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BEHAVIORAL ECOLOGY *and the*
TRANSITION *to* AGRICULTURE

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A Future Discounting Explanation for the Persistence of a Mixed Foraging-Horticulture Strategy among the Mikea of Madagascar

Bram Tucker

This chapter pursues dual goals. The first goal is to argue in favor of the use of future-discounting concepts when modeling choices among subsistence activities with dissimilar delay to reward, such as the choice to practice foraging versus farming.

While foraging theory makes the value of all options commensurate by expressing them as a rate of gain per unit time, people may subjectively devalue options with long waiting times, such as agricultural harvests. A literature review and guide to discount rates are presented for readers unfamiliar with these concepts. The second goal is to demonstrate the applicability of future discounting models by presenting a simple dynamic model explaining why Mikea of Madagascar prefer labor-extensive cultivation despite the high risk and low mean payoff, and despite their familiarity with the techniques and benefits of intensive farming. Mikea cultivate because the rewards are high compared with foraging, but they refrain from intensification because immediate needs limit their capacity for future investment.

Low-investment extensive horticulture, the planting of cultigens with minimal labor invest-

ment in patches of wilderness that remain more-or-less untended until harvest time, seems a curious strategy. Payoffs tend to be low on average, for the cultigens compete with wild plants for soil and solar resources. Returns are also highly variable, for the crop is left vulnerable to pests, predators, and unpredictable climatic conditions. Extensive horticulturalists compensate for low and variable harvests by hunting and gathering wild foods, which constitute the bulk of the diet in some years. Given this heavy reliance on foraging, one may well ask why plant cultigens at all? Conversely, why refrain from intensifying agricultural inputs to produce a more dependable and satisfying agricultural payoff?

As curious as the foraging/low investment horticulture strategy may appear, archaeological evidence suggests this was a persistent strategy for millennia in many parts of the world. Some of the first cultigens may have been domesticated rather rapidly, in the span of 20 or so plant generations (Hillman and Davies 1990a, b; Hillman and Davies 1992). There followed a long period of time in which people continued

to rely primarily on foraging while horticulture played an ancillary role. According to Bruce Smith (2001a), this middle ground between plant domestication and intensive farming lasted 3000 years in the Near East, 4000 years in some parts of North America and Europe, and 5500 years in central Mexico (see also Piperno and Pearsall 1998; Doolittle 2000).

Archaeologists interested in subsistence decisions have as a guide the behavior of living peoples, observed and documented with ethnographic and experimental methods and informed by evolutionary theories of human behavior (O'Connell 1995). This chapter describes Mikea of southwestern Madagascar, a contemporary ethnographic population who combine low-investment maize and manioc horticulture with foraging for wild tubers, honey, and small game.

The most important subsistence and cash crop for Mikea was, until recently, maize grown in slash-and-burn fields called *hatsake* (the “ethnographic present” for this chapter is before the government effectively banned hatsake cultivation in 2002). Mikea invest little labor and no other inputs into their maize fields. New fields are cleared by felling and burning trees. Old fields are reused for several years and then abandoned. They are usually cleared of weeds and saplings before planting, although some farmers reduce labor costs even further by planting among the weeds. After planting, no additional labor is invested until harvest time. The fields are exposed to severe sunlight, unpredictable rainfall, poor soil nutrition, weedy competition, and predation by grasshoppers and unsupervised herds of cattle and goats. Mikea are aware of a variety of intensification techniques that could increase maize yields and reduce risk of failure, such as tillage, irrigation, manure fertilizers, weeding, enclosure, and field guarding, but they rarely practice these. Instead, they return to their fields three months after planting and harvest whatever happens to be there.

Most Mikea households in the study area also grow manioc in permanent fields in the

savanna, alongside their Masikoro agropastoral neighbors. Masikoro cultivate manioc semi-intensively on a 12-to 15-month schedule. Some farmers plant in plowed furrows or mounds, and dig drainage ditches to avert flood damage; and they weed their fields three to four times a year. Fields are enclosed with fences and guarded with talismans to protect them from animal, human, and supernatural predators. Forest-dwelling Mikea rarely practice these techniques. Because they only check their fields during periodic visits, they often neglect to drain or weed in a timely fashion, if at all. Loss to livestock and thieves is common. Even when alerted that their field was being plundered by thieves in the night, two brothers in 1998 refused to save their crop, insisting that the wild tubers and honey in the forest were sufficiently plentiful.

Are Mikea cultivation decisions irrational? As foragers, Mikea are viewed as primitives who have yet to discover the intensive farming techniques of their more “advanced” Masikoro neighbors. Their horticulture would appear to be a transitional stage between foraging and farming. But such unilinear-evolutionary assertions are contradicted by Mikea ethnohistory and oral history, which indicate that Mikea and Masikoro are historically the same people. Mikea are descended from Masikoro who sought refuge in the forest to escape the slave raids and tribute demands of the Andrevola kings, and during the French colonial era, to avoid mandatory resettlement and taxation (Yount et al. 2001; Tucker 2003). Foraging is not just an occupation; it is symbolically significant to Mikea identity as refugees from Andrevola hegemony. Mikea have probably always planted some cultigens in combination with foraging. Fanony (1986, 139) reported Mikea cultivating crops in the late 1970s. Twenty years earlier, Molet (1958) documented maize and butter beans in swidden patches deep in the Mikea Forest. Mikea oral histories from the nineteenth century are replete with references to forest fields of maize, manioc, sweet potatoes, rice, sorghum, and taro (Tucker 2003). Shipwrecked sailor Robert Drury, circa

1710, observed that foragers of southern Madagascar “content themselves with small plantations” in addition to “the products of nature” (Drury 1826 [1729], 139). Mikea are active participants in Masikoro society, and indeed, all Mikea self-identify as being either Masikoro or Vezo in addition to Mikea. Mikea and Masikoro belong to the same clans, intermarry freely, and participate in the same family ceremonies. Mikea often labor in their neighbors’ fields for wage payments. So Mikea and Masikoro share the same knowledge of agricultural intensification techniques. Masikoro choose to intensify; Mikea do not. Nor do Mikea choose to specialize on foraging. For centuries many have chosen a middle path.

Which is most profitable: foraging or cultivation? This depends on how one defines “profitable.” Agricultural profitability is usually measured as yield per unit of land. But because mobile foragers’ harvest is not land-limited, it makes little sense to quantify wild tuber production as kilograms per hectare.

Alternatively, we can compare foraging and farming with the logic of foraging theory. Foraging theory calculates rewards as a net rate of energy gain, or net acquisition rate (Pyke et al. 1977; Stephens and Krebs 1986, 9). When digging wild ovy tubers (*Dioscorea acuminata*), Mikea children average 500 net kcal/hr, while adults gain 1200–2700 kcal/hr (Tucker and Young 2005). If cultivated rewards are calculated in the same manner, then foraging is clearly an inferior choice. The most extensive form of Mikea cultivation is planting maize in an unweeded hatsake field, for which the only required investment is 11 person-hours of planting labor per hectare. The net acquisition rate is approximately 165,215 kcal/hr.¹ In a survey of 247 hatsake in 1998 and 1999, only 6.5% of fields were cultivated in this manner. In the majority (57%) people cleared weeds before planting, adding an extra 24.7 person-hours of labor investment to the venture. This increases average yield from 500 kg/ha to 910 kg/ha. But the net acquisition rate is actually lower: 92,469 kcal/hr.² Net acquisition rate does not

adequately describe the value of foraging and farming, nor does it explain the costs and benefits of intensification.

