Domestication and the origins of agriculture: an appraisal

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Abstract: The first domestications of plants and animals, which occurred between 10 K years and 5 K years BP, and which underpinned the inception of agricultural systems, represent a major turning point in cultural and environmental history. Whilst much has been written on these topics, new archaeological discoveries and the development of new methods of data collection require that these issues should be reappraised. One example of a new archaeological discovery is that of evidence for rice cultivation prior to 10 K years BP in the middle Yangtze Basin of China. This region is now considered to be the likely centre of rice domestication and, because of the discovery of settlement structures, it may have been home to China's oldest civilization. In addition, further age determination may establish this region of China as the earliest centre of agricultural innovation, instead of southwest Asia.

New methods of age estimation, notably by radiocarbon, have necessitated a reappraisal of the origins of agriculture in Mesoamerica, whilst biomolecular techniques are contributing to the identification of the wild relatives of domesticated plants and animals. Genetic analysis has also been applied to modern human populations in order to establish the relationships between different groups and thus to attempt to determine the movement of peoples in prehistory. Such relationships in Europe have been related to the spread of agriculture from its centre of origin in southwest Asia, although this is speculative rather than conclusive. Despite these advances, however, there is still no unequivocal evidence as to why agriculture was initiated.

Key words: crops, domestication, early agriculture, environmentalism, materialism.

I Introduction

Today, almost 75% of the earth's habitable land surface has been disturbed to a greater or lesser degree (Hannah *et al.*, 1994). Moreover, deforestation in the tropics alone is currently occurring at a rate of *c*. 8% per annum (World Resources Institute, 1996) which means that land transformation globally remains highly significant. Whilst mining, logging and urbanization have contributed to this alteration of land cover, agriculture has been, and remains, the most significant agent of environmental change. The extent

of this change is reflected in the fact that agricultural systems presently produce *c*. 2000 $\times 10^6$ metric tons of cereals per annum and *c*. 4000×10^6 cattle, sheep and pigs (World Resources Institute, 1996). These commodities, along with a vast range of other agricultural products, are the sole source of food energy for some 5000×10^6 people, and for many of them agriculture is the main source of wealth generation. It is therefore of considerable importance to appreciate the origins of this world-transforming activity in terms of where, when and why it emerged and subsequently developed.

In particular, the inception of permanent agriculture was a major turning point in both environmental and cultural history. On the one hand, it represented the increasing ability of humankind to manipulate other organisms; this is an important characteristic that is uniquely human and which facilitates the engineering of trophic energy flows in order to provide advantage. This ability to channel food energy paved the way for many subsequent technological and cultural changes, including the invention of pottery and metal technology as well as changes in the structure and organization of human communities. On the other hand, the emergence of agriculture marked the onset of a capacity of human communities to alter their immediate environment substantially through the removal of the natural vegetation cover and to set in train environmental change on a scale hitherto impossible by human agencies. Soil erosion, desertification, water pollution and soil degradation are intimately related to agriculture in terms of both the past and the present; they are not phenomena of the twentieth century. However, it could be argued that the most significant impact of agriculture, in the past as well as the present, is its power to destroy through extinction. Whilst soil erosion, desertification etc. are frequently reversible, this is not the case for the loss of organisms through extinction. Agriculture, therefore, has provided opportunities for the future through the generation of a reliable food supply but has also destroyed opportunities through extinction.

Defining domestication, and related terms such as agriculture and cultivation, is itself problematic. As Harris (1996) discusses, there is little agreement as to precisely what these terms mean. However, all refer to the interaction between plants/animals and humans, as is reflected in the classification continua proposed by Harris and given in Table 1. As the relationship between plants/animals and humans changed with time, genetic changes occurred to distinguish domesticated species from their wild counterparts; such changes are unlikely to have occurred as a result of natural selection on wild populations.

Whilst much has been written on domestication and the origins of agriculture, there have been several recent developments which have prompted a reappraisal of existing ideas. In terms of where the domestication of plants and animals occurred, there is general agreement that the main centres of origin are southwest Asia, southeast Asia, Mesoamerica, the tropical Andes, eastern North America and sub-Saharan Africa. The evidence for this derives from archaeological and palaeobotanical investigations, and new discoveries, especially in China, mean that this crucial development in the people–environment relationship requires constant reappraisal. These recent investigations will be examined below along with established evidence. Similarly, new developments in radiocarbon age determination, notably the advent of accelerator mass spectrometry (AMS), have begun to alter conventional wisdom about when the earliest domestications occurred. For example, new AMS age determinations from sites in Mesoamerica are beginning to change the chronology for agricultural development in

Table 1   Generalized schema to represent the relationship between plants/animals and humans over time

Crop production dominant, i.e., agriculture	↑ (T)	*Livestock production –* settled or nomadic transhumance
Cultivation with systematic tillage and relatively 'large-scale' clearance	T I	*Protective herding* *Free-range management*
Cultivation with minimal tillage and relatively 'small-scale' clearance	M E	*Specialized hunting* and *scavenging*
Gathering and *collecting*		*Generalized hunting* and *scavenging*

Decreasing reliance on wild stock

Source: Based on Harris, 1996.

the region. In addition, the advent of techniques to ascertain the genetic characteristics of plants and animals is generating a new body of evidence to identify the wild ancestors of domesticated species and thus to identify centres of domestication. Similar techniques are also available to examine the genetic relationships between human groups, and data so generated are being used to identify the movement of people in relation to the spread of agriculture. However the most enigmatic aspect of early agriculture concerns why it happened. While archaeological and palaeoenvironmental data provide information about the wild ancestors of domesticated species and the environmental context of early agriculture they do not and cannot reveal the motives for its inception. As is discussed below, most available evidence can be interpreted to support either a culturally based or an environmentally based rationale for such innovation, or indeed a combination of the two.

