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Millets and Their Role in Early Agriculture

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While the importance of such large grained cereal crops as wheat, corn and rice to the beginnings of agriculture are well understood, a small group of small-seeded grasses known as millets are often marginalized or ignored. When millets are incorporated into early farming models they are generally seen as a minor grain crop playing a secondary role in the agricultural strategy. Millets have been recovered from archaeological sites throughout the globe, yet rarely are they found in large numbers or perceived as a primary food source. This paper explores the occurrence of early millets in the archaeobotanical record and demonstrates how millets need to be better incorporated into interpretive models regarding early agriculture.

Millets

“Millet” is a generic term for a heterogeneous group of forage grasses known for their small “coarse” grains (Weber 1998). The term is well established, appears regularly in the literature, and cannot be avoided in any discussion dealing with seed crops. Yet there is still a need to develop a clear set of criteria as to which species should be considered a millet. Millets represented in the prehistoric world can be placed in to one of nine common genera; *Brachiaria, Digitaria, Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum, Setaria, Sorghum*. In addition, some authors would group with these other “minor” cereals such as *Coix* or *Bromus* (De Wet 2000) These include species that are cultivated and wild taxa that are collected (see Tables 1-2). Amongst “millets” are a wide range of grasses that have been domesticated in many different parts of the world (Figures 1-2). The most prominent and well known millets are the large or great millets of Africa, *Sorghum* and *Pennisetum*. These two taxa account for the majority of millet grain produced around the world. The rest of the millets are often referred to as the small, or minor millets (Table 2). While these small seeded grasses account for less than one per cent of food grain produced in the world today, they are essential food crops in some regions today (de Wet 1989), often amongst poor or marginal populations. Their importance in the past is likely to have been greater in several world regions, as explored by Austin (2006). In several parts of the world the earliest archaeological plant finds include millets, as is the case in regions of India, Mexico, China and Africa. These small millets, however, have received much less research attention by archaeologists and botanists than the “big” cereals (rice, wheat, barley and maize). The process by which these plants were domesticated and the mechanisms and pace by which they spread to other regions of the world is still being researched. While in some regions millet cultivation follows the introduction of domesticates, in other regions it appears to be an independent process preceding the introduction of crops from other regions, as in South India (Fuller et al. 2004; Fuller 2005a) and West Africa (Neumann 2004; Fuller 2005b). Until more research is carried out it is difficult to explain the spread of individual millets and whether these processes were rapid or slow, how many centres of original cultivation they came from (cf. Jones 2005), or whether these should be regarded as secondary domesticates brought into cultivation locally under the influence of cultivation based in introduced crops (as favoured by MacNeish 1992; for China see Cohen 1998; 2002; also, cf. Bellwood 2001; 2005).

Based on a combination of archaeological data and genetic studies of wild and cultivated populations, millets can be placed in likely, though somewhat controversial, geographical regions of origin (our current best guesses are summarized in Figure 1). Still questions remain regarding when and where some species of millets were first used and later domesticated, how many times each was domesticated, as well as the routes of their dispersal. Most millets are Old World in origin and they had their origins in a wide range of regions in Asia and Africa (De et 1989; 2000; Doggett 1989; Harlan 1992; Kimata and Sakamoto 1992;   Weber 1998, Fuller 2002; Fuller and Madella 2001). Despite historical and prehistorical evidence for millet crops in Europe (De Wet 2000; Jones 2005), more cultural emphasis and research effort has been placed on the early history of wheats and barley.

A few millets were independently being cultivated in the Americas in prehistory (De Wet 2000; Austin 2006), although these were relatively restricted and unimportant at the time of European contact. For example, *Panicum sonorum* was cultivated in the American Southwest in ethno-historic times, although it lacks an archaeological record (Nabhan and De Wet 1984). *Setaria macrostachya* and *S. parviflora* were a prominent part of the archaeobotanical evidence from Mexico prior to clear evidence for domesticated maize, and persisted into historical times as cereals in some regions (Callen 1967; Smith 1967; Pearsall 1995; reviewed in Austin 2006). While it may debatable as to whether these early finds were domesticated or might have been gathered wild (cf. Piperno and Pearsall 1998), they nevertheless attest to a forgotten importance of millets in the American past. The significance of these in diet and in civilization (i.e. in the diet of urban populations and elites) paled in comparison to maize, once domesticated maize became widely available. A similar story accounts for the demise of the South America minor cereal "mango" (*Bromus mango*), which had been cultivated in parts of Chile until the 18th and 19th century AD, when it was replaced by wheat and barley that had been introduced by Europeans (De Wet 2000: 113).

These well-documented cases from the Americas suggest parallels to processes in the Old World in which original millets decline in importance as newer crops replaced them. This might include crops that were more productive and were preferred for social reasons. In the case of several parts of India, the availability of African millets has marginalized indigenous small millets that were earlier (Weber 1998; Fuller 2003; 2005). Of particular importance has been the spread of rice, which has often been preferred for taste and for its high productivity under intensive cultivation, often connected to more complex, hierarchical societies (Fuller 2005: 769; 2006: 193; Smith 2006; Morrison 2006).

Although many different species are represented, millets are generally seen as annual warm-weather grasses that grow in semiarid zones of moderate rainfall. However, both wild and cultivated varieties of millets are found in a variety of environments including the subtropical and tropical regions of the world. They have a relatively short growing season of three to four months (Rachie 1975; Rao 1989). Their high genetic diversity and self-fertilization results in lower human input. Millets grow well in dry-land farming systems and respond well to irrigation (Rachie 1975; Rao 1989). The small millets are especially adaptive ecologically, in that they grow well in a variety of soils including sandy soils or those with high acidity or alkalinity. With limited input, these species can survive in sub-marginal areas of limited rainfall (30-40 cm annually) and relatively high temperatures (Seetharam et.al. 1989).

While the manner in which millets are managed or cropped differs depending on the species and environment in which they are grown, there are some general patterns that distinguish these crops. The small millets are often rain-fed crops growing in dry-land farming conditions even though they respond well to irrigation. Because they grow well in warm weather and are dependent on rain, cropping is often associated with summer moisture systems like the South Asian monsoons. Fertilizers will increase yield, yet this is often not practiced (Seetharam et.al. 1989). Field pests and diseases are a concern, as is a need for weeding. Yet grain yield can be significant with minimal energy relative to the more traditional crops.

