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New evidence on the development of millet and rice economies in the Niger River basin: archaeobotanical results from Benin

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Abstract

The Niger River is second only to the Nile in length in Africa, and is host to dense populations of agriculturalists that supported in historical times states such as the kingdoms of Songhay and Mali. This is also the region to which the origin of the Niger-Congo language family, including its Bantu offshoot is attributed. Despite this, archaeobotanical evidence for the development of agricultural systems based on both ancient West African crops, like *Pennisetum glaucum* (L.)R.Br. , *Vigna unguiculata* (L.) Walp. and *Oryza glaberrima* Steud., and crops introduced to the Niger Basin, such as *Sorghum bicolor (*L.) Moench. and *Gossypium* L. sp. has remained limited. In particular the role of multiple crop systems, that included both the wet (rice) and the dry (millets), has not been directly documented archaeobotanically. The present paper presents new archaeobotanical results from 12 sites in Benin that suggest that the rise of larger populations and population centers, like the urban site of Birnin Lafiya, developed only once agriculture diversified beyond pearl millet cultivation to include multiple cereals, as wet rice. The 12 sites are split in four time periods. Flotation results indicate that sites of the first phase (first millennium BC) were dominated by pearl millet, but included sorghum and cowpea. However by the second period (300-900

AD), rice dominated samples, correlated with increasing urbanism, a pattern congruent with existing evidence from Mali. In addition, we report evidence that probable fonio (*Digitaria* cf. *exilis* (Kippist) Staph.) also appeared first in this era of diversification, calling into question previous inferences about the antiquity of these West African millets. The third phase, 900-1400 AD, is characterized by an increase of pearl millet and a decrease of African rice. During the last time period, 1400-1950 BC, we notice a disappearance of rice and a diminution of pearl millet and sorghum. Also, the utilizations of tree fruit such as baobab (*Adansonia digitata* L.), oil palm (*Elaeis guineensis* Jacq.), and African olive (*Canarium schweinfurthii* Engl.) are in constant evolution since the second period. We conclude that agricultural diversification helped to promote urbanization and state formation in the Niger River basin, and that diversification included both use of wetter environments for rice and more marginal dry environments for millet and sorghum.

Introduction: previous work on West Africa agricultural origins

That western Africa was host to indigenous domestications, was first argued by Murdock (1960), who essentially saw this area as a center of origin to be added to the maps of Vavilov (1950). Botanical studies through the 1960s-1970s, by Harlan and colleagues, clarified the distribution of wild progenitors of many African crops, and highlighted a distinction between three ecological zones, the Guinean forests, the west Sudanian savanna and the Sahelian Acacia savanna (see zonation in Fig. 1). The southern Guinean forest zone, or its margins, was source region of tubers (e.g. *Dioscorea cayenensis* Lam., *D. dumetorum* (Kunth) Pax), oil palm (*Elaeis guineensis*), and a more northerly open woodland savanna zone (Sudanian) was the source area of African rice (*Oryza glaberrima*), cowpea (*Vigna unguiculata*), Bambara groundnut (*Vigna subterranea* (L.)Verdc.), and the fonio millets (*Digitaria exilis, Brachiaria deflexa* (Schumach.) C.E.Hubb. ex Robyns). Pearl millet origins were inferred to lie beyond this zone, further north in the Sahelian zone (Harlan 1971, 1992; Harris 1976; De Wet 1977; Fuller and Hildebrand 2013). Comparative ethnography and historical linguistics has inferred an indigenous West African vegeculture complex, focused around yams (*Dioscorea cayanensis, D. dumentorum*) but including several forest tree fruits, such as cola seeds (*Cola* spp.), African olive (*Canarium schweinfurthii*), African plum (*Dacryodes edulis* (G.Don) H.J.Lam.), and Mobola plum (*Parinari curatellifolia* Planch. Ex Benth.). These trees and tubers have a deep antiquity among Niger-Congo speaking groups, at least as far back as Proto-Benue-Congo, several proto-language grades prior to the emergence of proto-Bantu, and thus inferred to go back to perhaps 2000-3000 BC (Blench 2006; Bostoen 2014). Unfortunately there remains no archaeological hard evidence, such as from charred yam parenchyma or starch on ancient tools, that confirms the antiquity of yam cultivation. Among the tree fruits, use of oil palm is widely documented on archaeological sites back to the Late Stone Age, ca. 3000 BC (D'Andrea et al. 2006), with use of *Canarium* evident from 4000-5000 BC at a rock shelter in Cameroun (Lavachery 2001).

What is evident archaeologically is the penetration into the forest zone, or at least in its northern margins, by cultivators of pearl millet, which has its origins further north in the Sahel zone of Mali and/or Mauretania. Recent evidence from impressions in ceramics and a directly AMS-radiocarbon dated grain from the Tilemsi Valley suggest that domestication was well underway by 2500 BC, and completed by 2000 BC at the latest (Manning et al. 2011; Manning and Fuller 2014). Further west in Mauretania, impressions of domesticated pearl millet occur in pottery by 1700-1500 BC (Fuller et al. 2007), in what appears to be a distinct cultural tradition, therefore suggesting two regional trajectories to pearl millet cultivation in the Sahel zone (MacDonald et al. 2009; Manning and Fuller 2014). Elsewhere in Mali south of the Niger River, pearl millet dates back to ca. 1800-1600 BC at Ounjougou (Ozainne et al. 2009; Eichhorn and Neumann 2014) and perhaps at the poorly-dated Windé

Koroji (MacDonald 1996). While this plausibly represents the migration of millet cultivating pastoralists (plausibly Nilo-Saharan speaking, cf. Blench 2006), further south in the woodland savanna we can imagine diffusion of food production into new cultural groups. Here pearl millet is found in the Kintampo culture in Ghana, where cowpea and oil palm are added to the subsistence system, thus integrating forest and grassland subsistence systems (D'Andrea and Casey 2002; D'Andrea et al. 2006; Logan and D'Andrea 2012).

Elsewhere in the savanna zone pearl millet cultivation and villages become established over the course of the second millennium BC, from Burkina Faso to Lake Chad (e.g. Neumann et al. 2001; Höhn and Neumann 2012; Zach and Klee 2003). It is possible these go back to the early second millennium BC near Lake Chad (Klee et al. 2004). Finds in Senegal and further south in central Nigeria (the Nok Culture) indicate pearl millet cultivation by the first half of the first millennium BC (Murray and Deme 2014; Kahlheber et al. 2009), with penetration further south, in the central African rainforest zone, by the 4th century BC (Kahlheber et al. 2014). Linguistic evidence suggests that spades and axes were the most important implements for creation and maintenance of agricultural plots (see Blench 2014).

What is striking from these data is the absence of early finds of African rice (*Oryza glaberrima*), fonio millets (*Digitaria exilis, Brachiaria deflexa*), and sorghum, all grain crops important in the traditional agricultural diversity of western Africa. The present contribution reports archaeobotanical findings from northern Benin, along the Niger River, which provides new evidence for the diffusion of such crop diversity into West African savanna agriculture. In addition, we report evidence for adoption of cotton cultivation, and use of a number of tree fruits.

