INTRODUCTION

Traditional Arid Lands Agriculture

Known Unknowns

Scott E. Ingram and Robert C. Hunt

The purpose of this book is to stimulate research and advance understanding of traditional agriculture in arid lands, past and present. Each chapter focuses on what is not known or well understood about specific aspects of traditional agriculture (nonindustrial plant cultivation for human use). What is known is discussed to provide context and explanation for what is unknown. Each chapter addresses four questions: What do we not know about a specific topic related to traditional agriculture?[1] Why do we need to know more? How can we know more? What research questions can we pursue to know more? These questions were developed by us (Ingram and Hunt) to achieve our goal of stimulating future research. With answers to each of these questions, paths to create new knowledge and understanding are revealed. In brief, the book is about known unknowns in traditional arid lands agriculture.

The book was developed for students, practitioners, and scholars of traditional agriculture from many disciplines, professions, and regions. For students, each chapter identifies research questions and projects to advance understanding of traditional agriculture, now and in the past. Herein lies stimulus for papers, theses, dissertations, and careers. For practitioners concerned with influencing the way agriculture is conducted

now or in the future, the book is a valuable reference for policy making. Policies and programs can be based on what is known and what is not. For scholars, we hope the book becomes an essential reference to provide ideas for future research projects, to cite to justify such research, and to provide thesis and dissertation ideas for graduate students.

The North American Southwest (past and present) is the geographical focus of the book. The region includes Arizona, New Mexico, southern Colorado, southern Utah, and much of Sonora and Chihuahua in northwestern Mexico. The region (hereafter referred to as the Southwest) is characterized by physiographic, biotic, and climatic diversity. The northern Southwest includes the Colorado Plateau and the southern Rocky Mountain provinces, with broad plateaus, high mountain ranges, and incised canyons (Fenneman 1931). The western and southern portions of the southwestern United States and much of northwestern Mexico are dominated by the Basin and Range province, comprised of narrow mountain ranges and wide, sediment-filled desert basins. To the east lies the massive Great Plains province, originally dominated by relatively flat and rolling grasslands. The mountainous Sierra Madre Occidental province dominates western Chihuahua and eastern Sonora. Biotic communities of the region include forests, woodlands, grasslands, deserts, wetlands, and riparian communities that also support a wide range of animals (Brown 1994). Mean annual precipitation in the region ranges from about 5–20 inches (127–500 mm) and generally increases with higher elevation due to orographic processes (Sheppard et al. 2002). Rainfall patterns are unimodal (summer peak) in the east and bimodal (summer and winter peaks) in the west. Streams and rivers (intermittent and perennial) are found throughout the region. Average daily temperatures are about –7°C (20°F) during the winter at higher elevations and 35°C (95°F) during the summer at lower elevations.

Arid lands, including the Southwest, are characterized by low precipitation, high evapotranspiration, and high annual and interannual spatial and temporal climate variability. We use the term "arid land" broadly and leave climatic zone delimitation, aridity indices, and formal definition and discussion of classifications to others (e.g., Maliva and Missimer 2012; Middleton and Thomas 1997). The Southwest is also classified as a "dryland," a unifying term now used worldwide that includes a range of systems, many threatened by desertification. Drylands include "all terrestrial regions where water scarcity limits the production of crops, forage, wood, and other ecosystem provisioning services" (Millennium Ecosystem Assessment 2005:1). Drylands "occupy 41% of Earth's land area and are home to more than 2 billion people—a third of the human population in the year 2000" (Millennium Ecosystem Assessment 2005:1). Thus, the

subjects discussed and issues raised in this book should be of interest to those trying to understand and improve conditions in drylands worldwide (e.g., Reynolds et al. 2007).

Traditional agriculture has been practiced in the Southwest for at least 4,000 years and intensely studied for 100 years. Many plant species were grown, including maize, beans, squashes, indigenous and undomesticated plants, and in some areas cotton and agave. Maize has received the vast bulk of scholars' attention, as it does in this book. At the same time, it is clear that other plants were important, that there are substantial amounts of unknowns involved, and that they also are candidates for research in the future. The practitioners of "traditional" agriculture are past and present Native Americans (see Ortiz [1979, 1983] for an encyclopedic, though somewhat dated, summary of what is known about these peoples). Dozens of socially distinct cultures occupied the region (Cordell 1997) for millennia, cultivating plants throughout a range of environmental conditions with a variety of technological strategies. This social, environmental, and technological diversity contributes to the broad applicability of research on traditional agriculture in the Southwest.

