Persevering with Great Abandon

An Archaeobotanical Investigation of Resilience and Sustainability in Eastern African Irrigated Terrace Agriculture

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Abstract

The site of Engaruka in northern Tanzania has been the focus of decades of archaeological research regarding the development of terraced field systems in East Africa. Engaruka is a vast agricultural landscape, occupied from the 14th century and abandoned in 18th century. The abandonment of such a large and intensively cultivated area has been interpreted by some policy makers as a response to a failure of the agronomy, as has been argued elsewhere. This PhD research represents the archaeobotanical component of the AAREA (Archaeology of Agricultural Resilience in East Africa) Project, which was focused on establishing the efficacy of applying archaeological results that are in a dynamic state of development to policy decisions regarding agricultural resilience and sustainability.

This study focuses on the identification of crops in cultivation at Engaruka during its occupation based on the analysis of archaeobotanical residues (e.g. charred plant remains), as well as historic and ethnographic observations of cultivation throughout the region. The results confirm the presence of sorghum and other millets as well as several pulses, disproving the argument that ancient Engarukans were practicing sorghum monoculture. These data have been queried to address questions about the presence and preservation of millets and pulses and non-crop taxa in both expected and unlikely contexts, providing information on a range of issues including cultivation strategy and practice, specifically relating to harvesting techniques, the role of wild and weedy taxa, and differential use of space. Discussion is based upon detailed investigations of plant cultivation, collection/harvest, and exploitation through quantification of charred plant macrofossils, gathered weeds/wild taxa, and interview data relating to farming practices, thus highlighting the strengths of a multi-disciplinary approach for understanding resilience, sustainability, and, more generally, what it means to subsist in a challenging and dynamic agricultural landscape.

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Author’s Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

For Huggie and Mowgli

1 Introduction

This body of research represents the archaeobotanical component of the Archaeology of Agricultural Resilience in Eastern Africa (AAREA) Project, which is focused on establishing the ways in which archaeology can contribute to assessments of agricultural sustainability and resilience. A sustainable agricultural system is one that persists continuously for a long time, whereas a resilient system is able to survive short-term shocks, such as flooding, or long-term trends, such as climate change. Definitions of sustainability all share a temporal dimension, since all are about adapting to change to manage resources through time, which lends itself to archaeological enquiry. Archaeologists, such as Redman and Kinzig (2003), have argued that archaeological data are pivotal to making these assessments.

Resilience in Focus

Conceptualisations of resilience have become ubiquitous across many disciplines including ecology, socio-ecology, physics, social work and psychology, disaster management, business and personal management, and engineering. With each application, a nuanced definition has been developed to describe the unique focus of the discipline, while attempting to maintain relatability to other uses of the concept. A few notable examples demonstrate the similarities and differences between these definitions. In engineering, for instance, resilience is viewed as an “ability to sense, recognise, adapt and absorb variations, changes, disturbances, disruptions and surprises (Dekker et al. 2008, 9).”

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By the 1970's, social scientist and psychologists were also developing theories of social resilience. For the influential theorist Norman Garmezy, leader of Project Competence, a landmark study of vulnerability in childhood based at the University of Minnesota, applied an environmental view of resilience founded on the idea that external factors, such as the nature of family relationships and degrees of community and/or institutional support, impact childhood vulnerability (Garmezy 1973), which corresponds to the role of risk in ecological models of resilience discussed below. Indeed, over the next three decades theorist began to connect social and ecological definitions of resilience to one another. Neil Adger (2000) reviewed this connection in detail and argued that while these definitions are similar, communities characterized by diverse socio-economic systems and/or situated in ecologically resilient regions are not necessarily socially resilient.

Common themes permeate these definitions: Resilience involves some degree of adaptability or resourcefulness in restoring an idealised equilibrium (rebounding or recovery) following a significant disturbance, though see below for refinements of what is meant by equilibrium. At its core, a resilient system is one that is well-equipped to absorb shocks without changing states. Gunderson (2000, 426) divides the array of resilience definitions into two categories: those that assume a single state of equilibrium within a system and those that assume that there are multiple states of equilibria within a system.

The current study is tasked with relating environmental archaeology to resilience and thus a discussion of resilience theory in ecology is a logical place to begin, however, it is also appropriate because this is the discipline in which the concept gained its earliest scholarly foundation. Resilience theory was first framed in ecological terms by theoretical ecologist C. S. Holling in the early 1970s. Holling (1973) contrasted resilience with stability, a mainstay of systems theory, which also deeply confounded ecologists because it relied too much upon a single state of equilibrium that is often difficult to pinpoint (and probably non-existent) in natural systems. He defined it as follows:

> Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables driving variables and parameters and still persist. In this definition, resilience is the property of the system and persistence or probability of extinction is the result. Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance. The more rapidly it returns and with the least fluctuation, the more stable it is. In this definition, stability is the property of the system and the degree of fluctuation around specific states the result (Holling 1973, 17).

To further illustrate the application of resilience to ecological system organisation and dynamics, Holling (1986) introduced the adaptive cycle as a thought tool for understanding the intertwined processes of destruction and reorganisation (Figure 1).

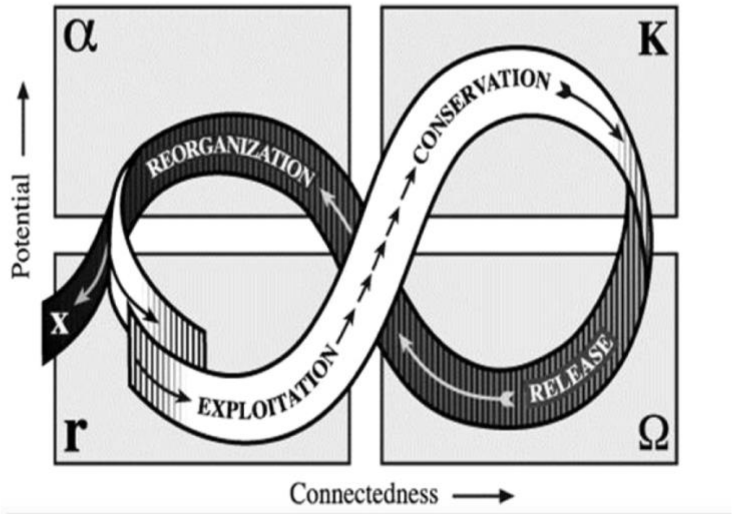

Figure 1. The adaptive cycle developed by Holling (1985), as presented in Panarchy: Understanding Transformations in Human and Natural Systems (Holling and Gunderson 2002, 34).

The framework is divided into four distinct phases:

1. Growth and exploitation, r
2. Conservation, K
3. Collapse or release, Ω
4. Reorganization, α

The cycle illustrates how ecological systems alternate between long steady periods of acquisition and transformation of resources (r to K) and shorter periods that create opportunities for innovation (omega to alpha), which, in turn, often necessitate reorganization of the system as a whole to accommodate these changes. As resources are slowly harnessed and conserved, the system becomes increasingly interconnected, interdependent, and stable. Forces of competition lead to certain species advancing ahead of others and becoming dominant. This results in reduced diversity, but the cached resources provide the potential for the development of new ecosystems and environmental outcomes. Whether or not a system does transition into one of these new states is dependent upon its adaptive capacity, or its ability to remain in a stable domain, as the shape of the domain changes (Gunderson 2000).

To account for system complexity, adaptive cycles are nested amongst one another across time and space to form what Holling and Gunderson (2002) term panarchy (Figure 2). Relating these concepts to the current study, adaptive cycles and panarchy are particularly useful to archaeologists because the residues of specific subsistence activities can be linked to the phases or at least to transitions between phases within these frameworks.

This is particularly well-suited to studies of agricultural societies where it is possible to clearly see how social systems and ecological systems necessarily

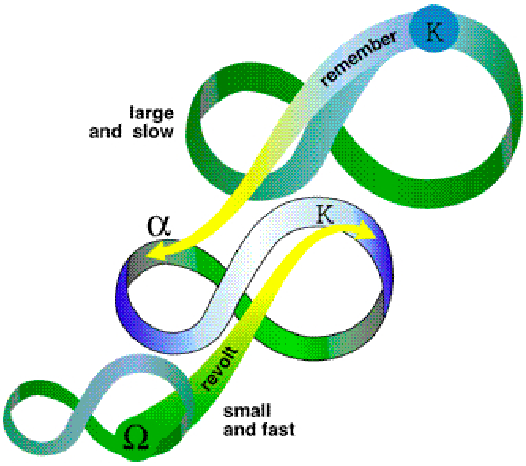

Figure 2. Adaptive cycles nested across time and space are defined as panarchy, from Holling and Gunderson (Holling and Gunderson 2002, 75).

adapt together. For example, during the transition from r to K, farmers develop new techniques (and technology) and form relationships with one another that may help to determine the maximum potential for the accumulation of resources during that particular phase of the cycle. These types of processes are the building blocks of adaptive cycled nested intimately into a complex socio-environmental panarchy.

Sustainability at Centre Stage

Where resilience and archaeological studies of socio-environmental systems do not mesh well is the determination of an idealized state of equilibrium or even several states of equilibrium. From an archaeological perspective, one can make an argument that an action has the potential to contribute to the resilience of a system, but labelling a past anthropogenic system as resilient (or not) is highly subjective. It is easy to judge a system based on the desire for a particular outcome and indeed this is characteristic of Folke's (2016, 44) categorization of resilience having the capacity to persist in the face of change, to continue to develop with ever changing environments. When resilience is always viewed as a positive trait (it contributes to long term sustainability), persistence is seen as the key to achieving this. However, whatever the desired end goal is for the system is based on the perspective of the of the person making the assessment, which creates bias and also runs afoul of Adger's (2000) questioning of whether social resilience is central to sustainable development, as mentioned above.

These issues guided the AAREA project's focus on Engaruka and Konso where contrasting perceptions of very similar systems has resulted in one being seen as resilient because the Konso agronomy is still in existence, while the other is seen as a failure because the Engarukan agronomy was eventually abandoned. Furthermore, neither assessment is based on sufficient understanding of the long-term history of the sites. Ethnographic studies at Konso have presented the state of 20th century "traditional" agriculture and how farmers have persevered, but very little archaeology has been done and that which had been done did not address these questions (Kimura 2004). Meanwhile at Engaruka, archaeologists and researchers from related disciplines have pursued these questions, but with very little archaeobotany and with ethnographic data based on modern Maasai agropastoralists that lack a cultural connection to the farmers that originally constructed and managed the system (reviewed in detail in Chapter 2 below). Also, it is not possible to understand the dynamics of the systems that have allowed farmers to persevere without evidence of the historical crop repertoires and changes in agricultural biodiversity that support the sustainability of the system; archaeobotany can provide these data.