II   The precursors of agriculture: hunter-gatherer communities

Agriculture did not emerge from an untapped resource base or randomly distributed family or tribal units of *Homo sapiens sapiens*. It emerged as the result of efforts by highly organized ecologically canny communities composed of skilled hunter-gatherers. Such skills had developed over a long time period; the ancestors of modern humans had always practised gathering. Several early ancestors, such as *Australopithecus afarensis*, are considered to have subsisted on a wholly plant-based diet, as is indicated by wear patterns on fossil teeth (Lewin, 1993). Although plant foods must have continued to play a major role in hominid diet, just as they do today, the evidence for this is scanty. Where it does exist, it comprises carbonized seeds, husks, etc., or occasionally macroscopic plant remains which have become sealed in anaerobic sediments.

Evidence for plant use prior to 12 K years BP,[1] i.e., prior to the end of the last glaciation, is particularly scarce. A rare example of plant-food remains is that of Zhoukoudian, near Beijing, China, where hominid fossils of *Homo erectus* have been discovered. The cave deposits also contain the remains of Chinese hackberry, walnut and hazelnut and are dated to between 460 K years BP and 230 K years BP(Rukang and Lanpo, 1994). Another example is the upper Palaeolithic site of Dolni Věstonice II in the Czech Republic which has been investigated by Mason *et al*. (1994). This site is dated to *c*. 25 K years BP; pollen and plant macrofossils indicate the presence of a wide range of plant species and the likely consumption of roots of species of Asteraceae/Compositae. Moreover, Loy *et al*. (1992) and Loy (1994) have applied biochemical techniques to the detection of plant foods on stone artifacts, from the Solomon Islands, which are dated to 28 K years BP. The starch residues discovered are those of taros which were being exploited as a food source. Plant remains from Wadi Kubbaniya in Egypt also attest to the exploitation of a range of plant species in preagricultural times. These remains are dated to between 18 K and 17 K years BP; some 25 different types of seeds, fruits and vegetable tissue have been identified, the modern species of which are used by present-day hunter-gatherers (Hillman, 1989). A recent survey of plant use and the remains of food-processing apparatus in Europe by Zvelebil (1994) also highlights evidence for the consumption of hazelnuts, acorns and water chestnuts. In addition, Kubiakmartens (1996) has presented evidence from Calowanie, an upper Palaeolithic/Mesolithic site in the Polish plain which was used as a habitation site between *c*. 11.4 K years BP and 8.3 K years BP, which indicates that roots and tubers of arrowhead (*Sagittaria sagittifolia*) and knotgrasses (*Polygonum spp*.) were being consumed.

In contrast, there is abundant evidence for hunting, a food-procurement strategy that characterized communities of *Homo erectus*, an early hominid ancestor of *Homo sapiens sapiens*. This species is considered to have evolved *c*. 2×10^6 years BP in Africa from whence it migrated into Europe and Asia (Lewin, 1993). Although there is little direct evidence for hunting until after *c*. 500 K years BP, Lewin asserts that the anatomy of skeletons of *H. erectus* indicates small gastrointestinal tracts, as they are in predators generally in contrast to herbivores. This decrease in gut size has been interpreted as a means of compensating for the increased metabolic rate associated with the relatively large brain size of *H. erectus* (Aiello and Wheeler, 1995). It is likely that decreasing gut size occurred as larger brains evolved and that both were associated with the acquisition of hunting skills. Indeed, the cave sediments of Zhoukoudian referred to above contain tools and bone remains of the thick jaw-bone deer (*Megaloceros pachyosteus*) and sika deer (*Pseudaxis grayi*) which were hunted (Rukang and Lanpo, 1994). For the period 40 K years BP to *c*. 10 K years BP, evidence for hunting derives from a variety of sources. For example, there are several cave sites in Europe wherein hunters depicted their prey in paintings. The oldest of these, Chauvet in France, is dated at 32 K years BP. Another example is the famous Lascaux paintings in the Dordogne, France, which are dated to *c*. 17 K years BP.

This art is the work of archaic (*Homo sapiens*) or modern (*H. sapiens sapiens*) humans and reflects the sophistication of hunting strategies. The Neanderthals (*H. neanderthalensis*) were also active hunters and according to Hublin *et al*. (1996) they coexisted with modern humans until *c*. 34 K years BP when they became extinct. Another example of an archaeological site with evidence of hunting is at Mezmaiska Cave, northwestern Caucasus, Russia. The remains of ungulate species include steppe bison,

Caucasian goat, Asiatic mouflon and reindeer and the site is dated *c*. 35 K years BP. Similarly, at Makarovo and Varvarina Gora, archaeological sites near Lake Baikal, Russia, there are tool assemblages and bone assemblages which reflect hunting activities *c*. 38 K or 39 K years BP (Goebal and Arsenov, 1995). In southwest Asia, archaeological sites that immediately predate domestication attest to the hunting of bezoar goat, aurochs, wild boar and mouflon. All these species were subsequently domesticated, as discussed below. However, there are some other species which are well represented in the bone assemblages of preagricultural sites (see, for example, Henry, 1989) but which did not subsequently become domesticated. One of the most significant of these was the mountain gazelle. This begs the question as to why certain species were domesticated whilst others were not, as discussed by Clutton-Brock (1992). Overall the archaeological evidence from these sites attests to the high degree of organization within a society which may have adopted, or was approaching, a sedentary lifestyle.

III   Plant domestication

There is a considerable body of archaeological and palaeobotanical evidence which indicates where plant domestication occurred. Moreover, the application of radiocarbon age determination has allowed a chronological sequence of events to be constructed, though revisions are now necessary because of anomalies produced by improvements in the radiocarbon technique.