I argue that the best way to model the choice between foraging versus cultivation is with a future-discounting model. When offered a choice between a small reward available now versus a larger reward after a delay, decision-makers often prefer immediate gratification, indicating that they subjectively devalue rewards for which they must wait (Samuelson 1937; Mazur 1984, 1987; Rachlin et al. 1991; Myerson and Green 1995; Green and Myerson 1996; Frederick et al. 2002). To borrow Woodburn’s (1980) terms, foraging is an “immediate return” economic system while farming is a “delayed return” economic system. The reward for a few hours’ foraging is a certain catch of food: small in comparison to an agricultural harvest, but available for immediate consumption. A day spent cultivating is rewarded with sweat, blisters, and an empty stomach, along with the promise of a large quantity of food some time in the future. Exogenous factors such as high risk of crop loss may make agriculture an empty promise. Factors endogenous to the household, such as food supply adequacy, may limit a household’s ability to survive on promises alone. Mikea cultivate because the rewards are high compared with foraging, but they refrain from intensification because immediate needs limit their capacity for future investment.

This chapter has two goals. The first is to present a theoretic argument for the use of a future discounting framework when modeling the choice to forage or to farm. I begin with a critical evaluation of the way foraging theory deals with time. Then I present a brief review of descriptive models, methods, and explanations from future discounting studies in economics, psychology, and anthropology. I follow with a guide for modelers to choosing discount rates. The second goal of this chapter is to illustrate the applicability of future discounting to modeling subsistence decisions. To this end I return to the Mikea example provided above, and present

a future-discounting model to explain why Mikea practice a mixed foraging-horticulture strategy.

TIME AND FORAGING MODELS

Foraging theory was developed in the 1960s and 1970s to explain predatory behavior (MacArthur and Pianka 1966; Schoener 1974; Charnov 1976; Pyke et al. 1977; Stephens and Krebs 1986), and was soon after applied to the decisions of human foragers in ethnographic contexts (Winterhalder and Smith 1981; Hawkes et al. 1982). Models from foraging theory such as the encounter-contingent prey choice model (MacArthur and Pianka 1966; Schoener 1974) and the patch use model (Charnov 1976) make specific predictions about the selection and exploitation of food resources. Options such as prey and patch types are evaluated according to their gross energy payoff (the number of calories gained by consuming the resource) minus the energy and time costs involved in locating the resource and its "handling" (pursuit, harvest, transport, processing, etc.). Foraging theory models assume that decision-makers evaluate time and energy information together as a rate; they maximize average net rate of energy gain (Pyke et al. 1977; Stephens and Krebs 1986, 9). This maximization assumption has proven sufficiently general to explain a wide range of subsistence behavior (Pyke et al. 1977; Smith 1983), including choices under risk (Stephens and Charnov 1982; Winterhalder 1986; Weissburg 1991).

Average rate maximization may be insufficient when options differ significantly by delay-to-reward (see discussion in Stephens and Krebs 1986, 147–150). Average rate maximization asserts that one rabbit worth 1000 net kcals caught in one hour is equivalent in value to one deer worth 100,000 net kcals caught in 100 hours, or one giraffe worth 1,000,000 net kcals caught in 1000 hours; all have a net acquisition rate of 1000 kcal/hr. But from a forager's perspective there may be a significant difference between dedicating oneself to a one-hour rabbit

chase versus a 1000-hour giraffe hunt. The latter requires the forager to defer consumption for a longer period of time (he would have to pack a lunch). Since time spent foraging cannot be allocated to alternative tasks—longer foraging time has greater opportunity cost—the giraffe hunter would have to make arrangements to manage his nonforaging activities during his absence (he would have to hire a babysitter). Also, there is more uncertainty associated with a longer hunt. The forager has less information in a Bayesian sense about the outcome. And from a statistical perspective, one failed giraffe hunt is devastating, while the consequences of a failed rabbit hunt are comparatively minor.

Experimental studies suggest that decision-makers evaluate time and energy information separately, rather than together as a rate (Reboreda and Kacelnik 1991; Bateson and Kacelnik 1995). Captive starlings were offered a series of choices that varied in reward amount and reward delay. The average rate was held constant for all choices, so that if the birds evaluate options in terms of energy-per-time rates, they should be indifferent among all options. Interestingly, subjects indicated little preference (positive or negative) for variability in amount. This supports the use of average rate maximization in stochastic foraging models (for example, Stephens and Charnov 1982; Winterhalder 1986; Weissburg 1991). But the birds preferentially chose options with variable delays. Time, manifested in delay to reward, affects perception of value in a subjective manner that is not captured by rate maximization alone.

Foraging models have provided a useful starting point for explaining the inclusion of low-ranking plants into an ecological relationship favorable to domestication (Winterhalder and Goland 1997) and the adoption of cultivated foods into a foraging economy (Gremillion 1996a). Because agriculture involves lengthy delays from when cultivation decisions are made to when fields are harvested, agricultural options should be discounted in value when compared with the immediate rewards of foraging. The

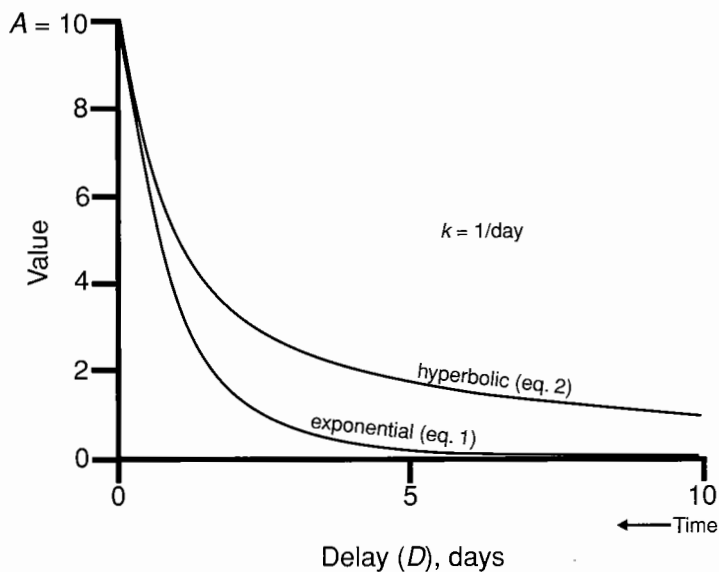


FIGURE 2.1. Demonstration of the exponential and hyperbolic discounting functions, using arbitrary values. Note that time passes from right to left, as delay to reward counts down to zero at the origin.

simplest way to model this is to modify the value of the delayed option by a discount rate.

FUTURE DISCOUNTING: A REVIEW

DESCRIPTIVE MODELS

Behavioral researchers have long been interested in the effect of time on value, a phenomenon known alternatively as intertemporal choice (Loewenstein and Prelec 1992), time preference (Rogers 1994; Becker and Mulligan 1997), temporal discounting (Green et al. 1994a; Myerson and Green 1995; Green and Myerson 1996), patience (Godoy et al. 2004), or impulsiveness/self control (Green et al. 1981; Logue et al. 1987, 1988). Economists have, since the eighteenth century, discussed time in the context of savings behavior and differences in individual and national wealth (Böhm-Bawerk 1970 [1889]; Fisher 1930; Loewenstein 1992; Frederick et al. 2002). Psychologists have empirically explored impulse control using choice experiments with animal and human subjects (Green et al. 1981; Mazur 1984, 1987; Rachlin et al. 1991; Green et al. 1994b; Kirby and Herrnstein 1995; Myerson and Green 1995; Green and Myerson 1996). Anthropologists have long recognized the applicability of intertemporal choice to such topics as

life history tradeoffs (Hill 1993, 81–82), reciprocal exchanges (Hawkes 1992, 285–287), and resource conservation and inheritance (Rogers 1991, 1994; Alvard and Kuznar 2001), but so far there has only been one major ethnographic investigation of time preference (Godoy et al. 2001, 2004; Kirby et al. 2002).

