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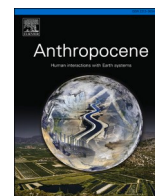
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South Caucasus greening and Neolithisation: What happened 8200 years ago?

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ABSTRACT

In the South Caucasus, located north of the Fertile Crescent and between Black and Caspian Seas, the Neolithic way of life emerged relatively late, around 6000 BCE (8000 cal BP). This delay, compared with regions such as Anatolia or the Kopet Dag, has long been discussed by archaeologists and generally attributed to geographical or technical constraints. Climate has also been considered a key factor, particularly the 8.2 ka event, which is often linked to the spread of farming and herding from the Fertile Crescent into neighbouring regions. This event is believed to have triggered a transition from hunter-gathering to agropastoralism. However, its direct impact on the South Caucasus remains debated. Recent palaeoenvironmental studies indicate that the region underwent a major ecological transformation around 8200 cal BP, coinciding with the Early–Middle Holocene Transition. This period was characterised by increased precipitation. As a result, vegetation expanded, particularly grasslands dominated by Poaceae, which provided favourable conditions for livestock grazing and fodder production.

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Unlike the abrupt 8.2 ka event, this longer-term shift significantly reshaped the environment of the South Caucasus. This review argues that it was not the short-term climatic anomaly but rather the sustained increase in precipitation during the Early–Middle Holocene Transition that created the conditions necessary for the emergence of the Caucasian Neolithic. The expansion of vegetation and natural resources provided an ecological basis for the gradual adoption of agriculture and herding, ultimately leading to the development of an agropastoral system in the region.

1. Introduction

Neolithisation is initially defined as the adoption of a productive economy by societies that practised agriculture and animal husbandry, developed an increased sedentary lifestyle, adopted a large number of technical innovations and renewed their symbolic forms of expression. It spreads from the Near East, particularly the Fertile Crescent, across western Eurasia. The mechanisms and rhythms of this significant shift in human behavior from its core area are anything but a linear process and differ from region to region. Its spread seems to be directly linked to human mobility, be it through social and cultural contacts or territorial colonisation. Meanwhile, it also required optimal environmental conditions to ensure the settlement and success of agriculture. The “Neolithic way of life” in the Fertile Crescent dates back to the late 10th/early 9th millennium BCE. To the north-east, in the South Caucasus (SC), this process occurred fairly late around ca. 6000 BCE (8000 cal BP; (Badalyan et al., 2022; Chataigner, 2024; Marro et al., 2019; Nishiaki et al., 2019; Orange et al., 2021; Palmisano et al., 2021; Palumbi et al., 2021), especially when compared with similar developments in the nearby Fertile Crescent (Fig. 1). North of the Caucasus, Neolithic communities possibly contemporary to those of the SC are attested (Ryabogina et al., 2019; Scott et al., 2022).

The archaeological community has long debated the reasons for this gap, often seen as a time-lag compared with Central and South-Eastern Anatolia, the Elborz and the Kopet Dag (Chataigner et al., 2014;

Guarino-Vignon et al., 2023; Lyonnet, 2022; Lyonnet et al., 2016; Marro et al., 2019). The SC is located between the Black and Caspian Seas, also called the Transcaucasus (Shahgedanova, 2003). The area includes the southern part of the Greater Caucasus mountain range, the entire Lesser Caucasus mountain range and surrounding valleys and lowlands such as the Colchis and the Kura-Aras. This region is located north of the Fertile Crescent. The SC, like large parts of Anatolia, is characterized by mountainous terrain, deep valleys and high plateaus, with abundant natural resources including minerals, water and pastures (Orange et al., 2021). The neolithisation of the SC is contemporary with that of Thrace and Bulgaria (Marinova, 2007) and developed only slightly later than in the southeast of the Caspian Sea (Leroy et al., 2019a). These data question the technical obstacle hypothesis put forward to account for the time-lag. Is this due to a lesser interest in the mountainous areas of the SC than in the vast Anatolian plateaus? And if so, what made this region attractive for Neolithic groups after the 8.2 ka event?

