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# Emergence of agriculture on the Taman Peninsula, Russia

## Émergence de l'agriculture dans la péninsule de Taman, Russie

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**Abstract** – The temporal and spatial diffusion of early agriculture across Europe from the Fertile Crescent has been widely studied, but data from the Caucasian corridor are still rare. This study shows the first evidence for the cultivation of cereals and anthropogenic fires in southern Russia, between the Black Sea and the Azov Sea, 7000 years ago. It suggests that the Caucasian corridor contributed to the spread of agricultural practices throughout the steppes of Eurasia. This study also shows the strong impact of these practices on the dynamics of local coastal and forested ecosystems.

**Keywords:** Early agriculture, radiocarbon chronology, Caucasian corridor, Taman Peninsula, Russia

The onset of agriculture in the Fertile Crescent of Southwest Asia, about 10,000 years ago, and the spread of Neolithic plant economies from the Near East are considered as decisive events in human history (LEV-YADUN *et al.*, 2000; COWARD *et al.*, 2008). Far from the Azov Sea and the Taman Peninsula, the Neolithic, which will later spread by the Caucasus-Caspian corridor and other passages, emerged in the Levantine Corridor, a narrow geographic region located between the northeast Mediterranean Sea and the desert to the southeast (KISLEV *et al.*, 2004; BLOCKLEY and PINHASI, 2011). It is now also clear from high-resolution archaeobotanical evidence, genetic studies and cultural chronologies (MORRELL *et al.*, 2003; ARMELAGOS and HARPER, 2005) that agriculture also emerged as the predominant form of food production in a second region of the Eurasian continent, China (BELLWOOD, 2001, 2005). While early agriculture in China was just as revolutionary as that in Southwest Asia (rice agriculture in the Yangtze River area; foxtail millet and broomcorn millet in the Yellow River area), and may have a similar chronology (UNDERHILL, 1997; LI *et al.*, 2007; ZHAO, 2011), this second region had no influence on the neolithization of the western Eurasian steppe (LI *et al.*, 2007).

While the nature and geographical distribution of Neolithic plant economies in Europe and the Near East have recently become clearer (BOOGARD 2004; COLLEDGE *et al.*, 2005; WEISS *et al.*, 2006; CONNOR *et al.*, 2013), and even if routes of diffusion of early crop agriculture

**Résumé** – Les processus de diffusion spatiale et temporelle de l'agriculture à travers l'Europe depuis le Croissant fertile ont été largement étudiés, mais les données concernant le corridor caucasien sont encore rares. Cette étude montre les premières évidences de culture de céréales et de feux anthropiques au sud de la Russie entre la mer Noire et la mer d'Azov dès 7000 ans avant l'actuel, et suggère donc que le corridor caucasien fut l'une des routes de diffusion des pratiques agricoles vers les steppes de l'Eurasie. Cette étude met également en évidence un fort impact de ces pratiques sur la dynamique des écosystèmes côtiers et forestiers locaux.

**Mots-clés:** Début de l'agriculture, chronologie radiocarbène, couloir caucasien, péninsule de Taman, Russie

practices have been long studied (COLLEDGE *et al.*, 2004; WENINGER *et al.*, 2006; COWARD *et al.*, 2008; LINSTÄDTER *et al.*, 2012), the Caucasus-Caspian corridor and the western Eurasian steppe (MOTUZAITE-MATUZEVICIUTE, 2012) still suffer from a paucity of data (GERASIMENKO, 1997; KANIEWSKI *et al.*, 2015). Debates on the Neolithic are essentially focused on estimating the timing of plant domestication (e.g. PRINGLE, 1998; SALAMINI *et al.*, 2002; KISLEV *et al.*, 2006; LEV-YADUN *et al.*, 2006a, 2006b; TANNO and WILCOX, 2006; HARTMANN *et al.*, 2006; WEISS *et al.*, 2006) and the spread of agricultural practices towards western Europe (e.g. PINHASI *et al.*, 2005; WENINGER *et al.*, 2006; ZEDER, 2008), neglecting the Caucasus-Caspian corridor and the wide Eurasian steppe, which cannot be considered as a uniform zone of neolithization (DOLUKHANOV *et al.*, 2005; VELICHKO *et al.*, 2009).

Here we show that i) the emergence of agriculture in southernmost coastal Russia, at the intersection between the Black Sea and the Azov Sea, occurred 6900 years ago, and ii) this emergence seems to be coherent with an agricultural dispersal that followed the Caucasus-Caspian corridor and the Eurasian steppe according to the scarce data already available. We also reinforce our suggestion with a numerical-derived environmental proxy based on a detailed pollen record retrieved from the Taman Peninsula, which details the landscape evolution following the introduction and development of agricultural practices.