Crop processing models, based ethnographic studies of non-mechanized techniques suggest some variability depending on the type of millet and its intended use (see: Reddy 1997; 2003; Harvey and Fuller 2005; Fuller and Weber 2005). Schematic representation of the primary processing stages are outlined in Figures 3 and 4. As can be seen in these figures, the large and small millets are cut, threshed, winnowed and stored differently (Harvey and Fuller 2005; Seetharam et al 1989). The large African millets are often cut at the top of the stalk while the smaller varieties are cut at the base (Reddy 1997; Harvey and Fuller 2005). As a result, small millets require more intensive labor for processing, and more processing stages. It is only through an understanding of these crop-processing stages that archaeologists can begin to explain the archaeobotanical assemblage.

The extensive array of uses of millets also influence processing (Figure 5), and these uses in turn are influences by cultural traditions of food consumption and taste. Milling to remove the outer bran (pericarp) of the grain is the most common way millets are processed, a technique similar to those seen with rice, which serves to lighten the color and lead to faster cooking of softer products (Malleshi 1989). Also, as with rice many millets are reported to be parboiled in India (Kimata 1983; 1989; Kimata and Sakamoto 1992; Kimata et al. 1999). Less than 10 percent of millets today are grown for fodder or for medicinal use. Malting for a drink, or popping and boiling for food are also important but less common than milling (Seetharam et.al. 1989). In some regions minor millets remain cultivated only on a small scale but are culturally important for particular foods stuffs, such as ritual breads made from *Brachiaria ramosa* in restricted districts of South Inda (Kimata et al. 2000) or beer made by the Garo in northeast India from Job's tears, *Coix lachrymal-jobi* (Arora 1977). In large parts of East and Southeast Asia there is a preference for sticky (glutinous) cereal that can be boiled or steamed to provide a sticky meal staple (Sakamoto 1996; Yoshida 2002: 37). This has led to artificial selection for genetically distinct varieties that become sticky when cooked, and such varieties are found not only in the native East Asian *Panicum miliaceum* and *Setaria italica,* as well as *japonica* rice, but in introduced species such as *Sorghum bicolor* and even barley, *Hordeum vulgare,* and *Amaranthus hypochondiracus* (Sakamoto 1996). Genetic data from *Setaria italica* indicates that this glutinous condition evolved perhaps 4 times in eastern Asia, indicating that farmers in this region have favourably selected glutinous mutants for propagation (Fukunaga et al. 2002b). This provides evidence for impact on plant genetics by a preferred taste and food preparation method. Much is still to be learned about the role of food preferences in agricultural history (cf. Fuller 2005; Smith 2006).

As millets can grow and thrive under difficult conditions, even producing some seeds in years with minimal rainfall, they have become an essential food in areas where the major cereals fail to give sustainable yields. In many instances, they have become a dependable and staple food of the poor. Their low status aside, millets, especially the small millets, are nutritionally superior in many ways to more traditional cereal crops (Rachie 1975; Rao 1989). In terms of proteins, minerals and vitamins, the small millets have higher nutritional value than either the common cereals of wheat, rice and corn or the large millets (Table 3). The small millets can also be stored longer, nearly three years. With good productive returns, little management, and high nutritional values, small millets are often the crop of choice for impoverished societies where labor is cheap and organized on a small scale. With these advantages, one would expect to find good evidence for millet use in the archaeological record.

Millets in the Archaeological Record

To accurately assess the use and importance of millets in early farming communities we need to identify and examine the archaeobotanical record. The frequency with which millet grains have been recovered from archaeological sites is limited. If we simply count the number of archaeological sites dating from before the Iron Age or the early Historic Period, with at least one millet seed, we end up with fewer than 200 sites world wide (Figure 6). This figure excludes a comprehensive tabulation of European data, but some fifteen years ago Marnival (1992) collected data on 50 sites in Europe through the early Iron Age, and the number is greater today. Even if this count were underestimated by 10 or 20 percent, on a global scale this is a rather small number of sites. If we limit our count to sites with more than one seed, from well documented and dated contexts and correctly identified, the number of sites with millets drops significantly. In comparison the number of sites with such well known seed crops as corn, wheat or rice would probably number in the thousands. Were millets used less than these more productive crops, do they play a secondary role as a minor crop, or are millets under represented in the archaeobotanical record for other reasons? We need to identify why the database for millets is so limited before we can understand the significance of millets in prehistory.

There are many issues involved in understanding the archaeobotanical record (see: Fuller and Weber 2005). These include plant morphology, pre-charring activities, charring and deposition, post-depositional factors, recovery and interpretive issues. First and foremost, seeds need to be carbonized to be preserved. Non carbonized seeds are generally seen as recent containments. Only under unusual circumstances, like in sealed jars, or extreme arid or waterlogged conditions will seeds preserve without being exposed to fire. Nearly all early finds of millets in the archaeological record are as carbonized grains. As shown in Figures 3-5, millets are regularly exposed to fire and they can easily become carbonized as they are processed. The most common ways in which millets become carbonized include drying or parching the crop, accidental burning during cooking, through burning of trash or waste material (e.g. from dehusking and winnowing), and when millets are used in a fodder and then the resulting dung being burned as a fuel (Reddy 1997; 2003; Harvey and Fuller 2005; Fuller and Weber 2005).

Pre-charring, charring and depositional activities impact the formation of the archaeobotanical assemblage. Since millets are being used and processed differently than the larger cereal grains, millet recovery may also be disproportional. This is especially significant for the very small millets, often less than 2mm in length, which are processed differently and where the lemmas and paleas are more likely to be destroyed through charring (Harvey and Fuller 2005). Since an intact lemma and palea are important identification criteria for some millets, mis-identification may result (Fuller 2003; Fuller et al. 2004). Recent developments in more systematic morphological and metrical identification criteria, and the use of an SEM to examine micro-morphologcal patterns, such on the husks of *Setaria* or *Brachiaria*, offers to improve and revise our identifications of archaeological material (Dahlberg and Wasylikowa 1996; Liu and Kong 2004; Fuller et al. 2004; Nasu et al. 2006). In fact, millet mis-identification may be a larger issue than is realized and may even have an impact on our understanding of the distribution of millets across the globe.