The identification of so-called centres of plant domestication was initially undertaken by the Russian botanist Nikolai Vavilov in the 1930s (see Vavilov, 1992). He suggested that centres were likely to coincide with those areas characterized by high diversity of crops, i.e. regions in which many potential sources of plant foods are present and where the wild relatives of domesticated species are abundant. This assumption is rather simplistic and flawed, as Harris (1996) has discussed. Nevertheless, a plentiful supply of wild foods may have encouraged the adoption of sedentary lifestyles by hunter-gatherers and then, when conditions changed for whatever reason (see below), agriculture may have ensued. The centres proposed by Vavilov are given in Figure 1, along with later modifications by Harlan (1992b), MacNeish (1992) and Smith (1995). The main loci of origin are: southwest Asia, southeast Asia, Mesoamerica, the tropical Andes, sub-Saharan Africa and northeast North America, and possibly the southern Andes, the Horn of Africa and peninsular southeast Asia.

The major crops, where they were domesticated and approximate dates for domestication are given in Table 2. Until recently, the earliest dates were from sites in southwest Asia, notably for the domestication of wheat and barley *c*. 10 K years BP (Zohary and Hopf, 1993) but new evidence from China may push back the initial domestication of Asian rice to *c*. 11 K years BP. A recent report (Normile, 1997) summarizing new discoveries in China highlights the significance of abundant rice remains from more than 100 sites along the Yangtze River. Of these, the oldest, with a median age of 11 500 years (Normile does not state whether this is a calibrated date), occur in the reaches of the middle Yangtze. If this proves correct, it shifts the earliest agriculture to southeast Asia, and the middle Yangtze River Valley in particular, from southwest Asia. Further research in China and southeast Asia, possibly incorporating phytolith analysis
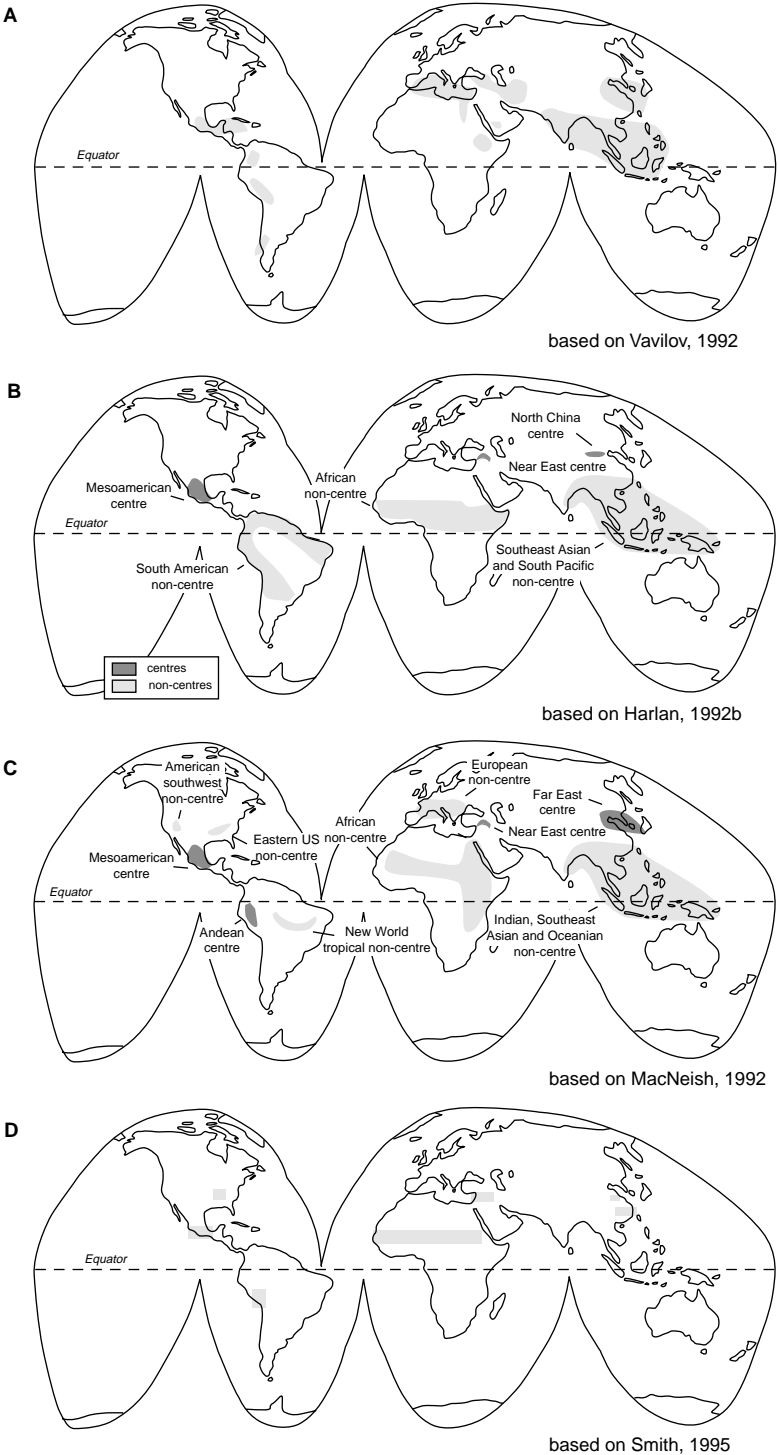
A

B

North China
centre

Near East centre

Mesoamerican
centre

African
non-centre

Equator

South American
non-centre

Southeast Asian
and South Pacific
non-centre

centres

non-centres

based on Vavilov, 1992

based on Harlan, 1992b

C

American
southwest
non-centre

European
non-centre

Far East
centre

Near East centre

Eastern US
non-centre

African non-centre

Mesoamerican
centre

Equator

Andean
centre

New World
tropical non-centre

Indian, Southeast
Asian and Oceanian
non-centre

based on MacNeish, 1992

D

Equator

based on Smith, 1995

Figure 1   The centres of crop origin

(phytoliths are opal silica deposits with plant species-specific shapes, increasingly being used to determine the presence of plants in sediments and archaeological sites) to distinguish between wild and cultivated rice, as suggested by Jiang (1995) and Pearsall *et al.* (1995), may reveal more detail in relation to where and when domestication

