Cultivation of cereals by the first farmers was not more productive than foraging

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Did foragers become farmers because cultivation of crops was simply a better way to make a living? If so, what is arguably the greatest ever revolution in human livelihoods is readily explained. To answer the question, I estimate the caloric returns per hour of labor devoted to foraging wild species and cultivating the cereals exploited by the first farmers, using data on foragers and land-abundant hand-tool farmers in the ethnographic and historical record, as well as archaeological evidence. A convincing answer must account not only for the work of foraging and cultivation but also for storage, processing, and other indirect labor, and for the costs associated with the delayed nature of agricultural production and the greater exposure to risk of those whose livelihoods depended on a few cultivars rather than a larger number of wild species. Notwithstanding the considerable uncertainty to which these estimates inevitably are subject, the evidence is inconsistent with the hypothesis that the productivity of the first farmers exceeded that of early Holocene foragers. Social and demographic aspects of farming, rather than its productivity, may have been essential to its emergence and spread. Prominent among these aspects may have been the contribution of farming to population growth and to military prowess, both promoting the spread of farming as a livelihood.

labor productivity | technological change | time discount | certainty equivalent

A parsimonious and widely held explanation of the advent of farming is that at the end of the Pleistocene, hunter-gatherers took up cultivation of crops to raise (or prevent a decline) in their material living standards (1–3). In this view, the initial cultivation and subsequent domestication of cereals beginning about 12 millennia ago, and the somewhat later domestication of animals (4, 5), is emblematic of the economic model of technical progress and its diffusion (6). Like the bow and arrow, the steam engine or the computer, in this model cultivating plants rather than foraging wild species is said to have raised the productivity of human labor, encouraging adoption of the new technology and allowing farming populations to expand.

Population did increase following domestication (7), but evidence that many of the first farmers were smaller and less healthy than early Holocene foragers casts doubt on improved material living standards as the cause (8). The findings reported here—that the first farmers were probably no more productive than the foragers they replaced, and may have been considerably less productive—favors a social rather than technological explanation of the Holocene revolution, one based on the demographic, political, and other consequences of adopting farming as a livelihood (9–14). The evidence is also consistent with the long-term persistence in many populations of "low-level food production" without a transition to a full reliance on farming (15, 16), as well as with recent evidence that the domestication of cereals was not a one-off event but rather a process extending over as many as 5 millennia [as in the case of rice in China (17)]. The implication is that the process of prehistoric technical advance—whether it be cultivation of crops, the use of fish hooks, or the production of microlithic stone blades—may be explained at least in part by changes in how people interacted with one another rather than simply as a series of innovations in how individuals interacted with nature (18, 19).

The puzzle of the forager-to-farming transition may be considered as either a decision problem—why would a forager initially cultivate plants (perhaps as a small part of the family's livelihood)?—or an evolutionary problem: how would groups that took up farming subsequently reproductively outproduce those who did not? As we will see, the measures of productivity relevant to these two questions are not identical. However, answers to both questions require information about the material benefits and costs of subsisting on cultivated as opposed to hunted or gathered wild species, as these might have been experienced during the late Pleistocene and early Holocene.

There is little question that cultivation increased the output of nutrients and other valued goods per unit of space. The more difficult question, and the one relevant to both the decision problem and the evolutionary problem just mentioned, concerns the productivity of labor rather than of land: was the energetic output (calories) per unit of direct and indirect input of work (henceforth termed "productivity") initially higher for farmers than for foragers?

Data on contemporary and recent foragers exploiting wild species and farmers using hand tools in relatively land-abundant environments, as well as archaeological data, may provide some answers. However, one must first devise an accounting method that will provide a common measure of the returns to human labor expenditure, given the very different technologies involved in cultivation and foraging. Chief among these differences are the degree of delay in returns, the number of species exploited (and hence the extent of risk exposure), and the extent of use of storage, tools, and other intermediate inputs. A second challenge is that even using such a comparable system of accounting, are data from populations in the historical and ethnographic record informative about the relevant costs and benefits of cultivation during the early Holocene?

Statistical Methods

Estimating the Productivity of Labor at the Dawn of Farming. I begin with five distinct facets of this second challenge. First, contemporary farmers—even those with only hand tools—use metal axes, machetes, and other implements that were not available during the early Holocene. The same is true, although to a lesser extent, of foragers. The result may be an upward bias to the farmer-productivity data relative to the forager data. (I have excluded data in which any motorized equipment or firearms were used, but for farmers and foragers alike, it is not possible to exclude data in which any metal implements are used.) Likely biases in the data are summarized in Table 1.