While preservation and identification are important issues, a variety of post-depositional factors are equally significant. Small seeded materal like millets are differentially susceptible to living organisms and geologic processes than the larger grained cereals like wheat and barley. The chance of seed recovery by an archaeologist is equally influenced by the grain size. Isolated finds of carbonized seeds observed in the soil during excavation is more likely to occur with the larger grains. Since tiny millets are difficult to spot and rarely recovered in the field by the excavator, it is not surprising that millet occurrences have remained scarce till the advent of flotation. In many cases the 'big' cereals, like maize, wheat, barley and rice have been recovered without systematic recovery through flotation, and this is less likely to be the case with millets. The systematic collection and extensive flotation of soil has led to a significant increase of charred millet remains. This is especially true for the small millets, which generally pre-date the larger varieties.

Millet recovery from the Indus Civilization site of Harappa exemplifies this issue. The site, occupied from 3300 to 1900 B.C., is located along the Ravi River in Northern Pakistan (Kenoyer 1998; Weber 1999). Its environment is one that is typified by wheat and barley cultivation, and where millets were believed to have been rarely used. Prior to soil flotation, seeds of wheat and barley were commonly recovered but never millets. Between 1986 and 2000, over 1500 liters of soil were floated leading to the recovery of nearly 150,000 carbonized seed or seed fragments (Weber 2003). The resulting analysis identified tens of thousands of small millet seeds demonstrating that small millet cultivation was practiced at this site thousands of years earlier than had previously been thought. Unless archaeologists appropriately look for millets, we may never know if they were in use and part of the subsistence strategy.

Recent contributions on the archaeologies of millets

East Asia

In discussions of early agriculture, millets have received particular attention in China, since they were the dominant traditional crops in northern China, including the Yellow River valley where the first Chinese states emerged (T. Chang 1983; K. Chang 1986; Barnes 1995; Liu 2004). Based on recent archaeobotanical research, the earliest well-documented millets are from ca. 6000 BC at Xinglonggou, in Eastern Inner Mongolia (Zhao 2005), far to the Northeast in China. This raises the possibility that the environmental context of early Chinese millet domestication is to be sought in the desert margins and semi-desert steppe of the dry temperate Mongolian north. Millet cultivation is regarded generally as established in the Yellow River basin by 5500 BC (the Beixin, Cishan, Peiligang and Dadiwan cultures), although no clear evidence for transitions from gathering to cultivation have been identified in this region (cf. Lu 2002). Nevertheless, like Mesopotamia, in which the spread of wheat and barley to the fertile flood plains of the Lower Tigris and Euphrates was a key factor in the emergence of civilization, it may be that the spread of millets to the higher productivity of the Yellow River and its tributaries provided for the essential food surplus that underwrote the later developments of Social complexity (on the archaeology of the later Neolihic and social complexity: Liu 2004).

The spread of millets in East Asia suggests that this was under way before the rice revolution in many regions. The earliest millets in Korea were adopted 4000-3000 BC, in the late Chulmun period, whereas the earlier Holocene economy had focused on acorns (Barnes 1995; Crawford and Lee 2003; Ahn 2004). Unambiguous rice finds date from ca. 2000 BC—based on the earliest direct rice AMS date at Oun 1 (Crawford and Lee 2003; Ahn 2004), but with recent somewhat controversial finds of rice, wheat and barley from Daecheon-ri (at Okcheon-gun, South Korea) from 2800-3000 BC (Central Museum of Hannam University 2003), and several other sites with remains that could be early Third Millenium (Ahn 2004). The Daechon-ri material is well-illustrated and botanically unambiguous, although the dating of the plant assemblage may be queried. (The more generally accepted arrival of wheat is ca. 1000 BC: Crawford and Lee 2003). Unfortunately earlier reports of Sorghum from Korea (mentioned, e.g. in Nelson 1999; Fuller 2003: 256), appear mistaken attributions which are actually *Panicum miliaceum* or not grains at all (Ahn, personal communication; and personal observations of photographs).

Recent evidence for foxtail millet in the Daxi cultural phase of the middle Yangtze region (4400-3300 BC) indicates that this crop may have spread southwards before rice had spread north into Yellow River agriculture. Based on current evidence rice was added to this agriculture in northern region (Henan, Shaanxi, southeast Gansu and Shandong) only in the Third Millennium BC, with a few rice finds from Late Yangshao contexts (3000-2500 BC) and many more from the Longshan period (2500-2000 BC) (Crawford et al. 2005).

The spread of rice from mainland China to Taiwan (and perhaps Southeast Asia more generally) appears to have occurred in the same time horizon as millets, but scholarship has tended to place more importance on the origins of rice than the millets. Current evidence for the earliest crops in Taiwan put them at ca. 2500-2000 BC (Tsang 2005). This is of particular interest because despite the general belief that agriculture should come to this island from the adjacent mainland of Fujian province and ultimately form the Lower Yangze region (e.g. Bellwood 2005; Jiao 2006), archaeobotanical data from the Lower Yangzte region to the north indicates a rice-based agriculture, thus far without millets. This raises questions as to whether there might have been independent millet domestications in Taiwan (which might gain support from some of the genetic diversity there, cf. Fukunaga et al. 2006), or whether millet and rice actually spread to Taiwan from somewhere that already had both, such as the Shandong province further north.

Africa

Early Holocene use of wild millets is now well-attested in the Sahara region. This includes the evidence from Nabta Playa and other sites in Egypt's Western Desert (Wasylikowa and Dahlberg 1999; Barakat and Fahmy 1999) as well as finds from rock shelters in the Tadrart Acacus of Southwest Libya (Wasylikowa 1992; 1993; Castelletti et al 1999; Mercuri 2001), and impressions in ceramics from the central Sudan (Magid 1989; Stemler 1990; Fuller 1998; Fuller and Smith 2004). Despite earlier excitement, there is no evidential basis for inferring cultivation of sorghum, but rather *Sorghum* happened to be part of the mix of grasses available in the eastern savanna zone (then the Eastern Sahara), but not in the west (represented by the Libyan finds). The earliest domesticated sorghum finds remains those known from India, e.g. at Rojdi (Weber 1991; Fuller 2003) and at Kawa from the First Millennium BC in the Nubian Nile valley (Fuller 2004). More widespread evidence is available from Nubia and southern Libya from the end of the First Millennium BC (see Pelling 2005). This implies that in the large archaeobotanically unsampled regions away from the Nile valley, such as in Western Sudan or Chad, sorghum domestication still awaits discovery.