## I - Methods

All the biological indicators derive from a 975-cm continuous core (ORI 09, 45°9'59.80"N, 37°39'22.86"E; + 1.5 m MSL) drilled on the Taman Peninsula (Fig. 1), about 25 km from the Azov Sea and 37 km from the Black Sea. These biological indicators (pollen grains, charcoal fragments, spores) were used to: (i) identify the first traces of agriculture on the peninsula; (ii) radiocarbon date the emergence of agricultural practices on the southwestern Eurasian steppe; and (iii) better understand the impact of early agriculture on ecosystem dynamics.

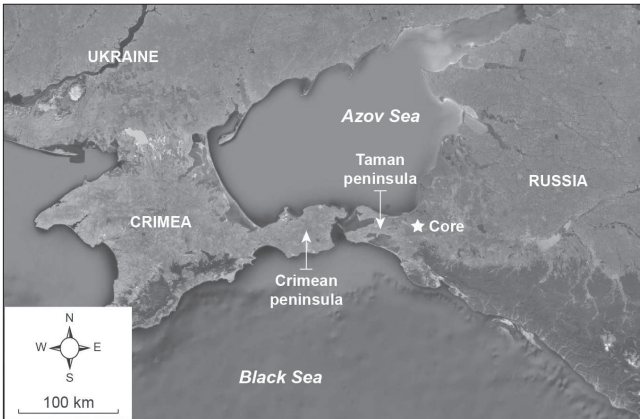


Fig. 1 – Geographical location of the core ORI 09 on the Taman Peninsula, Russia

### I.1 - Chronology

The chronology for the emergence of agriculture on the Taman Peninsula is based on five accelerator mass spectrometry (AMS) radiocarbon ( $^{14}\text{C}$ ) dates on short-lived samples (seeds and small leaves) and charcoal remains (see Table 1) retrieved from the core ORI 09 (GIAIME *et al.*, 2016). Absolute dating was calibrated (1-sigma [ $\sigma$ ] and 2 $\sigma$  calibrations, respectively 68 % and 95 % of probability) using CALIB REV 7.0.4. [<http://calib.qub.ac.uk/calib/>]. Compaction corrected deposition rates have been calculated between the intercepts of adjacent  $^{14}\text{C}$  ages. Because samples have been taken at regular distances along the 975 cm sediment column, the time resolution is directly dependent on the sedimentation rate.

### I.2 - Biological data

A total of 98 samples were prepared for pollen analysis using the standard palynological procedure for clay

samples (FAEGRI and IVERSEN, 1989). Pollen and dinoflagellate cysts were counted under x 400 and x 1000 magnification. Pollen frequencies (%) are based on the terrestrial pollen sum excluding local hygrophytes and spores of non-vascular cryptogams (Fig. 2). The aquatic taxa scores are calculated by adding the local hygrophytes-hygrophytes to the terrestrial pollen sum (Fig. 2). Dinoflagellate cysts were counted on pollen-slides and are displayed as concentrations (cysts per  $\text{cm}^3$ ). All pollen data were transformed into pollen-derived biomes ( $^{\text{Pd}}$ Biomes) (TARASOV *et al.*, 1998), with the following categories: Desert, Steppe, Xerophytic woods/scrubs, Warm mixed forest, Cool mixed forest, Temperate deciduous forest, Cool conifer forest and Cold mixed forest.

### I.3 - Fire history

The fire history of the coastal plain, linked with agricultural practices (Fig. 3), was reconstructed by counting charcoal particles (50-200  $\mu\text{m}$ ) from the 98 slides prepared for pollen analysis as well as from larger charcoal remains (> 200  $\mu\text{m}$ ) (GAVIN *et al.*, 2006; HIGUERA *et al.*, 2007). The 50  $\mu\text{m}$  size criterion was chosen to avoid confusion between microscopic charcoal fragments and opaque minerals, which are typically < 50  $\mu\text{m}$  (PARSHALL and FOSTER, 2002; PEDERSON *et al.*, 2005). Macroscopic charcoals, extracted with  $\text{Na}_2\text{HPO}_4$ , were sorted and counted under a binocular microscope (at  $\times 36$ ).

### I.4 - Statistical analyses

All biological data were analyzed using the software package PAST, version 2.17c [<http://nhm2.uio.no/norlex/past/download.html>]. Principal components analysis (PCA) was performed to test the ordination of samples by assessing major changes in the  $^{\text{Pd}}$ Biome-scores (Fig. 4). Cultivated species, weeds and freshwater plants (hydrophilous and hygrophilous species) are excluded from the matrix. The main variance is loaded by the PCA-Axis1. Polynomial and sinusoidal smoothing curves (regression model) were also selected to synthesise the main changes observed at the site. The best smoothing was chosen according to the highest  $R^2$ . The PCA-Axis1 has been plotted on a linear age-scale (Fig. 4) with the cultivated species and weeds (*Centaurea*, *Plantago*, *Polygonum*, and *Rumex*). A first matrix plot (individual scatterplot) was computed for the PCA-Axis1. A second matrix plot, with two individual scatterplots (PCA-Axis1 versus Cultivated species), was also computed to assess the relationship among these two

