment: Policy and Practice*, *12*(3–4), 434–477. https://doi.org/10.1080/17567505.2021.1957264

Plieninger, T., Höchtl, F., & Spek, T. (2006). Traditional land-use and nature conservation in European rural landscapes. *Environmental Science & Policy*, *9*(4), 317–321. https://doi.org/10.1016/J.ENVSCI.2006.03.001

Riebsame, W. E., Meyer, W. B., & Turner, B. L. (1994). Modeling land use and cover as part of global environmental change. *Climatic Change*, *28*(1–2), 45–64. https://doi.org/10.1007/BF01094100

Sarlöv Herlin, I. (2016). Exploring the national contexts and cultural ideas that preceded the Landscape Character Assessment method in England. *Landscape Research*, *41*(2), 175–185. https://doi.org/10.1080/01426397.2015.1135317

Schachner, A. (2019). *Hattuşa: efsanevi Hitit İmparatorluğu'nun izinde* (G. Ergin (Ed.); I. R. Işıklıkaya-Laubscher (Trans.); 1st ed.). Homer Kitabevi.

Shirvani Dastgerdi, A., & Kheyroddin, R. (2022). Policy recommendations for integrating resilience into the management of cultural landscapes. *Sustainability (Switzerland)*, *14*(14), 8500. https://doi.org/10.3390/su14148500

The World Bank. (2020a). *Agricultural irrigated land (% of total agricultural land) - Türkiye*. https://databank.worldbank.org/source/world-development-indicators/Series/AG.LND.IRIG.AG.ZS

The World Bank. (2020b). *Forest area (% of land area)*. https://data.worldbank.org/indicator/AG.LND.FRST.ZS

Tudor, C. (2014). An approach to landscape character assessment. *Natural England*, 65, 101716.

UNESCO. (2007). Climate Change and World Heritage: Report on predicting and managing the impacts of climate change on World Heritage and strategy to assist State Parties to implement appropriate management responses. *World Heritage Reports*, *22*, 1–55.

Uzun, O., U., Kargın, S., & Aygüneş, K. (2015). *Yeşilırmak Basin Landscape Atlas* (U. Osman, S. Kargın, & K. Aygüneş (Eds.); P. Yiğit (Trans.); 1st ed.). Ministry of Forestry and Water Affairs.

Uzun, O., Müderrisoğlu, H., Demir, Z., Gündüz, S., Kaya, L. G., & Gültekin, P. (2018). The Concept of Landscape Quality in the Planning of Rural Spaces: Yeşilırmak Basin Example. *Planning*, *28* (50), 118–128. https://doi.org/10.14744/planlama.2018.96967

Van Eetvelde, V., & Antrop, M. (2009). A stepwise multi-scaled landscape typology and characterisation for trans-regional integration, applied on the federal state of Belgium. *Landscape and Urban Planning*, *91*(3), 160–170. https://doi.org/10.1016/j.landurbplan.2008.12.008

Vos, W., & Meekes, H. (1999). Trends in European cultural landscape development: perspectives for a sustainable future. *Landscape and Urban Planning*, *46*, 3–14.

Wascher, D. M. (2005). *European Landscape Character Areas – Typologies, Cartography and Indicators for the Assessment of Sustainable Landscapes*, (No. 1254). Landscape Europe.

Webb, L. B., Whetton, P. H., & Barlow, E. W. R. (2008). Climate change and winegrape quality in Australia. *Climate Research*, *36*(2), 99–111. https://doi.org/10.3354/cr00740

Wittenberg, H., & Schachner, A. (2013). The ponds of Hattuša – early groundwater management in the Hittite kingdom. *Water Supply*, *13*(3), 692–698. https://doi.org/https://doi.org/10.2166/ws.2013.025

Yılmaz, M. (2015). Türkiye'de kırsal nüfusun değişimi ve illere göre dağılımı (1980-2012). *Doğu Coğrafya Dergisi*, *20*(33), 161. https://doi.org/10.17295/dcd.71070

Zhang, F., Kung, H. T., & Johnson, V. C. (2017). Assessment of land-cover/land-use change and landscape patterns in the two national nature reserves of Ebinur Lake Watershed, Xinjiang, China. *Sustainability (Switzerland)*, *9*(5), 724. https://doi.org/10.3390/su9050724