Curiously, the earliest finds in Nubia of a domesticated millet are not one of the African species. Well-identified finds from *Panicum miliaceum* have been reported from Ukma, a Kerma period site in Nubia (Van Zeist 1987), which probably dates to the early to mid Second Millennium BC. It also occurs at Kawa in the mid-First Millennium BC (Fuller 2004). How this Asian domesticate came to be in Nubia, when there is no early evidence for its cultivation in Egypt, remains mysterious.

Also of interest are finds of *Setaria sphaceleata* from sites in Nubia from the First Millennium BC and the Medieval period (Fuller and Edwards 2001; 2004). While it is unclear whether these finds represent cultivars or wild-gathered materials, or even animal fodder, this species, which has a wide range of forms in tropical Africa (Clayton 1979), is reported to be a gathered food source (see Austin 2006).

Recent years have seen continued progress in the study of Pearl Millet (*Pennisetum glacum*) domestication in West Africa. Many new finds have been reported from Ghana, Nigeria and southeast Mauretania (D'Andrea et al. 2001; D'Andrea and Casey 2002; Zach and Klee 2003; MacDonald et al. 2003). None of these finds, however, is older than 1700 BC, by which time domesticated pearl millet had reached India (see Fuller 2003). Nor is any sequence tracking a transition from wild to domesticated pearl millet yet known. The early history of West Africa's small millets (*Digitaria exilis, D. uburu, Brachiaria deflexa*) remains obscure.

India

Millets have long been a point of discussion amongst South Asian archaeologists (e.g. Allchin 1969; Possehl 1986). One area of particular interest has been the adoption of millets of African origin in South Asia (Weber 1991; 1998; Misra and Kajale 2003; Fuller and Madella 2001: 342-344; Fuller 2002: 288-292; Fuller 2003, the latter with a critical reassessment of many identifications). Of particular importance has been the realization that African millets have been adopted into existing millet dry-cropping systems that were already established on the basis on native millets (Weber 1998; Fuller 2003; 2005a). Archaeobotanical evidence has been mounting that there were probable a few distinct centers of indigenous millet agriculture in South Asia (Fuller 2002; 2006). Of particular interest is the evidence for little millet, a staple crop of Protohistoric Gujarat

(Weber 1991) as well as a crop of the eastern Harappan zone already by the Ravi Phase at Harappa (Weber 2003). It is not yet clear whether this implies two origins for this crop or a single origin and early dispersal. Meanwhile in South India, *Brachiaria ramosa* appears to have been the first staple millet (Fuller et al 2004), and has also turned up as an early crop/resource in the Neolithic Ganges (Harvey et al. 2005). By contrast several other millets, although of South Asian origin, remain poorly understood in terms of origins. Some, such as kodo millet (*Paspalum scrobiculatum*), which occurs in quantities on peninsular sites of the Iron Age or Early Historic period (see, e.g. Kajale 1984; 1991; Cooke et al. 2005), may represent later secondary domesticates of what had earlier been crop weeds.

Also of interest is recent work in historical linguistics, which indicates the ancient importance of a range of millets in parts of India. Amongst Dravidian language speakers in particular there are numerous millets for which ancient knowledge can be inferred from etymological reconstructions (Southworth 2005; 2006; Fuller 2006). Of interest is evidence for two early terms for millet in Late Proto-Dravidian (ancestral to all South and Central Dravidian languages), since Neolithic sites in South India recurrently have evidence for two millets, *Brachiaria ramosa* and *Setaria verticillata.* By contrast at a later period, Proto-South Dravidian has at least five distinct millet terms (Southworth 2005; 2006) which therefore is congruent with archaeological evidence that during the Iron Age and Early Historic several additional millet species came to South India (cf. Fuller 2005; Cooke et al 2005). A particular problem that is raised by the linguistics is the issue of semantic shift, when the name from a more ancient crop is transferred to a newer, but increasingly important crop-- the way the in American English “corn” regularly means maize (*Zea mays*), which in Britian and in older English documents, corn could be any grain and most often meant wheat (*Triticum aestivum*). Evidence for differing referent millets in related modern languages that must derive from the same ancient root word, imply that semantic shift has occurred in the linguistics history of Southern India just as different millet crops have changed in importance. Some preliminary suggestions about this process can be found in Southworth (2006) and Fuller (2006) but more work combining linguistic and ethnobotanical research are needed. Important contributions of an ethnobotanical nature (e.g. Renglakshmi 2005; Kimata et al 1997; 2000; Kobayashi and Kimata 1989) need to be augmented by careful linguistic recording. In some cases ancient names for millets appear to have been transferred to rice, no doubt as rice has become an increasingly popular crop in South India. Similar processes have occurred in other non-Dravidian languages as well.

Millets and Future Studies

Today, millets are seen as minor crops that are often used as a food for the poor or fodder for animals. Europeans and American are most familiar with millets in bird seed. Is this view influencing our interpretation of millets in prehistory? Is the archaeobotanical record therefore skewed against the small millets? Were millets more important in the past? Some assessments suggest that this was the case (cf. Dove 1999; De Wet 2000; Austin 2006). The existence of “lost millets” that have been abandoned as cultivars, in particular regions or altogether, tends to suggest that they were more important in the past. Should there be a more prominent role for millets in agricultural practices today or in the future? These are some of the issues that archaeologists and botanists are still coming to terms with.

Our understanding of millet use in the contemporary, historic and prehistoric world is improving. With the increased frequency of soil flotation the record of charred millet seeds has significantly increased. As archaeologists begin to look more frequently for millets their recovery rates improve. Ethnographic and experimental studies are improving our knowledge of crop-processing and its influence on seed preservation and the formation of the archaeobotanical record. In conjunction with the charred millet grains, phytoliths and weed seeds are also being used to infer crop-processing activities. The study of the genes of modern and charred millet remains is helping reveal the spread of millets from region to region, although such data is still limited to just a few of the millet species (e.g. Tostain 1992; 1998; M. Jones 2005; Fukunaga et al. 2002a; 2002b; 2006). Harvesting experiments and ecological studies of wild millets can aid in developing better expectations for archaeological study of domestication processes (Lu 1998; 2002).