Table 2 Some of the world's most important crop plants and their approximate dates of domestication

Crop	Common name	Approx. date (K years BP) (uncalibrated radiocarbon years)
A The near east		
Avena sativa	oats	9.0
Hordeum vulgare	barley	9.8
Secale cereale	rye	9.0
Triticum aestivum	bread wheat	7.8
T. dicoccum	emmer wheat	9.5
T. monococcum	einkorn wheat	9.5
Lens esculenta	lentil	9.5
Vicia faba	broadbean	8.5
Olea europea	olive	7.0
B Africa		
Sorghum bicolor	sorghum	8.0
Eleusine coracana	finger millet	?
Oryza glaberrima	African rice	?
Vigna linguiculata	cowpea	3.4
Dioscorea cayenensis	yam	10.0
Coffea arabica	coffee	?
C Far east		
Oryza sativa	rice	<10.0*
Glycine max	soybean	3.0
Juglans regia	walnut	?
Castanea henryi	Chinese chestnut	?
D Southeast Asia and Pacific islands		
Panicum miliare	slender millet	?
Cajanus cajan	pigeonpea	?
Colocasia esculenta	taro	9.0
Cocos nucifera	coconut	5.0
Mangifera indica	mango	9.2
E The Americas		
Zea mays	maize	4.7
Phaseolus lunatus	Lima bean	5.0?
Manihot esculenta	cassava	4.5
Ipomea batatus	sweet potato	4.5
Solanum tuberosum	potato	5.0
Capsicum annuum	pepper	8.5
Cucurbita spp.	various squashes	10.7?
Gossypium spp.	cotton	5.5

Note: *Unconfirmed recent data – see Normile, 1997.
Source: Based on Evans, 1993, with additions.

initially occurred. It has been suggested by Glover and Higham (1996), for example, that rice may have been domesticated in the Yangtze delta region though dates so far available are no older than 7 K years BP. It is quite possible that the species was domesticated in different places and at different times. The second centre of domestication in China is located where the Yellow River leaves the western highlands and enters the plains. According to An (1989) broomcorn millet and foxtail millet had been domesticated here by *c*. 8 K years BP.

The current annual production of rice is 567×10^6 metric tons (FAO, 1997); this feeds almost a fifth of the world's population. In terms of volume, rice production is second in importance to wheat of which 579×10^6 metric tons are produced annually (FAO, 1997). According to Zohary and Hopf (1993), wheat was domesticated, along with barley, *c*. 10 K years BP in southwest Asia. It is thought that modern bread wheat originated as a hybrid between emmer wheat and another *Triticum* species (*T. tauschii*) (see comments in Evans, 1993). From its area of emergence in the region south east of the Caspian Sea, bread wheat along with emmer wheat were introduced into Europe and Asia. Recent work on the genetic constitution of numerous wild einkorn lines in the region between southeast Turkey and western Iran has also helped to establish where domestication of this species occurred. Heun *et al*. (1997) examined DNA from 68 lines of cultivated einkorn and 261 wild einkorn lines from this region and nearby. Their results show that the most distinct lines genetically come from the Karacadag Mountains, southeast Turkey. Moreover, these lines were also the closest genetically to the cultivated lines, implying that the wild lines comprised the ancestors of cultivated einkorn. This possibility is also supported by the fact that archaeological sites in the region contain remains of both wild and cultivated einkorn. These sites include Cafer Höyük, Cayönü and Nevali Cori which are some of the earliest agricultural settlements in southwest Asia. Barley, lentil and olive were other early domestications in this centre from whence they influenced the development of agriculture in Europe and Asia as did flax which was selected for its fibre (for details, see Zohary and Hopf, 1993). The adoption of domesticated species, along with the continued use of wild cereals and pulses, was widespread by *c*. 9 K years BP as is evidenced by remains of wild and domesticated plants at several archaeological sites in the valley of the middle Euphrates (Willcox, 1996). As with rice and other crops, there is considerable debate about the possibility of multiple domestications of individual crops as compared with single domestications, i.e., polyphyletic evolution and monophyletic evolution. In relation to the crop assemblages that originated in southwest Asia, genetic data indicate that monophyletic evolution is most likely (Zohary, 1996).

The most important crop in terms of modern world agriculture to emanate from the sub-Saharan centre is sorghum. According to Harlan (1992b), the earliest evidence for this is a grain impression on pottery approximately four thousand years old. As Table 2 shows, many other crops were domesticated in this centre, including African rice, various millets, various oil crops, yam, coffee and old-world cotton. Although this centre produced a wide range of crops, little is known about the spatial and temporal patterns of plant domestication. Harlan has suggested that agricultural systems were emerging by *c*. 7 K years BP and that by 5 K years BP pastoralism based on cattle was widespread, with sorghum cultivation beginning *c*. 4 K years BP and pearl millet later at *c*. 3 K years BP.

There are three centres of plant domestication in the Americas, as shown in Figure 1.

Smith (1995) concluded that the first domestications in this region occurred at about the same time, i.e., *c*. 4.5 K years BP. This is, however, controversial because until recently the domestication of maize in the Mesoamerican centre was dated to *c*. 8 K years BP. However, Long *et al*. (1989) have presented revised dates of *c*. 4.7 K years BP; these are considered to be more accurate because the small samples required for AMS dating have allowed the age determination of actual maize cobs rather than carbonaceous material from the sedimentary matrix in which the cobs were found. Consequently, the chronology and sequence of agricultural development have required reappraisal, as discussed by Fritz (1994; 1995). Apart from the new dates being controversial, and the possibilities of errors in AMS dates have been raised by Rossen *et al*. (1996) in the context of likely cultigen specimens from the Zana Valley, northern Peru (part of the tropical Andean centre; Figure 1), they raise questions on related research elsewhere in the Americas, and in Europe (Rowley-Conwy, 1995). For example, the carbon isotope analysis of human skeletal bones from a range of sites in Central and South America, which reflects the type of plants consumed, indicates that maize was an important component of human diets by 6 K years in Mexico's Tehuacán region (Van der Merwe, 1982). A reconciliation of the two dates is only possible if the plant material consumed in Tehuacán was a wild ancestor and not domesticated maize. The AMS dates referred to above also call into question phytolith analysis of sediments by Pearsall (1994) from the Amazon Basin of Ecuador which is interpreted as reflecting maize cultivation as early as 8 K years BP. Further confusion arises when a date of 1.6 K years for the emergence of a maize-dominated diet in the Orinoco River valley of Venezuela is taken into account (see Bonavia and Grobman, 1989).