Second, the greater political and military power of farming societies since their inception resulted in the elimination and displacement of late Pleistocene foragers, many of whom had lived in resource-rich coastal, riparian,

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Table 1. Likely bias in using recent data to estimate early Holocene labor productivity

Source of likely bias	Bias	Comment (N, not directly accounted for)
Availability of metal tools	*c*	N; but modern equipment excluded (e.g., no vehicles or guns for hunters)
Tool and storage facility maintenance excluded	*c*	N; bias may be small given rudimentary storage facilities and tools
Availability of improved cultivars	*c*	N; edible fraction of harvest may have been 2/3 of estimated (modern) values.
Marginal habitats of modern foragers	*c*	N; resources of modern hunters inferior to prehistoric (especially fish and meat)
Farmers' labor intensive resource use	*w*	Bias limited as effects of land abundance simulated; intensive farming excluded
Farmers' reduced diet breadth (nutrition)	*c*	N
Farmers' reduced diet breadth (increased risk)	*c*	Hypothetical orders of magnitude for reproductive success estimated
Farmer's reduced spatial mobility (increased risk)	*c*	N
Farming's delayed returns (time discounting)	*c*	Hypothetical orders of magnitude estimated (both reproductive and subjective)
Farming's delayed returns (others' appropriation)	*c*	N; bias possibly significant where individual property rights were absent
Foragers' marginal < average productivity(initially)	$w \rightarrow c$	Bias reverses for full scale farming (see text)

A likely bias overstating the relative returns of those exploiting cultivated and wild species is indicated by *c* and *w* respectively. Caloric return-rate data for the low-technology cultivation of nongrain early domesticates, such as avocado, bottle gourd, and squash (5) do not exist; these might show higher returns if their limited processing costs were not offset by the greater storage losses.

and other locations with easy access to high-caloric and protein-value fish (especially shellfish) and mammals. Data allowing economy-wide estimates of caloric return rates for these resource-rich foragers do not exist. Thus, available data on modern foragers' return rates may provide underestimates of returns rates for diets rich in terrestrial and maritime wild resources at the dawn of farming.

Third, a bias working in the opposite direction is a result of possible land scarcity among recent farmers: in some of the farming data, the ratio of labor to land is certainly higher than was the case at the initiation of farming. For this reason, the farming return data may underestimate the productivity of the first farmers' labor. However, the fact that the particularly land-abundant economies in the data do not show markedly higher return rates suggests that this concern may be of limited importance; one of the most land-scarce economies, Tepoztlan, Mexico half a century ago, shows the highest returns. In one of the economies studied, the available data permitted an estimate a production function allowing a calculation of the size of the effect on labor productivity of a hypothetical doubling of the land tilled, holding labor input constant (*SI Appendix*). I have used these estimates to account for the effects of presumed greater land abundance in the early Holocene.

Fourth, the food value per harvested crop and the seed yields of early cultivars must have been extraordinarily low; recent levels, which unavoidably are the basis of the estimates here, are the result of millennia of deliberate and unconscious selection by humans. Although full domestication of a wild cereal may occur over fewer than 10 (human) generations (20), contemporary cereals and other crops are undoubtedly substantially more productive than the initial cultivars. For example, the grain harvest yield per unit of seed increased at least fourfold in the last seven centuries (*SI Appendix*, Fig. S1 and Table S1). Modern crops are also much improved in the ratio of edible material to the gross harvest. For a stand of wild einkorn (*Triticum boeoticum*, a wheat), the ratio of edible to total harvest was 46% compared with 76% for modern domesticated einkorn (21). The ratio of edible to harvested rice in China rose from 58% four centuries ago to around three-quarters at the mid 20th century (22).

Fifth, although the caloric content of food produced is a convenient common measure across differing populations, it does not fully capture differences in nutrition between foragers and the first farmers, especially the likely greater diet breadth and protein adequacy of Holocene hunter-gatherers compared with the first farmers (23, 24).

Taking these five (and other) unavoidable biases into account (Table 1), it seems unlikely that the available data would understate the productive advantages of farming.