Studies of traditional agriculture in the Southwest emphasize water and maize. Irrigation appears early (Damp et al. 2002; Mabry 2005). Farmers (referred to as Hohokam by archaeologists) of the modern-day Phoenix Basin (central Arizona) built hundreds of kilometers of canals (Howard 1993). These irrigation systems were the largest in the New World north of Peru (Doolittle 1990:79–80). Smaller-scale ditch irrigation has been identified in many riverine areas and was likely a common strategy when conditions permitted. Technological strategies used (now and in the past) to manage soil moisture for crops include runoff systems, lithic mulch, rock wall terraces on hillsides, and floodplain cultivation (Doolittle 2000; see also Ford and Swentzell, Chapter 11, this book). Several chapters in this book are concerned with irrigation, but the other technologies for managing soil moisture should not be considered secondary. Rather, they are topics that have substantial unknowns and are candidates for future research.

We are adjured to try to understand the coupling of natural and social systems (Doyel and Dean 2006; van der Leeuw and Redman 2002). Understanding agriculture requires contributions from many disciplines. Some are visible in this book, including geomorphology and soil science. Others are relevant, including climatology, meteorology, hydrology, limnology, and agronomy. For developing knowledge about the social aspect we are consistent with Flannery and Marcus (2012) in having archaeology and social anthropology involved.

From Symposium to Book

This project started as a proposal for a symposium at the annual meeting of the Society for American Archaeology (SAA) in Sacramento, California, in 2011. The inspiration arose during Ingram's graduate school years studying southwestern archaeology. During that time, he began to especially value those scholars who clearly identified and argued (in print) what they did not know, the uncertainty in the assumptions they relied on, and what work needed to be undertaken to know. When the unknowns were clearly identified, the exciting possibilities for future research and how one could contribute became clear. Ingram proposed to Hunt the idea for the symposium. Hunt is a social and economic anthropologist who has been investigating Hohokam irrigated agriculture for only a decade. He has wide knowledge of traditional agriculture, particularly canal irrigation. Hunt's interest in irrigation and agriculture translated easily for this project.

Following the SAA symposium, participants met in Taos, New Mexico, on the Fort Burgwin campus of Southern Methodist University for an intensive four-day workshop in 2011. This workshop was hosted by Mike Adler, the executive director of the SMU-in-Taos program (and a contributor to this book). Mike secured the generous financial support from SMU that enabled the workshop. Without Mike and SMU, this book would not exist. Prior to the workshop each contributor prepared a chapter to be extensively critiqued by all participants. Each chapter was discussed in a series of hour-long sessions throughout the workshop. Following the workshop, each chapter was revised and edited, with many authors continuing to solicit reviews on their evolving chapters long after the workshop concluded.

All contributors were asked to answer the four questions noted above, and all were free to prioritize the questions using any approach and emphasis. These approaches range from specific identification of the questions as section headings to more subtle and repeated integration of the questions and answers as expertise and content focus dictated. As a result of the questions, readers will find more than a collection of symposium presentations repurposed into an edited book. They will find a purposeful book in which care has been taken to provide similar information on a wide range of topics associated with traditional arid lands agriculture.

The criterion for inviting symposium participants and book contributors was a deep interest in understanding aspects of traditional arid lands agriculture. We invited those whose work we knew and had informed and influenced our own understanding. An effort was made to invite those who would cover a range of factors that influenced agriculture in the Southwest (water, irrigation, soils, maize, climate, etc.) in different

places and under different social and environmental conditions. We did not attempt comprehensive geographical coverage or to survey traditional agriculture, so there are gaps in our coverage (see Minnis, Chapter 12, this volume). For example, discussions of agriculture in southern Utah and Colorado are missing. Contributors explored those areas they know best. Questions arising in one area, however, inform questions that can be considered in other areas. For example, deficiencies in our understanding of the water requirements of maize have regional-scale impacts on what we know about drought impacts on maize productivity.

