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Model building, model testing, and the spread of agriculture to the Tibetan Plateau

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ABSTRACT

Recent archeological evidence has revealed that a major transition in subsistence regimes took place around the second millennium BC. This paper argues that in order for archeologists to understand transitions in subsistence regimes in the past, it is necessary to develop models capable of outlining our frames of reference. It summarizes how ecological niche models (ENM) have contributed to our understanding of the spread of agriculture to the Plateau and situates ENM within the two current paradigms used for understanding subsistence change in archeological research (Optimal Foraging Theory and Niche Construction Theory) and argues that recent advances in computing and in spatial modeling should be employed by researchers seeking to make testable hypothesis about subsistence change on the Tibetan Plateau.

1. Introduction

A steadily growing volume of plant remains recovered from archeological sites on the Tibetan Plateau has revealed that a major transition in subsistence regimes took place around the second millennium BC. However, it is becoming increasingly apparent that relying on archaeobotanical data alone cannot explain the reasons why this transition took place when and how it did. Climate change, population movement and social reasons have all been implicated in explanatory frameworks for this transition, but only vague correlations have been noted and there have been few attempts to model how exactly these factors contributed to changes in subsistence patterns in this region.

Employing models that use a more detailed understanding of plant growth patterns is necessary for our understanding of transformations in subsistence regimes on the Tibetan Plateau. This article summarizes how recently published ecological niche models have contributed to our understanding of the spread of agriculture to this region. This article situates ecological niche modeling as providing a useful springboard for two paradigms currently used for understanding subsistence change in archeological research (Optimal Foraging Theory and Niche Construction Theory) and argues that recent advances in computing and in spatial modeling should be employed by researchers seeking to make testable hypothesis about subsistence change on the Tibetan Plateau. In particular, these models have revealed the mechanisms underlying the abandonment of millet agriculture on the margins of the Tibetan Plateau during the second millennium BC. In contrast to earlier scenarios for the spread of agriculture to the region, that painted millets as short season crops that were ideally adapted to high altitude and high latitude Eurasia (Jones et al., 2011; Liu and Jones, 2014), these models reveal that many of these assumptions relied on a misunderstanding of these crops phenological characteristics: millets were in fact, mal-adapted to the cooler temperatures that characterized the end of the climatic optimum. Other researchers have highlighted possible reasons underlying the delay behind the subsequent uptake of wheat and barley. Modeling rejects the assumption that the longer growing season of these crops is associated with an inability to occupy areas of higher altitude and latitude Eurasia. It demonstrated that length of the growing season is not an accurate measure of a crop's ability to survive in areas of higher altitude and latitude, but rather that growing degree days and frost tolerance were of prime importance in allowing wheat and barley to become the crops that eventually took became important on the Tibetan Plateau.

2. Ecological niche models and outlining frames of reference for subsistence change

Our understanding of transitions to agriculture in China has markedly improved introduction of systematic archaeobotany to Chinese archeology e.g. (Bettinger et al., 2010a; Fuller et al., 2007, 2009; Liu et al., 2007). Most efforts have been focused on understanding when, where and what type of plants were first domesticated. As these centers of origin have become better understood, we are able to shift our focus to documenting how an agricultural lifestyle spread outside these

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centers, to become the dominant lifestyle across East Asia. While there have been some attempts to discuss these transitions in terms of broader anthropological theory (Bettinger et al., 2010a; Hayden, 2011), I argue that our understanding of agricultural transitions in East Asia has suffered from a lack of explicit model building aimed at understanding the types of constraints faced by early agriculturalists.

Around the world, there have been recent calls to re-integrate model building into explanatory frameworks for agricultural origins (Gremillion et al., 2014). I argue, however, that few of the models currently employed by archeologists have been capable of correctly outlining basic conditions that affect the interactions between plants and humans: the biology of the plants themselves and how these respond to the biotic and abiotic variables that determine their patterns of growth. I discuss how, in the case of the Tibetan Plateau, the application of models that clearly outline these conditions have contributed to our understanding of change in human subsistence regimes.

Two key models for human behavior have been applied to examining changes in subsistence regimes: Optimal Foraging Theory (OFT) and Niche Construction Theory (NCT). OFT and NCT frameworks differ in several regards. In OFT, organisms (such as humans) modify their resource base according to the availability of low ranked and high ranked resources across the environment. In NCT, on the other hand, organisms both respond to and modify their surroundings, shaping their own niches (Lewontin, 1983; Odling-Smee et al., 2003; Smith, 2015). I argue that both OFT and NCT are important models for human behavior that can provide key insights about how humans transitioned to agriculture and made changes within agricultural regimes. Recent discussions have noted that for both NCT and for OFT, a major impediment to our use of these models for human behavior has been an inability to make accurate estimates of past resource distribution and density (see Gremillion et al., 2014; Smith, 2015; Zeder, 2012).