Archaeobotanical studies from the Crossroads of Empire project

We summarize here archaeobotanical data from twelve archaeological sites excavated as part of "Crossroads of Empires" project, directed by Anne Haour, in northern Benin (Figure 2). The project aims to document settlement patterns and materials in the Dendi region along the Niger River, to shed new light on the development of craft production and polities in this region. Four field seasons were carried out between 2011 and 2014 (Haour et al. 2011, Haour 2013), including investigation into oral history, and studies of iron working (Robion-Brunner et al. 2015). Archaeobotanical research has been an important element in the research program to provide a better understanding of the development of the agricultural economy in this region over time, how it relates to broader regional patterns of agriculture and locally to the support of larger population centers and social complexity.

The 12 archaeological sites are mainly located in the higher reaches of the Niger River valley but still lie relatively close to the flood plain. The sites are located in the Sahelian acacia savanna area. The large alluvial floodplain offers a rich environment for settlement and agro-pastoral activities and is bordered by semi-arid woodland savanna. The climate of this area is characteristic of the West African Sahara/Sahel sub-desert area with a low level of rainfall varying from 1000 mm to less than 100 mm. There are two flood peaks during the same inundation event (Fig. 3). The first is due to the local rainfall around the end of August creating a local flood peak. The second is attributable to the Malian flood peak progression, delayed by the slow release of water from the Inland Niger Delta, which acts like a seasonal sponge, generating a second peak around February (Gallais 1967, 1984; Rouch1950; McIntosh 1995; Van Driel 2001). During the dry period (after harvest), the flood plains are used for pastoralism and during the humid season (after the flooding) used for 'décrue" agriculture (e.g. Sorghum cultivation, *Sorghum bicolor*) or rice cultivation during the flooding. The flood system can be considered as a natural hydraulic system that depends on the rising and falling phase ("crue" and "décrue") from the natural flooding of the river. Usually the principal crop plant before the flood is the rice (*Oryza glaberrima* and *Oryza sativa*) but in the Inner Niger Delta the agricultural exploitation of “décrue” is turned to millet (*Pennisetum glaucum*) and sorghum cultivation (Harlan 1969; Harris 1976).

All 12 sampled sites were settlements. The oldest site, Alibori SIII, is the only one with Neolithic remains (i.e. with ceramics but no metal), dating from 2200-700 BC. Five other sites (Birnin Lafiya, Tintin, Alibori SII, Kantoro and Pekinga) relate to two subsequent time periods, dated from the first century to the 14th century AD. All five sites are small tells (settlement mounds). Other sites (Kozoungou, Geune Zeno, Bogo-bogo, Gourouberi, Madekali, Kargi) date to the fourth period, the last part of the second millennium AD, and were excavated as the precursors of current villages, as identified through oral history. Selected charcoal and seeds were submitted for AMS-radiocarbon dating to help establish a chronology.

Most of the excavated contexts are midden fill deposits, but two of the largest sites also produced contexts within domestic structures. The site of Birnin Lafiya, which, in light of its large area (dozens of acres) and the quantity and quality of artefacts found on its surface, is central to understanding urbanization in this region. Excavations revealed a portion of a house, a circular room paved with potsherds, dating to the 11th -13th century AD (Haour et al. 2016). The site of Tintin is also a settlement mound with evidence for houses, with seven separate potsherd pavements excavated (Champion and Haour 2013).

Over three field seasons (2012, 2013, 2014) 150 archaeobotanical samples were collected (comprising 2452 litres of sediment from 29 excavation units, across the 12 sites), of which 83 have been analyzed

and are summarized here. Sediments were processed manually by wash-over bucket flotation, through 0.25 mm mesh. After sorting, identification of charred seeds was made by comparing taxa with specimens in the modern reference collection housed at the Institute of Archaeology, University College London, with a focus on recognizable crops and major economic taxa. Many small seeds and seed fragments require further efforts for full identification, so results presented here should be seen as preliminary, in addition to ~70 samples still to be sorted and studied. For all the samples analyzed, whole vegetal items were recorded by count in a list of taxa, from which tables of relative frequency were constructed, and ubiquity could be calculated. Archaeobotanical results are summarized by time period (Table 1; Figure 4).

Period 1. Before 400 BC

Period 1 is represented by test pits at Alibori (5 samples) and Kozoungou (one sample, from the earliest layer). Radiocarbon dates put this period in the calibration plateau (800-400 BC), and plausibly also before this, i.e. 900-800 BC (Haour et al. 2016). As might be expected from previous work in western Africa, pearl millet dominates the identified remains from these samples, but cowpea and sorghum are also present. However, ~60% of the recovered remains are small seeds or seed fragments which have not been fully identified but include a range of small-seeded grasses, as well as fragments of probable nutshell that have yet to be identified.

After the end of Period 1 there is an apparent abandonment of the region with no known sites securely dated between 400-300 BC and ca. AD 300. This abandonment partly corresponds to the regional hiatus identified by Breunig and Neumann (2002) in sites from Burkina Faso as corresponding to an era of increased aridity (also Höhn and Neumann 2012). There is also evidence in southern Cameroun of an opening up of northern parts of the central African rainforest, starting ca. 500-300 BC, which has been attributed to increasing seasonality with a more pronounced dry season further south which in turn promoted the expansion of savanna farming systems (Ngomanda et al. 2009; Neumann et al. 2012a, 2012b; Kahlheber et al. 2014). It is therefore plausible that abandonments of the early farming sites in Benin correspond to a period of regional environmental change and cultural readjustment. Outside of the Dendi area, this period corresponds to the emergence of urban sites at Jenne-Jeno and Dia in the Inner Niger Delta in Mali, and Gao in the Middle Niger. Presently, the earliest evidence of African rice (*Oryza glaberrima*) is from these sites (Fuller 2000, McIntosh 1995; Murray 2007a; Gallagher and McIntosh 2015).

Period 2. From AD 300 to 900

For this period, archaeobotanical results are derived from 18 samples from 5 excavation units at the urban site of Birnin Lafiya. These contexts probably represent the initial development phase of the settlement of this site. African rice (*Oryza glaberrima*) dominates the plant assemblage (more than 60% of all remains), while sorghum (<5%), pearl millet (<20%), and cowpea remain present (Fig. 4). The rice remains are dominated by charred spikelet bases, the remains of routine on-site dehusking by-products; these spikelet bases are predominantly of the non-shattering morphology of domesticated rice (e.g. Fig. 4I), which can be separated from wild rices by criteria that parallel those of Asian rice (Fuller et al. 2009). Both baobab (*Adansonia digitata*) and African olive (*Canarium schweinfurthii*) fruits are also present. It is tempting to attribute part of the success of urbanization to the highly productive cultivation of wet, riverine environments with rice, as well as the use of dry, rainfed areas for millet and sorghum. This therefore suggests that rice cultivation spread down the Niger River after its earlier establishment in the Inland Delta and around the Niger bend also associated with the rise of the first urban centres in those regions.

