ARCHAEOLOGY

A model of agricultural origins

Agriculture is one of the key innovations of human societies, yet the nature of and reasons for its emergence are debated. A new model that hindcasts past global population suggests that an improving climate increased plant productivity and human population density, facilitating domestication.

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It is difficult to overstate the transformative effects the development of agriculture had on human societies and global ecology alike. Agricultural origins began 12,000–8,000 years ago in a number of world regions, including southwest Asia, China, and tropical Mesoamerica and South America (Fig. 1). Together with identifying the plants and their wild progenitors that formed the earliest crop complexes, ever-improving and expanding archaeo-botanical and genetic research, including now from ancient DNA studies, has revealed much the past 10–15 years concerning where and when agriculture emerged around the globe[1]. This information has brought scholarly consensus to some long-contested issues. Nonetheless, major questions continue to prompt strong theoretical and empirical debate. For example, why — after more than three million years of foraging (hunting and gathering) by our hominin and *Homo sapiens* ancestors — did farming emerge from the end of the last ice age (~12,000 years before present) or Pleistocene epoch, and continue into the current Holocene interglacial period? Why did farming not develop earlier? What were the environmental and social circumstances that surrounded agricultural origins, and were one or a few pre-eminent over others?

Some scholars have long-suspected that the near synchroneity of those origins independently in at least six to seven widely dispersed and culturally disparate regions of the world — when or shortly after the world's biota were experiencing profound shifts driven by the end-Pleistocene atmospheric and ecological perturbations — should cause us to look for common underlying processes that may have been widely influential[2–4]. Others believe general theories and explanations are unwarranted and that unique, locally specific cultural or environmental variables should have held sway[5]. In an important study in *Nature Human Behaviour*, Kavanagh et al.[6] evaluate these and other competing views in a novel way by constructing a sophisticated mathematical model to 'hindcast' or predict human population densities around the world from about 21,000 to 4,000 years ago, by which time many regions of the globe were supporting agricultural economies through either independent or secondary (diffusionary) developments[1] (Fig. 1). In the climatological and oceanographic sciences, hindcasting or backtesting is considered standard in model building as a means of ensuring that predictions using modern-day conditions are compatible with known past events[7]. The method had not been previously applied in archaeological reconstruction. Kavanagh et al. conclude that their results support a common global factor they termed the 'surplus' hypothesis; that is, the end-Pleistocene increase in atmospheric CO_2 and temperature improved environmental conditions for human populations, fostering higher resource productivity and increased human population density, and enabling successful plant cultivation together with the subsequent emergence of domestication.

To reach their conclusions, Kavanagh et al. first identified possible drivers of demography in foragers by examining the correlations between environments, population densities and two cultural traits (residential mobility and level of resource ownership) for 220 recent forager societies. The authors found that these variables explained most of the variability in forager population density, with environmental productivity having the largest effect. Kavanagh et al. then fit their population density model to palaeoclimate and cultural conditions at 1,000 year intervals of prehistory. For all but two out of the twelve regions considered where domestication and agriculture are known to have emerged, the improved environmental conditions fostered higher-density human populations shortly before the initiation of plant cultivation or when domesticates are apparent. In eastern North America, one of the two regions where the model predicted a brief population decline before a sharp increase in population density during the period of domestication (the other region is East Indian Ganges), a recent analysis of human demography through careful evaluation of numerous archaeological carbon-14 determinations does indicate significant population increase in the 1,000 years before domestication emergence[8].

Kavanagh et al. discuss a number of ways by which human population growth may have influenced why foragers became farmers. For example, more people may have meant reduced residential mobility and more innovators. Concurrently, increases in the productivity of wild progenitors of the early crops on the advent of the Holocene climate[9,10] may have increased the viability of plant cultivation, in turn fostering more sedentism and higher human population density.

The results, then, do not support regional uniqueness hypotheses, instead indicating that common factors relating to improving environments for both human and plant populations played significant underwriting roles in agricultural origins across the globe. This author believes the viability of the broadly conceived 'necessity' hypothesis (deteriorating environmental/resource conditions) should be examined at finer levels regionally, as different resource types may have been variably impacted by changing climate and ecology (as the extreme megafaunal demise in the Americas demonstrates), and increases in human populations may have, in addition to natural environmental changes, resulted in reduced availability of previously preferred resources[4,8]. Nonetheless, as Kavanagh et al. argue, it appears that overt 'population pressure' necessity hypotheses[3] that view human demographic increases exceeding carrying capacity probably do not offer a general underlying explanation for agricultural origins.