While it is becoming evident that millets, especially the small millets, played an important role in some early farming societies, the extent of millet use is still not adequately understood. What is needed at this point is to first construct a "cultural" history of millet use across the globe. This might lead to an alternative history of agriculture from the point of view of a crop of the poor, or one that focuses on minor or secondary crops. And secondly, there is need to bring together people who study millets in prehistory. At such a gathering standards for the collection, analysis, identification and interpretation of millets could be developed. These two objectives would help set the foundation for millet studies of the future.

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TABLES

Table 1.. Old World Cultivated 'Millets'

Species	**Common Name**	**Region of Origin and Cultivation**
Brachiaria ramosa (L.) Stapf.	Browntop millet, pedda-sama	South India
Brachiaria deflexa (Schumach) C. E. Hubbard var. *sativa* Porteres	Guinea millet, Animal Fonio	Fouta Djalon Highlands, Guinea, W. Africa
Coix lacrhyma-jobi L.	Job's tears [not always regarded as a millet; taxonomically closer to maize]	Northeast India, Southeast Asia, Southern China
Digitaria cruciata (Ness) A. Camus var. *esculenta* Bor	Raishan	Khasi Hills, Assam; Hill tribes of Vietnam
Digitaria exilis (Kippist) Stapf.	Fonio, Acha, Fundi	West Africa
Digitaria iburu Stapf.	Black Fonio, Iburu, Hungry Rice	West Africa
Digitaria sangiuinalis (L.) Scop.	Harry crabgrass	Eurasian origin; cultivated in Kashmir, formerly in Europe
Echinochloa colona ssp. frumentacea (Link) De Wet, Prasada Rao, Mengesha and Brink (=*E. frumentacea* Link)	Sawa Millet	Peninsular India(?), also cultivated in Himalayas
Echinochloa crus-galli var. *utilis* Yabuno	Barnyard Millet	Japan, Korea, northeast Asia
Eleusine coaracana (L.) Gaertn.	Finger Millet, ragi	East African highlands

Eragrostis tef (Zucc.) Trotter	Teff	Ethiopian highlands
Panicum miliaceum L. ssp. *Miliaceum*	Proso millet	China, and SE Europe(?)/ Caucasus; cultivated throughout South Asia
Panicum sumatrense Roth. ex Roem. & Schult. Subsp. *sumatrense* (syn. *P. miliare* auct. pl.),	Little millet, samai	India, especially peninsula
Paspalum scrobiculatum L.	Kodo millet	India, especially peninsula and Himalayas
Pennisetum glaucum (L.) R. Br (= *P. americium* (L) Leeke)	Pearl Millet	West African Savannah, cultivated through India
Setaria italica (L.) P. Beauv ssp. *italica*	Foxtail millets	China, and SE Europe(?)/ Caucasus, cultivated throughout South Asia and in parts of Southeast Asia
Setaria pumila (Poir.) Roem & Schult. (syn. *S. glauca* auct. pl.)	Yellow foxtail millet, korali	India (domesticated populations reported)
S. verticillata (L.) P. Beauv.	Bristley foxtail millet	South India (domesticated populations??)
Sorghum bicolor (L.) Moench. ssp. *bicolor*	Sorghum, jowar	African Savannahs, cultivated throughout South Asia

Table 2. New World millets

Species	**Common Name**	**Region of Origin and Cultivation**
Bromus mango Desv.	Mango [taxonomically closer to barley than other millets	Chile: Andes
Panicum sonorum Beal (=*P.hirticaule* J. Presl. var. *millaceum* (Vasey) Beetle)	Sauwi millet	American Southwest
Setaria parviflora (Poir.) Kerguélen	Knot-root foxtail	Mesoamerica
Setaria macrostachya Humboldt, Bonpland & Kunth	*Ne-kuuk-suuk* (Mayan)	Mesoamerica, cultivated(?) before rise in importance of Maize

Table 3. A comparison of nutritional components of millets and "big" cereals

	Grain Type	Protein (g) (Nx6.25)	Fat (g)	Ash (g)	Crude fiber (g)	Carbs (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Small millets	**Common millet**	12.5	3.5	3.1	5.2	63.8	364	8	2.9	0.41	0.28	4.5
	Foxtail millet	11.2	4	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
	Barnyard millet	11	3.9	4.5	13.6	55	300	22	18.6	0.33	0.1	4.2
	Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	107	0.15	0.09	2
	Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3	0.3	0.09	3.2
	Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Large millets	**Pearl millet**	11.8	4.8	2.2	2.3	67	363	42	11	0.38	0.21	2.8
	Sorghum	10.4	3.1	1.6	2	70.7	329	25	5.4	0.38	0.15	4.3
Comparable grains	**Wheat**	11.6	2	1.6	2	71	348	30	3.5	0.41	0.1	5.1
	Maize	9.2	4.6	1.2	2.8	73	358	26	2.7	0.38	0.2	3.6
	Rice (brown)	7.9	2.7	1.3	1	76	362	33	1.8	0.41	0.04	4.3

Sources: FOA 1995: Hulse. Laing and Pearson. 1980: U.S. National Research Council/ NAS. 1982: USDA/HNIS. 1984

Captions for Figures

Figure 1. The map of likely centres of origin for “millets.” Millets abbreviated: Pso: *Panicum sonoran;* Sm: *Setaria* cf. *macrostachya*; Bm: *Bromus mango*; Bd: *Brachiaria deflexa*; De: *Digitaria exilis*; Pg: *Pennisetum glaucum*; Sb: *Sorghum bicolour,* including Southern African zone where the race *kafir* may be an independent domesticate; Ec: *Eleusine coracana*; Et: *Eragrostis tef*; Ds: *Digitaria sanguinalis*; Pm: *Panicum miliaceum*, a separate Western origin remains unconfirmed; Si: *Setaria italica*; Ps: *Panicum sumatrense*: Br: *Brachiaria ramosa*; Sv: *Setaria verticillata*; Dc: *Digitaria cruciata*; Cl: *Coix lachrymal-jobi*; Eu: *Echinochloa crus-galli* var. *utilis.* The striped zone in India indicates the broader Indian millet zone within which several domestications remain to be better localized (*Paspalum scrobiculatum, Echinochloa colonum, Setaria pumila*), in addition to possible multiple domestications of *Brachiaria ramosa.*

Figure 2. The panicle form of selected millet crops, with rice for comparison. Lines of various types group cereals that have similar morphological attributes that might make them prone to linguistic confusion (such as semantic shift). (From Fuller 2006)

Figure 3. Management of small headed hulled millets (Modified from Harvey and Fuller 2004; Reddy 1997; 2003).