Tab. 1 – Details of the radiocarbon age determinations

TAMAN PENINSULA - CORE ORI 09 - RUSSIA								
Code	Depth (cm)	$^{14}\text{C}$ yr BP	Calibrated dates BP		Calibrated dates BC		Intercepts	
			1 $\sigma$ 68 %	2 $\sigma$ 95 %	1 $\sigma$ 68 %	2 $\sigma$ 95 %	BP	BC
Beta-375061	568	4130 $\pm$ 30	4655-4575	4825-4530	2705-2625	2875-2580	4625	2675
Beta-375062	590	4720 $\pm$ 30	5475-5450	5485-5445	3525-3500	3535-3495	5470	3520
Beta-375063	790	6050 $\pm$ 30	6945-6880	6975-6830	4995-4930	5025-4880	6895	4945
Beta-375064	830	6160 $\pm$ 30	7160-7000	7165-6955	5210-5050	5215-5005	7125	5175
Beta-375065	860	6340 $\pm$ 30	7275-7255	7320-7245	5325-5305	5370-5295	7265	5315

The radiocarbon ages are expressed in calibrated years BP and BC at 68-95% of probability.

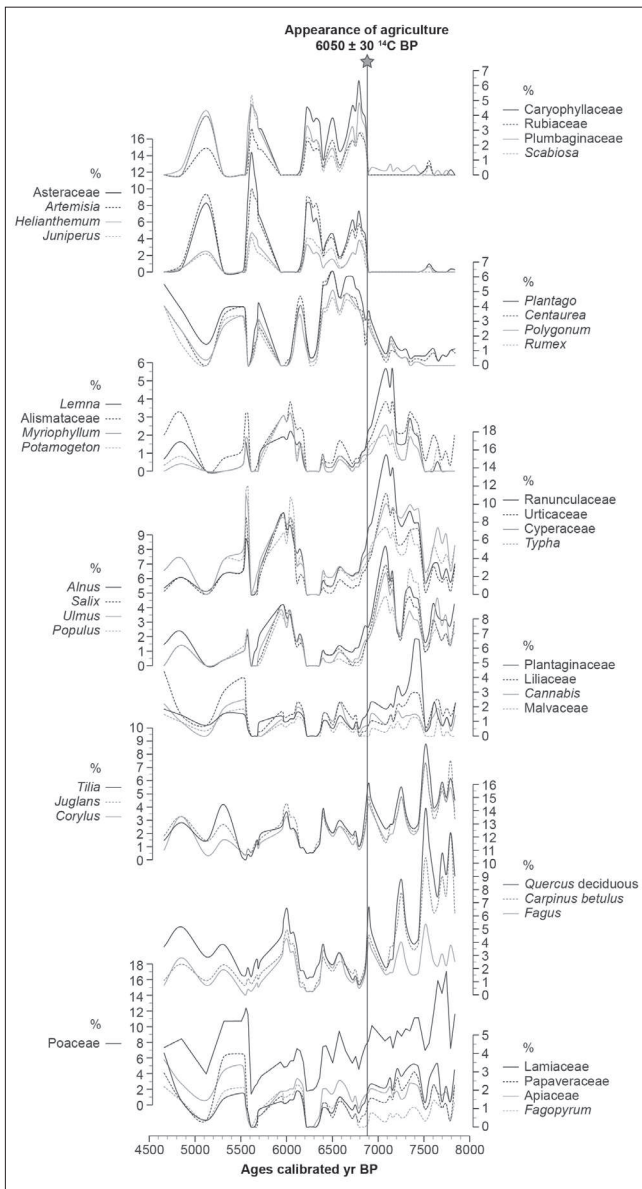


Fig. 2 – Simplified pollen diagram presented on a linear time-scale (cal yr BP)

variables. The weeds are displayed as a spindle diagram to illustrate the abundance of the secondary anthropogenic indicators through the core.