Comparative Accounting Framework. I turn now to the first challenge mentioned above: that of devising an appropriate system of accounting for the inputs and outputs associated with the exploitation of cultivated as opposed to wild species. First, although foragers sometimes built weirs and traps, preserved food, cleared forests, and undertook other investments to enhance long-run returns, delayed returns were more substantial in farming. This, along with the reduced diversity of sources of nutrition in farming populations, meant that farmers made greater use of storage. Estimates of losses during storage using modern data are about 10% of the crop for cereals (and double that or more for cassava and other tubers) (*SI Appendix*).

Moreover, these technical estimates do not include theft, which may have been significant at the initial stages of farming, except among those less-common forager groups already relying heavily on stored resources and adhering to individual possession-based property rights that minimize such losses (for example in California and the Great Basin in the United States and some parts of Australia, and among some fishers).

Farmers' greater use of stored food and storage facilities requires that account be taken of the indirect labor time required to produce and maintain these intermediate inputs. Because most of the farming economies in the sample (by design) make minimal use of tools (not much greater than foragers) and none use animal power (which was not part of the technology of the first farmers), the main differences between farming and foraging in the extent of indirect labor are the result of storage losses and the necessity to set aside seed.

Second, the processing time (dehusking rice, grinding maize) of the early cultivated cereals was substantially greater than for most sources of forager nutrition, sometimes accounting for half or more of the total time use in farming. I include experimentally estimated processing times in the estimates below.

A third difference between the exploitation of wild and cultivated species are the reproductive and subjective costs of the more delayed returns of cultivation. The fact that farming returns are delayed is relevant (albeit in different ways) to both the individual forager's decision (cultivate or not) and the evolutionary success of farming (the relative reproductive success of groups of cultivators). The extent of delay varies depending on the nature of the plants exploited. For cereals with a single crop per year the relevant delay extends from when the labor is performed (clearing, planting, cultivating, and harvesting) to when the crop is consumed, which is distributed throughout the year between harvests. The delay is subjectively costly because people are impatient. It is reproductively costly because the reproductive value of the farmer declines with age (because of mortality or other reasons for cessation of reproduction) and because contributions to earlier gene pools are of greater value (because of population growth) (25).

The costs of delay are represented by δ (the annual rate of time discounting), so that an hour of labor input occurring 1 y before consumption of the output has a present value (cost) at the time of consumption of $1 + \delta$ hours. Estimated rates of subjective impatience relevant to the decision problem are substantial, with values of δ in high-income economies in the neighborhood of 0.20 not uncommon (26). Estimates for foraging-horticultural populations in the Amazon and Madagascar are much higher than this (27, 28). Consistent with the view that farming would be unattractive to impatient individuals, among the Mikea in Madagascar, those engaged in foraging exhibited higher rates of impatience in behavioral experiments than did farmers (27). The cost of delay relevant to reproductive value is much less: the low adult mortality in forager populations and modest population growth before the Neolithic demographic transition suggest a fitness-based value of δ of about 2% (7, 29).

Fourth, by reducing diet breadth, cultivation increased risk exposure, for a serious nutritional shortfall is likely to occur if one relies on one or two crops rather than on many wild species. In contrast to farmers, foragers typically exploit a vast number of species of plants and animals (30–32). Those relying primarily on cultivated species face greater risks for two additional reasons: in contrast to foragers, the production cycle for farming extends for long