According to the Convention on Biological Diversity (2000, 100) agricultural biodiversity refers to

> *All components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems, also named agro-ecosystems: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes.*

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Agricultural biodiversity is a key driver of sustainability in farming systems. At the same time, human agents are only likely to sustain systems that remain valuable. Drawing upon archaeobotanical evidence, it is possible to identify activities that support system sustainability as well as those that put communities at risk.

The Archaeobotany of Sustainable Agriculture

There already exists a well-established body of scholarship regarding the applicability of archaeobotany to assessments of agricultural sustainability at sites around the world. Functional ecology is a sub-discipline of ecology that has been used by archaeologists to fill information gaps relating to crop husbandry and other aspects of agricultural landscape management. Such studies are based on a detailed understanding of the role a particular species plays in an ecosystem or community as well as the effect natural selective processes have on organisms (Calow 1987). Functional ecologists rely on patterns of traits found in a large number of species, determined by measuring a trait across individuals of a species and using empirical assessment of community dynamics and ecosystem processes as environmental adaptations. Archaeologists have used these techniques to determine the agricultural practices that past farmers used to invest in the long-term sustainability of their agronomies. These studies are discussed below.

An approach developed at the Unit of Comparative Plant Ecology at the University of Sheffield in the late 1980's known as Functional Interpretation of Botanical Survey, or FIBS, explores how ecological processes impact species distribution within a wide range of habitats (Hodgson 1989; Hodgson and Grime 1990). Over the last 30 years archaeologists have used the technique to help reconstruct agricultural practices used in the past on extinct farming landscapes. The approach has been used primarily at sites in Europe, the UK, and more recently in Egypt (Malleson 2016). Researchers have identified crop husbandry practices based on the identification of weeds (using weed ecology) and stable carbon isotopes. Weed ecology is the study of the relationships between a weed and another plant sharing the same environment. Archaeobotanists using the functional ecology approach focus on crop/weed relationships (Jones et al. 2005; Bogaard et al. 1999; Jones et al. 2010) and the identification of certain weed types, such as weeds of cultivation and weeds of irrigation, which can reveal the growing conditions (soil properties, soil preparation, and irrigation) (Fried,Petit and Reboud 2010) of the crops that shared the same fields. Research relating to the question of sustainability of ancient agricultural systems has explored manuring (Fraser et al. 2011; Bogaard et al. 2016c, 2013), weed ecology as evidence of agricultural intensity (Bogaard et al. 2000), and crop rotation (Bogaard et al. 1999, 2016a; Altieri and Liebman 1988). It should be noted that weed seeds are rarely recovered in archaeobotanical assemblages because the agents of preservation do not favour them, so the majority of these studies rely on isotope analysis. A significant outcome of the current study is the exception to this rule: weed seeds have been recovered and in many cases identified. Further studies planned for Engaruka (and discussed in Chapter 7) will delve deeper into weed ecology and the role it played in the agricultural biodiversity that helped to sustain the agronomy.

Risk Management as a Marker of Sustainability

In order to draw conclusions about the long-term sustainability of an agricultural system, we must first identify data points or patterns within archaeobotanical data that can be used to make these inferences. Economic multitasking is an effective way for mitigating risk and promoting sustainability. It is also an activity with a high level of visibility in agricultural archaeobotany. John Marston using the site of Gordion in Central Turkey as a landscape upon which to contextualise his arguments about the distinctions between diversification and intensification as agents of agricultural risk management (Marston 2011, 2015). He identifies diversification and intensification as risk-limiting mediators that have the benefit of being archaeologically visible. Diversification is a way of ensuring that subsistence returns remain relatively steady and this involves the application of strategies that promote the development of a variety of food sources (crop diversification) that can be harvested from many different locations (spatial diversification), as frequently as possible throughout the year (temporal diversification).

Intensification uses strategies that try to maximise the average level of production so that there is a comfortable surplus of food to cushion the community from the risk of starvation even in the most challenging of seasons. Marston (2011) identifies overproduction and irrigation as two key examples of strategies that involve a great deal of investment (e.g. land, labour, and time), but the costs are accepted because the outcome is the reassurance that there will be more than enough food for everyone. Strategies associated with both types of systems can help communities to avoid the risk of starvation and to mitigate the impact of crop failure. Diversification does this by avoiding over-reliance on a single strategy, while intensification aims to maximise the output of a system.

The markers of these types of risk management can be identified in the residues of food in the form of plant and animal remains in order to pin point social and environmental transitions. Indeed, the strength of the archaeobotanical results is that they provide key evidence of diversification, thus expanding upon the intensification strategies already revealed by traditional archaeological methods (Stump 2006b). Marston (2011) reinforces the argument illustrated in the current study that an interdisciplinary approach to evidence-gathering is needed if changes in risk management strategies are to be brought into focus. However, archaeobotany alone can reveal diversification strategies.

A Novel Archaeobotanical Contribution

Previous work applying archaeology and historical ecology to questions of resilience and sustainability have focused on explaining the trajectory of past societies and landscapes through investigations of the relationships between human decision-making and impact to the environment and human subsistence. The current study identifies the archaeobotanical markers of these relationships at sites of intensive agriculture in Eastern Africa, which feature prominently in debates relating past subsistence to development advice regarding the best ways to adapt to climate change impacts to agriculture. It also represents a unique methodological contribution to the field of archaeology for its application of archaeobotany to agricultural sustainability and resilience determinations, its focus on modern and archaeological weed ecology, and its regional focus in the East African interior, which is less well known archaeologically than the East African coast.

The primary aims of the study is to determine:

1. What is needed in order to *relate* archaeobotany to discussions of sustainability?
2. What can archaeobotany *contribute* to discussions of resilience and sustainability?

A major component of this work was aimed at developing a novel archaeological methodology which draws upon interpretations of weed ecology (relationships between crops and weeds) using tactics more commonly used by ecologists or by archaeologists interested in functional ecology. However, in the latter studies, charred weed seeds are rare to non-existent making such assessments more speculative. What makes these data unique is the that I have recovered charred weed seeds amongst the sorghum, millets and legumes of the hearths, fields, and discard middens; and where these weed seeds are identifiable, they have contributed to a more refined understanding of the relationship that Engarukans had with the wild plants in their landscape. These interpretations go beyond the assumed avoidance of wild and weedy intruders associated with farmers, such as weeding them from fields and removal of wild seeds from threshed grain, to include foraging for valuable wild foods during times of both feast and famine, sourcing plant medicines and raw materials for building and craft activities. These activities would have played a significant role in the suite of skills needed to survive

Objectives

1. To test and explore assumptions about preservation of archaeological plant material in specific irrigated dryland contexts, particularly fields, which are not commonly sampled because preservation is expected to be poor and interpretations are complicated by questions about whether seeds enter the archaeological record through site-local cultivation activity or if they wash in with irrigated sediment originating from the uplands.

2. To recover charred wood and seeds suitable for radiocarbon dating well-defined strata from fields, domestic hearths, and a village midden, thereby establishing the timeframes during which each site was active so that comparisons can be made to other archaeological sites and occupation can be linked to known ecological shifts.

3. To identify the full spectrum of plant use at each site, including those crops that were in cultivation in the fields and in use in domestic spaces, as well as potential crop weeds and useful wild plants (e.g. weeds of cultivation/irrigation and edible/medicinal wild taxa).

4. To facilitate an accurate comparison of the sites and site contexts by identifying the archaeobotanical signatures of each type of domestic or

agricultural activity area (middens, occupation floors, hearths, and fields).

5. To target the excavation and archaobotanical sampling of (1) agricultural contexts in order to establish how the fields were constructed, maintained, and planted; and (2) village contexts (hearths, floors, and middens) to explore the ways in which wild and cultivated plants were used domestically; and lastly, (3) the unique depositional pathways by which seeds travel through domestic spaces and irrigated agricultural landscapes.

6. To connect archaeobotanical evidence of plant utilization at each site to specific agricultural activities supporting the overall resilience and/or sustainability of the site.

Context and Justification of the Case Studies

The AAREA project focused on two case studies: Engaruka, in Northern Tanzania, and Konso in Southern Ethiopia. Both sites are significant for the overall aims of the project, discussed above for precisely the reasons that distinguish them from one another. Engaruka is an abandoned site with relatively low subsequent disturbance, which can only be studied archaeologically, making it a good place to explore archaeological approaches to sustainability assessments. Furthermore, Engaruka has been cited as an example of poor resource management (e.g. Koponen 1988, 383; Conte 2004, 25; see also Stump 2010, 1255), providing a hypothesis to be tested. Meanwhile, the agronomy at Konso is based on similar technology in terms of terraces, irrigation and sediment traps, but is still being farmed. This means that it can be studied ethnographically, historically, and archaeologically, with the potential disadvantage that subsequent cultivation may have disturbed the archaeological record. Notably, Konso has been featured as an example of apparently highly sustainable 'indigenous knowledge' in terms of agriculture and soil and water conservation (FAO 1990; Watson 2009).

The primary outcome of the research was the realisation that the archaeobotanical record can provide useful insights into strategies of risk mitigation by providing details of the crops grown and consumed at both Engaruka and Konso. Providing details of this kind is clearly crucial to an understanding of how these systems functioned in the past. The research is relevant and timely because it demonstrates that archaeobotany can help fill data gaps, and if we do not refine the details of these gaps it will not be possible to understand the dynamic changes to the subsistence strategies and the historic environments that occurred within 4 these historic agricultural systems. Without this understanding it is thus difficult to establish assessments of sustainability, or to model systemic changes (Kabora 2018).

Legacy of Engaruka Research

Engaruka has been featured as an example of "intensive agriculture" due to use of terracing and irrigation. Previous investigations (Leakey 1936; Sassoon 1966, 1967; Robertshaw 1986; Stump 2006b) and surveys (Sutton 1978) successively revealed the complexity of the site, which dates to the 14th to the 18th centuries

AD. These dates derive from artefacts, including imported glass beads, associated with the Late Iron Age and from radiocarbon dates (Stump 2006b; Westerberg et al. 2010). Other terraced and irrigated sites across Eastern Africa, both abandoned and extant, have the potential to be used as a model for understanding how Engaruka might have operated.

Prior to the current study and despite excavations carried out by five previous projects (Leakey 1936; Robertshaw 1986; Siiriäinen et al. 2003; Sutton 1986, 1978, 2004; Stump 2006a; Sassoon 1967, 1966, 1971; Stump 2006b), sorghum was the only crop found (Sassoon 1967), though no other site of intensive agriculture in Eastern Africa is known to have relied on a single crop. In an effort to contextualise the current study, the following section presents a summary of the agricultural landscape and a brief discussion of the interpretive arguments that have developed over the course of the site's investigation.