Chapters in This Book

Karen Adams, a paleobotanist, notes that although farmers in the prehispanic American Southwest grew maize, beans, squashes, gourds, and cotton, maize appears to have been the most important of these Mesoamerican crops.[2] Despite the prominent role of maize in ancient subsistence regimes, information is sparse concerning the growth requirements and environmental tolerances of indigenous maize landraces. The distribution of ancient maize suggests that maize is remarkably adaptable to different locales and their varied environments of altitude, heat, and moisture. In Chapter 1, Adams outlines what is known about the maize plant and then proceeds to a discussion of what we do not know. It is clear that moisture amounts and timing, along with a minimum number of frost-free days and adequate amounts of accumulating heat, act independently and in tandem to determine maize grain yield. Successfully tackling what we still don't know about maize calls for systematic agronomic experiments.

In Chapter 7, Mike Adler, an archaeologist, considers the evidence (and lack thereof) for prehistoric canal irrigation across the northern Southwest, specifically in the northern Rio Grande region. In fact, little is known. Constraints on our knowledge of the spatial and temporal extent of canal irrigation in this region include limited contact period accounts, a dearth of archaeological investigations of purported canals, lack of chronometric dating of archaeological deposits, and land modifications by later occupants of the region. A significant portion of recent archaeological investigations into precontact water control has been driven by court cases seeking to establish water rights settlements through litigation-based research. These litigation-based research reports often are classified documents, not subject to peer review, and not in the public domain. There are legal and ethical challenges associated with archaeological investigations of precontact water management technologies that constrain our discovery efforts.

Suzanne Fish, an archaeologist, ethnobotanist, and palynologist, and Paul Fish, an archaeologist, consider in Chapter 10 social anthropological questions regarding how Hohokam and related southwestern societies met the agricultural and social challenges arising from coalescing populations during aggregation. Their discussion combines archaeological evidence and ethnographic practices. They question how the societies of post–A.D. 1200 in the southern Southwest (1) provided heterogeneous coresidents with access to arable land and water, (2) boosted production to support enlarged populations by deploying correspondingly expanded labor pools, and (3) formulated new social roles and mechanisms for mediation among conjoined farmers to meet the changing demands and opportunities of agricultural production. The questions are new, and success in answering them would vastly improve our knowledge. The issues have implications for farmers worldwide as they continue to experience rapid demographic change, aggregation, and reorganization.

Richard Ford, an ethnobotanist and ethnographer, and Roxanne Swentzel, an artist and permaculture expert, discuss and illustrate in Chapter 11 the different agricultural field types and techniques of precontact northern New Mexico. The field types and techniques are placed in the context of Pueblo philosophy and beliefs and the Tewa agricultural calendar is presented. Swentzell has provided original illustrations of the water control systems especially for this book. Documentation of these traditional strategies is a valuable contribution to preserving and expanding these practices.

Robert Hard, an archaeologist, is joined by ethnologist William Merrill, archaeologists Art MacWilliams, John Roney, and Jacob Freeman, and paleobotanist Karen Adams. In Chapter 8, they investigate the apparent lack of aggregated settlements in a large swath of territory during the Ceramic period in central and southern Chihuahua, Mexico. The widespread use of *ranchería* settlement strategies in this territory is a poorly understood paradox, because the territory is situated between two areas with highly aggregated populations, the Casas Grandes region to the north and the Guadiana Chalchihuites region to the south. Their chapter proposes that precipitation regimes in central and southern Chihuahua allow for successful rain-fed farming, making available many potential farming locations. The ranchería settlement pattern continued into the historic period, and written records reflect dispersed but high population levels. There are two key exceptions to the ranchería pattern in the region: Medio period (A.D. 1200–1450) aggregated pueblos in the northern portion of the study area, and hilltop aggregated settlements in the south (A.D. 500–900). Pursuing a better understanding of these two exceptions would advance research into the relationships between agriculture and aggregation and the lack thereof.

Gary Huckleberry, a geomorphologist, considers postglacial climate and landscape change in the southwestern United States and northwestern Mexico in Chapter 3. This is the context of the northward diffusion of agriculture, but climate proxy evidence for this period (e.g., packrat middens, pollen, paleoflood chronologies, laminated sediments, etc.) is often contradictory. He reviews what is known and unknown regarding the middle to late Holocene climate in the Southwest and focuses on those aspects most relevant to indigenous agriculture and fluvial geomorphology. Both climate and geomorphology are important because they created limits and opportunities for precolumbian farmers. He further discusses climatic connections to floods and floodplain dynamics and concludes with recommendations for improving our understanding of Holocene paleoclimate and floodplain processes.