Period 3. From AD 900 to 1400

Several sites from the third period have been sampled, and a larger number of samples (n=47) has been studied from this period. During this period the Dendi area was more densely occupied than in previous periods. Birnin Lafiya seems to reach its largest extent (ca. 30 ha) and more intensive occupation (Haour et al. 2016). Other sedentary sites also emerge in this period, including Pekinga, Tintin (ca. 1 ha), Kantoro (ca. 10 ha), and Madekali. With the exception of Pekinga, all those sites gave evidence of African rice, but in a smaller proportion than during period 2 (around 20%). The pearl millet frequency is higher (around 50%), while the sorghum proportion stayed similar (around 5%). A few grains of *Digitaria* which could represent fonio (*D. exilis*) have been found, and a single occurrence of *Brachiaria* sp. Further comparative studies are needed to confirm species level identification in *Digitaria* or *Brachiaria* in this region. For the first time, a very small proportion of oil palm is noted (1%) and there are also remains of baobab (2%) (Fig. 4K-L).

This suggests expansion in the consumption of pearl millet at the transition from the first to second millennium AD. Given that the wetland area available for rice cultivation is highly constrained, we suggest that the area under wetland cultivation could not be increased from period 2 but that savanna agriculture expanded over more of the rainfed land away from the rivers.

As part of agricultural diversification in drier areas, use of marginal and poor soils is suggested by the presence of fonio (*Digitaria* cf. *exilis*). Previously, these have been suggested to be very ancient crops, with a widespread and patchy modern distribution representing relict populations (e.g. Portères 1976; Blench 2006). Alternatively, we hypothesize that the fonios are later secondary domesticates, taken into cultivation to complement pearl millet and sorghum as risk-buffering crops for poor soils. Much as oat (*Avena sativa*) and rye (*Secale cereale*) were domesticated in Europe from the Late Bronze Age/Iron Age to suit some more marginal regions (Zohary et al. 2012), we suggest that the fonio millets were taken up secondarily, probably more than once, to suit the more marginal agricultural conditions across the west African savannas. In this model, the evidence for fonio in the Mema of region of northwestern Mali (Takezawa and Cisse 2004) from the first half of the first millennium BC may be seen as a local development of cultivation in the interstices of established pearl millet agriculture and perhaps of early rice of the Inland Niger Delta.

There is also some evidence that suggests, rice cultivation may have started to be abandoned in some areas. In the site Kantoro rice is only found in the lower stratigraphic contexts. In the last occupation of Birnin Lafiya, houses of test-pits SIII and SX, no rice remains were recovered. Thus over the course of the second millennium BC prior to AD 1400 rice cultivation seems to have declined in the Dendi region.

Period 4. From AD 1400 to 1950

The final period, which includes colonial and premodern times, appears quite different from the others. Indeed, even if pearl millet is still to be the dominant grain crop of this period, evidence for trees utilization, such as baobab and oil palm, increase. Surprisingly, the presence of crops such as African rice and pearl millet decrease dramatically in this period, with rice ultimately disappearing from the assemblages. Whether or not this increase in trees represents a shift towards wetter conditions should be considered. As many older sites were abandoned in this period, it is possible there was a degree of reforestation, including more elements from the rainforest complex. However, we favor an alternative socioeconomic explanation, however, that the decrease in grain crops and the increase in tree products represents increasing importance of trade as an element in food supply. In this regard more oleaginous nuts could have been traded from the south. Certainly by this period the slave trade may have impacted labor availability and increased the potential to buy food with money, which would have necessitated less on-site crop-processing and decreased the visibility of grain crop evidence.

In this regard it is interesting that samples of this period give evidence of cotton (Fig. 4F-G), a classic cash crop which is labor intensive to process. Production of cotton would have provided a source of wealth also with which to buy cereal grain, perhaps from regions further north, and oleaginous fruits, perhaps from regions to the South. The major difference of the archaeobotanical assemblage of Period 4 suggests that this small study region needs to be seen increasingly as part of a world system and less in terms of local agricultural subsistence production.

West African agricultural development: an interpretive summary

The new data from the Dendi region contributes to filling in the broader patterns of agricultural evolution in West Africa. We have reviewed the available data from 31 sites that are older than 100 BC (Fig. 5), and some 64 sites from the first or second millennia AD (Fig. 6). Considered in terms of broad vegetation belts (as per Figure 1), we can summarize distinction by inter-related histories of crop use across the major biomes of West Africa (Fig. 7). Early grain farming in West Africa was based on the spread of pearl millet among agropastoralists. Over time farming systems diversified and supported increasing sedentism with additional grains crops, grain legumes (especially *Vigna unguiculata*), and various tree crops, mostly with oily seeds. At present, there is no hard archaeological evidence to determine the antiquity of tropical West African vegeculture, although this plausibly preceded cereals in wetter forest regions. Sorghum, from eastern savannas of northern Sudan (see Fuller and Stevens, this volume), diffused into west Africa starting early in the first millennium BC. However, in the Dendi region, and parts of the savanna of Burkina Faso, at least some settlements were abandoned in the middle to late part of the first millennium BC, perhaps suggesting that Neolithic cultivation regimes failed in some regions in response to climate shifts towards a more pronounced dry season. Subsequent re-establishment of agriculture tended to be more diverse, with a great range of cultivated taxa; this diversity can be suggested to have increased resilience by offering buffering against poor years in any one crop.

Another key element of agricultural diversification was the domestication and spread of African rice (*Oryza glaberrima*). While domesticated rice was present in the Inland Niger Delta before 400 BC, and probably by 800 BC (Murray 2007a), the earlier domestication of this species must have taken place in the 1000 or 1500 years prior to this, perhaps further up the Niger River or other tributary water ways to its south. Recent genomic analyses on *O. glaberrima* and *O. barthii* suggests that the maximum bottleneck associated with the domestication of *O. glaberrima* took place 1000-2000 BC (Meyer et al. 2016). Modern genetic differentiation within *O. glaberrima* also suggests that origins of the domesticated form, prior to geographical diversification should be placed somewhere between the Guinea highlands and the Inland Niger Delta, such as in western Mali (Meyer et al. 2016). Nevertheless, from the final centuries BC rice cultivation and urbanism increased in the Inland Niger Delta and began to spread downstream. The recovery of rice spikelet bases in our samples from Benin highlights the potential to track the domestication process for African rice in empirical evidence, once samples of suitable antiquity are available in the upper Niger River region or the Inland Niger Delta. Rice cultivation and urban growth took off in the Dendi area from ca. AD 300. At present there is no archaeological evidence for the dispersal of rice westwards into the Guinea highlands and coast and its subsequent diversification into southern and northern Guinea groups, suggested by geographical genetic structure (Meyer et al. 2016), as well as by historical linguistic data (Fields-Black 2008).

After this period, as populations grew, agricultural production grew through increasing expansion of cultivated area and infilling of rainfed and marginal soils. This is suggested by the relative increase of pearl millet at the expense of rice in the Dendi region sites. This may also be indicated in the appearance and use of marginal, minor cereals like fonio and black fonio, as suggested above. The alternative hypothesis that these were ancient indigenous crops over a wide area (e.g. Blench 2006), calls for testing through further archaeobotanical evidence.