In sum, the authors provide a novel and robust assessment of environmental and demographic influences in widespread agricultural beginnings, bringing these

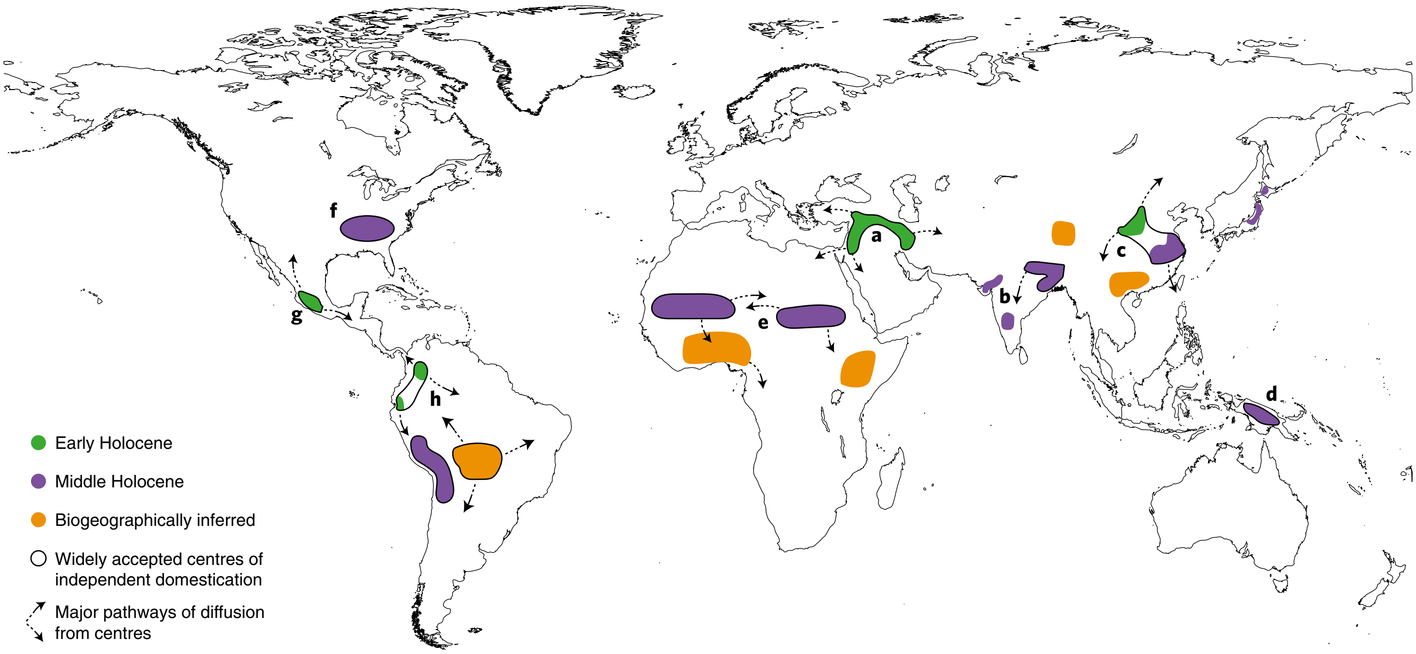

Fig. 1 | Known or likely centres of plant domestication. Black outlines surround the most widely accepted independent centres of domestication, and sources of major diffusions of domesticates are indicated by arrows. Green and purple regions are those where the domestication process took place during the late Pleistocene to early Holocene transition (12,000–8,200 years before present) and in the middle Holocene (8,200–4,200 years before present), respectively. Orange regions represent areas where, at present, the evidence for domestication is interpreted based on the presence of domestic forms indigenous to these regions found outside their native distributions. The letters a–h correspond to the following: a, Southwest Asia (wheat, barley, lentil, pea, chickpea); b, India (rice (indica), millets, mungbean); c, China (broomcorn millet, foxtail millet, rice (japonica), soybean, melon); d, New Guinea (banana, taro, yam); e, Africa (date palm, sorghum, pearl millet, African rice, oil palm); f, Eastern North America (acorn and spaghetti squash, sunflower, sumpweed, goosefoot); g, Mexico (maize, pumpkin squash, common and lima beans, avocado, chilli pepper); h, South America (chilli peppers, peanut, cotton, squashes (butternut and Hubbard), common and lima beans, manioc, sweet potato, white potato, yam, quinoa). Figure reproduced from ref. [1], PNAS.

two factors into better-understood, greater prominence and prompting new insights into present and future empirical data. ❐

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Competing interests

The author declares no competing interests.