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Archaeological markers of agricultural risk management

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ABSTRACT

Managing agricultural risk, or variance in annual production, is a priority for farmers and herders. This article reviews the ethnographic and historical literature on agricultural risk management and identifies diversification and intensification as two distinct approaches to managing risk. Quantitative analysis of plant and animal remains from archaeological sites produces robust datasets that can be used to test predictions of risk management models related to diversification and intensification strategies. I present a variety of established and novel paleoethnobotanical and zooarchaeological measures that have implications for risk management and argue that multiple lines of evidence are needed to identify risk-management practices from archaeological remains. The article concludes with a case study of the multiperiod urban center of Gordion in central Turkey, where quantitative analysis of plant and animal remains demonstrates diachronic changes in agricultural risk management over 3000 years of occupation.

Introduction

Risk, or probabilistic variance in returns from economic activity, is ubiquitous for people participating in any type of economy and managing such risks is critical for the long-term success of individuals and economic systems alike. Especially pertinent for the study of past human societies is managing risk in subsistence practices, which persists as societies move from foraging to food production (Cashdan, 1990b; Gremillion, 1996, 2002; Halstead and O'Shea, 1989a; Winterhalder, 1986; Winterhalder et al., 1999). Archaeological remains can provide important primary data that indicate how societies attempted to mitigate subsistence risk and give insight into processes of decision making in the past.

Although recent work in human behavioral ecology and economic anthropology has identified individual behaviors and social structures that mitigate subsistence risk, the direct archaeological implications of such behaviors remain poorly understood. This article reviews the ethnographic and historical literature on agricultural risk management and identifies two distinct ways that agropastoral societies practice risk reduction—diversification and intensification—and specific subsistence strategies related to each. I argue that many of these risk-management strategies produce specific correlates in the archaeological record that can be identified using standard paleoethnobotanical and zooarchaeological datasets and I present several quantitative measures for relative intensity of risk-management within an agropastoral system. I conclude with a brief case study of the multiperiod urban center of Gordion, in central Turkey, where multiple lines of evidence indicate that risk-management practices varied over time in response to regional patterns of demographic and economic change.

Defining risk and modeling risk management

The term "risk" is frequently used in ecological, economic, agronomic, and anthropological literature, but the meaning of the term differs both among authors and among fields. In both economics and behavioral ecology, risk is defined as probabilistic variance (Cashdan, 1990a, pp. 2–3; Clark, 1990; Knight, 1921; Smith and Boyd, 1990; Stephens, 1990); behavioral ecology models of risk management focus on the simple question of when foragers should prefer risky (variable) returns and when they should prefer risk-free (constant) returns if both choices offer the same mean return (Caraco et al., 1980; Stephens, 1981; Stephens and Charnov, 1982; Stephens and Krebs, 1986; Winterhalder, 1986; Winterhalder et al., 1999). This differs from definitions of risk used in agronomic and many ethnographic studies of food production, where risk is equated with chance of loss (e.g., Fleisher, 1990; Göbel, 2008; Goland, 1993; Halstead and Jones, 1989; Shutes, 1997). A related concept is that of "uncertainty," which is distinguished from risk in the economic literature to refer to chance occurrences that cannot be accurately ascribed a predicted probability, or situations of incomplete information more generally (Cashdan, 1990a; Clark, 1990; Knight, 1921; Smith and Boyd, 1990; Stephens, 1990; Stephens and Charnov, 1982). The distinction between these two concepts is central to economic research but often conflated in

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anthropological research, especially empirical case studies, presumably due to the inability of humans to predict real-world risk with complete accuracy. Many anthropologists who employ the term do not precisely identify the definition of risk that they employ, but most mean chance of loss (e.g., Goland, 1993; Gremillion, 1996; Mace, 1993a; Marshall and Hildebrand, 2002; Scarry, 1993) with relatively few focusing on variance alone (e.g., Allen, 2004; Elston and Brantingham, 2002; Fitzhugh, 2001).

Although there is a substantial conceptual distinction between these two definitions, they are compatible under a wide range of real-world circumstances, as demonstrated by behavioral ecology modeling. Early empirical data from animal behavior led to the development of a conceptual model, known as the *Z*-score model, which demonstrates that starving individuals prefer risky returns while well-fed individuals prefer lower variance in returns (Caraco, 1981, 1982, 1983; Caraco et al., 1980; Stephens and Krebs, 1986). Different subsistence strategies produce different patterns of returns that can be modeled as distinct probabilistic distributions and the *Z*-score model predicts that when subsistence strategies produce a mean return greater than a starvation threshold, those strategies with the lowest variance should be chosen (Fig. 1; Stephens, 1990; Winterhalder, 1986; Winterhalder and Goland, 1997; Winterhalder et al., 1999). This has the effect of minimizing the chance of subsistence failure, thus meeting the criteria for risk minimization according to both definitions of risk. In most food-producing societies, mean food production does at least meet base subsistence needs, so understanding risk from the perspective of minimizing chance of loss is a valid approach from an economic or behavioral ecology perspective as well as from an agronomic perspective (Halstead and O'Shea, 1989b). In the rare cases where mean food production does fall short of requirements, however, the two definitions of risk diverge. Historical and modern case studies of how agricultural behaviors change under long-term famine conditions would need to take this distinction into account (Kohler and Van West, 1996; Winterhalder et al., 1999).