Figure 4. Management of large headed millets (Modified from Harvey and Fuller 2004; Reddy 1997; 2003).

Figure 5. Processing of small millet: some alternatives. Note: parboiling is not shown.

Figure 6. A rough tabulation of archaeological evidence for millets, indicating the number of archaeological sites with millets for each region of the world. The total number of sites : 194

Table 1.. Old World Cultivated 'Millets'

Species	**Common Name**	**Region of Origin and Cultivation**
Brachiaria ramosa (L.) Stapf.	Browntop millet, pedda-sama	South India
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Coix lacrhyma-jobi L.	Job's tears [not always regarded as a millet; taxonomically closer to maize]	Northeast India, Southeast Asia, Southern China
Digitaria cruciata (Ness) A. Camus var. *esculenta* Bor	Raishan	Khasi Hills, Assam; Hill tribes of Vietnam
Digitaria exilis (Kippist) Stapf.	Fonio, Acha, Fundi	West Africa
Digitaria iburu Stapf.	Black Fonio, Iburu, Hungry Rice	West Africa
Digitaria sangiuinalis (L.) Scop.	Harry crabgrass	Eurasian origin; cultivated in Kashmir, formerly in Europe
Echinochloa colona ssp. frumentacea (Link) De Wet, Prasada Rao, Mengesha and Brink (=*E. frumentacea* Link)	Sawa Millet	Peninsular India(?), also cultivated in Himalayas
Echinochloa crus-galli var. *utilis* Yabuno	Barnyard Millet	Japan, Korea, northeast Asia
Eleusine coaracana (L.) Gaertn.	Finger Millet, ragi	East African highlands
Eragrostis tef (Zucc.) Trotter	Teff	Ethiopian highlands
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Setaria pumila (Poir.) Roem & Schult. (syn. *S. glauca* auct. pl.)	Yellow foxtail millet, korali	India (domesticated populations reported)
S. verticillata (L.) P. Beauv.	Bristley foxtail millet	South India (domesticated populations??)
Sorghum bicolor (L.) Moench. ssp. *bicolor*	Sorghum, jowar	African Savannahs, cultivated throughout South Asia

Table 2. New World millets

Species	**Common Name**	**Region of Origin and Cultivation**
Bromus mango Desv.	Mango [taxonomically closer to barley than other millets	Chile: Andes
Panicum sonorum Beal (=*P.hirticaule* J. Presl. var. *millaceum* (Vasey) Beetle)	Sauwi millet	American Southwest
Setaria parviflora (Poir.) Kerguélen	Knot-root foxtail	Mesoamerica
Setaria macrostachya Humboldt, Bonpland & Kunth	*Ne-kuuk-suuk* (Mayan)	Mesoamerica, cultivated(?) before rise in importance of Maize

Table 3. A comparison of nutritional components of millets and "big" cereals

	Grain Type	Protein (g) (Nx6.25)	Fat (g)	Ash (g)	Crude fiber (g)	Carbs (g)	Energy (kcal)	Ca (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)
Small millets	**Common millet**	12.5	3.5	3.1	5.2	63.8	364	8	2.9	0.41	0.28	4.5
	Foxtail millet	11.2	4	3.3	6.7	63.2	351	31	2.8	0.59	0.11	3.2
	Barnyard millet	11	3.9	4.5	13.6	55	300	22	18.6	0.33	0.1	4.2
	Kodo millet	9.8	3.6	3.3	5.2	66.6	353	35	107	0.15	0.09	2
	Little millet	9.7	5.2	5.4	7.6	60.9	329	17	9.3	0.3	0.09	3.2
	Finger millet	7.7	1.5	2.6	3.6	72.6	336	350	3.9	0.42	0.19	1.1
Large millets	**Pearl millet**	11.8	4.8	2.2	2.3	67	363	42	11	0.38	0.21	2.8
	Sorghum	10.4	3.1	1.6	2	70.7	329	25	5.4	0.38	0.15	4.3
Comparable grains	**Wheat**	11.6	2	1.6	2	71	348	30	3.5	0.41	0.1	5.1
	Maize	9.2	4.6	1.2	2.8	73	358	26	2.7	0.38	0.2	3.6
	Rice (brown)	7.9	2.7	1.3	1	76	362	33	1.8	0.41	0.04	4.3

Sources: FOA 1995: Hulse. Laing and Pearson. 1980: U.S. National Research Council/ NAS. 1982: USDA/HNIS. 1984