Following Samuelson (1937), most descriptive models of intertemporal choice have been discounted utility models. Imagine a decision maker faced with the choice between a smaller reward available now versus a larger reward available after a delay. The decision maker may prefer the immediate reward, implying that the value of the delayed option is subjectively discounted. Despite being of greater quantity, the delayed reward offers less utility in the present than the immediate option due to disutility associated with waiting. As time passes the delayed option is perceived to have increasing value.

Samuelson (1937) described discounted utility with an exponential function:

$$V = Ae^{-kD} \quad (1)$$

Where V is the discounted subjective value at time D (the D stands for delay, so $D = 0$ on

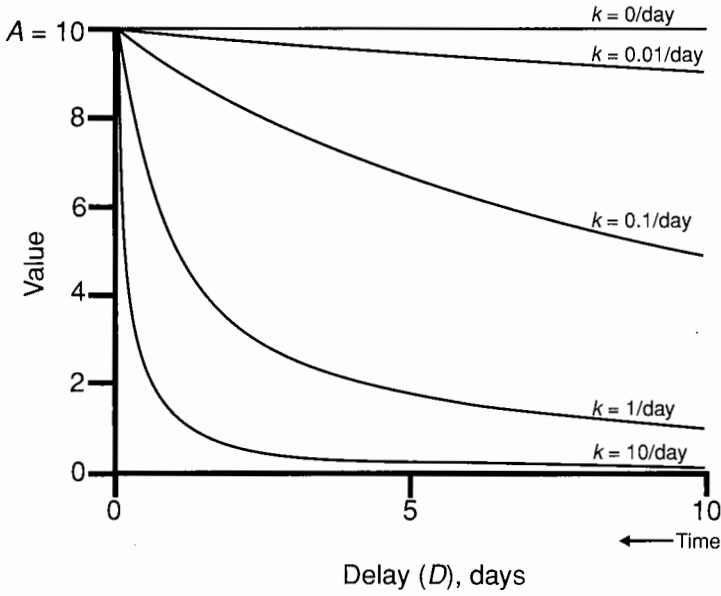


FIGURE 2.2. Hyperbolic discounting for a range of discount rates (k).

harvest day); A is the final reward value when $D = 0$; e is the exponential constant 2.71828; and k is the discount rate. While the exponential discounting function has enjoyed considerable use among development economists (for example, Pender 1996), many economists and psychologist alike prefer a hyperbolic model such as that offered by Mazur (1984, 1987):

$$V = A/(1 + kD) \quad (2)$$

Both the exponential and hyperbolic functions are graphed in Figure 2.1 using arbitrary values: a reward of 10 units available after 10 days discounted at $k = 1/\text{day}$.

The k variable is a measure of preference; it determines the extent to which a future reward is discounted. Figure 2.2 demonstrates hyperbolic discounting for a range of k values. A k value of 0/day indicates no discounting at all; the reward has the same value (equal to A) regardless of delay. As k increases, future rewards have decreasing value from a present perspective.

The hyperbolic model has several demonstrated advantages over its exponential counterpart. First, the exponential model assumes a constant rate of temporal discounting; a deci-

sion-maker devalues a future harvest at the same rate 50 days before harvest as he does one day before harvest. The hyperbolic function simulates increasing confidence in a delayed reward as harvest time draws nearer (Green and Myerson 1996, 497; Frederick et al. 2002, 366).

Second, the hyperbolic model accounts for a well-documented anomaly in intertemporal choice behavior: preference switching (Figure 2.3a). Imagine a decision maker faced with the choice between two delayed options, a smaller reward available sooner versus a larger reward available later. If the delay to both rewards is sufficiently long, the decision maker is likely to ignore time altogether and base judgment on quantity alone, thus preferring the larger, later option. But as time elapses, the smaller, sooner reward increases in value until it surpasses the alternative and preference switches (Green et al. 1981; Green et al. 1994b; Kirby and Herrnstein 1995).

Third, when the exponential and hyperbolic models are used in regression analysis to describe responses from choice experiments, the hyperbolic model consistently describes data better, with greater R^2 values (Mazur 1987; Rachlin et al. 1991; Myerson and Green 1995;

Green and Myerson 1996). Mazur (1987) and Rachlin et al. (1991) show that the hyperbolic model can achieve even greater accuracy if the denominator is raised to a power s .

It should be noted, however, that both exponential and hyperbolic models describe data quite adequately ($R^2 > 0.90$), and in the same general accelerating manner. Neither model is derived from explanatory theory. There remains a gulf between these descriptive models and possible explanatory variables. How might environmental, personal, or societal factors influence the rate at which individuals discount the future? What explains individual differences in discounting behavior?

EXPLANATION: WHY DO DECISION-MAKERS DISCOUNT THE FUTURE?

In 1834, economist John Rae, seeking to explain differences in wealth among nations, posited four determinants of ability to accumulate wealth by deferring consumption. The first two promote patience and frugality: (1) the desire to pass resources to future generations, and (2) the capacity for self-restraint. The latter two set limits on future investment: (3) the uncertainty and hazards of life, and (4) the pleasures of immediate gratification (Loewenstein 1992, 6–7; Frederick et al. 2002, 352–353). Recent theories have expounded upon these determinants.

(1). Conserving resources for the benefit of future generations requires limiting benefits in the present generation. Rogers (1991, 1994) has developed a theory of the evolution of time preference based on the intergenerational fitness costs and benefits of conserving resources. An individual may rationally choose to conserve resources if he stands to gain more fitness through the reproduction of his grandchildren than from his own children. An important constraint is the probability that someone other than the conservator's genetic descendants will benefit from the saved resources. If time preferences are at an evolutionary equilibrium, then the rate at which individuals trade off current versus future reproductive benefits will be equal to the rate at which they make intertemporal production and con-

sumption tradeoffs. Demographic data from Utah, Lybia, and Taiwan suggest that the real biological discounting rate is 2% per year, which is similar to the 3% long-term real interest rate for the economy, 1727–1900.

(2). Economists since Bentham and Jevons have theorized capacity for self-restraint with the concept of anticipated value; a decision-maker is able to wait when the pleasures of expectation are greater than pleasures of consumption (Loewenstein 1992, 10; see also Loewenstein 1987). Becker and Mulligan (1997) offer a theory in which anticipated value takes the form of “future oriented capital”: resources spent imagining the future. Imagine you have just found out that you will move to a new city in three months' time. It is tempting to spend your time and other resources imagining the move and all its associated arrangements. The more you plan—research real estate values, investigate schools, etc.—the greater the benefits once the move occurs; but planning occurs at the cost of the work already on your desk. Given a limited budget of resources, people must strategically allocate this capital between present needs and future plans.

Becker and Mulligan assert that time preference is a function of wealth, for the wealthy have more resources to spend on planning. Age is also a significant predictor. Children learn to imagine the future as they grow older, and the elderly make fewer plans during their waning years. Social and cultural institutions affect the value of future-oriented capital by making the future more or less “vivid” (their term). Schooling, good health (and therefore long life expectancy), visits to the elderly, and a belief in an afterlife make the future more vivid and thus worth investing in. The immediate satisfaction of drug use reduces the vividness of future opportunities.

(3). Several authors have noted that there is an implicit risk associated with delayed outcomes (Rachlin et al. 1991; Green and Myerson 1996). Longer delays mean less information about the outcome, as well as greater exposure to hazards that could avert the anticipated outcome. The decision-maker may decide to con-

sume what he assuredly has today rather than to hazard the investment failing in the future. Long-term investments are also higher-stake gambles, more eggs in fewer baskets.