Two other controversies surround maize domestication. The first concerns the possibility that there was more than one centre of origin. There is no doubt that Mexico was one centre but there may also have been an Andean centre. It is not impossible that additional loci may be discovered though present evidence requires a reconsideration of where maize domestication occurred and the routes whereby it spread into South America in particular. The second controversy concerns the wild ancestry of maize. This has arisen because Galinat (1992) has shown that the cob structure of the domesticated species is very different from wild maize types. Doebley (1990) has examined the anatomy and genetics of a range of related wild grass relatives and shown that the most likely ancestor of domesticated maize is a species of the annual teosinte (*Zea mays* subsp. *parviglumis* Iltis and Doebley).

The common bean and lima bean were also domesticated in Mesoamerica though recent evidence indicates that this was only one of two centres, the other being the Ecuadorian/Peruvian/Argentinian Andes (Sonnante *et al*., 1994; Salgado *et al*., 1995). The earliest remains of an upland new-world cotton which are associated with human activity derive from the Tehuacán Valley of Mexico and are dated 5.5 K years BP. It has been suggested, on the basis of comparisons with cultivated and wild cottons from Mexico, that it may have been originally domesticated in the Yucatan Peninsula (see review by Pearsall, 1992). Various squashes were also domesticated in Mesoamerica, the most common species being *Cucurbita pepo* which was also domesticated independently in the eastern USA. Original age determination of remains of *C. pepo* from Guilá Naquitz in the Oaxaca Valley of central Mexico, reported by Flannery (1986), gives a date of 9.3 K years. It was anticipated (Smith, 1995) that AMS dates on *C. pepo* remains would be considerably younger, as occurred in the case of maize (see above) but inter-

estingly Smith (1997) has recently reported AMS dates on domesticated specimens from Guilá Naquitz of between 10 K and 8 K years BP! According to Peterson and Sidell (1996), one of the earliest dates for domesticated *C. pepo* from the eastern USA is *c*. 5.7 K years BP from the archaeological site of Sharrow in Maine. This eastern centre of domestication was also the area of origin for sunflower (Smith, 1995). The Andean centre referred to above gave rise to another crop that has changed the character of agriculture worldwide. This is the potato. The oldest remains of domesticated potato are from the Chilca Canyon, Peru, and are dated to 7 K years BP (Hawkes, 1991). Nuna beans (see Tohme *et al.*, 1995) and quinoa (see Smith, 1995) also originated in this Andean centre. The latter is now being reintroduced to Peru in an effort to improve agricultural productivity.

IV   Animal domestication

Relatively few animal species have been domesticated when compared with the range of plant species, though together domesticated plant and animal species represent a tiny fraction of the earth's biodiversity. Moreover, several of the centres of plant domestication were centres of animal domestication, notably southwest Asia and the tropical Andes, as shown in Figure 2. Although most animals were domesticated after crop plants, the oldest fossil of the first animal to achieve domesticated status, the dog, is dated to 14 K years BP (see Clutton-Brock, 1995). The fossil is a mandible from a grave site at Oberkassel in Germany and it predates by 2 K years fossil remains from southwest Asia which has been suggested by Davis (1987) as the locus of initial domestication. Fossil remains of dog from a variety of places show little evidence of butchering, indicating that the animal, which was domesticated from an unidentified subspecies of wolf, was prized for its ability to herd, hunt and guard, though it may also have been exploited for its pelt. There is the additional possibility that it was domesticated in several places (see Morey, 1992; Dayan, 1994).
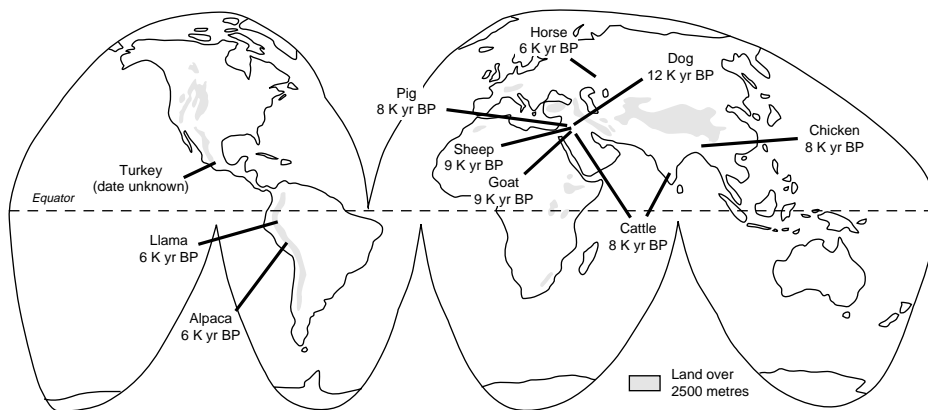

Figure 2   The places of origin, with approximate dates, for the most common domesticated animals
Source: From Mannion (1995)