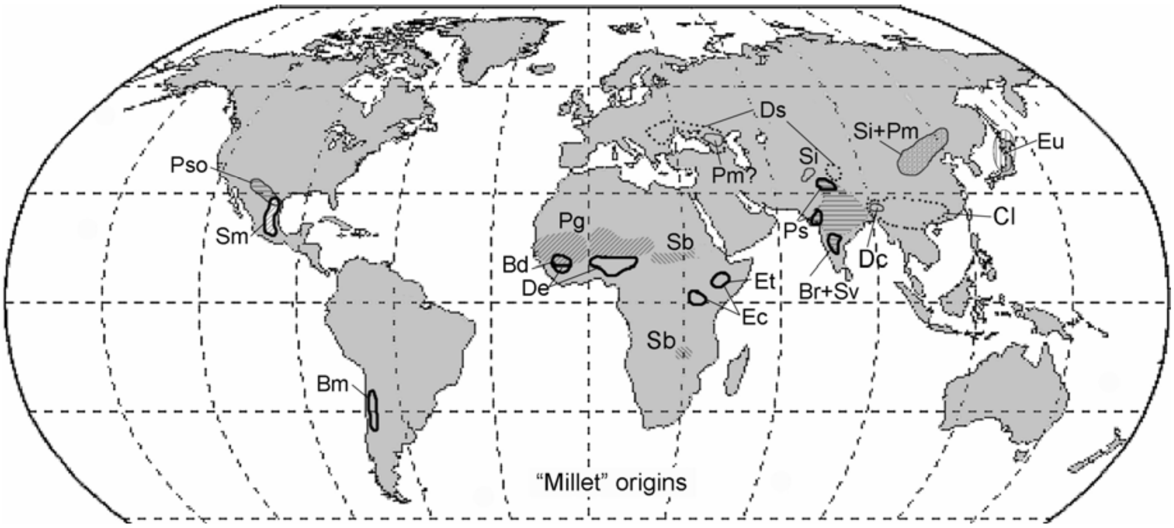

Figure 1. The map of likely centres of origin for "millets." Millets abbreviated: Pso: *Panicum sonoran;* Sm: *Setaria* cf. *macrostachya*; Bm: *Bromus mango*; Bd: *Brachiaria deflexa*; De: *Digitaria exilis*; Pg: *Pennisetum glaucum*; Sb: *Sorghum bicolour,* including Southern African zone where the race *kafir* may be an independent domesticate; Ec: *Eleusine coracana*; Et: *Eragrostis tef*; Ds: *Digitaria sanguinalis*; Pm: *Panicum miliaceum,* a separate Western origin remains unconfirmed; Si: *Setaria italica*; Ps: *Panicum sumatrense*: Br: *Brachiaria ramosa*; Sv: *Setaria verticillata*; Dc: *Digitaria cruciata*; Cl: *Coix lachrymal-jobi*; Eu: *Echinochloa crus-galli* var. *utilis.* The striped zone in India indicates the broader Indian millet zone within which several domestications remain to be better localized (*Paspalum scrobiculatum, Echinochloa colonum, Setaria pumila*), in addition to possible multiple domestications of *Brachiaria ramosa.*

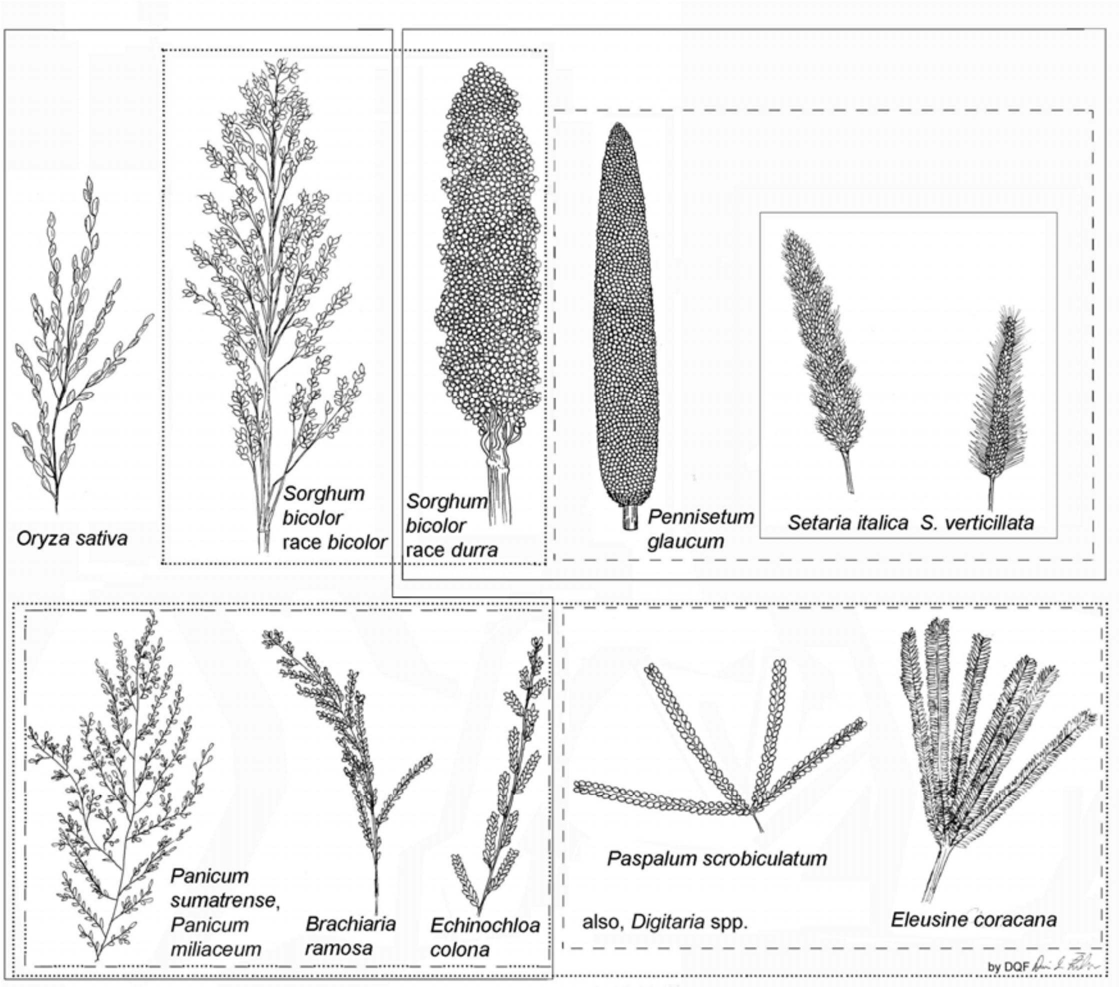

Figure 2. The panicle form of selected millet crops, with rice for comparison. Lines of various types group cereals that have similar morphological attributes that might make them prone to linguistic confusion (such as semantic shift). (From Fuller 2006)

Harvesting

<u>Cutting at base</u>

panicles/ long straw / weeds/ husk fragments
stem and leaf fragments including bilobes and crosses

Threshing and Winnowing

<u>Beating and Shaking</u>

products	*by-products*
spikelets / long straw / weeds	husk / stems/ weeds
same sized weeds / heavy chaff	chaff stored and used

Storage

products
spikelets and same sized weeds (only for hulled crops)

Parching (FIRE)

Milling and Pounding

products	*by-products*
grain /chaff and small weeds	husks and weeds
	chaff stored and used

Cooking (FIRE)

prime grain

Figure 3. Management of small headed hulled millets (Modified from Harvey and Fuller 2004; Reddy 1997; 2003).