In the medieval era, represented by Islamization, first along the Saharan fringes, grain trade and cash crop production began. This was already evident before the end of the First millennium AD at Essouk in north-eastern Mali, with evidence for cotton and imported wheat and sorghum (Nixon et al. 2011), as well as wheat and cotton from Dia (Murray 2007b). In our material from the Dendi region we see the adoption of cotton production after AD 300 and larger scale cotton processing after AD 1400, accompanied by a decline in staple crops. We suggest that increased trade of food grains, as well as of forest fruits into the Dendi region was balanced by production and export of cotton products. Cash crops production and grain trade became increasingly enmeshed into the economic exploitation of labor, including enslavement and slave trade. Slave and food trade was intensified by the increased frequency of European trade ships that sought both food supplies and slaves from the West African coast to support European wealth creation, for example via sugar starting XV AD (e.g. Mintz 1985; Carney and Rosomoff 2011).

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Table/ Figure Captions

Table 1. A summary of the archaeobotanical evidence from the Dendi region, Benin, in four chronological phases. Total numbers of identified specimens have been summed across sites from each phase. Sample by sample primary data in Champion and Fuller (in press).

Figure 1. Map of modern potential vegetation zones of western Africa. The zonation this map derived from GIS-shape file of Terrestrial Ecosystems of the World (Olson et al 2001; World Wildlife Fund 2017), with zones grouped into broader categories in line with White (1983).

Figure 2. Map showing the location of sites with archaeobotanical evidence discussed in this paper, and in relation to the wider western African region. Early zones of pearl millet cultivation and hypothetical West African vegeculture zone indicated (after Fuller and Hildebrand 2013; Manning and Fuller 2014).

Figure 3. Schematic representation of seaonality in the Dendi, incuding approximate distribution of average rainfall, river flood levels, and sowing and harvesting season. (Based on the sources noted in the texts and interviews with farmers conducted by LC.)

Figure 4. Examples of identified crop and economic species remains from Dendi region archaeological sites: A. Grain of *Pennisetum glaucum* from Birnin Lafiya (BLAF SXI C17 250-260); B. Involucre base of *P. glaucum* from Birnin Lafiya (BLAF SIX C12 120 130). C. Grain of *Sorghum bicolor*, race bicolor type, from Birnin Lafiya (BLAF SIX C11). D. Grain of *Sorghum bicolor*, race guinea type, from Birnin Lafiya (BLAF SXI C17 250-260). E. Spikelet base of *Sorghum bicolor*, probable dehusking waste, domesticated race bicolor (BLAF SIX C11). F. Seeds of cotton (*Gossypium* sp.) from Madekali (KLI-14-SI Bot3); G. Seed fragment (funicular "cap") from *Gossypium* from Gourouberi (GOB SI 60-70); H. Grain of rice (*Oryza glaberrima*) in dorsal and lateral view from Birnin Lafiya (BLAF SIV Pit 3); I. Spikelet bases and husk of *O. glaberrima* from Birnin Lafiya (BLAF SXI C17 250-260); J.

Spikelet bases of *O. glaberrima* from Tintin (TTK C19 355cm); K-L. Seed fragments with hilum of baobab (*Adansonia digitata*) from Madekali and Kozungu (KLI 14-RC1 Unit 6; KOZ-14-SI-80-100cm).

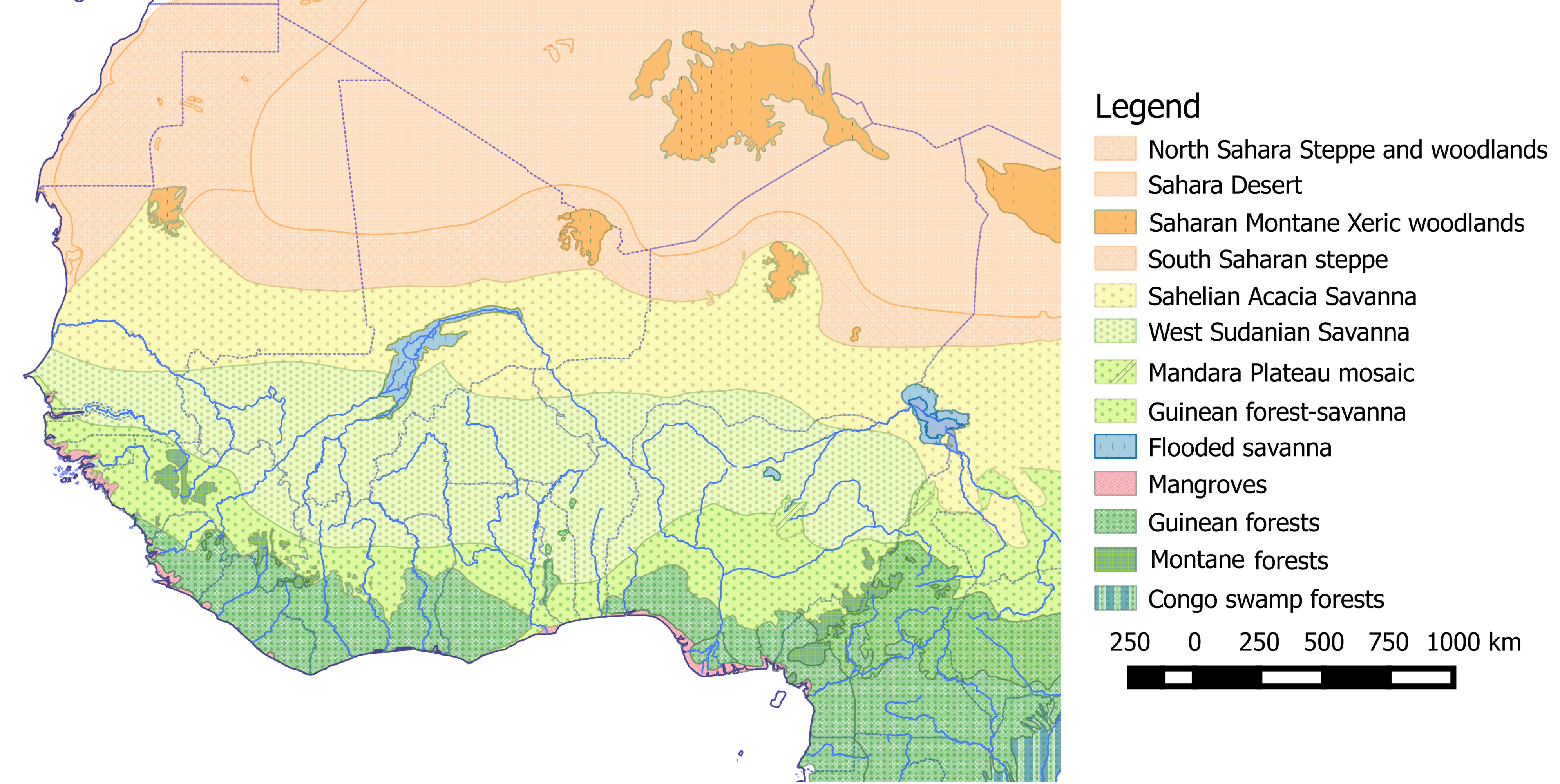
Figure 5. Map of West African sites with archaeobotanical remains older than 2000 Cal yr BP, sites numbered: 1, 2 Alibori SIII, Kozungu SII (the authors).3 Corcoba (Kahlheber 2004); 4, 5 Oursi West, Ti-n-Akof (Kahlheber and Neumann 2007). 6 Birimi (D'Andrea et al. 2001); 7, 8, 9 Boase: B4C, B5C, B6B (D'Andrea et al. 2007) ; 10 Kintampo: K6 (Stahl 1985); 11 AZ22 (the authors, unpublished); 12 Karkarichinkat (Manning et al. 2011); 13 Kolima Sud Est (Takezawa and Cisse 2004); 14 Ounjougou: Varves West (Ozainne et al. 2009); 15 Winde Koroji (McDonald 1996); 16 Dhar Oualata (Amblard and Pernes 1989); 17, 18 Dhar Tichitt (Munson 1976); 19, 20 Djiganyai, Oued Bou Khzama (Fuller et al. 2007a); 21 Oued Chebbi (Amblard and Pernes 1989); 22 Adrar Bous (Shaw 1976); 23 Akura (Kahlheber et al 2009); 24 Apa (Orijemie and Sowumni 2014); 25 Gajiganna (Klee et al. 2004); 26, 27 Janjala, Janruwa (Kahlheber et al. 2009); 28 Kursakata (Klee and Zach 2003); 29 Mege (Bigga and Kahlheber 2011); 30 Ungwar Kura (Kahlheber et al. 2009); 31 Walade (S. Murray and Deme 2014).