To establish if (i) the forested ecosystems were modulated by anthropogenic activities, (ii) the increase in weeds was influenced by agricultural disturbances, (iii) the fire activity was linked to the human pressures and, (iv) the increase in steppic components was favoured by successive fires, linear detrended cross-correlations ( $_{LD}CC$ ,  $P = 0.05$ ) were calculated (Figs 3-4). The  $_{LD}CC$  assesses the time alignment of two time series by means of the correlation coefficient. The time-series have been cross-correlated to ascertain the best temporal match and the potential delay between the two time-series. The correlation coefficient is then plotted as a function of alignment position. This numerical approach is well-adapted to detect and quantify potential links between environmental data and anthropogenic activities. Positive correlation coefficients are considered, focusing on the Lag0 value (with +.50 as the significant threshold). Negative correlations are also

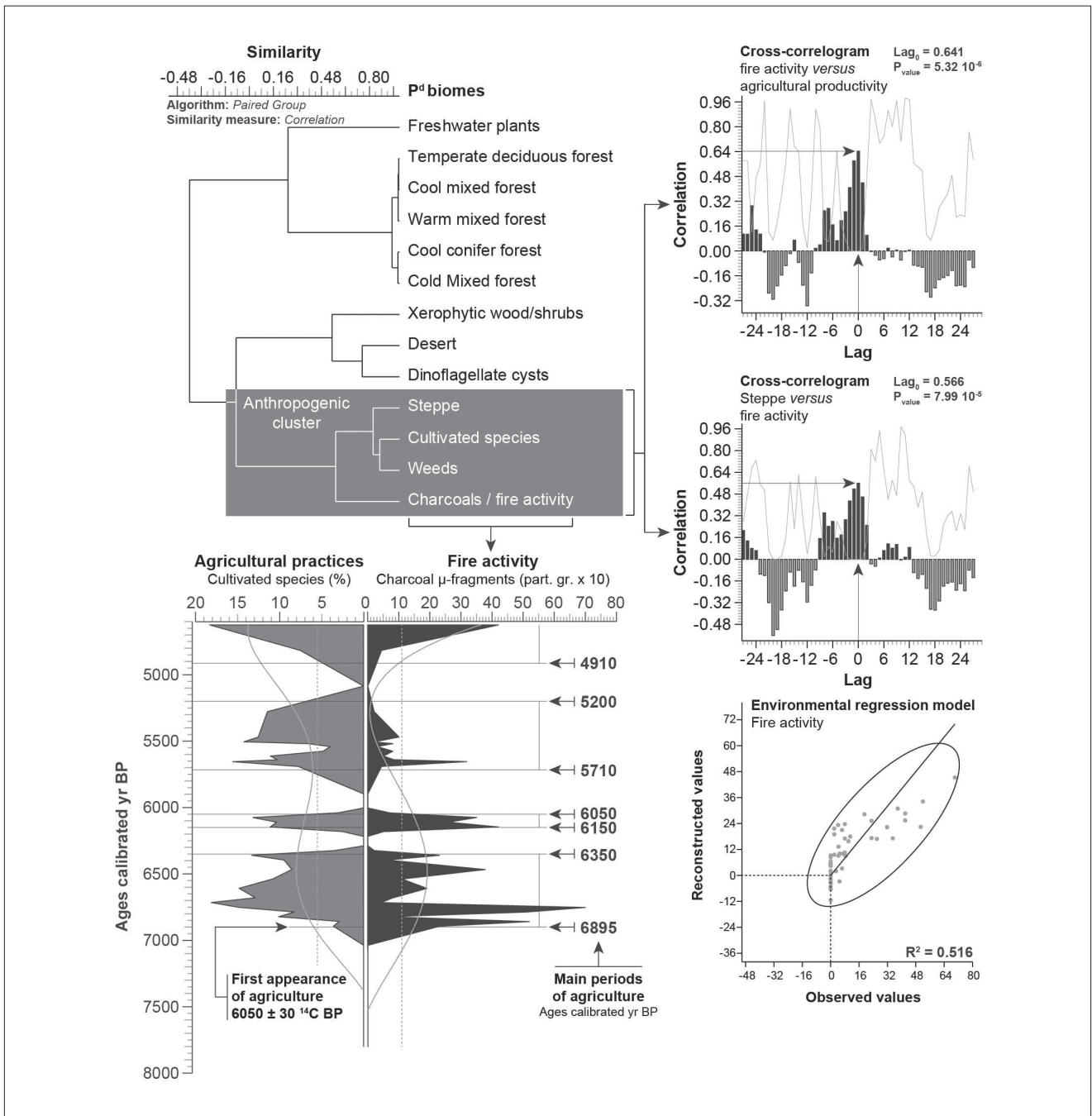
assessed to test the inverse- or non-correlation between the two time-series (with -.50 as the significant threshold). Non-significant values indicate a complete absence of correlation.

A cluster analysis (with paired group as algorithm and correlation as the similarity measure) was performed to group the  $Pd$ Biomes with the freshwater plants, dinoflagellate cysts and fire activity by categorizing the various data in such a way that the degree of association between the two variables is maximal when they have similar occurrences and minimal when they are dissimilar (Fig. 3).

The ecosystem dynamics were also analysed using CABFAC analysis (Fig. 3) to test the impact of human-induced fire activity. The CABFAC factor analysis (Q-mode factor analysis and environmental regression (CABFAC and REGRESS)). Anthropogenic data are regressed on the CABFAC factors using the second-order (parabolic) method, with cross terms. The regression model (RMA) reports the observed values against the values reconstructed from the factors. The selected data for this study are the cultivated species. The consistency of the reconstructed model is indicated by the  $R^2$ .