   Southwest Asia was a major centre of domestication and the modern counterparts of the animals domesticated there, notably cattle, sheep, goat and pig (see review in Hole, 1996; Uerpmann, 1996) are today the mainstay of pastoral and mixed farming systems. According to Davis (1987), the domestication of all these animals occurred between 10 K years and 7 K years BP in the loci given in Figure 3. The ancestors of the domesticated sheep, goat, cattle and pig are the mouflon, bezoar goat, auroch and wild pig respectively. In the case of domesticated cattle, there is biomolecular evidence based on the analysis of the mitochondrial deoxyribonucleic acid (mDNA) sequences in the mitochondria of modern species in Africa, Europe and India to indicate that there were at least two centres of domestication (Bradley *et al.*, 1996). One of these was probably southwest Asia whilst the other was in India. The application of such techniques to determine the genetic characteristics of domesticated plants and animals and their wild relatives will undoubtedly contribute much to the understanding of spatial and temporal patterns of domestication and the initiation of agriculture. The wild ancestors of these animals were all hunted prior to domestication along with other species such as the mountain gazelle, though the latter was never domesticated. Even after the domestication of cattle, sheep, etc., wild animals remained an important supplementary source of protein.
   According to West and Zhou (1988), the chicken is the earliest domesticated bird; this originated in southeast Asia from the red jungle fowl, for which there is genetic evidence (Fumihito *et al.*, 1994). From here it was introduced to China and Europe
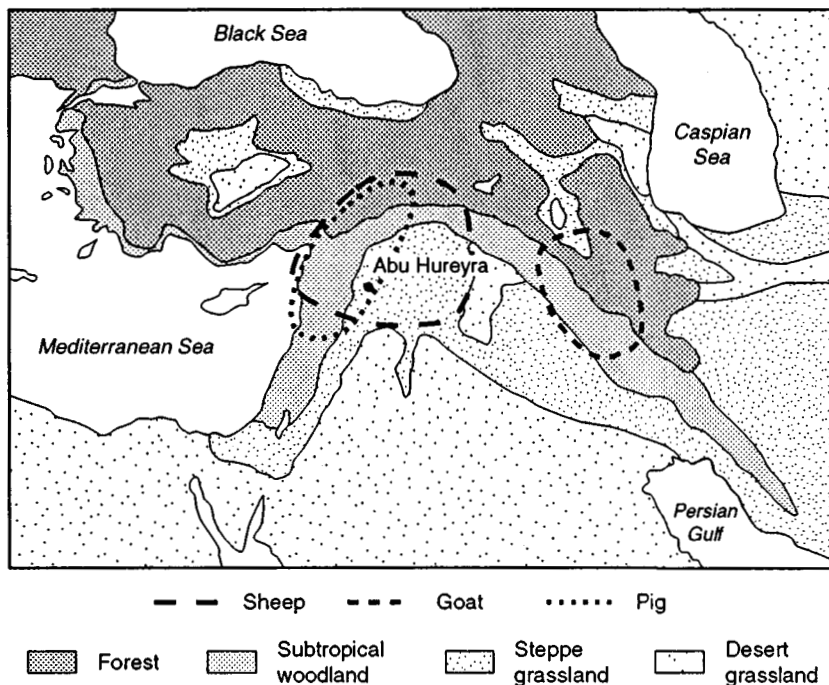

Figure 3   The areas of southwest Asia in which sheep, goat and pig were domesticated
Source: Based on Smith (1995)

c. 4000 years ago. Another animal domesticated in Asia is the water buffalo. Mitochondrial DNA analysis by Tanaka *et al*. (1995) indicates that there were at least two separate centres of domestication. One such centre may have been the Yangtze River delta where the oldest remains of water buffalo in China have been found and which are dated to *c*. 6.5 K years BP. A number of animals were also domesticated in Mesoamerica and in the Andean centre. In the former, the turkey was domesticated though it is not known when this occurred. In the Andean centre there is abundant evidence for the widespread hunting of the vicuña and guanaco prior to 6 K years BP; by this time the llama had been domesticated from the guanaco (see Bahn, 1994). Wheeler's (1995) analysis of bone assemblages, coupled with radiocarbon dating, of sediments from Telarmachay Rockshelter in the Peruvian Andes shows that prior to 7.2 K years BP general hunting of guanaco and vicuña was practised, and that specialized hunting emerged between 7.2 K years BP and 6 K years BP By this time anatomical evidence indicates that domestication had occurred and subsistence was based on a herding economy. The Peruvian Andes were also the locus of the domestication of the guinea pig which had occurred by *c*. 4.5 K years BP (Smith, 1995).

One domestication that occurred beyond the centres highlighted in Figures 1 and 3 is that of the horse. Herds of wild horses inhabited the steppelands of what is now the Ukraine and it is here that Anthony *et al*. (1991) indicate the horse was domesticated *c*. 6 K years BP (a calibrated radiocarbon date). This animal may have been exploited for several reasons: as wild game and as a domesticated source of meat, labour and transport, the latter including its use in hunting. The remains of domesticated horse have been discovered at the archaeological site of Dereivka, 250 km south of Kiev, in association with the remains of dog, cattle, sheep and pig. This assemblage is indicative of a herding economy though there is evidence from associated artifacts to support the additional possibility of the use of both dog and horse in ritual and/or religious activities.

V   Why did agriculture emerge?

The sections above consider the general patterns of plant and animal domestication and some of the factors associated with techniques of analysis and age determination. Whilst these are controversial issues, the available data facilitate a broad reconstruction of the spatial and temporal dimensions of early agriculture. Where and when early agriculture occurred has been roughly established though detail is often lacking. However, the advances in data acquisition and interpretation that have occurred since the days of Vere Gordon Childe (1936), who coined the term 'Neolithic revolution' to reflect the importance of the origins of agriculture, have not provided sound foundations on which to determine why the selection of specific plants and animals and their subsequent harnessing within a control system occurred. This issue is highlighted by Harlan's (1992b) statement:

> The question must be raised. Why farm? Why give up the 20-h [hour] work week and the fun of hunting in order to toil in the sun? Why work harder for food less nutritious and a supply more capricious? Why invite famine, plague, pestilence and crowded living conditions? Why abandon the Golden Age and take up the burden?