(4). The “pleasures” of immediate gratification may be related to the immediacy of resource requirements. A starving person who needs to consume 1000 kcals within the next hour to avoid death will prefer a one-hour rabbit hunt, while the larger giraffe offers zero effective value. Animal behavior studies suggest that decision-makers may follow simple cognitive “rules of thumb” relative to their energetic needs. Caraco et al. (1980) argue for an “expected energy budget rule” for choices under risk, in which decision-makers choose probabilistic rewards when in energetic deficit. Snyderman (1983) has found evidence for a similar decision rule with delayed rewards. He offered captive pigeons the choice of two feeding options, represented by red or green illuminated keys that blinked asynchronously. Pecking the red key yielded six seconds of grain access after a ten-second delay. Pecking the green key yielded two seconds of grain after the same ten-second delay. Thus it was always more profitable to peck the red key, especially since the delay to the green key’s reward represents an opportunity cost. Pigeons at 95% free-feeding body weight showed a strong preference for the larger reward. Pigeons at 80% free-feeding body weight would peck at any illuminated key without regarding its color. The decision-rule appears to be, when need is dire, take whatever you can get (seek risk, be impulsive).

These explanations are difficult to test comparatively for several reasons. First, they explain different phenomena: Roger’s (1991, 1994) model explains the evolution of our species-wide time preferences, but does not explain interindividual differences in time preference, except to predict that young people will discount the future more than older people. Becker and Mulligan’s (1997) future-oriented capital theory explains individual variation, but it does so without an evolutionary explanation for the benefits of valuing future-oriented capital. Uncertainty and hunger could be

incorporated into Becker and Mulligan’s model, for both reduce the vividness of future plans. However, Becker and Mulligan have, by their own admission, changed the order of causality normally associated with risk and time preferences. Neoclassical game theory assumes that preferences determine behavior (von Neumann and Morgenstern 1944). In Becker and Mulligan’s model, behavior (schooling, beliefs, wealth, etc.) determines time preferences.

Clearly more work is required to evaluate these explanations. I take from this discussion a list of candidate factors for determining an individual’s discount rates: wealth, income, health, age, education, drug use, uncertainty, risk, and hunger. There is mixed support for the effects of many of these factors. Godoy and colleagues (Godoy et al. 2004; Kirby et al. 2002), in their ethnographic study of time preference among Tsimane’ forager-horticulturalists of Bolivia, found that discount rates increase with age and education, while nutritional status, wealth, and moderate drug use have insignificant effects. In rural India, Pender (1996) found that wealthier individuals discount the future at lower rates, which he relates to their differential access to credit and their role as creditors themselves. In studies of Western subjects, Kirby and Herrnstein (1995) found a clear trend of decreasing discounting with increasing age. Kirby and Marakovic (1996) found a significant difference by sex, a factor not predicted by any of the explanations presented here.

METHOD AND EMPIRICAL RESULTS

Neoclassical economic theory posits that the equivalency of any two dissimilar options can be measured by examining the rate at which an individual is indifferent between bundles (quantities) of both, called the marginal rate of substitution. Fisher (1930), following the theoretic work of Böhm-Bawerk (1970 [1889]), formalized time preference as the marginal rate of substitution between present and future consumption (Loewenstein 1992, 16). Choice experiments reveal time preference by presenting an individual with a series of choices between

immediate and delayed options in which either the quantities or delays are adjusted, until the subject cannot perceive one to be worth more than the other. The hyperbolic model predicts that the indifference values (v_i) are related to delay in a linear fashion, at slope k :

$$v_i = A(1 + kD) \quad (3)$$

Thus, a single indifference value is sufficient to determine an individual's discount rate k .

I have made preliminary attempts to measure Mikea discount rates using two simple choice experiments. The methods, results, and interpretations are presented in detail elsewhere (Tucker in prep; Tucker and Steck in prep), but I summarize them here to illustrate how choice experiments work. The purpose of the first experiment was to test whether there are significant differences in time preferences among Mikea who primarily forage versus those who emphasize cultivation in their diversified portfolios. The reward amounts and delays were scaled to mimic the actual decision whether to forage or farm as closely as possible. Rewards were expressed as 100 kg gunnysacks of maize, which for logistical reasons were hypothetical rewards. The use of hypothetical rewards permitted repeated questions (see methodological discussions in Camerer and Hogarth 1999; Hertwig and Ortmann 2001).

The first question asked the participant to choose between one sack available now versus 12 sacks after six-months. If the participant preferred the one sack now, this indicates that his indifference value is greater than 12 sacks, for it would take some quantity greater than 12 sacks to make a six-month delay worthwhile. The next question is, which do you prefer, one sack now or 24 sacks after six months? If the participant prefers the 24 sacks, then his indifference value is greater than 12 and less than 24. A third question narrows the range. Which is better, one sack now or 18 sacks after six months? A choice of one sack now indicates the participant's indifference value is between 18 and 24 sacks. I record the indifference value as the midpoint of

this range, 21 sacks. A second trial repeated these questions with a delay of one month, and the third trial offered a delay of one year. As is typical in temporal choice experiments, results are expressed as the median k value because median is a more appropriate measure of central tendency than the mean in skewed and truncated distributions. Results suggest a median k value for the population as a whole of 2.00/month ($N = 27$). Median k value for those who primarily forage is 3.90/month, while those who emphasize farming discount at 1.40/month. This difference is statistically significant.

In the second experiment I offered a one-shot choice between a quarter-liter cup of cooking oil available now versus three cups after a delay of several days. This experiment offered real rewards, meaning that I actually gave the participant the cups of oil they chose after the promised delay. Cooking oil served well as a reward currency because it represents food value (cash is often spent on tobacco, which has its own unique utility curve); cooking oil is also easily storable and transportable, and highly desired. To limit potential jealousy related to unequal distribution of rewards, I offered the same choice to all participants in a given village and changed the delay to receive the three-cup option at each village visited. The three-cup option was delayed by two weeks at the first village, one week at the next site, and three days at the final location. A median indifference value was estimated for the population as a whole at 0.3–0.7/day ($N = 49$).

The only long-term ethnographic investigation of time preference among non-Western peoples was conducted by a team of researchers working among Tsimane' forager-horticulturalists of Bolivia (Kirby et al. 2002; Godoy et al. 2004). Their experiment consisted of eight choices between small, immediate rewards and larger delayed rewards, representing eight values for k as calculated by the hyperbolic discounting model. They repeated the experiment with the same 154 participants during five consecutive seasons, both to habituate participants to the procedure (the first season was

considered a training period and the data were not used) and to test for seasonal variation, although individuals' preferences remained remarkably stable over time. They estimate median k values of 0.12/day for cash and 0.14/day for candy (Kirby et al. 2002, 302).

Pender (1996) conducted one of the few temporal choice experiments among peasants, rice cultivators in Andhra Pradesh, India. In his first experiment, he offered 96 participants the choice between eight pairs of options. The first option was an immediate reward of 10 kg rice, while the second was X kg rice after a delay of seven months, where X increased from 9 to 20 kg over the questions. Subsequent experiments used different amounts and delays. Pender calculates a median discount rate of 0.26–1.19/year, although it should be noted that unlike the other studies discussed here, he uses the exponential equation rather than the hyperbolic model.

A MODELER'S GUIDE TO DISCOUNT RATES

USING EMPIRICALLY REVEALED k VALUES

I argue that modelers concerned with subsistence choice should modify the value of delayed rewards by a discount rate. But as Figure 2.3 demonstrates, modelers can basically tell any story they wish about the comparative value of immediate versus delayed rewards depending on the k value that is used. Since archaeologists and other modelers of prehistoric decisions cannot conduct choice experiments with their subjects, this section provides a rough guide to choosing reasonable discount rates, based on two lines of argumentation.