## 2 - Results and discussion

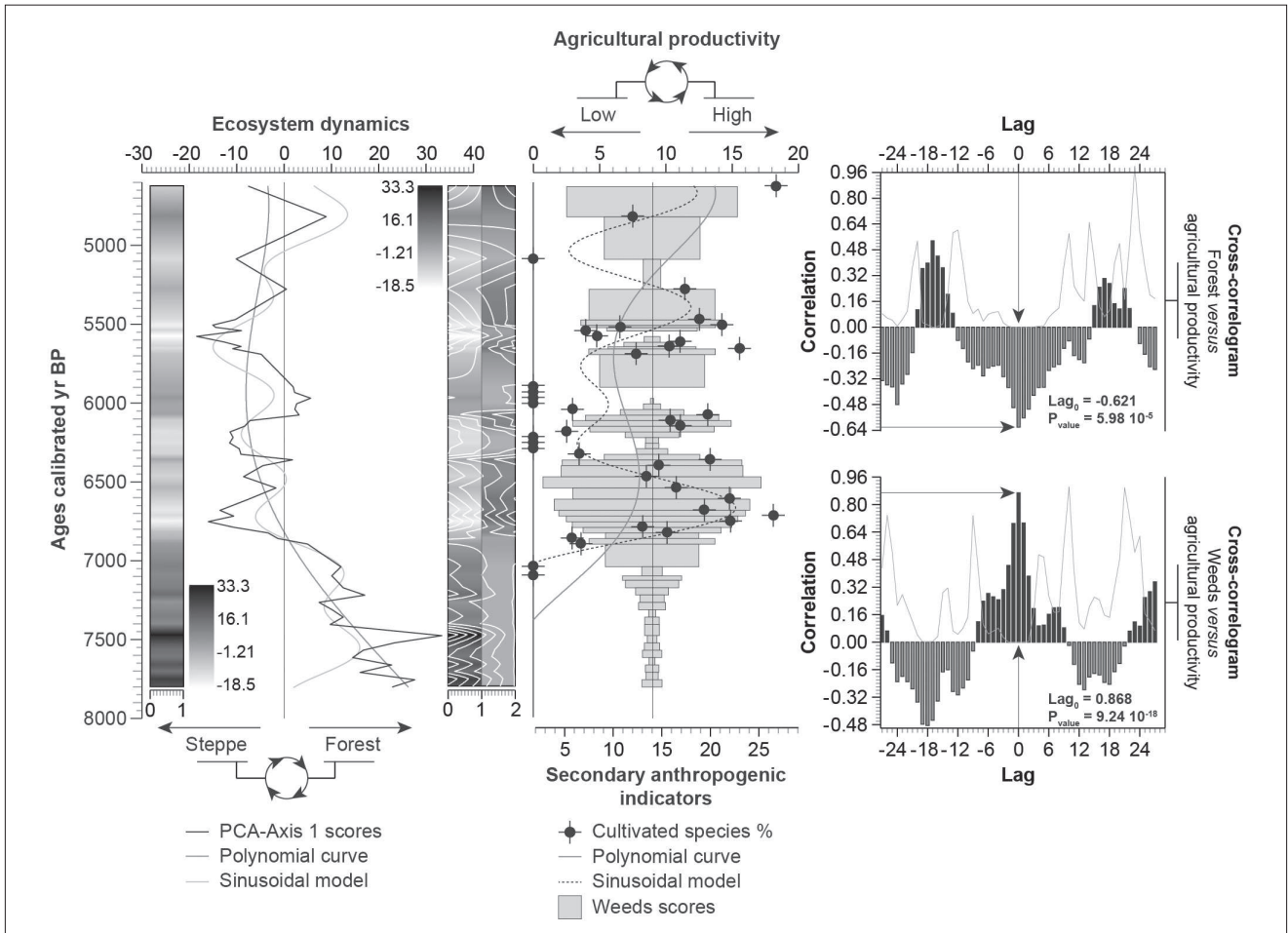
PCA ordination was applied to the core samples (Fig. 4). PCA-Axis1 explains 92.53 % of total inertia. PCA-Axes 2 and 3 respectively account for 5.58% and 0.98 % of the total variability. The PCA-Axis1 positive scores are loaded by the forested components whereas negative scores correspond to steppe vegetation types (Fig. 4). The PCA-Axis 1 scores shows that, for the 7800-4600 cal yr BP period, the coastal vegetation has evolved from a forest to an open steppe (Fig. 2). The first main inflexion of the PCA-Axis-1 curve is recorded from 6895 to 6750 calibrated (cal) yr BP, indicating a loss of forested areas resulting in an expansion of a steppe-landscape between the Azov and Black Seas. The same time-period is marked by the first peak in fire activity, cultivated species and weeds in the area, suggesting the occurrence of human-induced pressures on the ecosystem dynamics (Fig. 3). Before the emergence of agricultural practices, from 7800 to 6895 cal yr BP, the area was mainly covered by a dominant forest (e.g. *Carpinus betulus*, *Quercus deciduous* and *Fagus*) that probably corresponds to the pristine vegetation-type in the area (Fig. 2). The development of a forested vegetation has also been recorded in the Heraklean Peninsula and the Chyornaya Valley since ~7.5 kyr (CORDOVA and LEHMAN, 2005), but with dominant thermophilous taxa. The appearance of agricultural practices in the Taman Peninsula was radiocarbon-dated (AMS  $^{14}C$  date on seeds) to  $6050 \pm 30$   $^{14}C$  BP (Fig. 3), calibrated to 6975-6830 yr BP [2 sigma ( $\sigma$ ) - 95 % probability]. The intercept with the  $^{14}C$  calibration curve gives an age of 6895 cal yr BP, at the end of the Neolithic period, indicating that since this date, a clear