According to van der Horn et al. (2015), this arid climatic event would have facilitated the adaptation of populations and favoured the invention of water management in the Fertile Crescent. It would also have led to the dispersion of human groups, some of which may have reached the SC, and therefore introduced a Neolithic agro-pastoral way of life into this region. A study that compiled 14 C dating of archaeological data (Weninger et al., 2006) suggests that the arid episode of 6200 BCE may have been a triggering factor for the dispersal of farmers outside Western Asia and the Near East.

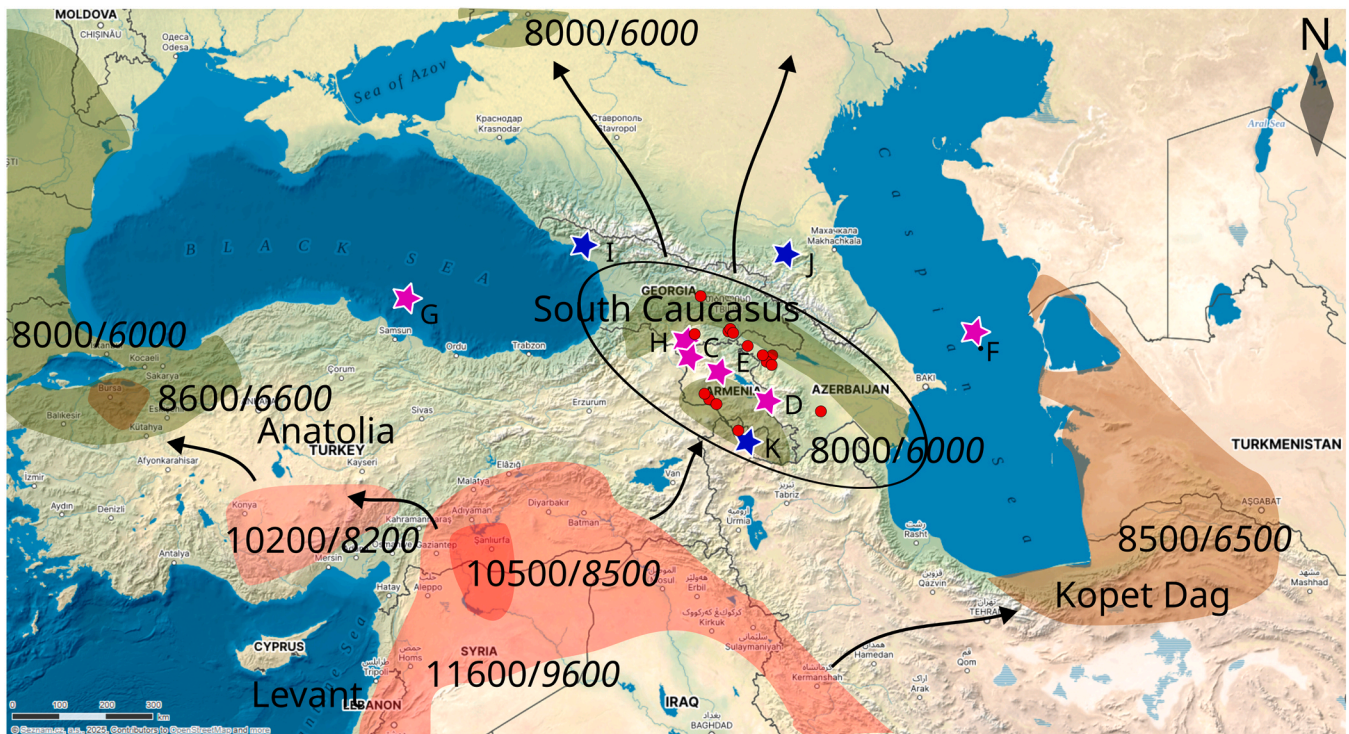


Fig. 1. Map of South-Western Asia centred on the South Caucasus (represented by the black oval), which illustrates the time-lag in the development of Neolithic culture and agropastoral lifestyle as a function of age in cal years BP/BCE compared to nearby regions (modified after Gronenborn and Horejs, 2023). The stars represent palaeoenvironmental records selected for Fig. 2 (pink stars) and those only discussed in this synthesis (blue stars). Red dots represent Neolithic archaeological sites in the South Caucasus region. Cartographic support: <https://en.mapy.cz>.