There have been many hypotheses to explain this turn of events; broadly speaking they can be classified into two groups: materialism and environmentalism (see review in Mannion, 1995). These ideas reflect a degree of polarization that originated in the 1930s and 1940s, notably in the work of Childe and Vavilov. The former advocated environmental change as the major stimulus to hunter-gatherer societies to alter their means of food procurement whilst the latter believed that cultural, or materialist, factors were of especial significance.

These approaches can also be described as having elements of need and greed (Mannion, 1995), as illustrated in Figure 4; they are not necessarily mutually exclusive. There is a further possibility: the so-called 'dump heap' hypothesis advocated in the 1950s by Anderson (1956) which emphasizes the development of co-dependency between specific plants, animals and human activity. This may have contributed to plant domestication if either environmental or material conditions (or both) prompted innovation in food procurement. The reality may, however, have been more complex than these hypotheses suggest.

The approach based on environmentalism reflects the influence of environmental determinism that prevailed in the late eighteenth and early nineteenth centuries and which focused on environmental factors, especially climate, as the over-riding controls on human activity (e.g., Huntington, 1915). There is no doubt that climate has played, and continues to play, a major role in determining the way society uses natural
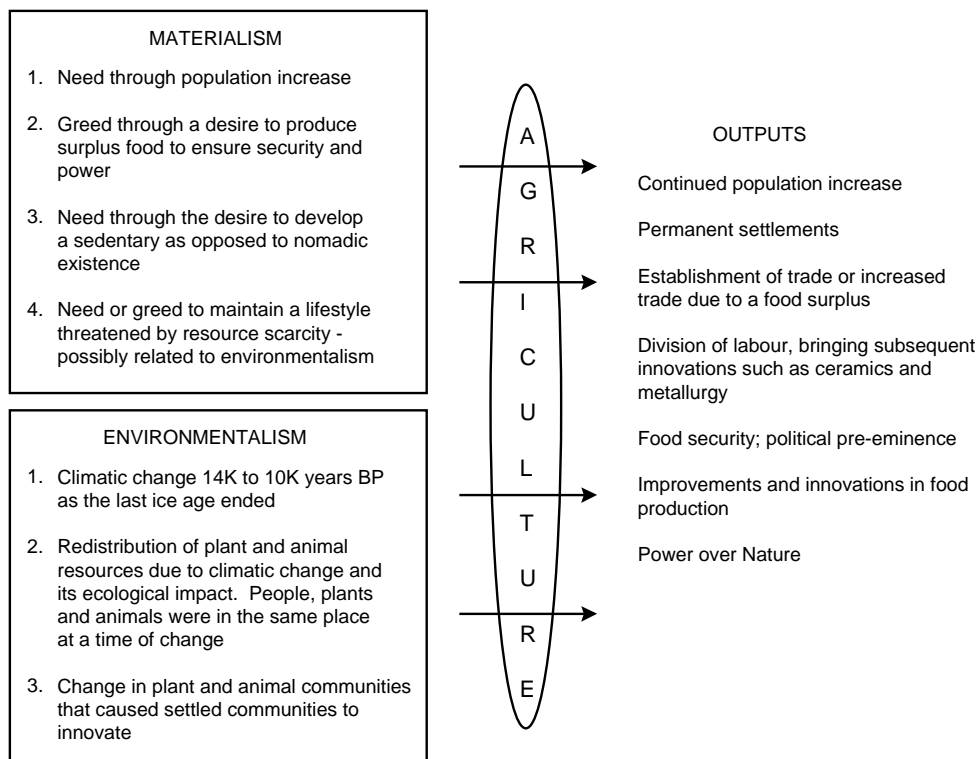

Figure 4 Two models for explaining the initiation of argiculture

resources and there is increasing evidence that climatic change may have been a major stimulus for the emergence of agriculture (see reviews by McCorriston and Hole, 1991; Moore and Hillman, 1992; Byrd, 1994). This evidence occurs in many forms and is widespread, ranging from polar to tropical ice caps, from temperate to tropical lake sediments and peats, and from polar to tropical ocean-sediment cores (see review in Mannion, 1997). For the period between 12 K years BP to 9 K years BP, as the last ice age drew erratically to a close, global temperatures warmed, cooled and warmed again. This created ecological instability which could hardly have failed to affect hunter-gatherer communities. In addition to palaeoecological evidence, it has been argued that the relative coincidence of dates between centres for early domestication (see Table 1) is another indication of the importance of climatic change. However, the problems of younger age determinations for Mesoamerican crops (see above), i.e., from *c*. 9 K years to 5 K years BP, rather refuted this idea until recently. The advent of new AMS dates for *C. pepo* as old as 10 K years BP could be considered as additional support for a degree of synchroneity, along with the new dates for rice cultivation in China, i.e., 11.5 K years BP. However, there is little additional evidence for permanent agriculture in the Americas, such as permanent settlement. Consequently, the AMS redating may simply have produced a coincidence. However, in southwest and southeast Asia there is supporting evidence for the initiation of agriculture. In southwest Asia, settlements came into existence at about the same time and, in southeast Asia, pottery was being produced. In these regions, pressures other than environmental change may have been at work, such as critical thresholds for population carrying capacity especially if some or all of the population had become sedentary, or because of developing trade links which required an increasing surplus of grain for exchange. Survival and/or status may have been threatened which prompted innovation. In particular, wild food resources may have become limited as environmental and ecological change forced changes in faunal and floral distributions. Scarcity reduced the human carrying capacity of a region and so populations were forced to innovate.