The first line of thought is empirical and comparative, based on the results of the choice experiments described above, and summarized in Table 2.1 (see also Tucker in prep). Modelers may choose reasonable k values in the range of those revealed in previous experiments. The key is that k must be expressed in the proper time units. Notice that the rates reported in the first Mikea experiment are expressed per month, while the

second Mikea experiment and the Tsimane' experiment report rates per day, and Pender's rate is per year. Table 2.1 converts discount rates across a range of time units. This reveals a problem with cross-study comparison: the value of k is highly sensitive to the scale of reward amount and delay length. Discount rates for small rewards over small time units predict unreasonably high discount rates over larger time units, and vice-versa, suggesting that decision-makers discount large rewards at lower rates than small rewards (Kirby and Marakovic 1996). The best way to counteract this is to choose k values from experiments with similarly scaled rewards and delays.

For example, if we wanted to compare results from different experiments, it would be inappropriate to compare the Tsimane' results with the Indian peasant results, even when k is converted into the same time units. Because the second Mikea experiment and the Tsimane' experiment use small rewards with delays spanning several days, we can justifiably compare them and conclude that both populations of forager-horticulturalists discount at similar rates.

EXOGENOUS FACTORS

The second line of argumentation is a theoretical speculation about the probable influence of our list of candidate determinants on an individual's discount rates for a particular activity. I divide these candidate determinants into categories: exogenous factors relate to the activity itself, while endogenous factors pertain to the decision-making individual.

The two exogenous factors are the rate and manner in which objective value appreciates over time; and production risk, or the probability that an activity will fail before the rewards are received. Generally speaking, faster accumulation of marginal value, low risk, and the ability to harvest early if necessary should decrease discount rates, while a contrary set of conditions should increase discount rates.

The longer the herder defers slaughtering his animals, the more their value appreciates through growth and reproduction (although disease, theft, etc. could lead to a negative

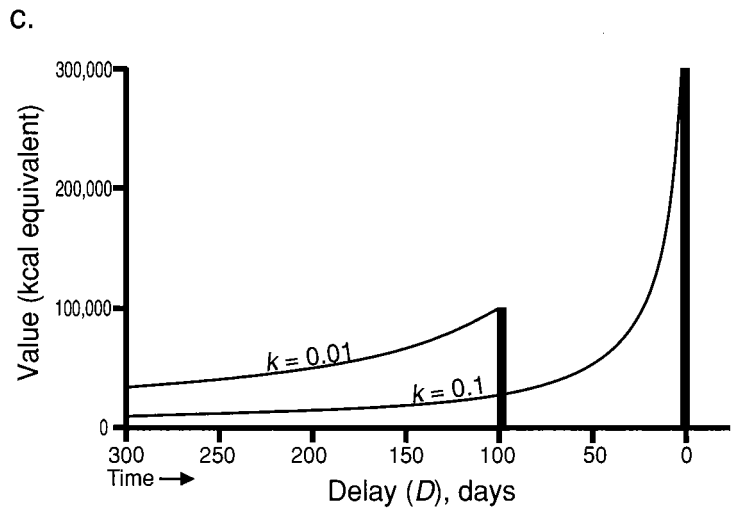
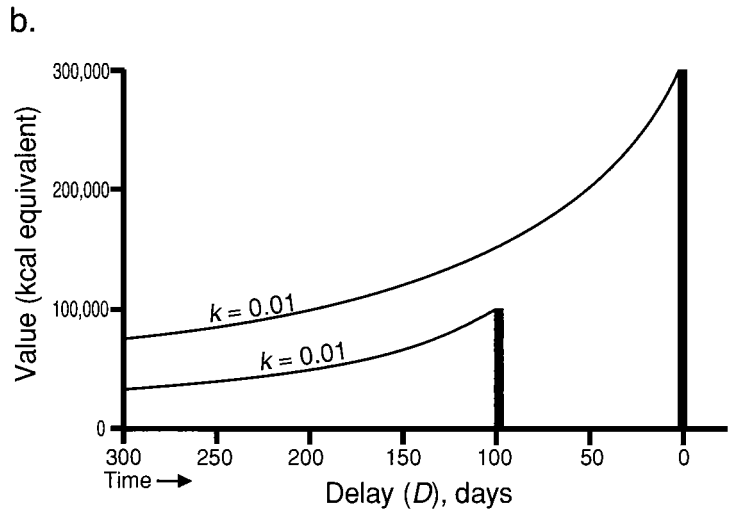
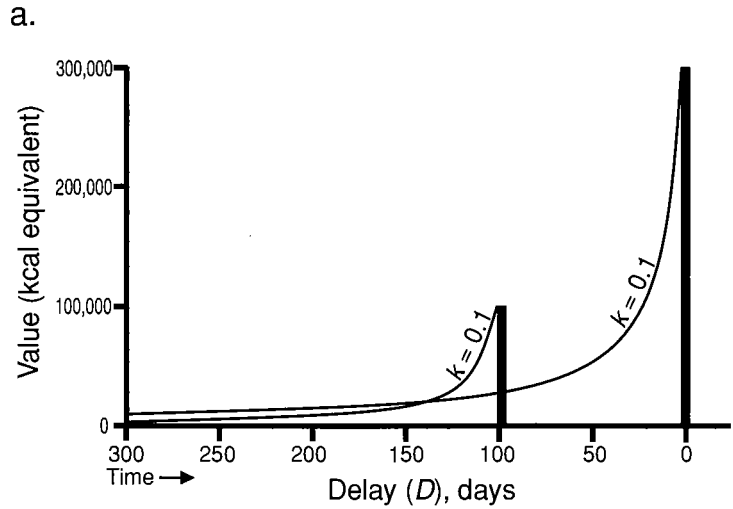


FIGURE 2.3. Given a choice between a smaller reward after a shorter delay versus a larger reward after a longer delay, a subject's preference depends entirely on discount rates. Figure 2.3a demonstrates "preference switching," at long delay, the larger reward is preferred, but preferences switches to the smaller reward when it becomes more immediately available. In Figure 2.3b, the larger reward is always preferred. In 2.3c, the smaller reward is always preferred. Intertemporal choice models depend entirely on which discount rate values are used.

TABLE 2.1

Discount Rates Revealed in Experiments with Nonwestern Peoples, Converted Across Time Units (Original Units in Bold)

POPULATION AND STUDY	N	REWARD CURRENCY	<i>k</i> /DAY	<i>k</i> /MONTH	<i>k</i> /YEAR
Mikea (Tucker in prep)	49	Real cups of cooking oil	0.30–0.70	9.13–21.32	109.65–255.85
Mikea (Tucker & Steck in prep)		Hypothetical 100 kg sacks of maize			
– all	27		0.07	2.00	24.00
– primarily foragers	10		0.13	3.90	46.80
– primarily farmers	17		0.05	1.40	16.80
Tsimané, Bolivié (Kirby et al. 2002)	154	Cash	0.12	3.66	43.86
		Candy	0.14	4.26	51.17
Indian peasants (Pender 1996)	96	Real kg rice	0.00	0.10	1.19

interest rate). Animals with rapid growth and reproduction such as sheep and goats should be discounted less than slow reproducers such as cattle and camels. But, as Mace and Houston model (1989), smallstock may reproduce rapidly, but they are more likely to die during droughts than are slow-reproducing cattle and camels. This risk should increase the discount rate for small stock.

With regards to plant foods, there may be a significant difference between plants with edible leaves, stems, roots, and tubers versus plants with edible fruit, seeds, and flowers. The former provide a small amount of objective value shortly after germination, followed by a long period of time during which they gradually increase in size or number. Eventually, appreciation diminishes asymptotically as leaves reach a maximum size and stems, roots, and tubers become increasingly fibrous. With these plants the decision-maker always has the option of early harvest (“cashing-in”), so they should be discounted less than the second category. The second category, plants with edible fruit, seeds, and flowers, provide no objective food value until several months after planting and germination, at which point they must be promptly harvested or the food value will degrade. The long delay to food value coupled with the shorter harvesting

window suggests that these rewards should be discounted more highly. To the degree that risk-minimizing strategies such as sharing (Winterhalder 1986, 1990; Hames 1990) and field scattering (Winterhalder 1990; Goland 1993a, b) can effectively reduce the variance, they may also decrease *k* accordingly.