Considerations of the Archaeobotanical Approach

We cannot try to understand sustainability at Engaruka and other abandoned sites without searching for the crops being grown, as well as knowledge of the vegetation that impacted other aspects of subsistence. The current study draws on the strengths of the archaeobotanical approach combining the identification of carbonised pant macrofossils with ethnobotanical interviews and exploration of local weed flora. The identification of carbonised seeds of crops, weeds of cultivation and irrigation, wild economic plants, as well as charcoal, help the archaeobotanist to establish an understanding of the day to day relationship that past peoples had with the plants in their environment. Crops reveal not only what people were cooking and eating, but also what sort of domestic and agricultural systems supported that food becoming a part of the diet. Information about the particular requirements of crops can reveal the management practices, such as clearing and harvesting practices, irrigation, soil preparation, and weed and pest management. Weed seed and charcoal presence and abundance help to identify the introduction of certain practices when the temporal relationship of contexts in explored, and with sufficient chronological precision can also define changes and fluctuations in these practices. Crops and weeds in domestic contexts, particularly in cooking areas such as hearths - where seeds are likely to be discarded and preserved through carbonisation - identify what people were actually eating with what was grown in the fields. They also help to differentiate different areas of activity. Charred fuelwood is generally associated with hearths, charred seeds are found in hearths, and chaff is recovered from food storage and processing areas. Economic weeds, wild (non-domesticated) plants that play a role in human subsistence or other aspects of human economy, found in domestic contexts may be indicative of utilisation of wild foods, medicinal and/or ritual practices, and utilitarian applications of plants, such as for craft production or building materials. Lastly, while this is not a typical method employed by archaeobotanists, viewing the relationship between crops and weeds as agents in a landscape of agricultural biodiversity can also help to identify the factors that farmers must mitigate in order to ensure that the system can support their families through challenging times. Indeed, Walshaw and Stoetzel (2017, 370) advance the idea that the exploration of local plant knowledge systems “can inform debates of recent concern, including land distribution, food security and sovereignty, climate change and natural resource exploration/extraction". This is precisely the type of application used in the current study to assess Engaruka's sustainability. I used ethnographic and archaeological information about modern and historic local plant use at Konso (and to a lesser degree at modern Engaruka, as well), to push the interpretation of the archaeobotanical assemblage at Engaruka, thus allowing me to identify the archaeobotanically visible features of risk management, which is inextricably linked to sustainability. Ethnographic methods thus further boost the interpretative power of traditional archaeobotanical enquiry.

The current archaeobotanical approach seeks to establish what was being grown and how these data can be applied to questions about the sustainability of the system of agriculture subsistence used at Engaruka during the time that it was occupied. There are certain issues of bias and other limitations that must be considered, which includes sampling, depositional, and preservation biases, as well as issues with archaeological visibility. Bias can occur when certain crops, such corms and tubers, famine foods, may be underrepresented in terms of importance because they are eaten irregularly. Bias also arises when plant food storage, processing, and consumption leave behind no visible trace. This might stem from the ephemeral design of features that would otherwise indicate specific processing or consumption activities, if they survived, such as buried or freestanding granaries. Preservation bias manifests because macrobotanical remains must be preserved through charring, desiccation, or waterlogging, the latter of which is not relevant at the current sites. These factors can be complicated by soil type, moisture conditions, and the action of plants and animals (bioturbation) (Johannessen 1988). Likelihood of preservation varies between types of plant remains based on the mechanism of preservation. At Engaruka, desiccated remains cannot be distinguished from modern botanical intrusions and waterlogging is not possible due to extreme dry conditions. The preservation of charred remains is subject to conditional biases from the time of deposition and fluctuates with the taphonomic conditions that follow (Johannessen 1988). Preservation bias can lead to both depositional and sampling bias, since, for example, waterlogging and charring can lead to the under- or overemphasis of certain crops based on how they are processed or discarded. For instance, because rice is usually boiled, it is unlikely to be found charred unless raw grains are dropped in the cooking fire or burned in a rubbish context. The seeds of crops that do come into direct contact with heat through roasting or toasting, such as millets, are more likely to be preserved.

Archaeological visibility is limited by the fact the day to day management of agricultural systems, such as fallowing, intercropping, crop rotations, manuring, and irrigation schedules, have not traditionally been established using archaeological methods. For instance, in the case of Engaruka, although irrigation features are visible on the surface, it is not possible to distinguish individual use events. Ethnographic studies, such as those carried out for the current study, indicate that irrigation schedules are complex in the present, and this is likely to have been equally true in the past.

Summary of the Thesis Structure

The thesis which follows is divided into six chapters in addition to the present introduction. The organisation is initially focused on identifying whether sustainability is visible in archaeobotanical assemblages supported by ethnographic analogies, thus establishing whether archaeobotany can contribute valuable data to debates regarding sustainability.

Immediately following the Introduction, Chapter 2 introduces and then develops the historical and archaeological context of the study through a discussion of the evidence of crop repertoires in the pre-colonial agriculture of East Africa. I begin with a review of the state of archaeobotanical knowledge of Iron Age crops which might have played a role in the Engaruka agronomy. This is developed through an archaeobotanical discussion of the domestication, the later integration of exotic crops, followed by an analysis of the evidence for the inland spread of African and non-African crops to the East African interior through historic travellers' accounts.

In Chapter 3, I present the methodology I developed to interrogate the objectives of the study. This is comprised of a description of the field methods and how the sampling strategy was developed to target specific agricultural and domestic contexts, including fields, habitation structures that contain hearths (referred to as buildings), and a midden. I then describe the various modes of environmental processing I used to extract the archaeobotanical assemblage, including tank and bucket flotation systems. Next, I discuss the development of the ethnobotanical components of the study. The chapter concludes with descriptions of the laboratory analyses, including the recovery and identification of charred plant macroremains, and lastly the simple statistics used to quantify the findings.

Chapters 4 and 5 report the archaeobotanical results first at Engaruka and then at Konso. The discussion of the findings begins with a summary of the excavations, followed by radiocarbon results, and then reporting of the assemblages and patterns encountered in domestic and agricultural contexts. At Engaruka this is broken down into sediment trap fields and domestic building in the village, while at Konso the reporting is divided between the local sediment trap fields, known as *yela*, and the midden at Kuile village.

In Chapter 6, I present the final discussion of the results, pushing the data to identify potential connections to sustainability. This begins with a discussion of the sediment trap fields at both sites, followed by the implications of the archaeobotanical evidence for the development and varied use of domestic space. The final discussion explores risk management as an archaeobotanically visible marker of sustainability. Lastly, I discuss the questions that still remain about the existing assemblages and detail the work yet to be done with these materials. In the final conclusion, Chapter 7, I summarise the key finding of the research and revisit the original aims to establish the efficacy of the method and, lastly, to pave the way for a discussion of the scope for future research.

2 Crop Repertoires in Pre-colonial and Modern East Africa

As noted in the introduction there has been little or no previous archaeobotanical research at either of the current project's two case-study sites. Previous excavations at Konso focused on lithic technologies (Kimura 2004; Arthur 2010), and of the five previous campaigns of archaeological excavations at Engaruka – Leakey in 1935 (Leakey 1936), Sassoon in 1964 and 1966 (Sassoon 1966, 1967, 1971), Robertshaw in 1982 (Robertshaw 1986), Siiriäinen in 2001 to 2004 (Siiriäinen et al. 2003) and Stump in 2001 to 2003 and 2010 (Stump 2006a, 2016) – none included a dedicated programme of archaeobotanical sampling and analysis. Indeed, at Engaruka only Sassoon reports archaeobotanical evidence, noting that during excavations within one of the settlement areas "small quantities of carbonized grain were recovered; some of these have been examined and identified as Sorghum" (1967, 207), although no sampling or methodological details are given. This lack of previous work is itself more than sufficient to justify the programme of archaeobotanical research reported here. However, the review of the existing archaeological, archaeobotanical, ethnobotanical, historical and ethnographic literature from across eastern Africa provides further justification and leads to two important conclusions of relevance to assessments of the sustainability of agriculture at both Engaruka and Konso. First, although agricultural decisions and dietary preferences are conditioned by local environments and cultural factors, some general patterns can be discerned. These allow us to predict the range of crops we would expect to find at Engaruka and Konso, and to aid interpretation of recovered archaeobotanical assemblages. Second, agricultural strategies in east Africa are adaptive and dynamic. Crop selection changes over time, as does the proportion of resources dedicated to crops over livestock, and this means that it is not possible simply to project ethnobotanical data from Konso (Engels,Hawkes and Worede 1991; Menfese 2010; Addis,Asfaw and Woldu 2013b, 2013a) into the recent or distant past, or to use the Konso ethnobotany results as a straightforward analogy for Engaruka.

This chapter presents a review of the literature that provides context to Engaruka, placing them within the larger framework of Iron Age agriculture in eastern Africa through discussions of the culture-history and archaeology of the region. The focus is placed on identifying crop repertoires and sustainable practices in eastern African intensive agriculture with the aim of assessing what the cropping strategies of analogous communities can tell us about likely farming strategies at Engaruka. First, I will provide context to the study through a description of the agricultural landscape at Engaruka, reviewing the archaeological, historical, and ethnographic literature presented as evidence for the construction of a feasible culture history of the people who constructed the system. I briefly introduce the other known agricultural communities in the region, which Widgren and Sutton (Widgren and Sutton 2004) called ‘islands of intensive agriculture’, highlighting potential links and/or similarities to Engaruka. Moving geographically further afield, I then formally introduce the Konso agronomy along with an overview of previous research as it relates to the current study, framing the discussion with regards to the fitness of Konso as a modern proxy for Engaruka with a brief review of research, which is overwhelmingly ethnographic, dedicated to the sustainability of intensive agriculture in the region.

In the section that follows, I briefly discuss the traits of domestication that archaeobotanists use to identify the crops discussed in the section following, which deals with the emergence of important East African crops. Here the archaeobotanical literature from across eastern Africa is reviewed, reflecting the fact that farming communities prior to European colonial contact employed a common set of crops distinct to the Iron Age agronomies. Following this, literature from archaeological and historical sources will be reviewed to note the introduction of non-African crops into crop repertoires in eastern Africa, starting with the evidence of these species at coastal sites, and then exploring their spread inland – the aim being to assess the likelihood that these crops could have been grown at Engaruka. The question of the spread of non-African crops is then expanded to include historical sources, highlighting that this might have been facilitated by the expansion of coastal trade routes into the interior from the 8th century AD. Trade along these long distance routes intensified during the 19th century, and has been cited as an explanation of why some communities along these routes intensified agricultural production through the construction of terraced landscapes and irrigation systems (Westerberg et al. 2010). In the final section I present a summary of the reviewed literature to demonstrate the dynamic and adaptive nature of African agriculture, and to assess the strengths and weaknesses of archaeological versus historical sources in discerning the crop repertoires of abandoned or historic agricultural systems. The conclusions drawn in this final section therefore directly inform the methodology for fieldwork at Engaruka and Konso presented in Chapter 3. However, given that the results of the archaeobotanical and ethnobotanical study at Konso are primarily employed here to aid in the interpretation of the Engaruka archaeobotanical assemblage, the review presented in the current chapter principally focusses on what the existing literature can tell us about Engaruka.