However, even if population dispersal was prompted by unfavourable climatic conditions in the Fertile Crescent, it remains to be explained why the mountain environments of the SC suddenly became attractive for human populations. Especially since the arid and cold climatic event of 8.2 ka, which lasted about two centuries, does not offer beneficial conditions for animal breeding or agriculture of plants adapted to warmer lowland regions. Furthermore, this event contrasts with the climatic optimum of the Holocene, which is a long period of increased precipitation between 8000 and 6000 cal BP (6000–4000 BCE), particularly in the eastern Mediterranean region and the Near East (Bar-Matthews et al., 2003; Djamali et al., 2010; Roberts et al., 2008; Stevens et al., 2006, 2001). Moreover, the age of 8200 cal BP marks the transition from the Early (Greenlandian) to the Middle (Northgrippian) Holocene, as defined by the International Commission on Stratigraphy (Cohen et al., 2025). In the Caucasus, palaeoenvironmental studies indicate a significant increase in precipitation during the Early-Middle Holocene Transition (EMHT) (e.g. Joannin et al., 2014), which may have promoted more abundant vegetation, thus creating favourable conditions for the adoption of the Neolithic way of life. This observation raises a central question: is neolithisation of the SC linked to the 8.2 ka event and/or to the greening of the Caucasus, a consequence of shifting precipitation regimes?

Climate change, as reconstructed from palaeo-records, may be temporary or long-lasting. According to the literature on Quaternary and Holocene time scales, an episode of rapid (abrupt) climate change lasts a few centuries, exceeding the decadal variability typical of the interval studied (Sanchez Goni and Harrison, 2010) and is generally considered temporary, because the climate system eventually returns to its initial state (Alley et al., 1997). This corresponds to the definition of an event. In contrast, long-term climate change represents a modification of the global or regional climate regime (or mode), signalling a shift in the balance of the climate system without a return to previous conditions. These changes can be gradual or abrupt, often due to non-linear climatic responses, notably through climate system teleconnections, which refer to interactions between oceanic and atmospheric circulation systems (Tsonis et al., 2008; Wang and Schimel, 2003). Thus, the 8.2 ka event would have temporarily altered the intensity and trajectory of the westerly winds, increasing winter precipitation across arid Central Asia, including the Caucasus, around 8000 cal BP (Chen et al., 2008, 2022). Therefore, it should be distinguished from a climatic shift (Leroy et al., 2019a).

This paper aims to assess the palaeoenvironmental changes recorded in the SC in order to test the hypothesis of greening, i.e. vegetation development and expansion. To this end, a synthesis was carried out, mainly based on available pollen data. In order to assess the respective influences of the shift in precipitation regimes during the EMHT and the relatively short 8.2 ka event, additional proxy data are presented for the period between 10,000 and 6000 cal BP (8000–4000 BCE). The causes and timelines of these changes will also be addressed to assess the climatic mechanisms that influenced the Caucasus and Eurasia and thus contributed to the debate on greening of the SC and its late neolithisation.

2. Palaeoenvironmental data

The archives presented here are shown on the map in Fig. 1. The selected data come from pollen analysis, which provides information on greening by reflecting the temporal dynamics of trees (Arboreal Pollen = AP). These data are presented as reported in the source articles. They include the development of trees expressed as percentages, as a temperate deciduous forest score (TEDE), as the first principal component (PC1), as oak (*Quercus*) percentages, which is a key tree in SC ecosystems. In addition to tree indicators, other indicators of palaeohydrological changes are presented, such as the percentage of aquatic sedge pollen (Cyperaceae) and the water-depth index, which corresponds to the ratio between aquatic pollen and non-pollen

palynomorphs (NPPs). NPPs are micro-remains of organisms other than pollen, such as cyanobacteria, fungi, and algae. Two other indicators are presented for comparison: the first principal component of X-ray fluorescence data (XRF) and $\delta^{13}\text{C}$ values of stalagmites. Carbon isotopes reflect variations in vegetation cover (Wolf et al., 2024). These two records offer the advantage of a higher temporal resolution (Fig. 2). More information on these archives is available in Table S1.