There is further evidence that supports the environmentalism hypothesis. This concerns the work of palaeopathologists who have examined human skeletal remains from preagricultural and agricultural horizons in southwest Asia (see Roosevelt, 1984; Layton *et al*., 1991; Molleson, 1994). Such remains from the agricultural horizons of the archaeological site of Abu Hureyra, in present-day Syria (see Figure 3) have been discussed by Molleson (1994). They reflect the effects of hard physical labour and poor diet; those from preagricultural horizons reflect a better diet and less wear and tear. The hard work that cereal cultivation and preparation required is supported by the patterns of wear found on grinding stones and mortars in the region and it has been suggested by Wright (1994) that people would only have turned to grasses, etc., as a source of food if other types of food became scarce. Moreover, the environmental changes of the period might have favoured the spread of wild grasses as competition with shrubs and trees diminished and as their shading was reduced. This body of evidence does indeed point to climatic change as a significant factor in the initiation of agriculture. However, it rather militates against the possibility that the change in atmospheric carbon dioxide from *c*. 200 to 270 parts per million, which occurred between 15 K years and 12 K years BP, was a key factor as Sage (1995) has proposed. Whilst this may have caused an increase in primary productivity by enhancing the availability of carbon dioxide for photosynthesis, i.e., a fertilization effect, it does not explain why so much additional

work was required, or why people were prepared to undertake it. The immediate initiation of agriculture appears to have been accompanied by a decline in the quality of life, at least for women who probably undertook most of the grinding and possibly a large proportion of the cultivation while the men were engaged in hunting.

However, this evidence is circumstantial and may represent coincidence rather than cause and effect. Alternative possibilities must be considered, including the possibility of population increase which is a dominant factor in the materialism approach to the initiation of agriculture. Population increase is often invoked as a cause of changes in material culture and settlement patterns (e.g., Boserup, 1965) but in prehistory there is often little foundation for this. Assessing population densities in prehistory is as enigmatic as assessing the motives for the initiation of agriculture. However, the possibility of population growth and movement cannot be ignored as a factor in the initiation and spread of agriculture. This has been addressed by several studies on the genetic characteristics of modern human populations throughout Europe (e.g., Cavalli-Sforza *et al*., 1994; Weng and Sokal, 1995; Richards *et al*., 1996). The premise is that the genetic differences between established groups of people reflect genetic distances caused by the separation of groups over time. Cavalli-Sforza *et al*. (1994) and Cavalli-Sforza (1996) have compared maps of genetic distance with maps based on dated evidence for the onset of agriculture and have concluded that a high degree of correspondence exists. They believe that this reflects the spread of people, i.e., that demic diffusion occurred, as well as the spread of ideas. It has been estimated that demic diffusion occurred at a rate of *c*. 1 km per year on average. However, there have been many criticisms of this approach and, indeed, it requires rigorous testing. Nevertheless, it seems sensible to assume that people were moving, if only locally, to produce satellite settlements. The question then arises as to why this expansion was occurring. Was it because of population pressure? Or was it a response to changing climate which made resources scarce and so reduced carrying capacity? Alternatively, the desire to annex resources elsewhere may have prompted a form of prehistoric colonialism. The genetic evidence, whilst contributing to an understanding of the spread of agriculture, can be interpreted in either the context of environmentalism or of materialism, as a combination of both or indeed as a red herring.

A further possible explanation for the inception of agriculture involves the development of mutual dependence between certain types of plants and human presence. This is Anderson's (1956) dump-heap hypothesis, which involves elements of environmentalism since it focuses on the ecological preferences of specific plants, and materialism which arises incidentally. This hypothesis invokes the process of domestication and the inception of agriculture as being passive and symbiotic. It rests on the fact that many domesticated species have wild relatives that thrive best in open and/or disturbed habitats. In an area with a population of organized hunter-gatherers the many campsites they used would have associated middens enriched with organic wastes and many would be in open situations around water sources. The middens would also have been a rich seed bank from which seeds could be collected by humans. Some of these seeds may already have been mutants, having been selected by hunter-gatherers, with advantageous traits. This availability, or times of scarcity for whatever reason, could have encouraged the exploitation of such resources so that a mutual, symbiotic relationship evolved between the two and from which agriculture developed. Whilst this is a feasible explanation for the inception of agriculture, it

implies that life was made easier whereas the palaeopathological evidence implies quite the opposite. It does not, however, help to pinpoint when and where domestication took place, though such a process is not at variance with either the environmentalism or the materialism hypotheses.

VI   Conclusion

In the last two decades, a vast amount of information about domestication and early agriculture has been accrued from many different spatial and temporal contexts and from new techniques of analysis. This has contributed substantially to the current appreciation of where and when agriculture began. This new corpus of information has, however, failed to provide a sound basis for the establishment of why agriculture was initiated.

In relation to where domestication occurred, a significant new discovery concerns the archaeological sites of the Yangtze River valley in China. It is entirely possible that southeast Asia will prove to be the region in which the earliest agriculture developed. This will represent a shift of emphasis from southwest Asia as the hearthplace of civilization. The most important development in the context of when domestication and early agriculture occurred is the advent of AMS radiocarbon age determination. This, by dating seeds, fruits, etc., of domesticated plants directly, has altered the timescale for the inception of agriculture in Mesoamerica especially. In the next decade, the application of AMS to crop-plant remains elsewhere, and particularly in southwest Asia, may alter the temporal dimensions of early agriculture substantially.

Other innovations that have had a significant impact on studies of early agriculture include the application of a wide range of techniques for the analysis of ocean sediments, ice cores and continental lacustrine and peat sequences. In summary, the 14 K years to 10 K years BP period was unequivocally one of considerable environmental change. It seems highly improbable that such a climatically and ecologically dynamic environment failed to contribute to the inception of agriculture in some way. In addition, the application of genetic analysis to human populations, as well as the wild relatives of domesticated crop and animal species, is providing information on a range of subjects relevant to the inception of agriculture. The identification of unequivocal ancestors of crop plants and animals is now possible. Moreover, the determination of the genetic characteristics of modern human populations, and eventually of human remains, is generating vital data on the temporal and spatial inter-relationships between human groups, including their role in the spread of agriculture. The major issue which remains as equivocal as ever is why the domestication of plants and animals and the inception of agriculture occurred initially.

Note

1.   Unless otherwise stated, BP dates are uncalibrated radiocarbon dates.

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