Engaruka: The Agricultural Landscape

Engaruka sits below the east-facing escarpment of the East African Rift (1000 m above sea level) just east of the Crater Highlands. Water irrigating the field systems at Engaruka originates from rivers fed by watersheds collecting the high rainfall on the eastern face of Lolmalasin, an extinct volcano of the Crater Highlands. The abandoned field system is comprised of terraces, stone-lined fields, cairns, stone circles and irrigation furrows situated on (and overlapping) the alluvial fan created by the aforementioned rivers flowing off Lolmalasin. The Engaruka River is currently the only perennially flowing water source, but the engineering of the terraces and furrows indicate that all five of the rivers have been used for irrigation in antiquity (Sutton 2000; Stump 2006b, 2006a). The stone structures were built up with pebbles and reinforced with the abundant local stones and boulders. Sutton (1986) and Stump (2006b) have suggested that some of the stone circles could have been used to house livestock in order to supplement agricultural activities as necessary. The inhabitants of the site lived upslope from the fields on steeper terraced platforms extending from

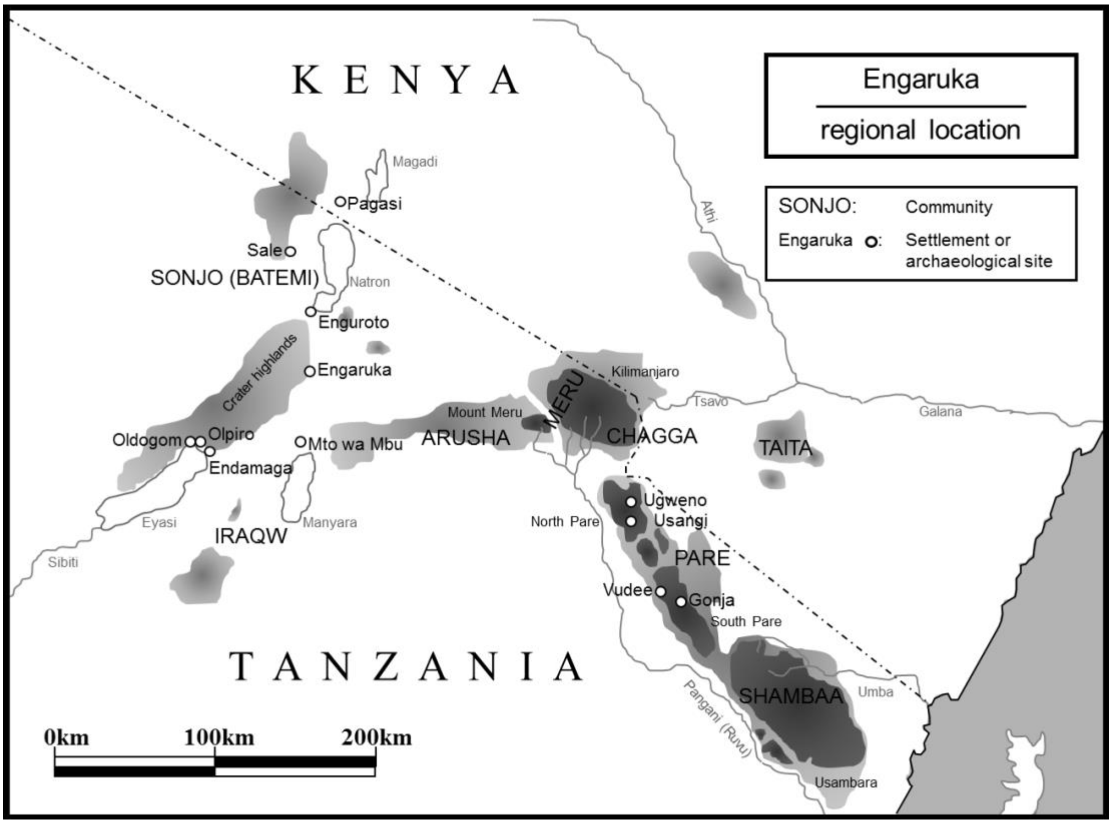


Figure 3. Agricultural centres in the vicinity of Engaruka, taken from Stump (2006b, 70).

about 1 km north of the southernmost Olemelepo River, to just north of what Sutton (1978) has termed the 'Intermediate North Gorge': a now dry river gorge that has no local name.

Population estimates based on habitation areas suggest that the nearly 2000 hectares of intensive agricultural terraces at Engaruka supported a population as high as 5,000 (3,000-4,000 on average) (Sutton 2004, 59; Davies 2010, 209), or 6,000 to 11,000 (Laulumaa 2006, 101). These estimates are lower than the modern population of Engaruka, which is 11,121 (Caretta et al. 2014, 37), though this census-based figure includes dispersed pastoral homesteads in the landscape surrounding the two modern villages of Engaruka Chini and Engaruka Juu.

Within the landscape today, modern agropastoralists benefit from the reliability of mixed agriculture and a constant water supply that originates from the perennial Engaruka River, and farmers occupying the modern Engaruka villages cultivate a mixture of crops, which include sorghum, finger millet, lablab, tomatoes, castor bean, tobacco, maize and bananas. This cultivation of a range of crops is a common feature of farming systems in eastern Africa both today and in the past, and despite the fact that sorghum was the only crop encountered during previous excavations at Engaruka (Sassoon 1967, 207) researchers have been hesitant to accept that the pre-colonial farmers at Engaruka practiced sorghum monoculture (Sutton 1978, 57). It is an unlikely explanation for the demise of the system, especially given that there are no ethnographic examples of agronomies relying on a single cultivar prior to the development of agricultural mechanization. Moreover, the decision to invest the labour input necessary for the manipulation of the landscape in order to make it hospitable to any type of agriculture is inconsistent with the limiting choice of monoculture. Rather than providing a satisfactory solution to the question of why the system collapsed, the potential outcome of accepting such an explanation would inevitably lead to further questions about the logic of adapting such a method given the evidence. The population simply would not have been able to survive the shocks, which are known to have occurred during Engaruka's occupation (e.g. Westerberg et al. 2010) if monocropping based on sorghum was their primary mode of subsistence. Furthermore, it is difficult to rationalise the justification of labour and resource allocation needed to engineer such an elaborate irrigation system for a single crop.

Current rainfall averages and past climate fluctuations further complicate arguments regarding the sustainability of the system. Site occupation spanned from the 15th to mid-18th century (Sutton 2000; Seitsonen 2005) and possible as early as the late 13th century (Sassoon 1966). Lake level changes and pollen records at Emakat Lake (Ryner,Holmgren and Taylor 2008), 15 km away from Engaruka, suggest that between c. AD 1500 and 1670 the local environment was much drier than the current semi-arid conditions. This suggests that the local inhabitants may have endured and adapted to agriculturally challenging climatic conditions without causing cultural or ecological upheaval. Westerberg et al. (2010) argue that these revelations have the potential to recast the Engarukans as an environmentally resilient people who survived and perhaps even thrived through periodic shocks to their way of life. However, while pollen records reported by Ryner et al. (2008) tell us something of the changing environment at this time, such changes cannot be directly related to the agronomy at Engaruka without an understanding of the crops cultivated.

The Nature of Intensive Agriculture in Eastern Africa

Since both Engaruka and Konso are landscapes featuring both agricultural terracing and irrigation structures, this brief section will focus on what Widgren and Sutton (2004) have termed “islands of intensive agriculture” in eastern Africa: i.e. small areas of apparently labour intensive cultivation systems within a broader ‘sea’ of more expansive agriculture. However, a detailed summary of all of these ‘islands’ will not be presented, for which see Adams and Anderson (1988), Grove and Sutton (1989), and Stump (Stump 2006b, 2016). Instead, the aim here is to use these systems as historic and modern analogies to illustrate the complexity of agricultural management that are not reflected in either the archaeobotanical or historical sources, with a particular focus on the practice of intercropping.

Having noted that Engaruka is not the only abandoned agricultural system in this part of Tanzania it should be stressed that it is by far the largest terraced and irrigated landscape in Eastern Africa to have been systematically abandoned prior to exploration by the first European travellers who arrived in the mid-19th century. The size of the site thus offers important opportunities to examine how this system changed through time, with the focus of the current thesis being potential changes in crops cultivated.

In the final section of this chapter I will summarise the strengths and weaknesses of using historical accounts to help predict the crops that may have been grown in locations such as Engaruka prior to the 19th-century. However, before doing this it is also worth reviewing 20th-century accounts of east African agriculture. This is because of an evident weakness in the 19th-century sources, which often list crops grown but rarely provide details on how they were cultivated.

The following section is comprised of summaries of what is known of agricultural sites that are analogous to Engaruka, based on ethnographic accounts and studies carried out by historians based on primary sources. Communities relevant to the current study include the those of the Batemi (Sonjo) and Iraqw, those of the so-called Kilimanjaro ‘cluster’ (Chagga, Pare, Usambara, Meru, Arusha) or Ukara Island, or Konso due to use of similar technologies including terraces and irrigation.

An important method of cultivation that is hinted at but not discussed in the 19th-century sources is the common practice of intercropping, i.e. the growing of two or more crops interspersed in a single plot. Described by Richards (1985) as akin to polyrhythmic drumming in terms of Africa’s unique contribution to world culture, intercropping has several advantages over concentrating on one crop, or even on rotating several crops over successive years. Although to do so limits the potentially higher yields than can be gleaned by focusing on a single cultivar, the planting of multiple crops in an individual plot can create disease breaks, allow one crop to provide shade for another, combine nitrogen fixing plants with nitrogen extracting crops, provide structure with one plant required by another climbing plants, and or use one plant as a green manure to provide nutrients for another (e.g. Amborn 1989: 78-9 on Konso, cited by Stump 2006b). Perhaps more importantly, intercropping creates flexibility during the cropping season, allowing farmers to adapt their strategy during the growing season, for example by removing low-yielding but drought tolerant crops in wet years, or weeding out ‘thirsty’ plants in dry years. The potential importance of this last strategy will be returned to below in reference to modern agriculture at Konso, but it is clear from the more detailed 20th-century ethnographic and agronomic studies that this approach formed part of risk mitigation strategies in several east African rural economies and is likely to have influenced the sustainability and resilience of agricultural systems in pre-colonial eastern Africa.

The Engaruka Complex and Sonjo

The archaeological site of Engaruka is the largest of a series of sites identified on the basis of stone- lined furrows and fields, referred to as the Engaruka Complex by Sutton (Sutton 1986, 1978). In addition to Engaruka, the Engaruka Complex includes the sites of Mto wa Mbu to the north of Lake Manyara; Oldogom, Olpiro and Endamaga to the immediate north of Lake Eyasi, and Enguroto, the most northerly of the site in the Complex located to the south-east of Lake Natron (see Figure 3). Each of the sites feature agricultural terraces and irrigation furrows thereby indicating a relationship with the Engarukan agronomy (Sutton 2000).