Figure 6. Map of West African Sites with archaeobotanical crop remains younger than 2000 Cal Yr BP, sites numbered: 32 Juffure (Gijanto and Walshaw 2014); 33 Cubalel (Murray et al. 2007); 34 Sincu Bara (Murray 2008); 35 Arondo (Gallagher 1999) ; 36 Sorotomo (Morris 2013); 37 Dia-Shoma (Murray 2007b); 38 Jenne-jenno (McIntosh 1995); 39-40 Toguere Galia, Toguere Doupwil (Bedaux et al. 1978),41 Tellem (Bedaux 1972) ,42 Tongo Maare Diabel (MacDonald 1996, Under study by LC); 43 Sadia (Huysecom et al. 2011, Under study by LC); 44-50 Oursi, Oursi hu-beero, Kissi 22 & 40, Kolel Nord, Saouga, Corcoba (Kahlheber 2004); 51 Gao Saney (Daphne Gallagher App. V. in Cisse 2011 PhD); 52 Gao Gadei (Fuller 2000); 53 Essouk (Nixon et al. 2011); 54-64 Birni Lafia, Madekali Road,

Madekali, Kantoro, Pekinga, Tintin, Guene-Zeno, Bogo Bogo, Kargui, Goroberi, Kozungu SI (Champion and Fuller, this paper); 65 MAS541 (Dueppen and Gallagher 2013); 66 Yohongu (Kahlheber and Neumann 2007); 67 Kirikongo (Dueppen 2008); 68-79 Banda 13, 27,41,Kuulo Kataa, Ngre Kataa ,Makala Kataa, Bui Kataa, A-212, B-112 (Logan 2012); 80 Daima (Connah 1981); 81,82 Elkido North, Dorota (Magnavita 2002); 83-91 Mongossi (Marliac 1991), Jiddere Saoudjo (Otto 1996), Kayam, Salak (Otto 1998), Tchere, Balda Tagamre (Otto 1996), Goray (Marliac 1991, Otto and Delneuf 1998), Louggero, Mowo (Delneuf and Otto 1995); 92-94 Be, Sumpa, Douloumi (David 1976,1981);

Figure 7. Schematic timeline of the antiquity of major western African crops based on current archaeobotanical evidence across four ecological zones (see Fig. 1). Evidence from sites plotted in Figures 5 and 6. Question marks on occurrence of *Elaeis* in the Niger River valley account for the possibility that these were imported from further south.