2.1. The climate shift of the Early-Middle Holocene transition

The transition of the Early-Middle Holocene is referred to the literature also as the Early and Mid-Holocene climatic Transition (EMHT). Stager and Mayewski (1997) define it as a climatic reorganization recorded in Africa and in polar regions. It was recorded between 8200 and 7800 cal BP and lasted 200 years or less, in both marine and terrestrial records (Stager et al., 2003; Stager and Mayewski, 1997).

In Arid Central Asia (ACA), the sudden onset of wetter conditions around 8000 cal BP was initially documented in a compilation of palaeoenvironmental data covering a large region of Eurasia, from Lake Van in the west (i.e. 43°E) to eastern China (i.e. 117°E; Fig. 2J; Chen et al., 2008; Jin et al., 2012). In the SC, sedimentary records are reported in a north-south distribution. Based on various palaeoenvironmental proxies, we observe an increase in forest cover and its stabilization around 8400 cal BP at Paravani (Fig. 2H; Georgia; Messenger et al., 2013), as well as around 8000 cal BP at Zarishat (Fig. 2C; Armenia; Joannin et al., 2014), where sedges mark a fen development. Terrestrial pollen, aquatic pollen, and NPPs, as well as sediment elemental composition (XRF), also reveal the expansion of the Shenkani wetland in the Tsaghkahovit Plain around 8200 cal BP (Fig. 2E; Armenia; Cromartie et al., 2020) and the rise in the level of Lake Sevan, observed in Vanevan around 8600 cal BP, followed by the stabilization of the oak forest around 8400 cal BP (Fig. 2D; Armenia; Robles et al., 2022). In Nakhichevan, the formation of the Abbas Göli wetland also appears around 8000 cal BP (Fig. 1K; Kuzucuoğlu et al., 2022). Therefore, the process of “greening” of the SC is mainly accompanied by the formation of grasslands dominated by Poaceae, and to a lesser extent by the expansion of forests and forest-steppes from the northern slopes, associated with the activation of hydrographic networks and wetlands. This marks the end of an Early Holocene dominated by steppes that range from warm to cold depending on the altitudinal gradient.

East of the SC, the pollen data from the Caspian Sea (which acts as a trap for pollen from the surrounding vegetation, especially from the west of the Caspian Sea) indicate that the vegetation was dominated by shrubs, followed by tree development at 8400 and at 8200 cal BP in sediments of the GS05 and GS18 sequences, respectively (Fig. 2F; Leroy et al., 2014, 2013b). To the northeast of the SC, the Shotota swamp record indicates that the landscape remained devoid of trees; however, the climate became less dry from 8200 cal BP onwards, as demonstrated by an increase in the diversity of herbs. Nevertheless, a remarkable spread of woody vegetation, specifically deciduous species, is only observed from 7400 to 6700 cal BP northeast of the Caucasus (Dagestan; Ryabogina et al., 2019, 2020). In the Greater Caucasus, a stalagmite reveals stable vegetation cover and climatic conditions between 8000 and 3000 cal BP compared to the Lateglacial part of the record (Fig. 2I; Sarma Cave; Wolf et al., 2024). Finally, in the southern Black Sea, forest expansion and water salinization, linked to the opening of the corridor separating the Black Sea from the Mediterranean Sea, took place around 8300 cal BP (Fig. 2G; core 22GC3; Shumilovskikh et al., 2012).

The palaeoenvironmental data presented here converge on a major change at the EMHT, despite differing temporal resolutions and dating uncertainties that are difficult to control. This could explain a very coarse synchronicity that, however, does not contradict the observed greening.