There are other sites in the region with similar features could also be part of the Engaruka Complex (Sutton 1986), but continued agricultural use of the sites makes it difficult to establish the antiquity of the features. Chittick (1974; cited in Sutton 1990), who first reported on Enguroto, also observed irrigation furrows at Peniñ (Peninyi) to the west of Lake Natron in an area that has been used for much of the last 100 years by the local Batemi community, a cushitic group popularly known as Sonjo, a commonly used identifier afforded to them by the Maasai. More of these features at the Batemi villages of Sale and Oldonyo

Sambu, further indicate that this culture may have links to the Engaruka Complex (Sutton 1993b, 1986), and thus Engaruka itself.

Furthermore, a linguistic argument exists relating to the question of whether the Sonjo and the Engarukans existed at the same time and interacted, resulting in shared use of words relating to agriculture (Sutton 1990, 54, 1993a). Stump (2006b), however, regards this argument as speculative given that the language spoken by the Engaruka community is unknown. In point of fact, the non-lingustic evidence for a possible kinship (either cultural or economic) between the Batemi and the ancient Engarukans is compelling enough on its own, but not without significant gaps. The center of the Sonjo region is situated to the west of Lake Natron and roughly 80 aerial kilometers from Engaruka. By the 19th century, a caravan route passed nearby (Figure 4) and prior to that the distance was not insurmountable for there to have been interaction between the two groups. Unfortunately, the possibility of even a temporal overlap between the groups is not well evidenced given that the Batemi occupation of the region has not been directly dated. Similarities that are acknowledged are based on the fact that the Batemi live in nucleated terrace villages and practice a form of mixed agriculture that is very much akin to Engaruka. It is characterized by intercropping of sorghum (the dominant crop), with other millets, and sweet potato, in irrigated and rainfed fields, as well as limited stock keeping in stalls (Gray 1963). Future research, discussed in Chapter 7, will seek to fill these gaps by incorporating ethnobotanical case studies comparing and contrasting the agricultural practice of modern Batemi farmers and Maasai farmers at Engaruka with the archaeobotanical conclusions revealed in the current study.

Iraqw

Modern agriculturalists at Iraqw'ar Da'wa – a community located approximately 50km to the south of Engaruka, employ agricultural terracing and drainage irrigation, and practice the cultivation of sorghum, *Eleusine*, *Pennisetum* (bulrush or pearl millet), wheat, and cassava alongside numerous vegetables. Intercropping of maize and beans occurs in valley plots and tobacco and coffee are planted on hillside fields as cash crops together with edible species (Börjeson 2004, 77).

Ukara Island

Intercropping was also a key element of cultivation on Ukara Island located towards the southeast corner of Lake Nyanza, though it has also been cited as an example of overly intensive agriculture (Koponen 1988). Netting (1993, 52) argued that growing population density may have pressured the community to intensify production through the implementation of continuous intercropping (pearl millet with Bambara ground nut), crop rotation, canal irrigation (principally for rice), gully planting of Euphorbia for the prevention of soil loss (Stump 2006b, citing Ludwig 1968, 120; Thornton and Rounce 1936, 31).

This small island is reported as being entirely covered with agricultural plots in the late 19th century (von Schwienitz and Krain 1893: 483, cited by Koponen 1988, 235), and by the early 20th century included dry-stone agricultural terraces up to 2m high, irrigation networks, and the artificial revetment of streams (Thornton and Rounce 1936, 31). By the early 20th century the islanders practiced year-round intensive agriculture, with the main food crop being *Pennisetum*, closely followed by Bambara groundnuts (*Voandzeia subterranean*), and supplemented with sorghum and cassava (Thornton and Rounce 1936; Ludwig 1968, cited by Stump 2006b). Two indigenous legumes, *Crotalaria striata* and *Tephrosia* sp., were interspersed with *Pennisetum* and tilled into the soil once they had reached maturity at eight or nine months old (after the grain was harvested), acting as a green manure for the next planting (Thornton and Rounce 1936). Some indigenous weeds were also allowed to grow for the same reason (ibid.) – a point retuned to below in reference to weed assemblages recovered by the current study at Engaruka. Following the harvest of the millet crop, sweet potatoes were often planted as a cash crop while rice was grown in fertile river valleys irrigated by damming streams. Interestingly, the rice was seeded in nursery beds and later transplanted (ibid.).

Located towards the northeastern extent of Lake Nyanza in what is now Kenya, the islands of Mfangano and Rushinga provide further examples of intercropping within agricultural systems that include terracing and irrigation, with the most complex system of intercropping employed in lakeside localities. Conelly (1994) notes intercropping of maize, sorghum, cassava, sweet potatoes, sugar cane, bananas, fruit trees and multiple vegetables in these favourable lakeside locations. Indeed, on Rushinga, even agricultural plots that are described locally as grain fields are reported by Conelly (1994: 160) as being planted with a combination of sorghum and cowpeas, or sorghum, maize and cowpeas, with fodder species and weeds also grown or tolerated within crop fields to provide shade or act as green manure. To return to a theme discussed in the preceding section, Rushinga thus demonstrates the importance of African domesticates for local economies well into the late 20th century, but the reference to intercropping also demonstrates the complexity of farming practices. This complexity cannot be inferred from archaeobotanical assemblages of crops alone, and thus highlights the need to combine archaeological studies with information drawn from historical, ethnographic and ethnobotanical studies.

The Kilimanjaro Cluster

Furrow and irrigation systems exist at sites throughout the Kilimanjaro region, in South Pare and in the Usambara mountains. It is known that banana cultivation began around 1000 years ago (De Langhe et al. 1995), though since the region receives enough rain to support them that it is unlikely that the furrows were built solely for that purpose. Dating the introduction of the furrow system would aid in understanding the agricultural adaptations in use, however sub-regional variability has complicated matters. Linguistic evidence drawn from Stahl's (1964) oral histories was used to argue that irrigation began when the settlements were founded in the 16th and 17th centuries (Masao 1974). Tagseth (2004), however, rejected the dating formula and argued that it did not take into account practice variability among the clans that occupy the region.

Intercropping practices supported by irrigation and cattle keeping (Kimamabo 1996a, 74, Spear 1997, 27) allowed for the production of surplus, which in turn, later allowed for the development of market economies in the Chagga chiefdoms of Kilema and Machame (Rebmann, 1848, cited by Stahl 1964), in South Pare (Kirsten 1869,25 and 71, cited by Håkansson 1995, 305), and in North Pare (von der Decken 1978 [1871], 17, cited in Sheridan 2002, 83). The markets allowed the region to benefit from the caravan trade, whose routes were well-established in the region by the 19th century (Stump 2006b, Sutton 1991).

Terraces and irrigation furrows in North and South Pare were cultivated until at least the 1980s, when the practice began to decline (Sutton 1985) and for some signaled a reduction in productivity (Kimambo 1991, 141), though in recent years Tagseth (2008) has described the maintenance and expansion of the irrigation system as still quite active.

Contributions of Previous Konso Research

The importance of including ethnobotanical data and insights from observations and interviews with modern farmers at Konso forms an important aspect of the current thesis. In terms of the legacy of research, Konso represents a meaningful contrast to Engaruka. While Engaruka has been the subject of nearly a century of archaeological work, the traditional agriculture still practiced throughout the Konso region has been studied heavily by agronomists and anthropologists, with relatively little archaeology having been undertaken. This fascinating and still functioning traditional system of irrigated terrace agriculture has been recorded by ethnographers and archaeologists targeting different aspects of past and present ways of life. The most relevant research is summarised briefly. Hallpike (1970, 2008 [1972]) produced very detailed research through traditional ethnographic studies of Konso culture. Watson (2009) looked at the political and social conditions that supported the sustainability of the traditional system of agriculture. Beshah (2003) focused on indigenous water management. Amborn (2008) has explored the relationship between land use and socio-political aspects of intensive agriculture. Ethnobotanical studies of the plant genetic resources, living plant material that is of real or potential human value, of the Konso Agronomy were carried out by Engels and Goettsch (1991) and Menfese (2010) has looked at the use of trees as an adaptive agricultural strategy. Addis et al. (2013b, 2013a) have explored the impacts of wild and semi-wild edible plants on food sovereignty.

The scope of previous archaeological enquiry has been much more limited than the ethnographic studies, placing more focus on traditional material culture rather than the environment-focused methodologies in which the researchers of the AAREA project specialise. Kimura (2004) carried out a spatial analysis of Konso settlements in order to establish a culture history focused on spatial and political hierarchies. Arthur (Arthur 2010) spearheaded an ethnoarchaeological study of gender based on Konso women who manufacture flaked stone tools for hide-working. Conversely, the AAREA research that has been published thus far by Ferro-Vázquez et al (2017) integrates archaeology and soil science with existing policy and development narratives, to interrogate and present the potential for archaeology to inform real-world problems.

Archaeobotanical Evidence for Crop Repertoires During the East African Iron Age

There are significant gaps in the record of crops and the development of agricultural systems in East Africa (cf. Walshaw 2005, 2010, 2015b), and the sparsity increases as we move inland from the coast. Accounts of the agricultural development and tradition in this region have largely relied upon interpretations of historical linguistics and assumptions about the relationship between archaeological culture complexes and the spread of agropastoralist groups (Philippson and Bahuchet 1994, 103–120). Unfortunately, solid archaeological evidence is lacking for the presence of certain crops in particular regions and periods making it difficult to confirm these assumed cultural associations. However, in broad terms, evidence for the domestication of African wild plants is well attested and is relevant to the current review because indigenous domesticates remained the mainstay of inland east African arable economies well into the 19th century. Understanding their domestication and spread is thus important to the current discussion as it helps explain the social and economic environments to which they were adapted, and thus their continued cultivation.

Domestication Syndromes in Cereals and Pulses

2 Crop Repertoires

In order to identify the earliest instances of a given crop, it is necessary to establish the traits that distinguish domesticated forms from wild progenitors. Domestication is the adaptive process by which a wild plant (in this case) evolves over time, usually by selective breeding, into a form that is beneficial-- and thus preferential-- to humans. While the discussion which follows this section refers to a variety of crop types, the current study is preoccupied with the cereal and legumes recovered during macrobotanical analysis of the Konso and Engaruka assemblages. As a result, here I discuss the array of phenotypical attributes, known as a domestication syndrome, that are selected for during the process of domestication, under the conditions of cultivation. Cultivation in plants involves the deliberate management of wild or domesticated taxa for human use. Domestication syndromes provide the criteria by which archaeobotanists can distinguish wild and domesticated taxa in their assemblages (Zohary and Hopf, 2000; Harlan et al., 1973). However, the process of trait selection varies based on differing patterns of cultivation and domestication, so domestication traits are not associated with the same morphological features across all taxa.