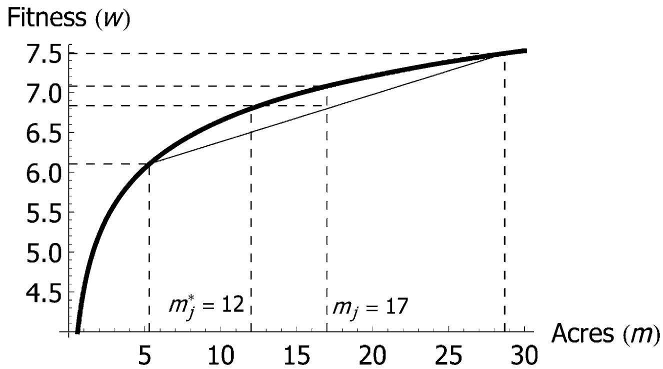

Fig. 1. Illustration of the certainty-equivalent level of material resources of a particular risk-exposed individual. The estimated $w(m)$ function is the solid curve, where m is the amount of land each woman farms and w is the number of children surviving to age 5. The material resources of this particular woman, indexed by j ($m_j = 17$) would yield $w_j = 7.08$ were the average yields to occur with certainty. Suppose however, that just two states occur with equal probability: yields are equivalent to that which would result from access to 17 ± 11.69 acres in the two states (good and bad). Then expected fitness is the equal-weighted average of fitness in the good [$w(m^+) = 7.49$] and bad [$w(m^-) = 6.10$] states, or $w_j^* = 6.80$. Then the certainty equivalent (m_j^*) is the level of resources that, if acquired with certainty, would yield w_j^*: that is, the value of m_j satisfying $w_j^* = w(m_j)$ or $m_j^* = 12.00$, so the risk discount factor for this woman is $\mu_j = m_j^*/m_j = 0.71$. The estimate of μ for the entire population is just the average all of the m_j^* divided by the average m_j or what is the same thing, the average of the μ_j. The algorithm used in the estimates is more complicated than this illustrative example (*SI Appendix*).

periods, over which risk is more systemic than idiosyncratic. An individual forager may have a bad day or a bad week, but an entire group of farmers more typically would have a bad year or even a bad decade. As a result, foragers may readily smooth their consumption over short periods through reciprocal sharing between the lucky and the unlucky (33). For farmers, by contrast, the systemic and long-term nature of the risk make such consumption-smoothing arrangements both more difficult to sustain and less effective (34). Lacking long-time series and other necessary data on any of the economies for which caloric return data are available, I can do no better than to provide an illustration of plausible magnitudes of the costs of risk exposure.

The uncertainty of the hunt or the harvest is costly because of diminishing returns to nutrition: the (negative) effect on both fitness and subjective well being of a shortfall is greater than the (positive) effect of a surplus of the same size. This fact is sometimes captured by specifying an arbitrary survival minimum and calculating the chances of falling below this level. However, a more flexible method that allows empirical estimation and captures decreasing returns over the entire range of nutrition levels is to let fitness or well-being (w) vary with material resources according to $w = w(m)$, where the function is increasing and concave in its argument: the cost of risk exposure will be greater, the larger the variation in the availability of the population's sources of nutrition and the more concave (more rapidly diminishing returns) is the function $w(m)$.

I estimate the function $w(m)$ using measures of fitness (children surviving to age 5) and nutritional adequacy (farm land available) among women engaged in low-technology cultivation in Kenya (Fig. 1 and *SI Appendix*, Figs. S3–S5) (35). The extent of temporal variations in resource availability is based on rainfall-based maize yield estimates for precontact farmers in what is now southwestern Colorado over the period 600 to 1300 (36) (*SI Appendix*, Fig. S2). I use the temporal variance of crop yields along with the estimated fitness function to compute the expected fitness of each woman experiencing these variations, and from this number, the level of resources that, if received with certainty, would yield this risk-affected level of fitness (termed the "certainty-equivalent" level of resources).

The risk discount factor is then $\mu = m^*/\underline{m}$ where m^* is the population average of the individual women's certainty equivalents and $\underline{m}$ is the average resource availability. Multiplying observed average caloric yields by μ gives the yields that, if received with certainty, would be equivalent in fitness or well-being terms to the observed data subject to weather-induced temporal variations. Equivalently, $1/\mu$ (> 1) gives the mean availability of a resource exposed to risk that would yield the same fitness as one unit of the resource received with certainty.

Fig. 1 illustrates how the estimate of risk exposure and the fitness function allow the estimation of a cost of risk exposure for a single individual exploiting a single species. The risk discount used in the estimates presented below is based on farmers exploiting not one (as in this example) but two crops with uncorrelated shocks and experiencing the full range of predicted (nonnegative) yields rather than just a good and a bad state (*SI Appendix*).

The farmers' risk exposure is estimated on the assumption that they exploit two species of equal importance in their diet, each with a yield variability as estimated above, assumed to be uncorrelated across the crops (thus downward biasing the estimate of risk exposure, given that shortfalls in one crop are very likely to be associated with generalized shortfalls). We perform the same procedure for the exploitation of wild species, but assuming that each of nine animal and plant species are subject to the same variations in availability, as are the rainfall-estimated maize returns. Using "f" and "h" superscripts to refer to farmers and hunter-gatherers, respectively, the above calculations (*SI Appendix*) give: $\mu^f = 0.92$ while $\mu^h = 0.98$, meaning that the certainty-equivalent reduction in productivity is 8% of the average labor productivity for farmers and 2% for foragers. [In the *SI Appendix*, I show that an alternative calculation using annual data on actual wheat yields between 1211 and 1349 in England gives values of $\mu^f = 0.86$ and $\mu^h = 0.96$, indicating a greater risk