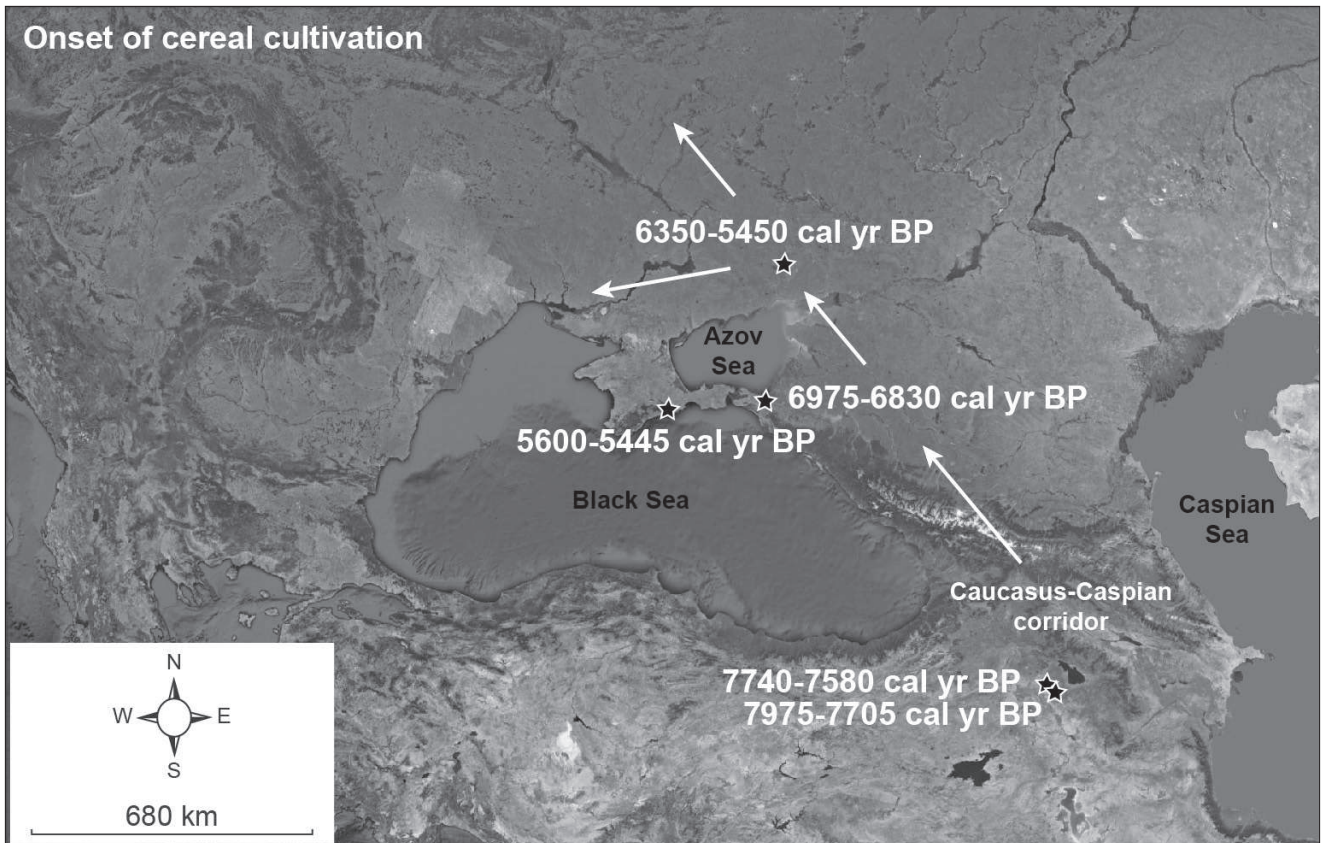
**Fig. 3** – Agro-pastoral farming and human-induced fire activity on the Taman Peninsula for the period 7800-4600 cal yr BP. The cultivated species and charcoal-fragment curves are plotted on a linear timescale. The emergence of agriculture is indicated on the cultivated species curve. The cluster analysis details the components of the anthropogenic group. The linear detrended cross-correlations ( $P=0.05$ ) are displayed with the  $Lag_0$  score and the associated  $P_{value}$  on each graph. The regression model from the CABFAC analysis is shown with the  $R^2$  value depicted on the graph.