The most visible traits amongst domesticated crops are the increase in seed size in cereals and the loss of natural seed dispersal in cereals and legumes. In cereals, these traits were selected for as humans preferred to cultivate (manage and harvest) larger grains that remained attached to the plants (non-shattering varieties), rather than collecting small seeds that fell to the ground during natural dispersal. With humans boosting the propagation of grains with these characteristics, distinct populations came into existence that early humans could reliably harvest. Eventually the practice of storing and sharing seeds developed as agricultural practice formalized within a given community and seeds with a consistent set of domestication traits began to be traded between groups as well, often travelling great distances across oceans, mountain ranges, and entire continents.

Amongst the cereals and pulses there exist a few distinct domestication traits that archaeobotanists can use for identification purposes. In grains (except pearl millet), for instance, it is known that grain size selection evolved one or two millenia before non-shattering ears and panicles, while in pulse domestication seed size does not seem to have been the earliest selected trait (Fuller 2007, 1). In addition to methods of harvest, traits can also arise as a result of preference for specific soil conditions and techniques used in crop processing, such as threshing and winnowing.

Fuller (2007) identifies six criteria for the domestication syndrome of grain crops:

1. Elimination/reduction of natural seed dispersal
2. Reduction in seed dispersal aids
3. Trends towards increasing seed/fruit size
4. Loss of germination inhibition
5. Synchronous tillering and ripening

6. More compact growth habit

Each of these traits benefits the propagation of a given crop given the preferences and resulting agricultural practices of a farmer. This is a trade-off, because the plant can no longer survive on its own without human interference, but the plant is cared for and encouraged through each of its life stages, and this is ensured for subsequent generations as well. The first trait, eliminating or reducing natural dispersal, is the most fundamental hallmark of domestication, affecting both grains and legumes. Archaeobotanists can identify this trait through the analysis of chaff, including rachises and spikelet bases and the basis of smooth rip scarring where the seed separated easily from the inflorescence as is the case with free threshing (wild) grain. The second trait, reducing seed dispersal aids, is the result of a reduction the selection for characteristics that promote wild dispersal and propagation. In grasses, domesticated forms are more smooth and less aerodynamic than their wild counterparts (see Hillman and Davies, 1990). It can be difficult to distinguish charred seeds on this basis because hairs are usually lost in the process. The third trait, an increase in fruit and seed size, is an early indicator of semi-domestication used by archaeobotanists (Fuller 2007) and may have come about as a response to deep burial during planting (Maranon and Grubb 1993) and increased viability of larger seedlings (Baskin and Baskin 2001). The fourth trait, loss of germination inhibition, refers to the seed no longer waiting for precise conditions to germinate. This trait is archaeologically visible in the form of thinning of the seed coat in domesticated varieties. However, the means of preservation of the seed, especially charring, do not often leave the seed coat intact, so other traits must be identified. The fifth trait, synchronous tillering and ripening, is result of preference for seeds of plants that have been subjected to discreet and non-overlapping periods of planting and harvest, so that the entire crop is brought in all at once on an annual schedule (Fuller 2007). The final trait, a more compact growth habit, like the non-shattering trait, makes the seed easier to harvest and thus preferred.

The traits that distinguish domesticated sorghum, sorghum bicolor, from its wild progenitor include visibly rough rip scars in spikelet bases and larger grain size. The characteristics like this came about due to the processing practices used by humans who harvested the shattering variety of wild sorghum, which involved extra labour to remove the husk and winnow the grain before it was suitable for use. Additionally, increased grain size and dense panicles would have increased crop yield.

Domestication status of archaeological sorghum can best be established by looking at the chaff rather than the seed itself because the characteristic rip scar is a straightforward indicator

Fuller and Stevens (2018) have identified three types of diagnostic spikelet bases:

1. Shattering wild types with smooth scars.
2. Those with rachilla still attached are most frequent in domesticated populations.

3. Domesticated types with “rip scars”, with a torn base and rachilla absent.

In addition to the increase in size and condition of spikelet bases, Fuller and Stevens (2007) identify the potential shortening or complete loss of awns (Adunga and Bekele 2013) that might be associated with sorghum domestication.

The domestication of cowpeas, the second most important crop in the context of the current study, is a more complicated to see in archaeobotanical specimens. It is grown extensively across Africa and persists in challenging environments, providing a nutritious and environmentally hardy protein source for humans and cattle, alike. Cowpea*, Vigna unguiculate*, is a popular choice for intercropping with sorghum and pearl millet. Ng (1995, 329) has argued that the selection of indehiscent pods in domesticated cowpea was the result of its initial use as animal fodder as herders would uproot the entire plant and thus bestowing selective preference on seeds held within pods that remained closed and securely affixed to the plant. Later planting for human consumption motivated the additional selection of reduced seed dormancy and larger seeds and pods. Unfortunately, these characteristics are not usually visible in archaeobotanical specimens and further complicating matters is the wide distribution of its wild progenitor, as well as morphological variability resulting from hybridization (Ba et al. 2004). Archaeobotanists often overcome these issues through consideration of the contexts from which the specimens originate and the conditions which preserved them. Charred legumes found in a hearth, for instance, are very likely to be domesticated.

A key takeaway of this discussion is the importance of understanding how crops are processed and ethnography is a powerful tool for achieving this (Harvey and Fuller 2005, Hastorf 1988, Jones 1987, Hillman 1984). This is why ethnobotanical methods (detailed in Chapter 3) were employed so extensively at Konso.

Domestication and Spread of African Crops

The three major native East African cereals, sorghum, pearl millet, and finger millet are geographically distinct with regard to origins. Sorghum (*Sorghum bicolor*) was first domesticated by the fourth millenium B.C. in the savannas of north Africa, with current evidence pointing to Chad, Sudan or Ethiopia (Fuller 2003; Stemler,Harlan and de Wet 1975; Snowden 1936). Recent research by Fuller and Stevens (2018) has pinpointed the earliest date more than 3000 years BC in the eastern Sudan near the Atbara and Gash rivers. Despite the discovery of these early finds, the evidence of the process of domestication and early cultivation remains unknown, though this recent research has made significant headway towards understanding early domestication, as well as the evolution and geographical dispersal of the sorghum races. The study reviewed and mapped archaeobotanical finds from 113 sites, identifying 16 probable morphological races of sorghum on the basis of archaeobotanical and genetic data. Following Sudanese domestication, race bicolor emerged in South Asia at around 2000 B.C. and reappears in Africa in the Niger Basin post 1000 BC

(Champion and Fuller 2018). The original race of domesticated sorghum, like most early grains, has tight husks surrounding the grain that must be removed during processing. Subsequent races of sorghum, including race “caudatum” found at both Engaruka and Konso, were selected for free-threshing and larger-grains, thus simplifying processing and increasing yield. Caudatum is currently believed to have been selected from two races: ‘durra’, the Sahelian variety that first emerged in India (Fuller, in press), and the forest race ‘guinea’ from West Africa. The latter went on to produce ‘mageritiferum’, an ancestor of the guinea and ‘kafir’ races of southern Africa. This evidence points to a savannah dispersal pattern for eastern African sorghums (bicolor and caudatum) and dispersal via the central African rainforests for the southern African varieties. The guinea types are inferred to have taken place from southeastern Africa across the Indian Ocean.

Pearl millet (*Pennisetum glaucum*) originated in the west African Sahel (Brunken,De Wet and Harlan 1977; Fuller 2003; Kahlheber and Neumann 2007). Domesticated pearl millet has been identified in Northeast Mali from the latter half of the third millennium BC (Manning et al. 2011). By 2000 B.C, pearl millet and sorghum were fully integrated into agronomies of modern day India (Fuller and Boivin 2009). Evidence from India is significant here, in part because it fills gaps in the African chronology, though Boivin *et al.* (Boivin et al. 2014) (and most other researchers) recognize that this gap is the result of a low number of excavated sites, rather than a legitimate absence. Until recently, Sudanese sorghum was dated only as far back as the fifteenth century B.C.

(Beldados and Costantini 2014; Fuller 2011) and Boivin et al. (2014) stated that evidence of pearl millet, domesticated sorghum, and cowpea did not appear in northwestern Africa until after they are recorded in India (by 1700 BC). Prior to this, Haaland (1999) argued that sorghum could have been moved as a wild plant from Africa to India where it was domesticated, and then re-introduced to Africa in the first millennium BC. However, a recent study (Winchell et al. 2017) of chaff impression in ceramic sherds from fourth millenium B.C. Kassala in the far eastern Sahel region of Sudan has identified wild and domesticated sorghum, thus pushing back the start of cultivation well before the earliest appearance in India. Both sorghum and pearl millet reached southern Africa by the second half of the first millennium AD (Mitchell 2002; Manning et al. 2011).

Together, sorghum, pearl millet and finger millet can be referred to as the pan-African cereals, as all evidently spread from their respective centres of domestication to be grown across the entire continent. The spread of the pan-African cereals throughout East Africa may have been directly associated with the migration of Bantu-speaking agriculturalists, though whether this reflects the migration of people or the spread of language and technology continues to be debated (Boivin et al. 2014, citing Holden 2002). The majority of the early evidence for cereal crop dispersal comes from the first millennium AD and onwards, which supports the plausibility of a Bantu dispersal of cereal farming in eastern Africa as this broadly coincides with the spread of Bantu languages and associated farming technologies. Indigenous African crops and domesticates were essential during the earliest phases of agriculture in the region and continue to feature prominently in modern farming strategies. The most important of these taxa, as featured in Boivin *et al.*(2013), are the three pan-African cereals: three beans (cowpea, Bambara groundnut, and hyacinth bean), and a variety of starchy domesticated underground plant food storage organs, including indigenous African yams and ensete.

Finger millet (*Eleusine coracana*) was originally cultivated between the Ethiopian highlands and the Great Lakes region of East Africa. Unfortunately, these data have not advanced significantly since Harlan's (1971) original analysis. *Eleusine africana*, its wild progenitor is distributed across Africa (Hilu and De Wet 1976b; de Wet et al. 1984) and the earliest domesticated types come from the 1st to 2nd century AD at Ona Nagast in Ethiopia (D'Andrea 2008) and at Kursakata in Nigeria (Klee,Zach and Neumann 2000). Finger millet became widespread from the 8th century AD (Giblin and Fuller 2011; see also Walshaw and Stoetzel 2017). Finger millet appeared in East Africa at Deloraine, Kenya by the ninth century cal AD (Ambrose and Collett 1984, 79–104).

The three major legumes that originated in Africa are cowpea, Hyacinth bean, and bambara groundnut. The cowpea (*Vigna unguiculata*), the most widespread of these crops, was domesticated in West Africa (Fuller 2003), but, like finger millet, its wild progenitor is found across sub-Saharan Africa (Feleke,Pasquet and Gepts 2006; Ba,Pasquet and Gepts 2004). The earliest specimens from Eastern Africa date to the first few centuries of the common era. Notably, cowpea is absent along the East African coast, though late fifteenth century cowpea may have been recovered from Madagascar (Wetterstrom and Wright 2007).