As an example, consider the effect of exogenous variables on the discounted value of the two most significant cultivated plants for Mikea: maize and manioc. A maize field offers zero objective food value until very late in the delay. The earliest a farmer can “cash in” on his investment is to consume immature green corn, which is mealy, difficult to digest, and 20% less calorie-rich than mature maize grains (Morrison 1954, 569). O’Shea (1989, 61) has suggested that green corn consumption, which was common among pre-contact Native Americans, was a strategy to minimize risk. Farmers accept a 20% loss to offset the probability of crop loss before the maize is properly ripened. Mikea do not harvest green corn, but they do harvest a portion of their crop to eat as corn-on-the-cob.

In maize hatsake, risk is greatest shortly after planting. If rainfall is insufficient, the seed will fail to germinate. Mikea commonly say that the best strategy is to plant the day *before* the first

heavy rainfall (a strategy called *katray* or *soima*), but this is obviously difficult to predict. It is not uncommon for hatsake farmers to replant a field a second or third time if the previous planting failed to result in germination. Once the maize has sprouted, risk increases steadily as the plant becomes a larger and more tempting target for grasshopper swarms. Because hatsake are not guarded or enclosed, mature maize stalks are frequently lost to livestock and thieves. Stories of farmers losing entire crops a day or two before harvest are common. Because maize is a long-term investment that yields little food value until the end of the delay, and because the field is likely to fail up until the last moment before harvest, hatsake are likely to be highly discounted compared to other activities.

Manioc differs significantly from maize in that the plants have objective food value a month or two after planting, in the form of growing tubers (as well as leaves). The farmer is free to harvest the crop at any time, but the longer she defers harvest, the larger and more valuable the tubers become. Manioc tubers grow fastest during the rainy season, but this is also the time of greatest risk of crop loss due to rot and flooding. Mikea and their neighbors typically practice three strategies. The first strategy is to plant and harvest manioc continually. They harvest what they need to eat each day, then replant the stems immediately to harvest them again four months later. The tubers tend to be small, bitter, and require high processing labor per unit food, but manioc grown in this fashion resembles an immediate-return investment. This method is mostly practiced by Mikea in lakebed gardens. The most common strategy among Masikoro is to let manioc grow for 12 months before harvest. The field is planted before the first rains (November or December) to take advantage of the rapid tuber growth in the wet soil. It is then harvested and replanted just before the next rainy season, thus maximizing maturation time while obviating the risk of a second rainy season. A third strategy, called *aritse*, requires leaving manioc to mature for 16 to 24 months, thus enduring two rainy seasons. Because manioc can potentially be harvested at any

time, future manioc harvests should be discounted less than maize. A farmer can often preemptively harvest ahead of floodwaters or thieving neighbors. However, delays to large harvests are typically much longer than for maize.

ENDOGENOUS FACTORS

Endogenous factors include age, sex, education, drug use, health, wealth, income, and hunger. Generally speaking, greater age (at least until advanced years), education, wealth, health, and income should lower discounting rates, while greater use of drugs and hunger should increase discounting. Archaeologists may not be able to distinguish individual age and sex differences, and drug abuse and formal education may have less meaning in prehistoric contexts. I suggest that immediate food supply may be the endogenous factor with the greatest tractability and causal salience. Individuals with low health status, wealth, or income may discount the future because they are hungry. As hunger changes over relatively short spans of time, discount rates may also experience fluctuation.

FUTURE DISCOUNTING AND THE MIKEA ECONOMY

A FORMAL MODEL OF FORAGING AND FARMING

Here I demonstrate the application of future discounting to subsistence choice by providing a possible explanation for the persistence of the mixed foraging-horticulture strategy among Mikea and other populations occupying Bruce Smith's middle ground.

I propose that Mikea cultivate because the potential rewards from agriculture are very high compared with daily foraging gains, even when the value of the future harvest is discounted in the present. But because agricultural labor yields no immediate food value, every day spent farming increases the households' hunger. Increasing hunger, as an important endogenous factor, increases the rate at which agricultural rewards are discounted, until farming is valued less than foraging, leading to a switch in preference to

immediate gratification. Foraging solves immediate food needs, reducing the discount rate again. But time spent foraging robs anticipated labor from agriculture, thus reducing the expected value of future harvests. The result is a downward spiral of expectations. Despite a clear motivation to farm, and although more labor investment would provide a greater reward, immediate needs cyclically limit the household's capacity to invest "future oriented capital."

I formalize this explanation as a simple dynamic model below, then discuss its basic behavior using values from Mikea research (which I have operationalized in a spreadsheet). Like all simple models, this one requires a certain relaxation of "real world" accuracy in favor of increased generality. Modelers commonly make this tradeoff when offering a new hypothetical set of interactions; the number of interacting variables are kept to a minimum so that the effect of each can be easily understood (Starfield and Bleloch 1986). The important simplifying assumptions of this model are that every day must be spent either foraging or farming (no resting or engaging in other activities). A day spent doing either activity provides a constant gain, either in the present (foraging) or in the future (farming).

The first element of the model is the anticipated outcome of agriculture. The household imagines that working a field will yield a quantity \hat{A} when $D = 0$ (time is measured as delay D , a countdown to harvest). The variable A_D is a cumulative measure of value invested in the field up to delay D . A_D starts at zero and increases by a each day the household spends doing agricultural labor. Meanwhile, if important agricultural labor is neglected, expectations are lowered and \hat{A} decreases. Eventually, \hat{A} (the expectation) and A_D (the reality) will converge. The value of agriculture on any given day before this convergence is the discounted value of \hat{A} .

$$\hat{A}/(1 + kD) \quad (4a)$$

After the convergence, the decision to spend the day farming means that more labor will be

invested into the field than was originally anticipated. The value of farming becomes:

$$(\hat{A} + a)/(1 + kD) \quad (4b)$$

In contrast, a day spent foraging will yield a certain immediate gain of food value g , which is not discounted. The gains from foraging are in addition to the value the household has confidently invested in its field up to this point. A day spent foraging has the value:

$$g + [A_D/(1 + kD)] \quad (5)$$

If (4) is greater than (5), the household will spend the day working in the fields, contributing $+a$ to A_D (as well as to \hat{A} after the convergence). But spending the day cultivating also carries an opportunity cost. By choosing not to forage, the household has failed to gain any more immediate food value. The increased threat of hunger contributes a penalty h to the discount rate k .

If (5) is greater than (4), the household will spend the day foraging. Because a day spent foraging produces immediate food value, hunger is satisfied, and k is reduced by h . For current purposes I set the condition that k can never diminish below its initial value. Before the convergence of \hat{A} and A_D , there is an opportunity cost to foraging. Because the anticipated value of the field is based on an implicit prediction of labor investment, a day spent foraging cannot be used to achieve \hat{A} . Thus, \hat{A} is reduced by a .

If h is sufficiently large, cyclical changes in k , \hat{A} , and A_D cause preference switches between foraging and farming producing the result that households spend less labor on agriculture than they originally anticipate. The household must forage to meet immediate needs, limiting their capacity to invest in future harvests.