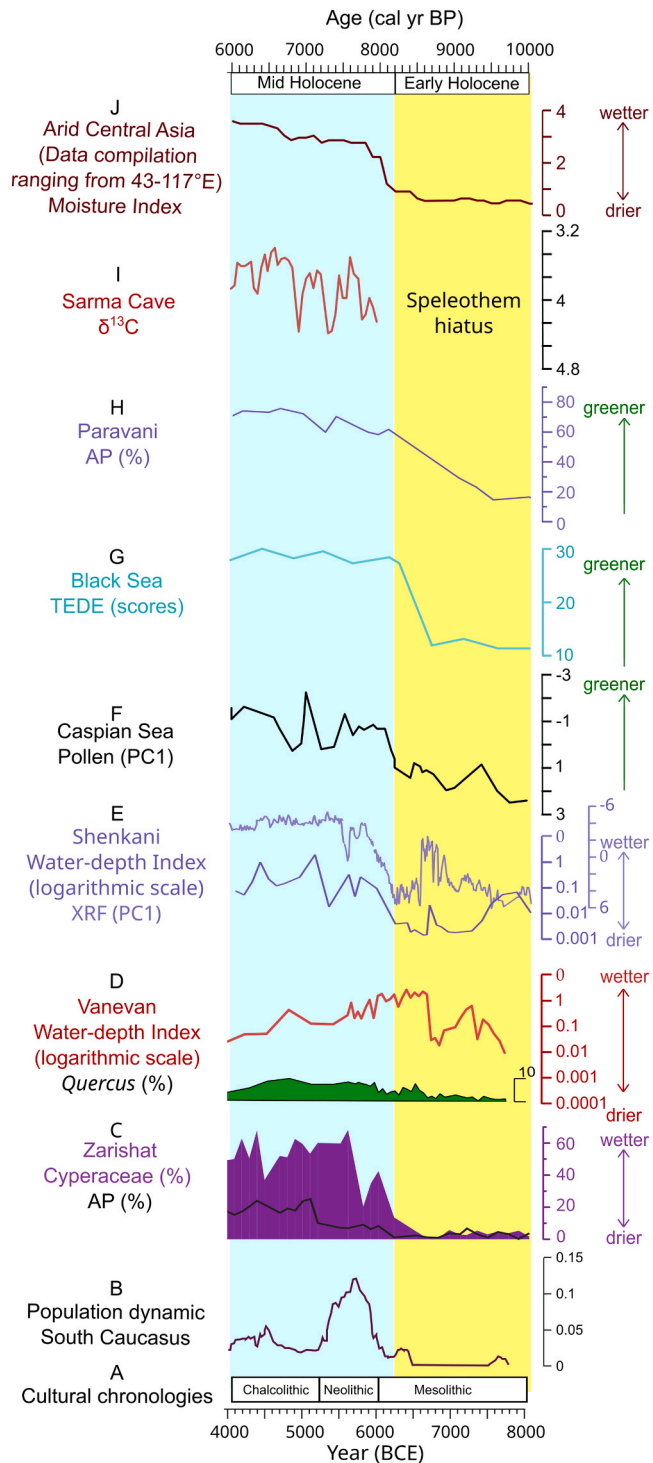


Fig. 2. Comparison of palaeoenvironmental proxies in the studied area between 10,000 and 6000 cal BP (8000–4000 BCE): A) cultural periods in the South Caucasus (Smith, 2015); B) Summed probability distribution of population dynamics in the South Caucasus (Palmisano et al., 2021); C) Cyperaceae and Arboreal Pollen (AP) in Zarishat (Joannin et al., 2014); D) Oaks (*Quercus*) and water-depth index at Vanevan (Robles et al., 2022); E) Water-depth Index and first Principal Component measured by PC1 of X-Ray Fluorescence (XRF) core scanning at Shenkani (Cromartie et al., 2020); F) Pollen first Principal Component (PC1) from Caspian Sea (Leroy et al., 2014); G) Temperate deciduous forest (TEDE) score from Black Sea (Shumilovskikh et al., 2012); H) AP in Paravani (Georgia); I) $\delta^{13}\text{C}$ in Sarma Cave (Wolf et al., 2024); J) Moisture index in Arid Central Asia (Chen et al., 2008).