Cowpea and bambara groundnut have been reported from 7th–9th centuries AD Zimbabwean sites, such as Lanlory and Leopard's Kopje (Huffman 1979). The bambara groundnut (*Voandzeia subterranea*) originated in West-Central Africa. It was traditionally cultivated on Madagascar, but it has been replaced there and across East Africa by peanuts from South America. Hyacinth bean (*Lablab purpureus*) originates in East Africa and was initially cultivated in Ethiopia (Maass et al. 2005). It is part of the modern crop repertoire at Engaruka, but it is not widely eaten by the local Maasai agropastoralists who cultivate it, because it is considered to be a food for the poor (see Chapter 6 for further discussion). Interestingly, there is no evidence of hyacinth bean or bambara groundnut at any mainland coastal East African site.

The Baobab (*Adansonia digitata*), a common feature of the landscape at Engaruka, was introduced to East Africa from the savannas of West Africa. Indeed, the baobab tree is quite significant culturally and economically across the savanna regions of Africa. The pods, which encase the edible fruit and seeds, have been regarded as an easy to pack food source for mobile pastoralists (Blench 2007). The fruit is often dried and stored and/or used to make beverages (Baum 1995; Wickens 1982). Baobab utilisation in West Africa has been associated with early pearl millet cultivation at around 1000 BC and it appears in Senegal in the mid- first millennium AD (Murray 2007). The earliest evidence of its arrival in East Africa manifested as seed fragments and a pod rind from Mgombani and Panga ya Saidi along the Kenyan coast (Helm et al. 2012) and on the Swahili Coastal islands of Pemba (Walshaw 2010, 2015b) and Zanzibar (Crowther et al. 2016).

Through this review it can be concluded that these crops would be expected at Engaruka and Konso. Sorghum and pearl millet would certainly be expected – even without its tentative identification at the site by Sassoon (1967) – and given that these cereals are commonly found on late Iron Age sites in association with cowpea, the latter would be expected too. However, since it is known that Engaruka was occupied from at least the 14th century AD (e.g. Westerberg et al. 2010), it is also possible that the occupants cultivated introduced crops, several of which are well evidenced by this time on the east African coast. It is thus necessary to also review this evidence, and to assess the likelihood that one or more of these crops could have spread inland as far as Engaruka.

Ethnobotany of the East African Coast and the Introduction of Non-African Crops

Harbours scattered along the coast of East Africa were busy ports of entry for a variety of South Asian botanical species that would become vital to the development of agriculture and species diversity on the continent. Evidence for the dates of crop arrivals along the coast is therefore valuable to the current study because it helps to shrink or expand the range of exotic crops available to inland agriculturalists, like those at Engaruka.

Before undertaking this analysis, however, it should be stipulated that the earliest direct evidence of agricultural domesticates from the east African coast is of African crops rather than introduced species. Sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and finger millet (*Eleusine coracana*) were unearthed in addition to legume seeds from Vigna sp. and seeds of the baobab tree (*Adansonia digitata*) from the Kenyan coastal sites of Mgombani and Panga ya Saidi, demonstrating that these were consumed and probably cultivated in the 7th century AD and certainly by the Middle Iron Age (Helm et al. 2012, 55) - though as a caveat it should be noted that due to the coastal location and morphological similarities it is possible that finds of Vigna sp. are one of the Asiatic varieties. Sorghum and finger millet have also been conditionally reported from the 7th century along the southern Mozambique coast at Chibuene (Ekblom 2004). This early presence along the coast and this far south lend support to the idea that sorghum and millet agriculture was well established in the East African interior by the time Engaruka was occupied.

Archaeobotanical evidence also indicates that African/Bantu agriculture was introduced to the islands off the coast of East Africa prior to the arrival of any Asian agricultural influence. The three pan-African cereals appear in the earliest levels at the site of Tumbe on Pemba Island by the 7th century AD (Walshaw 2005, 2010). They are also found in the 7th to 9th century levels at Unguja Ukuu on Unguja (i.e. Zanzibar) Island and in the 1st to early 2nd millennium in the Mikindani, southern Tanzania (Pawlowicz 2011, 282). While finger millet has not been found at Zanzibar (Crowther et al. 2010), evidence for the African crops at sites in southeastern Africa either predates or is contemporaneous with the east African coast, including the recovery of finger millet at Kadzi River in Zimbabwe in the 5th century AD (Boivin et al. 2013 citing Jonsson 1998 and Pwiti 1996). Pearl millet dating to the 4th century AD has been found at Silverleaves in South Africa (Klapwijk 1974, 22) (though is referred to as *Pennisetum americanum* by this source), and 7th-century AD sorghum was recovered from Nampula in Mozambique. At Magogo in South Africa, sorghum, pearl millet and finger millet were found in 6th–7th century AD contexts (Maggs and Ward 1984, 127).

The current consensus is thus that African crops had arrived on the east coast by the 7th century AD, but direct evidence remains scarce. More recent finds of the African domesticates of more recent date at sites from this region are also sparse. Pearl millet (n=1) was recovered from the 8th–10th century site of Kimimba on Pemba island (Walshaw 2005). Sorghum was found in an 11th–12th century house floor deposit at Kilwa (Chittick 1974, 52). All three African crops were found at Swahili sites: 11th–15th century Chwaka on Pemba (Walshaw 2010, 143), in the early 2nd millennium in the Mikindani region (Pawlowicz 2011, 282), and at the late 14th to early 16th-century site of Songo Mnara (Walshaw and Pistor 2011, 5).

Interestingly, archaeobotanical finds of the pan-African cereals from coastal sites dating to the 7th to 15th centuries occur outside the range of their modern cultivation, especially in the case of finger millet, which by the late 20th century was restricted to more interior and upland zones of Africa, as mapped by Hilu and De Wet (1976a). This is no doubt due to these crops giving way to introduced species on the coast. On Pemba island, for example, the importance of African cereals declined with the rise of Asian crops – rice (*Oryza sativa*) and mung bean (*Vigna radiata*) - from around the 11th century AD (Walshaw 2010). Current cultivation practices today have been heavily transformed by the spread of maize (mainly since the 19th century AD – see below) and by tree plantation crops, of which the most important in subsistence terms is undoubtedly the banana (*Musa sapientum*). This shift from agricultural economies based on African crop species to economies in which non-African crops predominate is also reflected in the archaeobotany of sites on the mainland east African coast. For example, at the sites of Amathwoya, Makaroboi and Koromio on the Kenyan coast maize (*Zea mays*) dominates archaeobotanical assemblages dating to the 19th century, and was evidently grown alongside other Asian crops including rice and coconut, though African domesticates of sorghum and baobab continued to be cultivated (Marshall and Kiriama 2017; Walshaw and Stoetzel 2017 citing Marshall 2011).

In summary, the presence and increasing dominance of non-African crops in coastal east Africa from the 7th century onwards demonstrates that these crops could have been cultivated at Engaruka from the earliest days of its occupation. However, direct archaeobotanical evidence for the spread of imported crops into the interior during this period is lacking, and it is thus necessary to review later historical sources to assess the likelihood of their recovery at Engaruka.

The Inland Spread of Non-African Crops

In terms of archaeobotany, there is very limited direct physical evidence of the cultivation of non-African crops in the interior of east Africa before the 19th century. In a recent review of archaeobotanical data, Boivin et al. (2013, 215-6, Table 1) note no records of Asiatic rice, mung bean, coconut or mangos from inland locations, although this review also highlights the high potential for a sampling bias since there has been far more archaeobotanical research on the coast than in the interior. For the interior of eastern Africa the only reported banana phytoliths are from sediment cores from Munsa, Uganda, for which Lejju et al. (2006) reported dates of 3200-2000 cal BC, dates which Boivin et al. (2013, 257) regard as "certainly dubious", with Neumann and Hildebrand (2009, 356–358) further concluding that the Munsa phytoliths are too ambiguous to be confirmed as *Musa*. Iles (2009) identified plant impressions on ironworking slag as being banana pseudostems, but the dated examples are comparatively late, dating to the 18th-19th centuries. Although the uptake of maize was evidently very rapid during the 19th and 20th centuries, maize appears to have not been widely cultivated until European colonialism in the 19th century (Feierman 1990; McCann 2005). Indeed, archaeobotanical evidence of the crop remains limited before the 19th century, even in coastal locations (Walshaw and Stoetzel 2017).

Despite the very sparse archaeobotanical data, several cases have nevertheless been made for the cultivation of banana and plantains (both hybrids of the species *Musa paradisiaca*) in the east African interior for over a millennium. Schoenbrun (1993, 1998) employs a primarily linguistic argument supported by archaeological data to argue that specialised banana cultivation was in place to the immediate northwest of Lake Nyanza (Lake Victoria) by AD 800, while Blench (2009) uses historical linguistics and the recovery of late 1st millennium BC banana phytoliths from Cameroon (Mbida et al. 2000) to argue that banana formed part of the Iron Age Bantu crop repertoire and thus spread across sub-Saharan Africa alongside the pan-African cereals and vigna. Based on the number of species variants on modern Kilimanjaro, Tanzania, and within the neighbouring Pare mountains, De Langhe et al. (1995) make a similar argument regarding Bantu crop repertoires, and suggests that banana cultivation in these Tanzanian highlands could be at least 1000 years old (see also De Langhe 2007). If these related hypotheses are correct in the assertion that bananas were a common part of the Iron Age crop repertoire we might expect to find evidence of banana cultivation at Engaruka, and indeed the plant is commonly grown in household gardens at modern Engaruka, as well as within some irrigated plantations. This suggests the crop is well suited to this environment, especially with supplementary irrigation.

Even without archaeobotanical corroboration of the early dates estimated by Blench and De Lange it is nevertheless clear from both archaeological and historical sources that the Kingdom of Buganda in what is now Uganda was well established and based on specialised banana cultivation by the 17th century AD (Reid 2001, 2003). Indeed, by the time the British explorer John Hanning Speke arrived in 1856 the kingdom had a centralised capital and a system of regional governors (Reid 2003). Bananas were thus certainly being cultivated in the region at the time of Engaruka's occupation, though information of this sort provides merely the possibility of its cultivation at Engaruka rather than any information on likelihood. Given the sparse and sometimes ambiguous archaeobotanical data for non-African crops it is nevertheless instructive to undertake a broader review of examples of these later historical sources since these at least provide information on the spread of non-African crops inland by the time of the first European accounts in the mid- to late 19th century.