WILD OVY TUBERS VERSUS MAIZE

To illustrate this model, let us consider the hypothetical case of a Mikea household of six individuals (two children, two adolescents, and two adults of both sexes) who plant a three-hectare

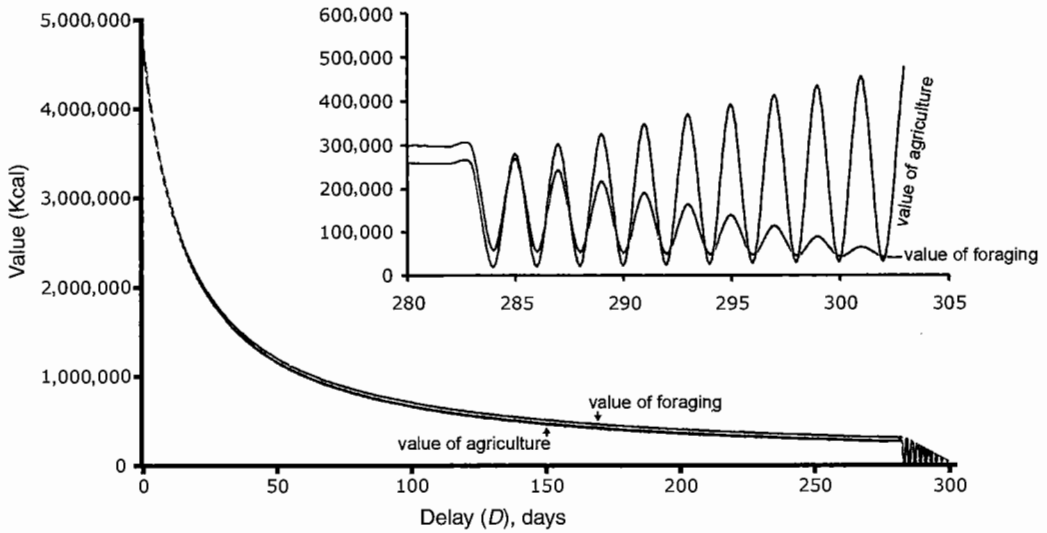


FIGURE 2.4. Results of dynamic simulation of foraging/framing preference model using reasonable values from Mikea research (see text).

hatsake. Consistent with time allocation data, all six household members forage while only the adolescents and adults contribute agricultural labor (Tucker and Young 2005). The simulation begins in the month of July, which is typically the time of year when Mikea decide whether and to what extent they should cultivate maize in the coming year; D begins 303 days before the maize harvest. The household imagines a three-hectare cleared hatsake. The anticipated value of this field is 930 kg/ha times 3640 kcal/kg times three hectares: \hat{A} begins at approximately 10,000,000 kcal. The daily gain from foraging is provided by mean age and sex-specific net acquisition rates reported in Tucker and Young (2005) times the average duration of tuber foraging trip, 300 minutes; $g = 39,400$ kcal/day spent foraging.

I assume that Mikea discount future agricultural rewards at the average rates revealed experimentally. Because this simulation involves large rewards and long-scale delays, the appropriate discount rates are those revealed in the sacks of maize experiment: $k = 2.00/\text{month}$ (Tucker and Steck in prep). I convert this into the daily rate of $k = 0.066/\text{day}$.

To begin with, let us assume that a day's agricultural labor contributes $a = 500,000$ kcals to

the final harvest. At this rate, the household will have to work 20.3 days to achieve an \hat{A} of 10,000,000 kcals. Let us further assume the hunger penalty is $0.5k$ (0.033/day). The results of this simulation are presented in Figure 2.4. The inset demonstrates oscillating values before the convergence point. The convergence point occurs on day 19. Up to this point, the household spends alternating days foraging and farming. They only contribute half the labor (ten days) to farming that they originally anticipated, and the final harvest is 5,000,000 kcal.

What happens if the discount rate is increased? Recall that preliminary experiments revealed that Mikea who primarily forage discount future sacks of maize at 3.9/month (0.13/day). Changing k by this magnitude has little effect on the model's predictions, except that one day fewer is spent farming, and the final reward is 4,500,000 kcal. At $k = 0.4/\text{day}$, only six of the anticipated 20 days of agricultural labor are invested, producing a final reward of only 3,000,000 kcal.

What happens if the discount rate is decreased? As k approaches zero, more days are spent farming. If we use the midpoint of Pender's (1996) value for Indian peasants, converted to days (0.0016/day), the household

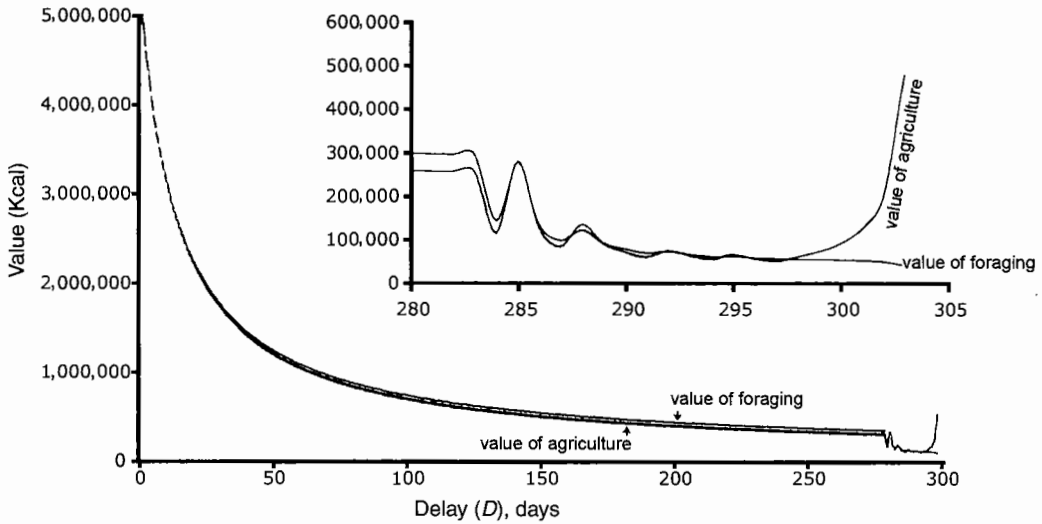


FIGURE 2.5. Results of dynamic simulation of foraging/farming preference model when the hunger penalty is reduced by an order of magnitude (see text).

accomplishes 13 days of agricultural labor. Because h is a fraction of k , the small h means value does not oscillate, and the 13 days are spent consecutively. The final harvest is 6,500,000 kcal. If $k = 0$, there is no discounting, and every day is spent farming.

What happens if the hunger penalty is decreased? Resetting k at 0.066/day, h is then reduced by an order of magnitude (0.0033/day). Results are displayed in Figure 2.5. The number of days spent farming remains at ten, but preference switches between foraging and farming at a different frequency. Six days of farming occur before the household is hungry enough to be forced into foraging; two days of foraging are required before the household can farm again. An artifact of the simplifying assumptions of this model is that increasing h beyond $0.5k$ has no effect on the model, for no matter how grave the effect of hunger after a day spent farming, a day of foraging resets k to its initial value.

ELABORATIONS

The realism of this model is constrained by its simplifying assumptions. To better approach "real life," this model could be modified in a number of ways. First, a household is unlikely to spend every day working. A day of rest would

still have subsistence value, for the household can enjoy the anticipated rewards of the labor they have already invested in their maturing fields. The value of a day of rest would be simply the discounted value of A_D . In order for rest to ever be worth more than foraging, the model would have to track the energetic costs of days spent farming, foraging, and resting. Resting is a cheaper way to spend the day. Alternatively, need for rest could affect k in a similar way as hunger.

Another limiting assumption is that any day spent foraging will produce the same amount of food, and any day spent farming will contribute equal marginal benefit to the eventual harvest. The variables g and a should really be nonlinear functions of D . The benefits of foraging and farming labor change over the course of time. Among Mikea, tuber foraging efficiency decreases over the dry season, as travel times to unharvested patches increases. Agricultural labor is of course highly seasonal, with regards to labor tasks and marginal benefits, and generally exhibits diminishing marginal returns to labor.