Ethnographic and historical research suggests that two distinct approaches are commonly used by human societies to reduce the chance of subsistence failure: diversification and intensification. Diversification strategies include mechanisms for varying the types of foods raised or gathered, where those food resources are grown, and when during the year they are harvested, and have the effect of reducing variance in subsistence returns. Intensification strategies, on the other hand, attempt to boost mean production well beyond the starvation threshold, thus reducing the chance that production will fall below that threshold in even the worst years. Both have the effect of reducing the chance of crop failure and starvation, at least as the result of certain types of potential hazards, although only diversification strategies necessarily reduce yield variance (Fig. 2). Irrigation, a form of intensification, may also affect the variance of agricultural production (Fig. 2d). In the following two sections, I categorize the risk-management strategies most common in the ethnographic and historical literature as either diversification or intensification strategies and then build a model for their application to archaeological plant and animal remains, as presented at the conclusion of this paper.

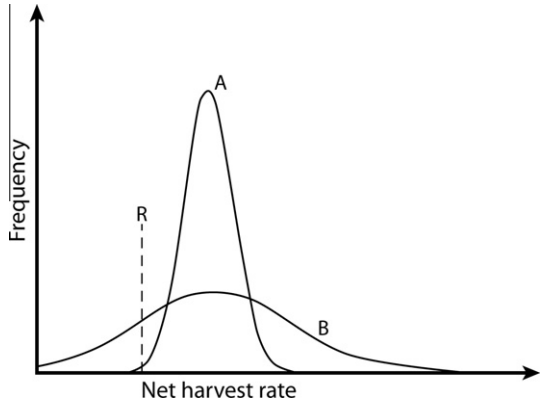

Fig. 1. A graph comparing the *Z*-score model for two subsistence strategies (A and B) in relation to the threshold level of nutrition required for survival (*R*). Since the means of the subsistence options are greater than *R*, the low variance option (A) should be preferred.

Diversification strategies

I argue that diversification strategies fall into three categories: crop diversification, spatial diversification, and temporal diversification. Each has the effect of averaging out risk across multiple dimensions of production, thus reducing variance in returns; such a broad definition of diversification includes all four types of "buffering mechanisms" (mobility, diversification, storage, and exchange) identified by Halstead and O'Shea (1989b, p. 3) and the σ-modifying behaviors (diversification, exchange, storage, and premature consumption of crops) described by Winterhalder and colleagues (1999, p. 331). The specific strategies through which food producers attempt to control risk, however, are varied and diverse. Some combination of diversification and intensification methods for risk management may employed in a given area, community, or household, and neighboring groups may choose different mechanisms for risk reduction when faced with practically identical subsistence challenges (Baksh and Johnson, 1990; Halstead and O'Shea, 1989b; Henrich and McElreath, 2002).

Crop diversification

Perhaps the most straightforward mechanism for reducing agricultural risk is crop diversification. An analogous diversification strategy has been well established in economics as a core strategy for investment portfolio management (Markowitz, 1952, 1959), as diversified holdings reduce the variance in expected returns over both short- and long-term holding periods. The same principle applies to food production: growing a diversity of food types helps to mitigate the variance in overall caloric production should an individual crop fail (as the result of an infestation or disease, for example). Diversification among crop types, between agriculture and foraging, and between farming and herding all minimize variance in food production and thus comprise risk-management strategies.

Planting multiple crop types together in the same field, a practice alternately termed multicropping, intercropping, or polycropping, is one common strategy to minimize crop failure. A related strategy is crop rotation, in which different crops are planted in the same field in alternate seasons or years. Different crops may respond differently to the soil type, slope, aspect, and rainfall present in a field over the course of a growing season, and thus multiple crop strategies can serve to reduce total agricultural risk through diversification. Such practices are common to both the New (Baksh and Johnson, 1990; Hames, 1989; Keegan, 1986; O'Shea, 1989; Scarry, 2008) and Old Worlds (Forbes, 1989; Gallant, 1991; Garnsey, 1988; Halstead and Jones, 1989; Legge, 1989; Smith, 2006).

One such multicropping strategy with archaeological implications is the planting of maslins, mixtures of seeds of related species deliberately prepared before planting to yield a mixed crop. Such a practice has been well documented on the Aegean islands of Greece during the last century (Halstead and Jones, 1989; Jones and Halstead, 1995), but may also have existed in prehistoric North America (Scarry, 2008). Maslins of the Aegean included both mixes of pulses and mixes of cereals, the latter category including maslins