anthropogenic imprint in the environment is recorded. No traces of gathering (annual plants from wild stands) or cultivation (wild plant genotypes systematically sown in fields) are recorded before this date, suggesting that the development of agriculture is based on domesticated species. Around 7000 BP, a similar drop in forest density leading to an expansion of steppic components was recorded in the lower Dniepr Valley, but interpreted as the outcome of climate change (KREMENETSKI, 1995). Because no radiocarbon dates were available for the emergence of agro-pastoral farming in the Taman Peninsula, our results have filled this knowledge gap by providing the first evidence of agriculture practices. This radiocarbon-dated evidence seems to be coherent with an agricultural

dispersal that followed the Caucasus-Caspian corridor and the Eurasian steppe (MOTUZAITE-MATUZEVICIUTE, 2012). Data from archaeobotanical investigations of Neolithic-Chalcolithic-period sites in eastern Ukraine and southwest Russia have previously defined the timeline for the earliest appearance and geographical origins of domesticated plants species in this region. Among the three possible corridors of influence upon agriculture (the Balkans, the Caucasus, and the Eurasian steppe), the spread of cereal cultivation into the eastern regions of Ukraine and southwestern Russia seems to have followed the Caucasian corridor and the Eurasian steppe, but only during the Chalcolithic period (MOTUZAITE-MATUZEVICIUTE, 2012).



**Fig. 4** – Ecosystem dynamics in the Taman Peninsula for the period 7800-4600 cal yr BP. The PCA-Axis 1 (92.53% of total inertia), cultivated species and weeds are plotted on a linear timescale. The linear detrended cross-correlations ( $P=0.05$ ) are displayed with the  $Lag_0$  score and the associated  $P_{value}$  on each graph.



**Fig. 5** – Geography of the onset of cereal cultivation south and north of the Caucasus-Caspian corridor (see text for references).

The cross-correlograms (Figs 3-4), resulting from the  $\text{LD}_{\text{CC}}$  ( $P = 0.05$ ), shows a positive and significant correlation between the extent of weeds (secondary anthropogenic indicators) and anthropogenic activities (+.868; e.g. deforestation, agriculture, pastoralism) for the period 7800-4600 cal yr BP, with a negative correlation with the forest components (-.621), suggesting that human pressures were a structuring factor behind the observed changes. Moreover, the fire activity is also positively and significantly correlated with the development of agriculture and the extent of steppic components. This suggests that, in the Taman Peninsula, the main parameter that may have predominantly influenced the ecosystem dynamics is the anthropogenic activities. This hypothesis is reinforced by the RMA (Fig. 3) that underlines the role of human-induced fire activity as a decisive factor, with an  $R^2$  of +.516 (Fig. 3). Although it is commonly believed that regions which experienced an early transition to Neolithic agriculture also became institutionally and economically more advanced (OLSSON and PAIK, 2012), the impact linked to these changing socio-economic models seems to have hastened strong environmental shifts in the Taman Peninsula.

Even if the first traces of modern human behavior date back to 23,000 years in Israel (KISLEV *et al.*, 1992, 2004), and while the first domesticated fruit appears in the Jordan Valley 11,700 years ago (KISLEV *et al.*, 2006), the diffusion of what will become the founding basis of complex societies in the Old World, seems to have been a long and complex process. The spread of agro-pastoral farming from Southwest Asia (COLLEDGE *et al.*, 2005; WENINGER *et al.*, 2006; ZOHARY *et al.*, 2012), and particularly the diffusion, and local inventions, of agricultural practices (DOLUKHANOV *et al.*, 2005; VELICHKO *et al.*, 2009), seems to have been one of the primary drivers behind human evolution but also behind the environmental shifts identified since the Neolithic (e.g. in the eastern Mediterranean, Europe, the Caucasus-Caspian corridor and the western Eurasian steppe). Clearly, there is also an environmental background behind the spread of the Neolithic (ROBINSON *et al.*, 2006; WENINGER *et al.*, 2006) and the adoption of farming in Western Asia, Europe, the Caucasian corridor and the Eurasian steppe that largely coincided with the Climatic Optimum of the Holocene (DOLUKHANOV and SHILIK, 2007) and the 8200 cal yr BP event. The 8200 cal yr BP event may have been one of the factors responsible for the Neolithic spread towards the west of the Mediterranean and the Black Sea, by migration of people whose initial territory came under major water stresses (STAUBWASSER and WEISS, 2006; WENINGER *et al.*, 2006). Climate pressures, mainly a drop in rainfall that generated irregularities in water supply of the first villages, could have caused a migration of peoples out of Turkey to the fertile plains of Macedonia, Thessaly, Bulgaria and the eastern coast of the Black Sea (WENINGER *et al.*, 2006).