2.2. Absence of the 8.2 ka event in the South Caucasus: limits and scientific debates

The difficulty of tracking the impact of the 8.2 ka event has sparked debate. This event is generally attributed to the draining of proglacial lakes Agassiz and Ojibway, located at the front of the melting Laurentide ice cap (LeGrande, 2009). Freshwater injection into the Labrador Sea temporarily altered the North Atlantic Ocean circulation for approximately 160 years (Ellison et al., 2006), weakening and deflecting southward the Gulf Stream ocean current as well as associated Westerlies, due to a more southerly repositioning of the Intertropical Convergence Zone (ITCZ). These changes were transmitted globally by atmospheric interactions (Jansen et al., 2007; Parker and Harrison, 2022). Although this event is generally considered to be cold and arid (e.g. LeGrande, 2009), it has a complex spatial structure, with regions sometimes reacting with a delay to the global cooling caused by the melting of the Laurentian Ice Sheet (Wanner et al., 2011). Furthermore, Rohling and Pälike (2005) showed that several cold episodes occurred in different regions over a period of 400–600 years. From a North Atlantic deep-sea sediment core, Ellison et al. (2006) observed a double cold peak, extending from 8600 to 8300 cal BP. Kilhavn et al. (2022) also noted that the response to the 8.2 ka event differed between regions influenced by air masses forming in the North Atlantic Ocean (i.e. Western Europe) and those under the influence of the Mediterranean Sea, i.e. the SC.

In the SC, the studies carried out on pollen and sediment cores report no sign of the impact of the 8.2 ka event (Joannin et al., 2014; Leroyer et al., 2016; Messenger et al., 2017, 2013; Robles et al., 2022). Cromartie et al. (2020) note an erosion phase between 8600 and 8000 cal BP, recorded by Titanium measured by XRF core scanning, which is not accompanied by a vegetation change. According to these authors, even if no obvious cause has been identified, the regional particularity of this phase suggests a potential link with the 8.2 ka event. Beyond the SC, palaeoenvironmental proxies extracted from sediment cores of the Caspian Sea reveal no well-defined signal of this event (Leroy et al., 2013b, 2014). In the S-E corner of the Caspian Sea, the TM sequence (Leroy et al., 2013a) does not record any change either, not an event nor a shift. Also in the Shotota Swamp, Dagestan (Ryabogina et al., 2019), and in Sarma Cave, Georgia (Wolf et al., 2024) provide no evidence of this event. In the southern Black Sea, Shumilovskikh et al. (2012) do not report the 8.2 ka event either.

In syntheses relating to the ACA, this event is not mentioned (Chen et al., 2019; Herzsuh et al., 2023; Shi et al., 2021; Tan et al., 2024). Chen et al. (2008) pointed out that available climate records in the ACA region were limited in their capacity to examine abrupt changes. Since then, the 8.2 ka event has been recorded in the $\delta^{18}\text{O}$ record from Baluk cave in Xinjiang (Liu et al., 2019) and in speleothems located at more southerly latitudes, in Oman (17–23°N) and China (25°N) (Cheng et al., 2009). Whether this event is “visible or not” as Schubert et al. (2023) described it, the scientific community is approaching the limits of temporal resolution for Holocene palaeoscience studies (Berger and Guilaine, 2009).

3. Greening of the South Caucasus and palaeoprecipitation at EMHT

According to Kuzucuoğlu and Tsirtsoni (2016), unlike arid or humid regions, semi-arid regions are particularly sensitive to even minor variations in intensity, distribution and quantity of humidity. During the EMHT, a replacement of Amaranthaceae-rich steppe ecosystems by grasslands appears to have occurred with ages varying around 9000–8500 cal BP (Shumilovskikh et al., 2012; Leroy et al., 2014; Cromartie et al., 2020; Robles et al., 2022). On the other hand, forests generally show a time lag in their expansion, which can be explained by biogeographic factors. This lag depends on various factors, the main one being the proximity to refuge areas, here located to the east of the Black

Sea (Colchis region) and to the south of the Caspian Sea (northern Alborz foothills) (Arpe et al., 2011). The Javakheti Plateau, for example, showed a rapid response of forest ecosystems, as evidenced by records from Paravani and Zarishat (Fig. 2C,H), while the forest response came later in Shenkani (Fig. 2E). Marine records from Black and Caspian Seas clearly demonstrate the development of forest ecosystems. Overall, the SC appears to have experienced an early development of grasslands, followed by afforestation during the EMHT, thus illustrating the process of “greening” of the region.