Table 2. Computing risk-adjusted and time discounted labor productivity for cultivated plants

Variable	Signifies
c^*	= {certainty equivalent of nutrition}/{processing and present value of direct and indirect labor input} = $Kfc\mu/H(p + s(1+ \delta d))$, where
K	Gross kilogram of output
H	Hours of cultivation labor
f	Fraction of unprocessed cereal that is edible and is not lost in processing
c	K calories per kilogram of processed cereal
μ	Ratio of certainty-equivalent to the mean calories attained
p	Ratio of total processing time to direct cultivation time (P/H)
δ	Annual discount rate for production (not processing) time
d	Average delay between cultivation and consumption (fraction of year)
s	Ratio of gross harvest to net cereal available for processing (net of storage losses and seeds)

Virtually all available data report or allow the calculation of the mean gross kilograms of unprocessed output (K) per hour of direct cultivation labor (H). For the needed measure—the present value of certainty-equivalent calories per total hour of work—the following must be done: (*i*) account for the food content of the harvest, namely the part that is edible and not lost in processing (f); (*ii*) convert kilograms of edible processed cereal to kilocalories; (*iii*) express the resulting nutritional value in certainty equivalent terms (μ); (*iv*) add both processing time (pH); and (*v*) the indirect labor namely that required to produce a kilo of stored cereal ready for processing, given the extent of storage losses and seed requirements [$(s-1)H$]; and (*vi*) express this (nonprocessing) labor as a present value at the time of consumption to take account of the fact that it (but not processing labor) occurs before consumption ($1+ \delta d$). (The assumption that no processing is done before storage may upward bias the estimate of c^* as it implies that no processing time occurs in advance of consumption or is expended on cereal lost in storage). The estimates in Fig. 2 do not make adjustment for time delay and risk and so $\delta = 0$ and $\mu = 1$.

exposure disadvantage of farming than the estimates I used. An alternative estimate of the fitness function $w(m)$ (*SI Appendix*) finds a substantially greater degree of concavity than the estimate used here, and would therefore imply greater differences between foragers and farmers in the costs of risk exposure.]

The fact that cereals and other early cultivars may be stored over more than a year mitigates risk exposure: the farmer who stores sufficient cereal so that each year's consumption is based on a harvest of 2 y rather than just 1 y has diversified risk in a way similar to exploiting a larger number of species (assuming that shocks are uncorrelated across species and from year to year). However, storage exposes the farmer to approximately equivalent losses (thefts, pests, rot) and so does not substantially reduce the risk problem (*SI Appendix*).

Results

Taking account of the above requirements for statistical comparability, I use the algorithm in Table 2 to estimate the labor productivity data in Fig. 2 and Table 3.

The estimates taking account of risk and delay appear in Table 3. In addition to the data with no adjustment for risk and delay (line 1, summarizing the data in Fig. 2), I distinguish between the decision problem and the evolutionary problem (results shown in lines 2 and 3, respectively). For the former, capturing the lone forager family's decision to commit modest resources to cultivation, I adjust the cultivated species' returns downward by the substantial subjective cost of delay. However, because a minor commitment to farming would not significantly reduce the number of species exploited, I apply the very modest foragers' risk adjustment. For the evolutionary problem—how would a group of farmers out produce a group of foragers?—I apply the farmers' fitness-based risk adjustment and the much lower fitness cost of delay based on mortality and reproductive value. Average productivity levels in cultivation appear to be in the neighborhood of three-fifths of the returns to foraging wild species, depending on the adjustment.

Discussion

What can we conclude from this evidence? No single estimate can possibly capture the likely benefits and costs of cultivation for the particular species and the locally specific abundance of wild resources, climate, and other conditions under which the archaeologically documented cases of farming first occurred. Moreover, available estimates are necessarily subject to considerable error. However, the evidence presented here is not consistent with the hypothesis that at the dawn of farming the productivity of labor in cultivation generally exceeded that in foraging; indeed it suggests the opposite. This conclusion is especially the case when account is taken of risk exposure and the more delayed nature of agricultural production; however, it holds even in the absence of these adjustments.