While the onset of agriculture dates back to the Pre-Pottery Neolithic A culture in the Near East (11,700/11,400-10,300 calendar yr BP; BLOCKLEY and

PINHASI, 2011), the first domesticated grains seem to have appeared later, during the interval 11,000-10,500 to 9300-9000 uncalibrated yr BP (LEV-YADUN *et al.*, 2000; SALAMINI *et al.*, 2002; WEISS *et al.*, 2006). Studies focused on wheat in northern Syria and southern Turkey have mainly shown an increase in the cultivated form during the Pre-Pottery Neolithic B culture, since 9250 uncalibrated yr BP (TANNO and WILLCOX, 2006). Focusing on the Caucasus-Caspian corridor (Fig. 3), the oldest charred botanical remains from the earliest known agricultural settlements in the Republic of Armenia, Aratashen and Aknashen, were radiocarbon-dated to  $6821 \pm 46$   $^{14}\text{C}$  BP ( $2\sigma$  calibration: 7740-7580 cal yr BP) and  $7035 \pm 69$   $^{14}\text{C}$  BP ( $2\sigma$  calibration: 7975-7705 cal yr BP), giving an accurate time-window for the emergence of cultivated plants (HOVSEPYAN and WILLCOX, 2008) near the Caucasus-Caspian corridor.

In Eastern Ukraine and southwestern Russia, archaeobotanical and archaeological evidence suggest that cereal cultivation began later, during the Chalcolithic period, with a maximum recorded for the Sredny-Stog culture (MOTUZAITE-MATUZEVICIUTE, 2012) at 4400-3500 cal yr BC (6350-5450 cal yr BP; TELEGIN *et al.*, 2003). In SW Crimea, the expansion of farming and pastoral activities was recorded since ~5000-4000 BP (CORDOVA and LEHMAN, 2003). A statistical analysis, based only on Early Neolithic sites distributed from the Eastern European Plain to Central Europe, shows a concentration of radiocarbon dates in the 5300-4900 cal yr BC (7250-6850 cal yr BP) time-window, but with a high heterogeneity and a potential maximum at  $6910 \pm 58$  cal BC ( $8860 \pm 58$  cal yr BP) for the Yelshanian Culture (8990-7950 cal yr BP; DOLUKHANOV *et al.*, 2005). The earliest evidence of domesticated wheat in the Crimea (site Ardych-Burun) dates back to the Chalcolithic (MOTUZAITE-MATUZEVICIUTE *et al.*, 2013), at  $4772 \pm 51$   $^{14}\text{C}$  yr BP ( $2\sigma$  calibration: 5600-5445 cal yr BP). In the northern Pontic area, it has been suggested that the gradual transition to pottery-making occurred at 8950 cal yr BP and that early farming cultures appeared around 7150 cal yr BP (DOLUKHANOV and SHILIK, 2007).

The emergence of agricultural practices at the edge between the Black Sea and the Azov Sea (Fig. 5) appears after evidence for domestication and early cultivation in the earliest known agricultural settlements of the Republic of Armenia (HOVSEPYAN and WILLCOX, 2008). It seems to be quite similar to the emergence of agro-pastoral farming in the Eastern European Plain, and precedes cereal cultivation in Crimea (CORDOVA and LEHMAN, 2003, 2005; MOTUZAITE-MATUZEVICIUTE *et al.*, 2013). The second main corridor through which Neolithic agriculture has spread into continental Europe, the Thracian Plain in the SE Balkans, may shed new light on the dispersal process. It has been suggested that the early Holocene aridity may have been a major deterrent to early agriculture on the Thracian Plain (CONNOR *et al.*, 2013). Lowland aridity may have conspired, with mountain barriers, to delay the transmission of agriculture through the eastern Balkans to the rest of Europe after 8200 cal yr BP (CONNOR *et al.*, 2013).

## Conclusions

Our study gives the first radiocarbon date for the emergence of agro-pastoral farming near the northern part of the Caucasus-Caspian corridor. Agricultural practices started ca. 6900 years ago (6895 cal yr BP) in the fertile area of the Taman peninsula, between the Black and Azov Seas. The Taman peninsula mainly suggests that agro-pastoral farming has significantly altered ecosystems since the introduction of cereal cultivation and pastoralism, leading to a loss of forested areas.

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