Sedimentary records and speleothems also confirm this major hydrological change at the EMHT in the SC. The activation of hydrographic networks is evidenced by the development of wetlands and higher lake levels, particularly on the highlands of the SC. Climate reconstructions based on pollen data from Zarishat show, using the Modern Analog Technique (MAT), that annual precipitation increased by 60 % around 8500 cal BP. Spring precipitation increased by 75 % compared to the Early Holocene, while winter precipitation responds earlier, from 9000 cal BP. The climate reconstructions of Robles et al. (2022), based on the Boosted Regression Trees (BRT), highlight the crucial role of summer precipitation, which increased at the EMHT, particularly on the shores of Lake Sevan, in Armenia.

Between Black and Caspian Seas, the change in precipitation regime during the EMHT is therefore marked in the Caucasus. This shift extends to the entire ACA, as defined by Chen et al. (2008), who relate the humidity index to summer insolation in the northern hemisphere. Chen et al. (2019), however, have restricted this geographic area to the “westerlies-dominated climatic regime”, extending east of the Caspian Sea. Tan et al. (2024) have revised Chen et al. (2019) and specified that this phenomenon rather applies to East Central Asia (ECA), where sites are more influenced by summer precipitation, while West Central Asia (WCA) and the Mediterranean region receive rain concentrated during winter (Kutzbach et al., 2014). In this latter area, Wick et al. (2003) suggested that the influence of Siberian high-pressure systems during the plant growing season (i.e. spring) have maintained arid conditions during the Early Holocene, in line with the compilation of palaeoprecipitation maps at the EMHT (Gerivani et al., 2024).

Despite different hypotheses on the seasonality of precipitation, precipitation played a driving role in greening of the SC. Around 8500–8000 BP, the Caspian Sea level, which has been low for several millennia, increased again to relative high levels, i. e. the Post-Mangyshlak highstand (Bezrodnikh and Sorokin, 2016; Leroy et al., 2019b, 2014). Around the same time, the Black Sea extension also increased owing to its connection to the Mediterranean Sea, and reached fully marine conditions (e.g. Shumilovskikh et al., 2012). These larger water bodies must have contributed more water vapour to the atmosphere and amplified the precipitation increase pattern at the EMHT by the “lake effect”.

The latitudinal window through which the westerly winds circulated at the EMHT must have been limited to mid-low latitudes (35–45°N), since the hydrological regime differs further south due to the influence of the position of the ITCZ and the intensity of the Indian summer monsoon (Djamali et al., 2010). In the present interpretation, precipitation peaks during the Holocene climatic optimum, centred around 8000 cal BP, as evidenced by the Sorek Cave (Bar-Matthews et al., 2003) and the isotopic synthesis of Roberts et al. (2008).

4. What is the role of the greening of the South Caucasus at EMHT in the late appearance of the Neolithic?

Orange et al. (2021) report that the 8.2 ka event was considered by Weninger et al. (2006) as a potential cause for the development of productive economies in the SC around 6200 BCE (8200 cal BP) (Sagona, 2017). However, Orange et al. (2021) consider this hypothesis to be provisional, because of the limitations of available data and the confusion that persists regarding the mechanisms explaining the relationship between this climate event and the rise of Neolithic economies,

mechanisms that sometimes appear to be contradictory (Marro et al., 2019). The present palaeoenvironmental synthesis clarifies this ambiguity by excluding the impact of the 8.2 ka event as an explanatory factor for the abrupt and late neolithisation of the SC. Instead, we suggest that it was the greening of the SC during the EMHT that created favourable ecological and resource conditions for a new transformation that was simultaneously socio-economic and cultural. While mineral resources, such as obsidian, were already exploited, other new techniques and knowledge were added (pottery, earthen architecture, new lithic assemblages). Agriculture appears in the low and high plains and valleys (see archaeobotanical syntheses in Decaix et al., 2016; Neef et al., 2017; Hovsepian, 2022). The crops planted are wheat and barleys, along with lentil, pea (see detail in Table S2). Animal husbandry is developing on an open landscape with meadows suitable for grazing and fodder for livestock (see archaeozoological syntheses by Bălăşescu and Radu, 2022, Berthon, 2014, Hirose et al., 2021). Domesticated animals are sheep, goat, cattle and pig (see Table S2 for detail). Other resources such as fishing (e.g. Bălăşescu and Radu, 2022; Ritchie et al., 2021) and forestry (e.g. Akashi et al., 2018), wood for cooking (Decaix et al., 2016) and water management (e.g. Ollivier et al., 2018), enrich this range of possibilities. These practices are highlighted in SC sites (Fig. 1) and listed in Table S2. Due to the paucity of Mesolithic sites in the SC, consequent scarcity of absolute dates as shown by population dynamics (Fig. 2B; Palmisano et al., 2021) and archaeobotanical and archaeozoological data (Janzen et al., 2023), studies cannot adequately document the impact of environmental changes favored by the EMHT. The main Mesolithic sites are also listed in Table S2. They are primarily identified through lithic material (Kmllo tools), and provide evidence of wild game hunting and the exploitation of wild plant resources.