OFT's primary applications have been to describe patterns among contemporary foragers where it is easy to gain data on the distribution, returns and processing costs (Kelly, 1995). In archeological research, we are faced with an additional challenge. We have to first be able to correctly identify what the environment was like and what returns were on the crops that were grown and wild foods that were harvested.

I first explain why such estimates are important in the case of a well-constructed diet breadth model. Diet breadth models (also known as prey choice models) aim to predict whether a forager should take a resource if they encounter it. This model assumes that resources are distributed in a homogenous manner across the landscape. When a forager encounters a resource, he/she will either decide to take it based on a knowledge of its quality, resource density (search costs), and handling costs or will move elsewhere to find something better. Diet breadth models divide the time spent acquiring the resource into two different periods:

1.) search time (or encounter rates) and
2.) handling time.

Search time accounts for the time it takes to locate the resource, and handling time accounts for the time it takes to process the resource once located. For each resource, the handling and search cost is described and ranked in terms of its return rate (Kelly, 1995:78). The return rate is the amount of energy gathered per unit of time after encountering a resource. The researcher can adjust for variables such as improvements in technology that reduce search or handling costs, seasonality or resource depression. Within OFT, "patch choice models" have been employed as a way of taking into account the fact that resources are rarely evenly distributed across a landscape, but rather form "patches" that vary according to microclimatic conditions (Charnov and Orians, 1973; Charnov, 1976). Patch choice is thus used to determine which resource patches (as opposed to which resources) should be included in a foray. However, like the diet breadth model they also assume that resources will be encountered at random and in proportion to their frequency. The "Marginal Value Theorem" (Charnov, 1976) predicts that a forager should leave a patch when the returns from the patch diminish to the point that moving to another patch would provide a higher return rate, or when staying in a patch provides a lower return than the average for the overall environment (Stephens and Krebs, 1986). As these models were developed for a given point in time (the ethnographic present), there has been little room in these models to develop a framework whereby plant density fluctuates over time (although for animals the human effects of predation on a population have been modeled (Stiner et al., 2000).

In many applications of a DBM, the model employed is one that is static in time and space. Plants are referred to as "likely" being present in a region or as being highly productive, however, little explicit modeling of their distribution or productivity has taken place (Gremillion, 1996, 1998, 2004; Piperno and Pearsall, 1998). Smith (2015) and Zeder (2012) have provided an elegant critique of this shortcoming of OFT. In some instances, practitioners of OFT have used modern analogies to gain data on caloric values and processing costs (Barlow, 1997, 2002, 2006; Gremillion, 1996, 1998, 2004; Terrell et al., 2003), but we haven't been able to answer if modern plant productivity is an accurate estimate of past conditions. With a few exceptions (Gremillion, 2002), this has resulted only in non-quantitative ranking of resources (Gremillion, 1996, 2004) and the heuristic application of a diet breadth model.

This has also made it difficult for researchers to apply patch choice models. "Patches" may change considerably due either to environmental factors, rates of human exploitation or intentional or unintentional niche construction. Changes in the patch should be expected to have an important influence on the choice of "prey." In order to understand which resource patches a forager might employ, we need to first have a good understanding of the spatial and temporal distribution of these patches.

In order to construct a DBM or a patch choice model for human behavior, it is first necessary to have a good understanding of the following parameters: a.) First and crucially, could a given plant or animal resource have completed its lifecycle in a given area in the past?; b.)In what density was this resource distributed across the landscape?; c.) How did the density of this resource fluctuate under past climatic conditions?; d.)What was the productivity of a given resource under past conditions?

For instance, the use of a DBM has lead researchers to argue that a switch to lower ranked resources as such grasses would only have taken place in the context of the depression of other resources (Gremillion, 2004). However, to argue that resource depression must have created a switch from highly ranked plant (or animal) A to a lower ranked plant B, we first need to gather accurate information about the limits of each plants (or animals) growth, productivity and model how this may have changed over time.

Whether we employ theoretical frameworks based in optimal foraging theory or niche construction, it is critical that we begin to build our models (and the assumptions that go into them) from the ground up. I argue that this should begin with striving to produce more accurate pictures about the input values for the models themselves: plant and animal distribution and productivity. In order to examine whether or not general models for human behavior hold true, we first need to build models from the ground up that can ask the question: does this model hold true under the particular set of conditions that were present at a given time in a given area of the world. In order to create such a model we must understand how what these conditions actually were. How did changing climates and anthropogenic modification affect the distribution of these resources? The need to construct locally and historically contingent models was a central concern of "New Archeology". Binford recognized the importance of constructing these "frames of reference" and in one of his final works, dedicated substantial effort to building a framework that describes the distribution of animals, plants