Phases	**Sites**	**Samples (n)**	**Volume (litres)**	***Pennisetum glaucum***				***Oryza glaberrima***				Indet seeds	Indet fruits	*Sorghum bicolor*	*Adansonia digitata*	*Elaeis guineensis*	*Canarium shweinfurthii*	*Vigna unguiculata*	*Gossypium* sp.	*Capparidaceae*sp.	*Digitaria*sp.	*Panicum* sp.	*Brachiaria*sp.	*Acacia* sp.	*Moraceae*sp.	
				Spikelet	involucre	Seed	**Total**	Lemma	Spikelet	Seed	**Total**															Total
Phase I	ALB-SIII KOZ-SII	6	120	0	1	20	21	0	0	0	0	183	53	15	0	0	0	7	0	0	0	0	0	0	0	269
Phase II	BLAF SIV,VIII,IX,XI,XIII	18	276	0	81	288	369	48	1144	10	1202	218	48	101	7	0	16	1	2	0	0	1	0	0	0	1965
Phase III	BLAF SIII, SIX, SX,SXIII TTK-SI PEK-SI KLI-RCI KRO-SII	47	752	0	245	2153	2398	14	879	9	902	678	310	275	101	44	10	13	2	0	3	5	1	0	0	4742
Phase IV	GOB-SI ROU-SI KOZ-SI,II GOG-SI KGI-SI KLI-SI	12	120	81	190	35	306	0	0	0	0	281	148	22	29	57	16	0	49	15	5	0	0	1	1	930
Total		83	1268	81	517	2496	3094	62	2023	19	2104	1360	559	413	137	101	42	21	53	15	8	6	1	1	1	7906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West Sudanian Savanna
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Flooded savanna
Mangroves
Guinean forests
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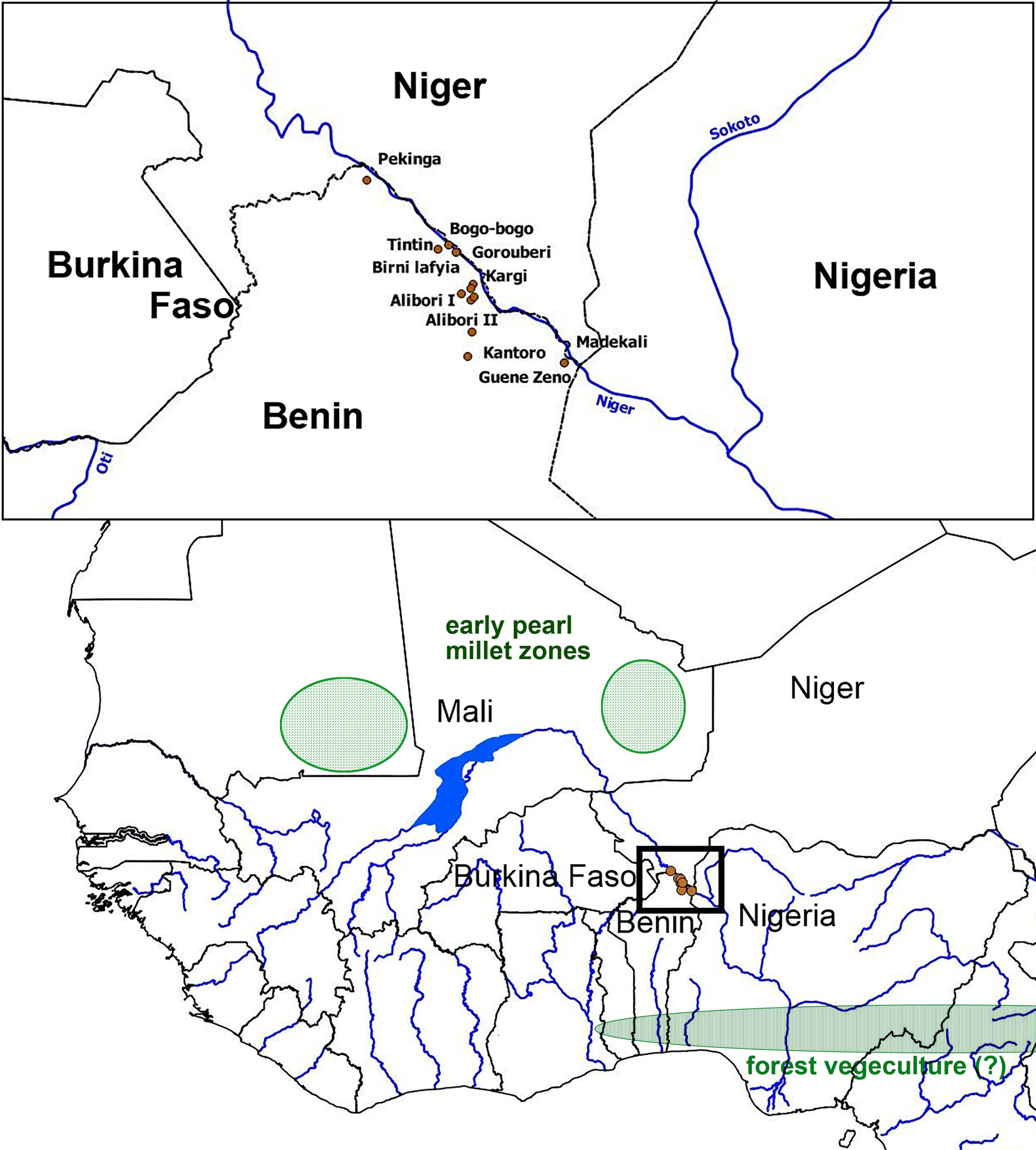