We argue that EMHT conditions spanned the entire Caucasus, as evidenced by emergence of settlements and by evidence of agriculture observed in the mountainous area of Dagestan between 6200 and 5500 BCE (8200–7500 cal BP; Ryabogina et al., 2019) as well as by animal husbandry (Scott et al., 2022).

5. Conclusions

In addition to the debate about processes of neolithisation, whether it concerns the dispersal of populations or the adoption of new practices by local populations, our palaeoenvironmental and palaeoclimatic synthesis offers new insights into climatic factors and their potential role for the time lag of the arrival of Neolithic people and culture in the SC.

Rather than focusing on the one-time impact of the cold and dry 8.2 ka event, we suggest that the climate at the Early to Middle Holocene transition played a key role in the greening of the SC, making possible the development of agropastoral economies characteristic of the Neolithic. However, the concomitance of the 8.2 ka event and the change in the precipitation regime had, until now, created some confusion which was pointed out by LeGrande (2009), who underlined orographic changes or those induced by the retreat of the Laurentide ice sheet. Additionally, available proxy data so far seemed insufficient to build a model for the Levant, Turkish and Aegean areas for the 8.2 ka event (Berger and Guilaine, 2009).

Beyond this debate, we hope to have reached a new step in understanding the links between populations of the SC and their environment. These conclusions result from an interdisciplinary collaboration between archaeology and palaeosciences in line with the recommendations of Izdebski et al. (2016). However, the current synthesis raises new questions.

Firstly, regarding the consequences of the neolithisation of the SC. Although it appears synchronous and abrupt, the pollen study of Sevan (1900 m a.s.l.) shows that cereal agriculture did not develop at an early date in this region (Robles et al., 2022). This observation is also valid for the highlands (>1900 m a.s.l.) of the Lesser Caucasus (Cromartie et al., 2020; Joannin et al., 2014; Messenger et al., 2013). We therefore need additional analyses from archives located at different altitudes to obtain

a complete picture of the impact of neolithisation in the SC. Such studies need to be conducted with higher temporal resolution in order to distinguish short-term events from regime changes.

Secondly, regarding the causes of the shift in precipitation regime at the EMHT, the climatic mechanisms at play have been intensely documented for Eurasia (e.g. (Barhoumi et al., 2021; Chen et al., 2019, 2024; Dugerdil et al., 2026; Shi et al., 2021; Tan et al., 2024; Wang et al., 2024; Xiang et al., 2023; Zhao et al., 2024) and the Mediterranean region (e.g. Ait Brahim et al., 2019; Magny et al., 2013; Roberts et al., 2011; Zielhofer et al., 2017). Westerly winds reinforced by positive feedback (such as water vapour replenishment due to the re-filling of Black and Caspian Seas) are frequently mentioned, which suggest that it would be relevant to examine the SC through model-data comparisons, in order to study its role as a link across the mid-latitudes of Eurasia.

Lastly, this greening phenomenon may be one component of a series of factors that contributed to the neolithisation of the SC. Improvements of agricultural and herding techniques, a greater ability of populations to be mobile, and a larger acceptance of population mixing may also have contributed at different levels to the neolithisation of the South Caucasus.

CRediT authorship contribution statement

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Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Joannin reports financial support was provided by French National Research Agency. If there are other authors, they declare that they have

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.ancene.2026.100535](https://doi.org/10.1016/j.ancene.2026.100535).

Data availability

No data was used for the research described in the article.

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