Robert Hunt is a social and economic anthropologist with a long-term interest in irrigation and agriculture. A key element in the study of prehistoric southwestern environments is the relationship of variation in moisture supply to variation in human behavior. Moisture variation is widely assumed to be correlated with variation in plant productivity; thus, moisture variation has a direct effect on food supply and in turn on human behavior. However, we know little to nothing about particular plant productivity responses to variation in water supply. The question Hunt addresses in Chapter 5 is, How did the Mesoamerican field crops (maize, beans, squashes, cotton) respond to variation in water supply? Hunt's chapter summarizes what we know about the yields of irrigated field crops in the Sonoran Desert part of the Southwest. It was possible to extract considerable information about maize but not about the other crops. Plausible approximations of maize's response to that variability are presented. Reviews of the situation for the other field crops reveal how little we know. The evidence supports Karen Adams's hypothesis in Chapter 1 that traditional southwestern maizes are adapted to different altitudes. The best solution for acquiring more knowledge of plant yields is to conduct systematic agronomy experiments.

Scott Ingram is an archaeologist, and in Chapter 4 he is concerned with human vulnerability to drought, a perennial interest in the Southwest. Agriculture is a critical link between climate and human behavior in arid lands. The purpose of his chapter is to direct archaeological attention to the domain of human vulnerability research as a new approach for investigating long-term climate–human behavior relationships in arid lands. He uses the "uneven" relationship between droughts (referred to as dry periods) and large-scale human population movements as an example of a problem that can be addressed with a vulnerability approach. The analytical objective is to identify conditions (e.g., demographic and environmental) that over the long term and in many places influence vulnerability

to dry periods. Identifying these conditions can better explain climate–human behavior relationships, now and in the past, and contribute insights for modern drought planning, mitigation, and adaptation.

Jonathan Sandor and Jeff Homburg are soil scientists, and in Chapter 2 they address a very important component of the environment of agriculture—soils. Soils form the foundation of agriculture, including the diverse farming systems of the prehistoric Southwest. Yet many questions about soils remain unanswered. What natural soils were chosen for agriculture, and why? How were soils and landscapes deliberately altered and managed for agriculture? Can prehistoric soil productivity be estimated? How did prehistoric farming impact soil resources? Although some advances have been made in addressing these questions, there is much more to learn. Challenges to understanding include the sheer complexity of soils, landscapes, and agroecosystems; the methodological challenges of reconstructing past events and processes; and the limited research relative to other areas of environmental archaeology. Studies are needed on a host of soils-related questions about southwestern prehistoric agriculture. Their relevance to current arid lands agriculture is presented.

Alan Sullivan is an archaeologist who has long worked at the western edge of the Colorado Plateau. In his case study from the South Rim of the Grand Canyon (Chapter 9), he examines various lines of evidence—assemblages, features, and terrain transformations—that, according to what he calls the "corn paradigm," are indicative of maize agriculture. However, after examining survey and excavation data, he finds little support for the proposition that food production in the region was dependent on corn farming. Instead, he interprets the economic data recovered from a variety of contexts, which are dominated by wild-plant pollen and macrobotanical remains, as evidence of ruderal plant production in burn plots created by intentional human ignition. He argues further that persistent and systematic understory vegetation management by low-intensity fire is a form of agricultural production even if domesticated plants were not the principal objects of cultivation. The theoretical merit of this contribution is that setting aside the "corn paradigm" as an explanatory framework unconstrains archaeologists to consider alternative ecological models (i.e., facultative vs. obligate) and their socioeconomic consequences.

Kyle Woodson is an archaeologist who has conducted extensive primary investigations of the Gila River Hohokam (near modern-day Phoenix, Arizona). In Chapter 6, he investigates an important question, that of the relationship of river behavior and Hohokam irrigation. A common claim in studies of Hohokam irrigation agriculture is that flooding events were problematic or even disastrous for canal system infrastructure and for irrigators. The sources for these hypotheses include records of historic floods in the Phoenix Basin, reconstructed streamflows based on

tree-ring research, and the geological history of river environments. This chapter examines what we do and do not know about floods, the effects of flooding on the landscape and on canal irrigation agriculture, and the human responses to flood impacts. Woodson describes the reasons why we need to know more about flooding and flood impacts on prehistoric irrigators, and he outlines a method for learning more about these topics. He also presents the types of evidence that can be used to test hypotheses about the impact of flooding on Hohokam irrigation agriculture.