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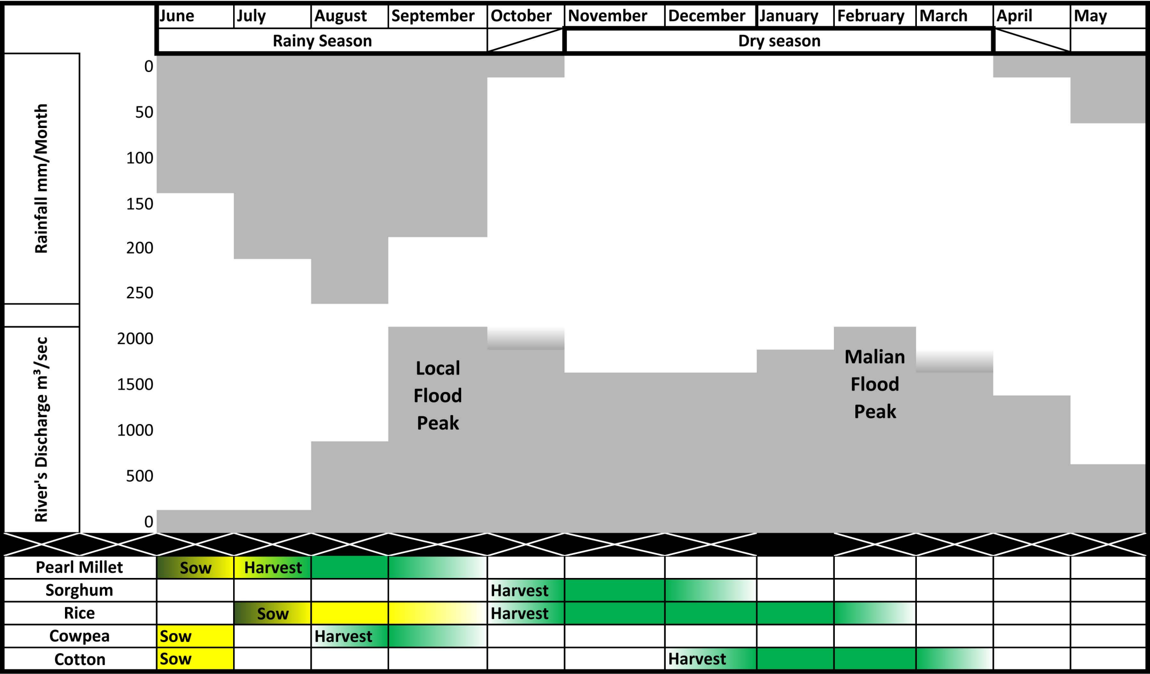
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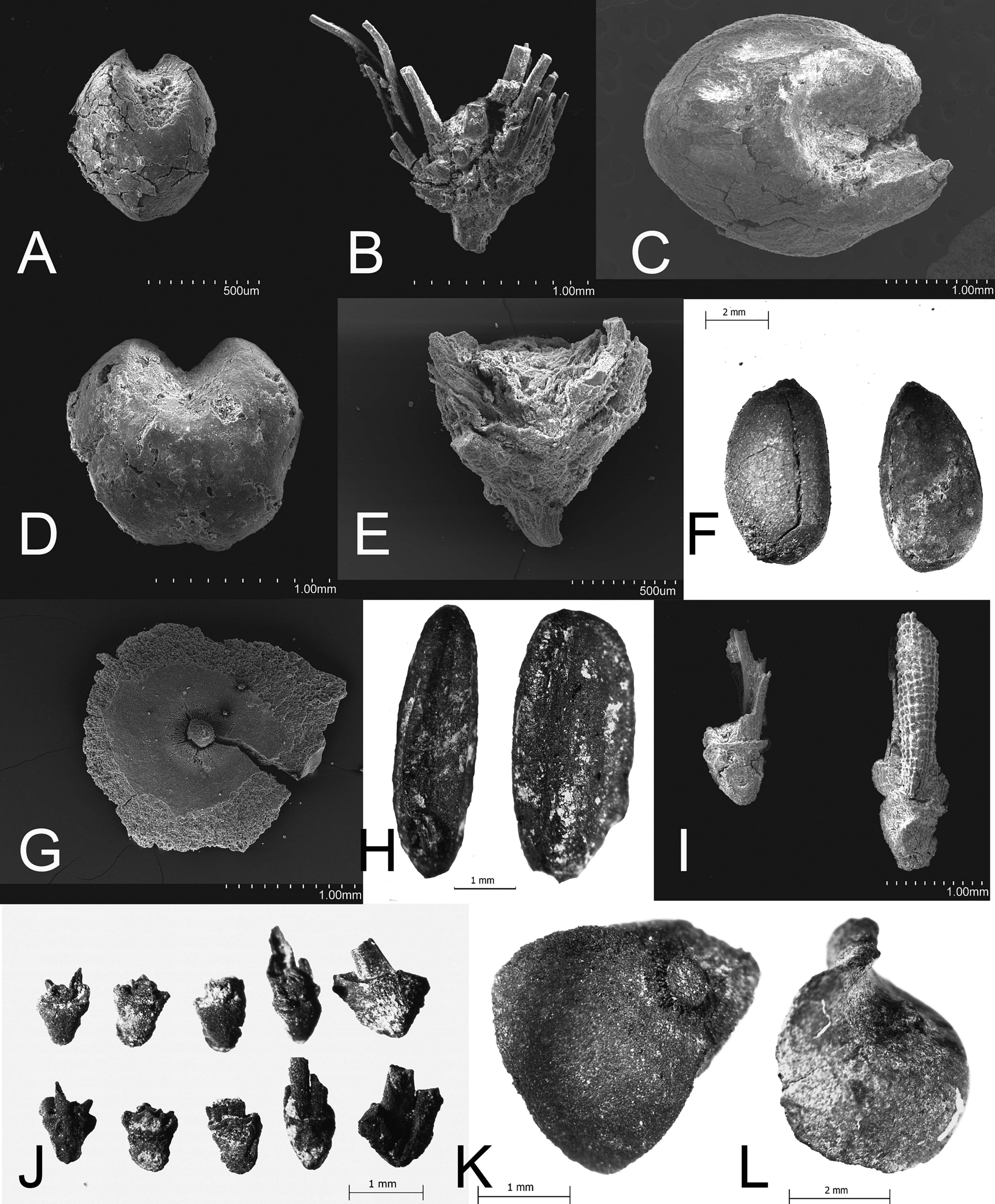
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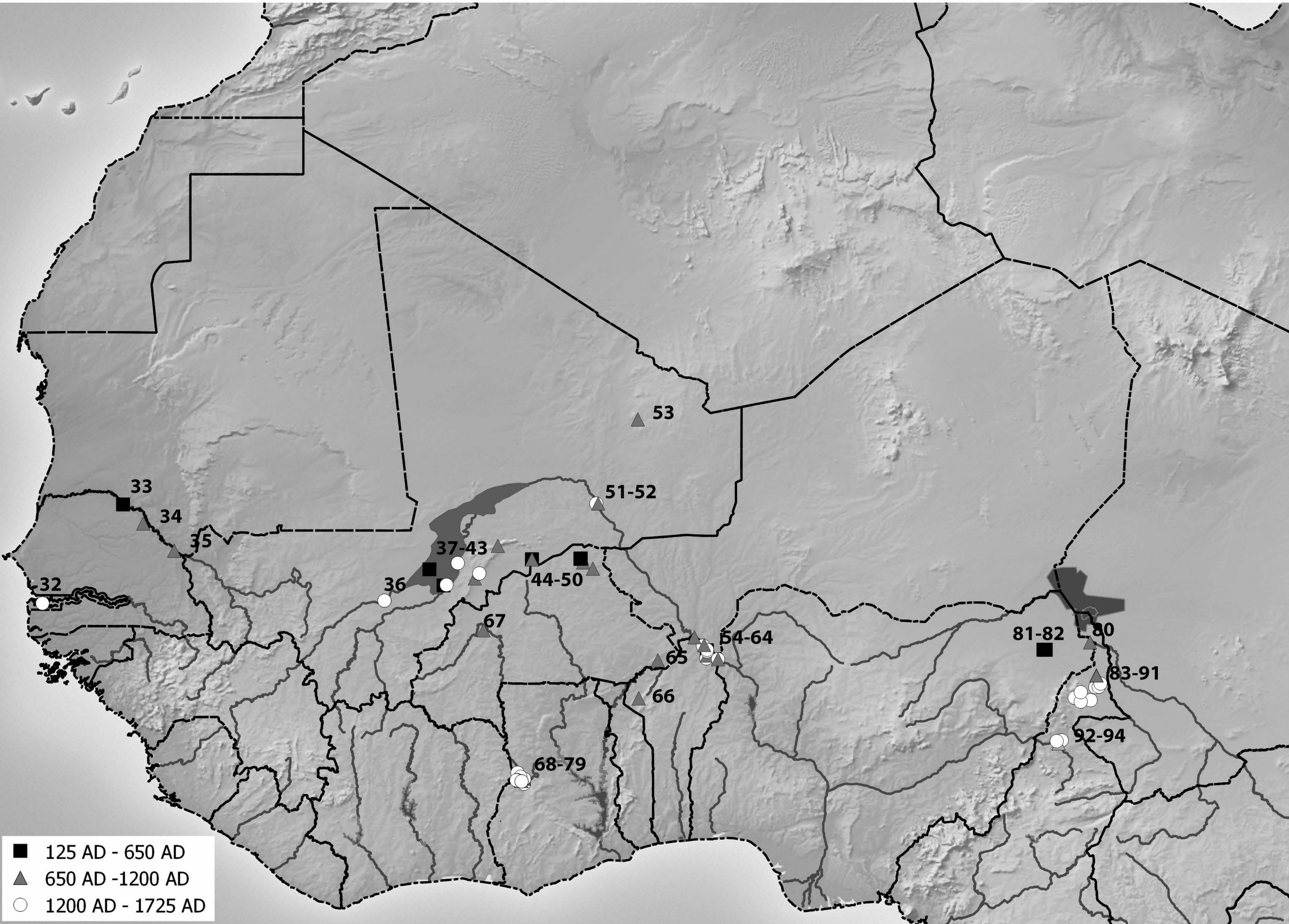