The model's insensitivity to increasing the value of the hunger penalty h suggests that this is probably not a constant value. It may take more than one day to accrue and pay off hunger

debts. Future research should explore the affect of hunger and other immediate needs on time preference.

IMPLICATIONS FOR THE EVOLUTION OF INTENSIVE CULTIVATION

If immediate food needs doom would-be cultivators to chronic under-investment of labor, how does intensive agriculture evolve? The model suggests two possible answers. First, exogenous factors could affect reward amounts and discount rates. If agriculture becomes more profitable or less risky (given the same level of labor investment), or if foraging becomes less profitable or more risky, the household will increase its allocation of labor to agriculture. This prediction is consistent with Price and Gebauer's (1995b) assertion that agriculture is adopted most readily in areas of resource abundance, in contrast to the traditional view that agriculture is a desperate invention to deal with food scarcity (Childe 1965; Cohen 1977). Second, endogenous factors could affect an individual's time preferences. Alternative sources for immediate food needs could eliminate the effects of hunger altogether.

Neighbors to Mikea are Masikoro intensive cultivators. Savanna farmers have access to better soils and more dependable and predictable rainfall, as well as surface water sources that can be used for irrigation. Cheap pesticides and herbicides have been made available in recent years. Masikoro farmers experience higher rewards with less risk, and so discount future harvests to a lesser degree.

Masikoro farmers have at least two sources to meet their immediate food needs that detract little from their farming labor: storage, and the market economy. Stored agricultural foodstuffs provide a constant source of immediate food value. Farmers subsist off these stores while waiting for the next harvest. They can also sell their surplus, or their surplus labor, to earn cash. Cash retains its value over time, and can be used to obtain food whenever the household is in need. Masikoro farmers use their cash to purchase foraged products from the Mikea,

thus gaining the same immediate gratification that Mikea gain from foraging.

Storage of large surpluses would be an effective way to limit preference switches between immediate and delayed rewards, favoring investment of future-oriented capital. Caches of seeds found in Archaic-period rockshelter sites in Kentucky and Arkansas suggest that storage predates intensive cultivation by millennia (Gremillion 1997b; Fritz 1997). These stores probably represent buffers of predictable, seasonal food stress. How could enough food be stored to support a household during the proceeding agricultural cycle? Surplus on this order of magnitude can only be produced by intensifying labor input, and intensification is impossible without stored foods from the previous year.

One possibility has been suggested by Flannery's (1986a) study of the emergence of agriculture at Guila Naquitz in Oaxaca, Mexico. In a computer simulation of foraging and incipient cultivation, Reynolds (1986) predicted that people would be more likely to practice experimental food producing strategies in wet years, and conservative strategies during dry years. Flannery (1986b, 503) suggests that adaptation moves fastest when the two states alternate; new strategies are introduced in wet years and then rigorously selected in dry years. This may be the case here. Surplus for storage is produced during an extremely good year, and then in the bad year that follows, large stores lead to more intensive labor investment.

Trade represents another source of immediate food value. Foragers and farmers may develop symbiotic relationships. Foragers assure immediate food needs so that farmers can invest intensively in higher-yielding agricultural pursuits. Farmers provide the majority of calories in the diet. The classic example is the relationship between the foraging Mbuti and Efe and their farming neighbors in the Congolese rainforest (Turnbull 1965). Relationships of this sort may have occurred at the origins of settled agriculture in the Levant, where foragers and farmers co-existed (Bar-Yosef and Meadow 1995). The need to exchange immediate and delayed-return

foods may help to explain the origins of the market economy.

CONCLUSIONS

This chapter has pursued dual goals: first, to review the future discounting literature and establish its applicability and appropriateness to studies of human subsistence decision-making, and second, to illustrate the potential of future discounting models by offering an explanation for the persistence of a mixed foraging-horticultural strategy among Mikea of Madagascar, and by ethnoarchaeological extension, to other populations in the middle ground between foraging and intensive cultivation. The main conclusions are as follows.³

1. The average rate maximization assumption of foraging theory is inappropriate when modeling choice among options with dissimilar delays to reward, such as the choice between foraging and farming.
2. Descriptive models of the effects of waiting time on value have usually taken the form of discounted utility models. While there are certain reasons for preferring the hyperbolic model, neither is derived from theory nor parameterized in terms of exogenous or endogenous factors.
3. Possible explanations for why people discount the future include the value of intergenerational inheritance, the value of anticipation, the risk and uncertainty of delayed outcomes, and the priority of immediate needs. Future research is required to better evaluate these theories.
4. When using empirically revealed discount rates in subsistence models, it is important to use rates from experiments with similarly scaled rewards and delays. Time preference is sensitive to scalar issues, so that preferences for small rewards over short delays may not adequately predict preferences for large rewards after long delays.
5. While a modeler interested in prehistoric decisions cannot conduct choice experiments, discount rates may vary predictably according to certain exogenous and endogenous factors, such as the rate objective value appreciates, risk, and immediate food supply.
6. One explanation for why many subsistence populations practice a mix of foraging and low-investment horticulture is that farming provides higher rewards even when discounted, but investment in future profits is limited by immediate needs.
7. A simple model demonstrates cyclical switches in preference between foraging and farming labor. The value of agriculture on a given day is the discounted value of the anticipated harvest; this expectation diminishes when agricultural labor is neglected. The value of foraging is a nondiscounted constant, added to the discounted value of labor invested in the field up to that point, which increases with every day spent farming. The discount rate oscillates as farming increases hunger without yielding immediately-available food.
8. This model predicts agricultural intensification when harvests increase in size or decrease in risk, consistent with Price and Gebauer's (1995b) assertion that agriculture is adopted under conditions of food abundance. Labor may also be intensified if immediate food needs are met somehow other than foraging (or another work activity), such as by storage or trade.

NOTES

1. I calculate the net acquisition rate for an uncleared hatsake as follows. Focal follow data suggest planting costs of 11 hrs/ha at 4 kcal/min. A survey of 16 fields in 1998–1999 (including fields with total crop loss) revealed a mean yield of 500 kg dry grain/ha. According to Wu Leung (1968), 1 kg maize = 3640 kcal. The gross gain is thus $(500 \text{ kg} * 3640 \text{ kcal/kg}) = 1,820,000 \text{ kcal/ha}$. Divided by 11 labor hrs/ha = 165,455 kcal/hr. Minus labor costs of 240 kcal/hr = 165,215 kcal/hr.

2. I calculate the net acquisition rate for weeded hat-sake in the same manner. Focal follow data estimate clearing costs of 24.7 hrs/ha at 5.8 kcal/min, and a survey of 141 fields including those with total crop loss revealed a mean yield of 910 kg/ha. The gross gain is $910 \text{ kg} * 3640 \text{ kcal/kg} = 3,312,400 \text{ kcal/ha}$, divided by 35.7 labor hrs/ha = 92,784 kcal/hr; minus labor costs of 315 kcal/hr = 92,469 kcal/hr.
3. Acknowledgments. Many of the ideas in this paper evolved during conversations with Bruce Winterhalder and Mitch Renkow. Bruce the ecologist encouraged me to think about how objective value changes through time, while Mitch the

economist urged me to consider the subjective value of deferring gratification. Insightful comments and encouragement were also provided by Doug Kennett, Daniel Steck, Robert Kelly, Kris Gremillion, Alyson Young, Richard Yerkes, Ivy Pike, Christopher Rodning, Amber VanDerwarker, Gregory Wilson, and James Yount. Fieldwork in Madagascar was funded by a Fulbright grant and a National Science Foundation Dissertation Improvement Grant. Fieldwork was facilitated by the hard work and cooperation of Tsiazonera, Jaovola Tombo, Tsimitamby, Gervais (Veve) Tantely, and our friends in the Mikea Forest.