Harvesting

Cutting at top	Cutting at base
panicles	panicles / long straw / weeds
husk fragments	husk fragments / stem and leaf fragments including bilobes and crosses

Threshing and Winnowing

Beating and Wind Winnowing and Sieving

products	*by-products*	*products*	*by-products*
spikelets / heavy chaff fragments /	husk frags .	spikelets / light chaff	husk frags. / stem
grain / husk fragments		grain / long straw heavy chaff and weeds husk fragments / weeds	weeds

Storage (only for base cutting by-products)

chaff stored
temper / fuel / fodder

Parching - none

Milling and Pounding

products	*by-products*	*products*	*by-products*
grain / chaff		grain / chaff /weeds	
husk fragments	husk fragments	husk fragments	husk frags. /
weeds			

Cooking (FIRE)

prime grain		prime grain	chaff stored temper / fuel / fodder

Figure 4. Management of large headed millets (Modified from Harvey and Fuller 2004; Reddy 1997; 2003).

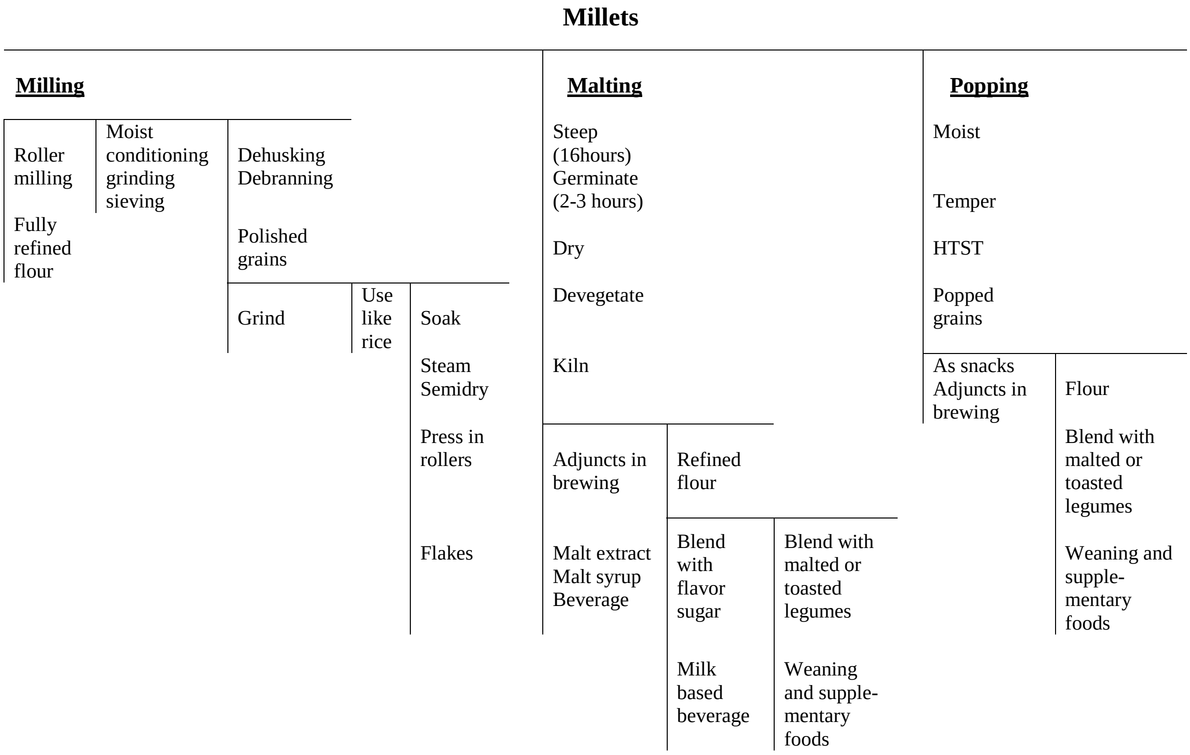

Figure 5. Processing of small millet: some alternatives. Note: parboiling is not shown.

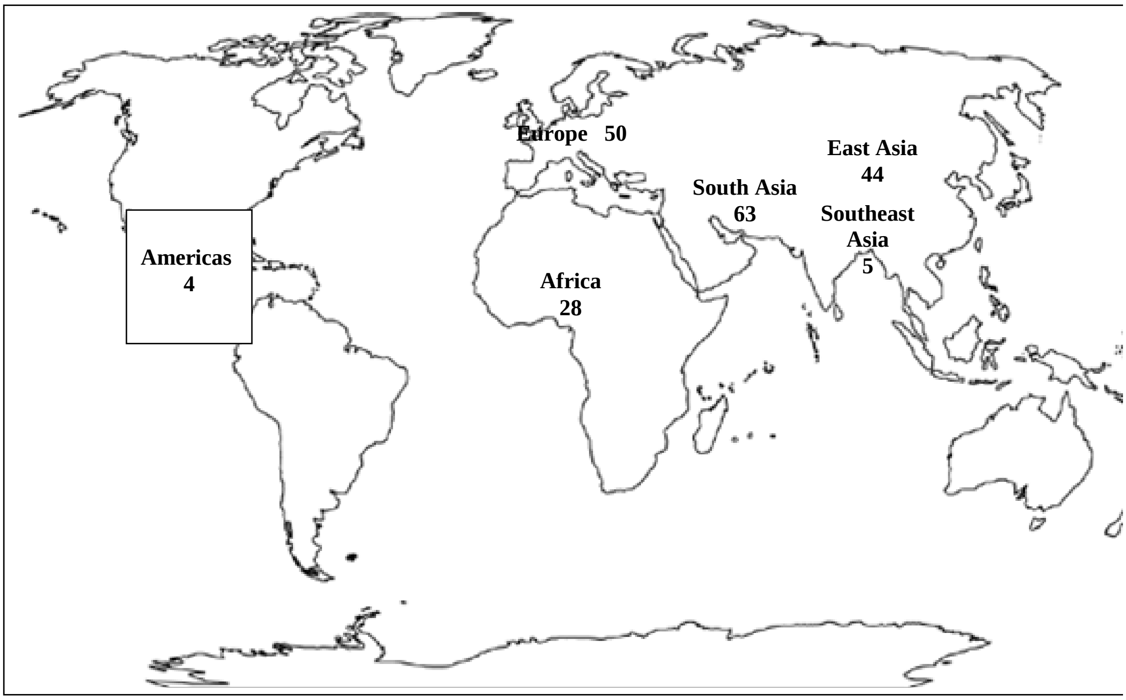

Figure 6. A rough tabulation of archaeological evidence for millets, indicating the number of archaeological sites with millets for each region of the world. The total number of sites : 194