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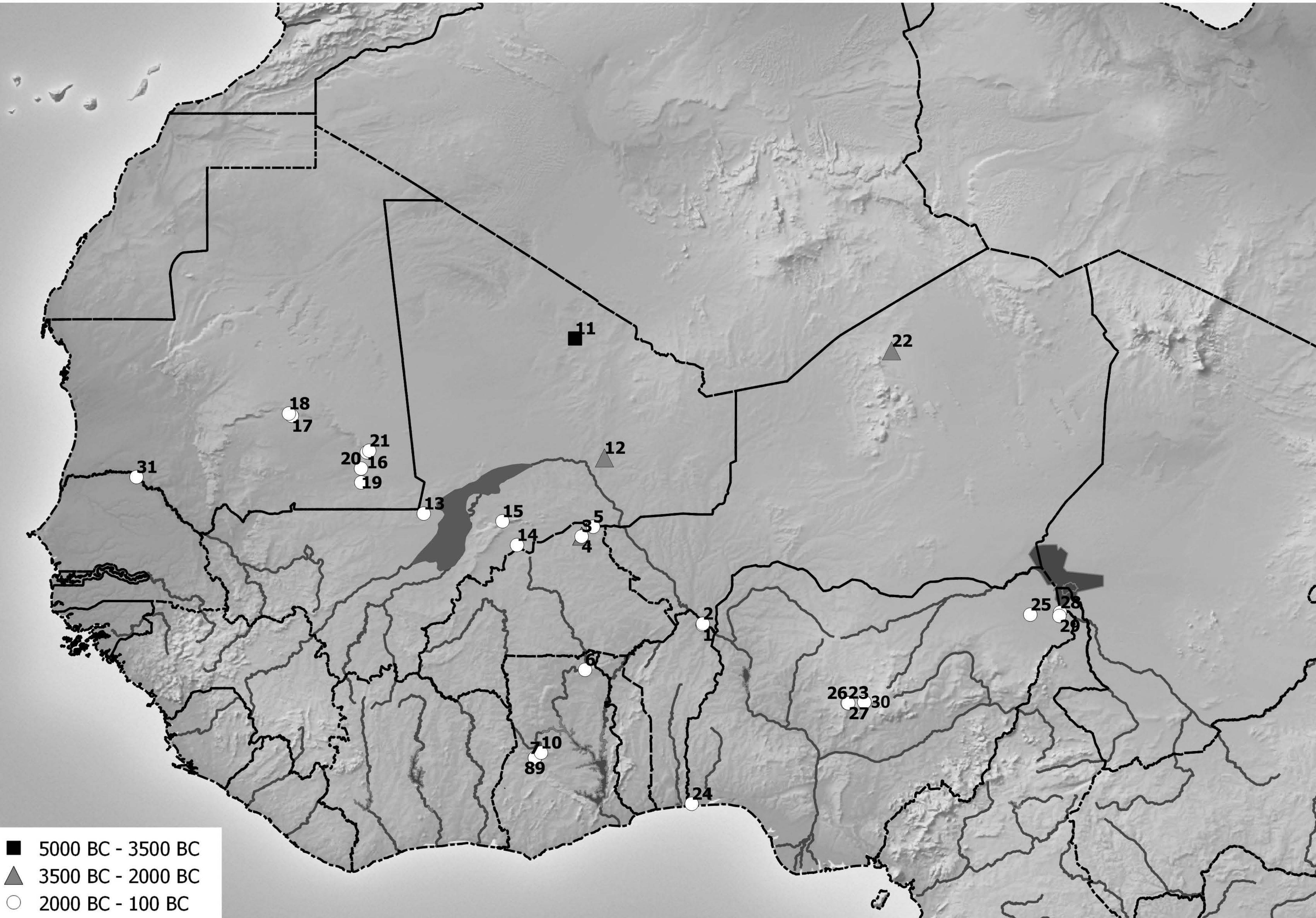
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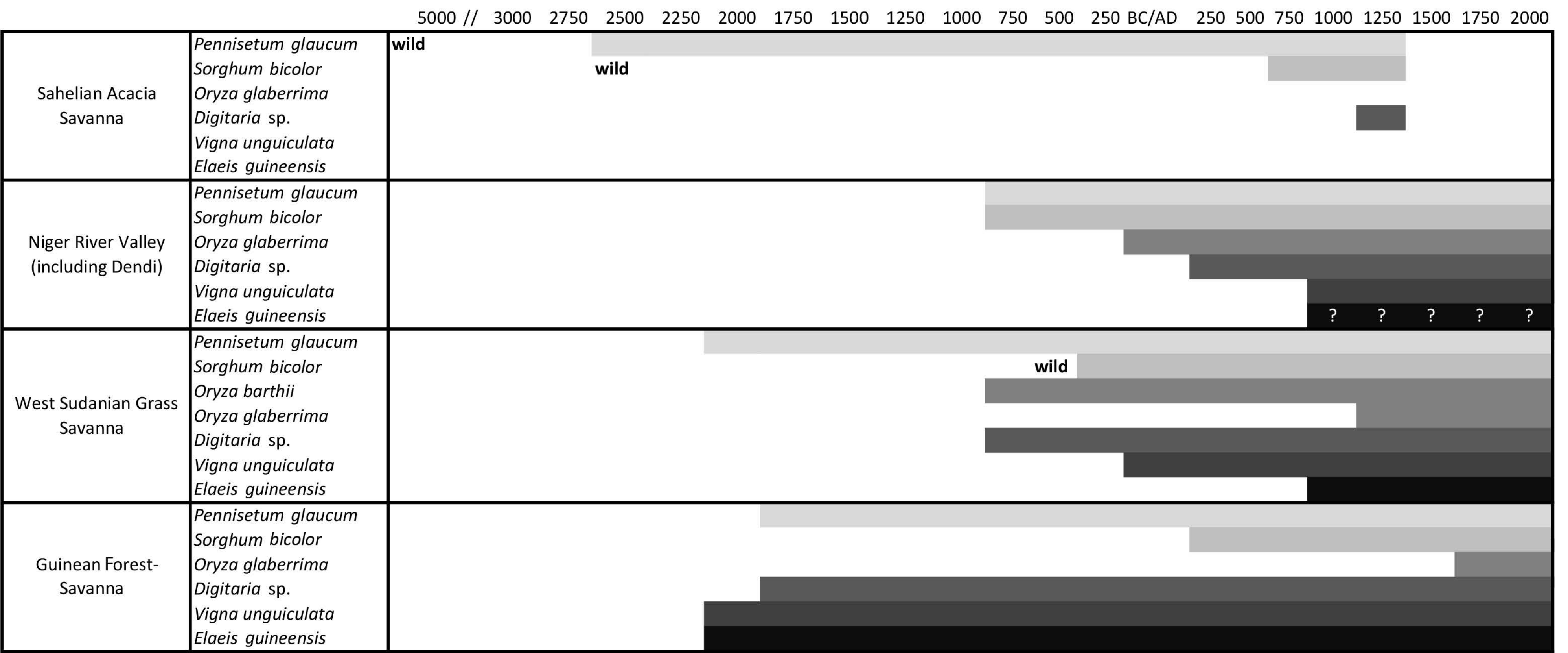
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Digitaria sp.
Vigna unguiculata
Elaeis guineensis
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wild
Niger River Valley (including Dendi)
Pennisetum glaucum
Sorghum bicolor
Oryza glaberrima
Digitaria sp.
Vigna unguiculata
Elaeis guineensis
? ? ? ? ?
West Sudanian Grass Savanna
Pennisetum glaucum
Sorghum bicolor
Oryza barthii
Oryza glaberrima
Digitaria sp.
Vigna unguiculata
Elaeis guineensis
wild
Guinean Forest-Savanna
Pennisetum glaucum
Sorghum bicolor
Oryza glaberrima
Digitaria sp.
Vigna unguiculata
Elaeis guineensis