If farming was not more productive than foraging, then we need to consider alternatives to the paradigmatic economic "farming was a better way to make a living" explanation of the Holocene technological revolution. The hypothesis of piecemeal adoption of cultivation (15, 37–39), along with the demographic

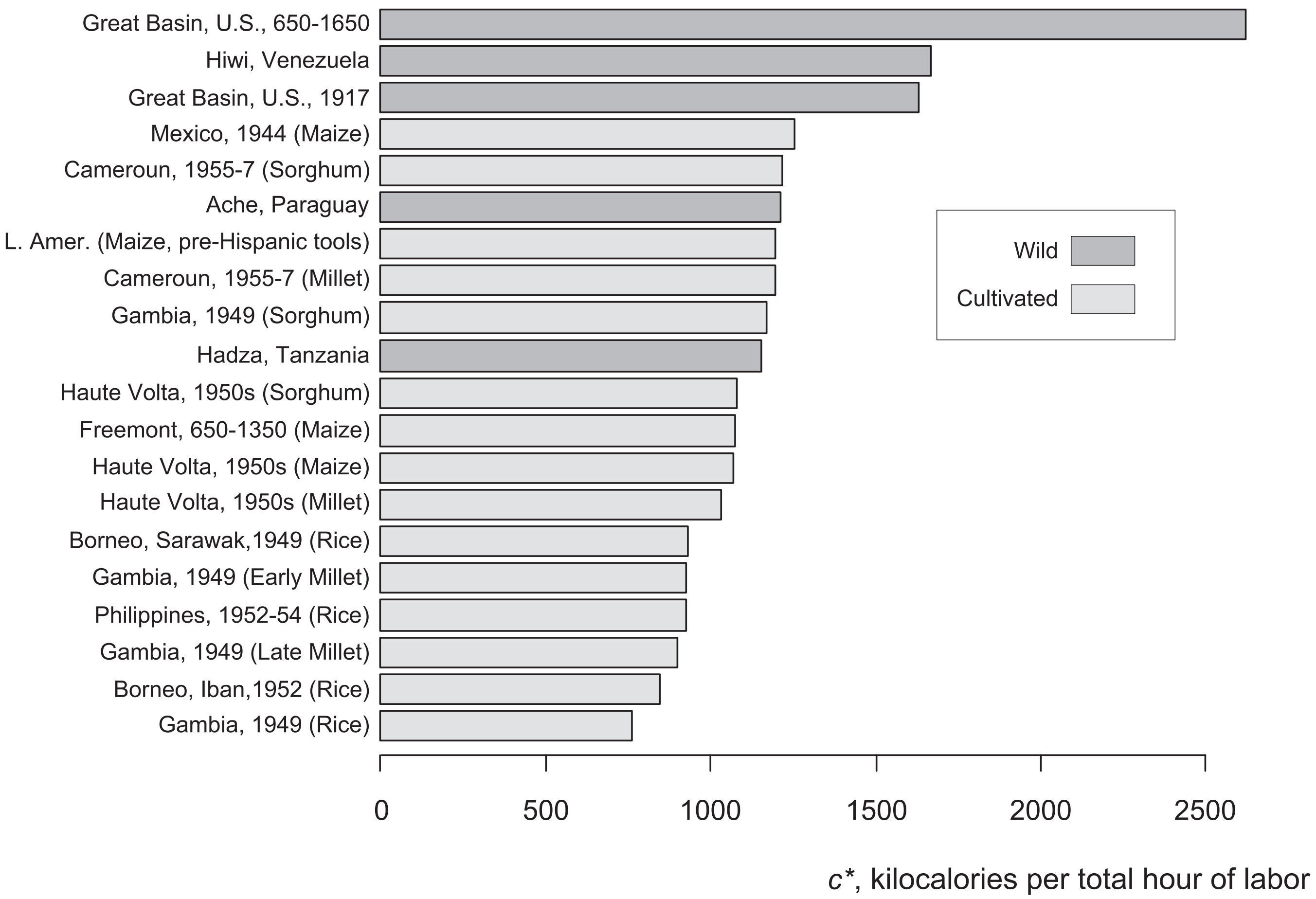

Fig. 2. Net kilocalories per hour of direct and indirect labor, c^*: wild and cultivated species. Methods and sources appear in *SI Appendix*, Table S2. Excluded are return rates for wild species in cases where atypically rich resource concentrations were encountered or where data were available for one sex only or for a limited span of time. Solid bars give returns for the exploitation of a large number of wild species. All cultivated yields are multiplied by 1.079 to adjust for the likely effect of greater land abundance in the Late Pleistocene.