Paul Minnis, an archaeologist and ethnobotanist, agreed to write the final chapter for the book and consider what had and had not been accomplished. He outlines the major remaining gaps in our knowledge, including (1) the full range of crops domesticated and cultivated, (2) the geographic distribution of research, (3) the dynamic social and historical contexts of agriculture, and (4) the ecological consequences of intensive and/or extensive farming. Despite these gaps, he finds that the results of the research are impressive, and future investigations will greatly expand our understanding of ancient history. He also advances a strong argument, with specific examples, of the relevance of ancient farming to specific stakeholders and more broadly to the modern world. Following Minnis, we conclude this introduction with discussion of the modern relevance of the study of traditional arid lands agriculture.

Modern Relevance

Advancing understanding of traditional agriculture as practiced in the ancient Southwest is of significant contemporary importance. Ingram (Chapter 4) advances this argument, and it is worth repeating here. Farming and farmers in the late prehistoric period in the Southwest share similarities with smallholder and subsistence farmers today in many areas of the developing world (see Morton [2007] for a discussion of definitions of smallholder and subsistence agriculture). Subsistence agriculture is "farming and associated activities which together form a livelihood strategy where the main output is consumed directly by the household, where there are few if any purchased inputs and where only a minor proportion of output is marketed" (Barnett 1997:1). There are many smallholder farmers worldwide. According to the World Bank (2007:3, 269), "Of the developing world's 5.5 billion people, 3 billion live in rural areas, nearly half of humanity. Of these rural inhabitants an estimated 2.5 billion are in households involved in agriculture, and 1.5 billion are in smallholder households [defined as operating a farm of 2 ha or less]." Many of these farmers live in arid lands; for example, the World Bank (2007:4–5) estimates that two-thirds of the rural population of sub-Saharan Africa live in arid and semiarid areas with poor market access. Many of these farmers

practice traditional agriculture, and improving understanding of strategies and utilized crops could improve food security in arid lands.

Maize and water are discussed in every chapter, and both have immense importance for global food security today. Understanding the water needs of indigenous maize (see chapters by Adams, Hunt, and Sandor and Homburg) is important to all of us who rely on this crop for food and other products. As increasing dryness due to a changing climate impacts maize-producing regions, our understanding of the attributes and benefits of traditional maize varieties adapted to the driest conditions (see chapters by Adams and Minnis) will become increasingly useful. Likewise, an understanding of traditional strategies for maintaining agricultural productivity in drier climates can provide insights for adapting to changing climatic conditions.

The Southwest and its 4,000-year history of food production constitute an important case study to consider human carrying capacity and sustainable development. Hunt contends that one of the more general purposes of this book is to make progress toward a deeper understanding of human carrying capacity in the Southwest. A better understanding of variation in agriculture and environment contributes toward that goal. It will also be necessary to make progress in understanding variation in human population (a subject not addressed in the book). Ingram agrees and asserts that we are also making progress on understanding sustainable development in arid lands. Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987:43). Carrying capacity and sustainability are closely related concepts. Carrying capacity is concerned with potential limits to human population growth, as is sustainability. How food is produced must be understood to advance understanding of either concept.

In conclusion, we hope this book serves as a primary source on what is currently known, unknown, and uncertain in our understanding of traditional arid lands agriculture. Identifying the known and unknown is a problem for all of us with wide-ranging and evolving research interests. Regardless of our expertise, each time we consider a problem outside of our training, we begin as novices. This effort is a familiar and fundamental requirement of creating new knowledge and understanding. We hope you find, as we have, that a focus on known unknowns is both exciting and productive.

Notes

1. The pronoun "we" includes all the authors contributing to this book. To the limits of our personal knowledge, we have attempted to identify what is currently

unknown or not well understood within the areas of specialization and disciplines we represent.

2. The terms "prehispanic," "prehistoric," "precontact," and "precolumbian" are used by the authors of this book to identify the period prior to European contact with or significant influence on the indigenous peoples of the Southwest. The time and place of this contact and influence varied greatly throughout the region but began with Coronado's *entrada* into the Southwest in A.D. 1540.

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