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Table 3. Mean caloric returns per hour of total labor (c^*) for wild and cultivated species with adjustments for risk and (for cultivation) land abundance and delayed returns

Estimate	Cultivated (1)	Wild (2)	$P <$ (for Δ wild − cultivated)	Ratio (1)/(2)
No risk or time delay adjustment (Fig. 2)	1,041 (152)	1,662 (590)	0.005	0.63
Decision: forager risk only and subjective delay	954 (147)	1,628 (578)	0.0003	0.59
Evolution: risk and reproductive delay	951 (139)	1,628 (578)	0.0003	0.58

The estimates relevant to an individual's initial decision to engage in some farming (line 2) entail no greater risk for the farmer (μ =0.98) than for the forager. The estimates relevant to average reproductive output for a group of farmers (line 3) account for the greater risk exposure of farmers (μ =0.92). The subjective and reproductive delay costs are δ = {0.20, 0.02} respectively. The *P* value for the difference between the wild and cultivated c^* distributions are from the Wilcoxon rank-sum test (not affected by the possibly exaggerated returns in the Great Basin prehistoric data). The Welch-Satterthwaite difference in means *t* test (unequal sample variances) gives (for the three rows in order): t = 2.33, 2.38, and 2.39 which even given the very limited degrees of freedom (4.2) are significant at $P < 0.078$, 0.055, and 0.054. SDs in parentheses.

or political (rather than labor productivity) effects of farming may provide part of an explanation.

The answer to the decision question—why did the first farmers farm?—provided by the piecemeal adoption hypothesis is convincing. For an erstwhile full-time forager to benefit by farming a little and foraging a little less, it is not required that the labor devoted to cultivation be more productive than the average of the foraging activities. Foraging a little less would mean forgoing the lowest-ranking components of the diet (that is, the wild plants or animals with the lowest caloric return rate as measured here). Thus, the decision—if and how much to farm?—depends on a comparison of the marginal (not the average) productivity of the two pursuits. The optimal distribution of working time between foraging and farming, that which would maximize total energetic yield (adjusted for risk and delay) for a given amount of labor input, equates these marginal productivities. Although no estimates of the relevant marginal quantities are possible, in a population that is engaged almost entirely in foraging, the marginal productivity of foraging labor is likely to be substantially lower than the average productivity (40). Thus, the data presented here (Fig. 2 and Table 3) do not preclude farming as a minor component of the livelihood of a population engaged primarily in foraging, as is widely observed in both the archaeological and ethnographic record (15, 27, 37, 39).

However, this distinction between marginal and average productivity does not reconcile the estimates reported here with the fact that in many populations farming would subsequently become the main source of livelihood (the phenomenon we are trying to explain). The problem is that the marginal calculation that initially favored a little farming would reverse once farming became the major source of livelihood: at that point, the few foraged resources that were still exploited would be the highest ranked of the full spectrum of once-foraged resources. The farmer-forager family considering devoting even more labor to cultivation and less to foraging would compare these high marginal foraging returns with the prospective returns to cultivation on patches that were not yet considered productive enough to be used. Thus, once farming came to occupy a substantial fraction of the farmer-forager's labor, the marginal productivity of farming labor would be below the average productivity reported here (because of increased travel time, even if good quality land was abundant), and the marginal productivity of foraging higher. The result is that as farming became more extensive, the bias of looking at average rather than marginal productivity is reversed and the reduction of foraging to insignificance becomes difficult to explain.

However, an evolutionary argument may be able explain the eventual spread of farming once it was adopted in a few places. Because of extraordinary spatial and temporal variations in weather, soil quality, scarcity of wild species, and other conditions that could make farming rather than foraging an efficient provisioning strategy, it is likely that a few groups would have found it advantageous (by the marginal conditions above) to take up farming as their primary livelihood. Then, in order for farming subsequently to be adopted by other groups—the evolutionary problem—farming need not have lessened the toil of subsistence. Even if health status and stature declined, the lesser mobility of farmers would have lowered the costs of child rearing (41). This lowering could have contributed to the dramatic increase in population associated with cultivation (7) and, hence, to the spread of farming (12). Or the fact that agricultural wealth (stored goods and livestock particularly) was more subject to looting may have induced farming groups to invest more heavily in arms and to exploit their greater population densities, allowing them to encroach on and eventually replace neighboring groups (11).

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