For example, the highlands of the Usambara Mountains, in what is now Tanzania, were visited by the Reverend Charles New in 1874 (1875), by the Reverend J. P. Farler (1879) and by the explorer Keith Johnston (1879), with the latter's *Notes on a Trip from Zanzibar to Usambara* intended to complement Farler's recent account with detailed geographical data (Figure 5). Although a relatively short distance from the Swahili coast (Figure 5) and an established supply location for trade caravans from at least the 18th century (Feierman 1990; Conte 2004), all three European travellers note the cultivation of both African and non-African crops, a contrast with the shift to non-African crops on the coast recorded in these same accounts and corroborated by the archaeobotanical data summarised above. New (1875, 418) marched from Pangani to Vuga through the Usambara Mountains to reach Mombasa, and reported that two non-African crops - maize and plantains - were the primary cultivated and consumed staples of the Wasambara peoples of Usambara. A local 'king' gifted him a basket of the local ginger, which was both wild and cultivated locally. He further noted that coconut palms were absent from the

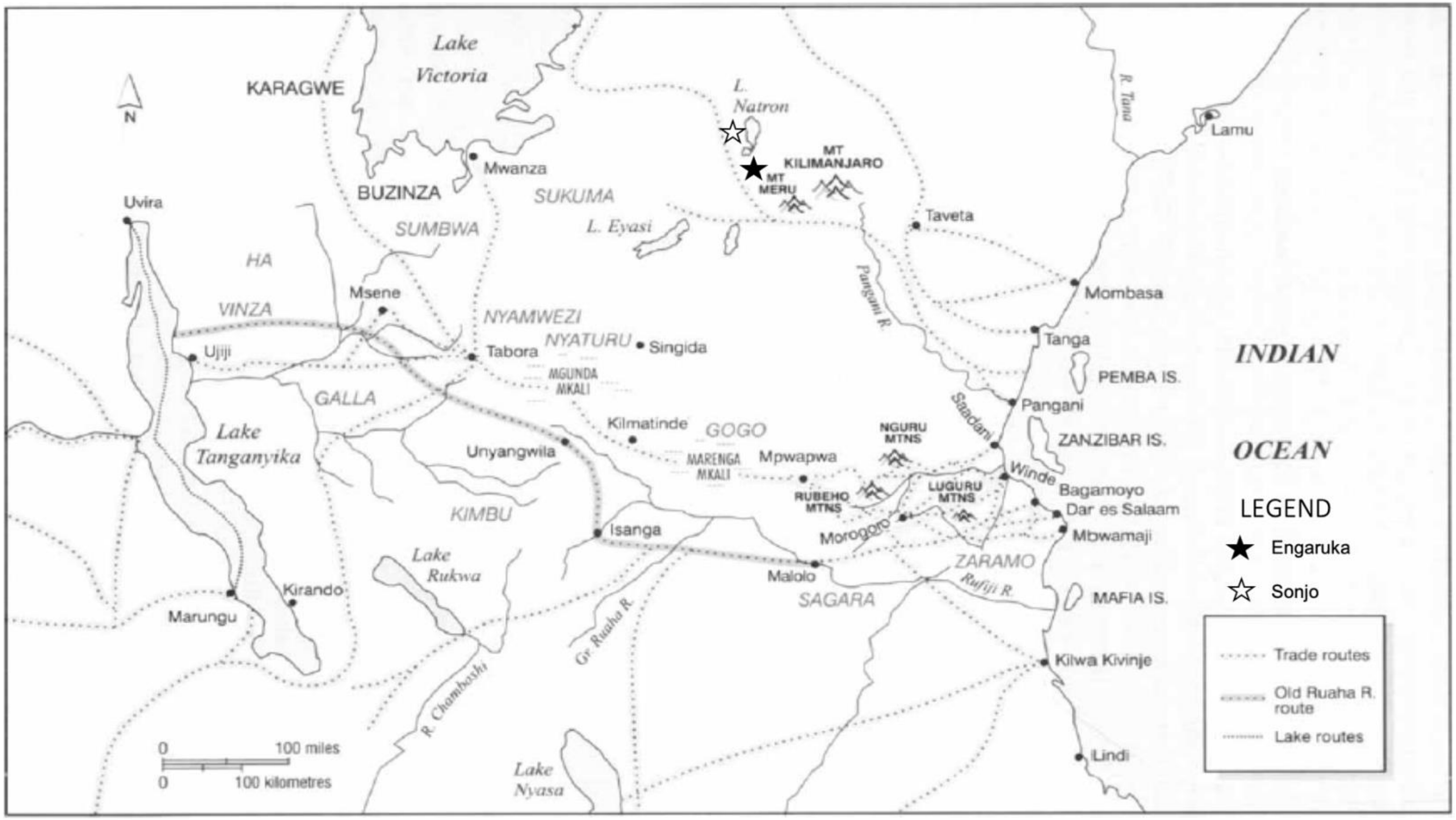


Figure 4. Map of trade routes of the 19th century, with particular reference to proximities to Engaruka and Sonjo. Adopted from Rockel(2006).

region owing to the local belief that “wherever that useful tree is planted their enemies will prevail” (New 1875, 418).

Farler’s (1879) account largely corroborates New’s observations regarding crop repertoires in Usambara. Reporting on the agricultural landscape on the southern downslope of the Usambara Mountains while traveling from Magila to Msasa, Farler again noted the dominance of non-African crops through the observation of plantations of rice and maize associated with villages situated in woodlands (1879, 89). In the next market town, Hababara, women were the chief traders and they exchanged bananas, maize, and tobacco for beads, cotton cloth, and – oddly - shark. Farler did not observe any “beach-people at the market” (presumably a reference to the Swahili), and the Kiswahili language was not used for trade (Farler 1879, 89). This potentially suggests that the trade networks of the Usambara and the Swahili were not well integrated at this point. Crossing the Zigi river, Farler’s party commenced the ascent of the Msasa Mountain (the peak of which is at 3500 feet above the sea level), where he encountered tobacco and maize agriculture at high altitudes. Just before reaching Vumba, the nearest Bondei town to the coast, which had been destroyed the year before in a Wadigo raid, Farler (1879, 87) reported the cultivation of rice, maize and sorghum, the latter important as it shows this African domesticate continued to be cultivated at this time. Farler (ibid.) then goes on to describe the party’s next move: an ascent up a hill to a stockaded market town called Umba where the Swahili traded dried fish, salt, iron hoes, and cotton cloths for rice, maize, tobacco, and honey. He claimed that the

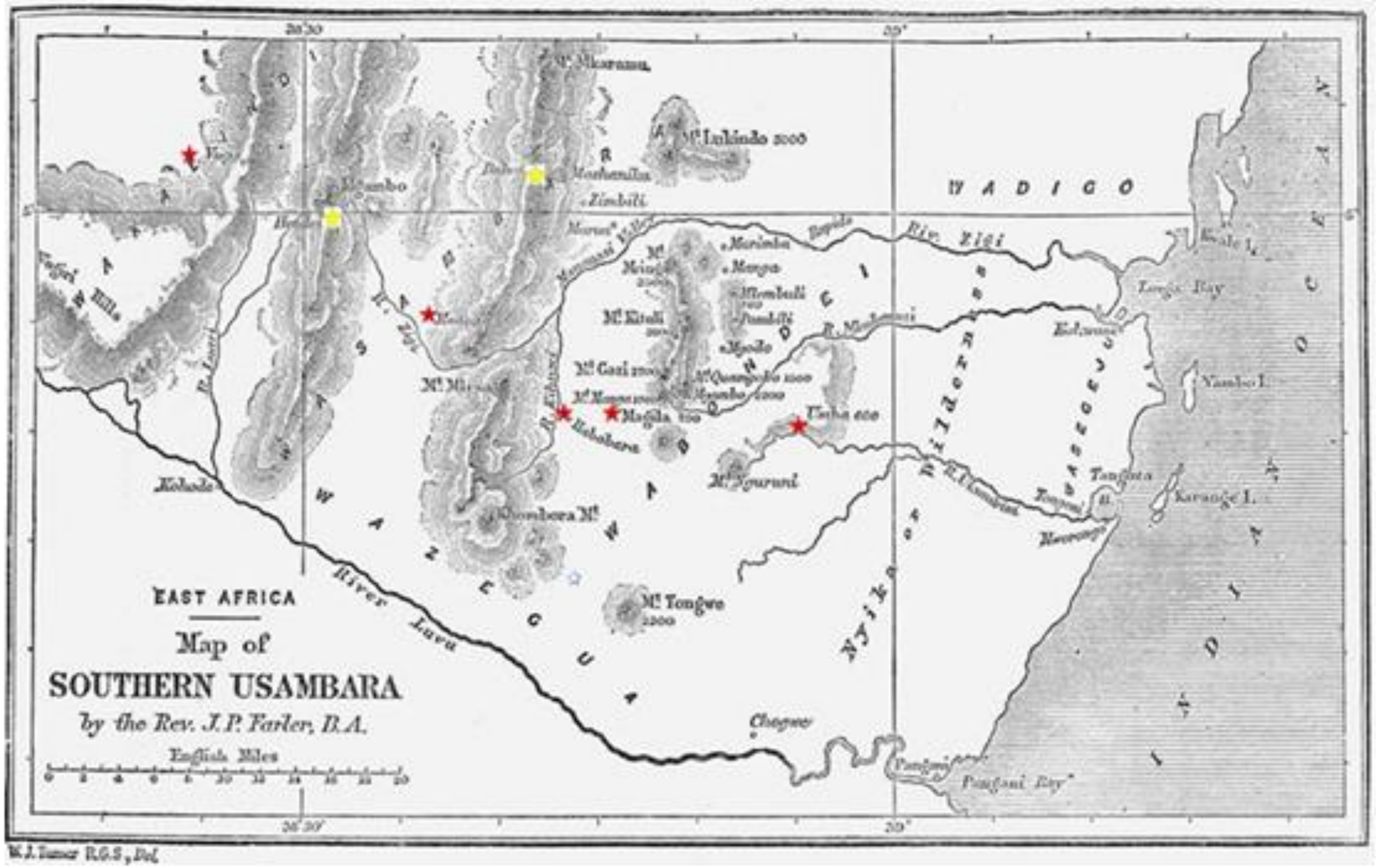


Figure 5. Farler's 1879 expedition map from Johnston (1879). The stars indicate the location of places mentioned in the text.

whole of the Tangata coastal district was supplied with grain from this market (Farler 1879, 87).

Johnston (1879) provides useful agricultural data for Pemba Island, and on the mainland provided additional details of cultivation along the Zigi valley and what he terms the Handei (i.e. Usambara) district, as well as along the Pangani River; the latter of which is of particular significance because it forms part of the caravan route from Pangani to Lake Natron, which passes close to Engaruka (Figure 4). It is unclear whether this caravan route was active at the same time as the agronomy at Engaruka, but observations of agricultural and trade practices along the route provide insight into what may have been going on at Engaruka. Johnston (1879) reported that the Zigi valley between Bulwa and Magila was dotted with villages with plots of cultivated ground mostly located in hollows between the wooded ridges. Rice, *mhogo* (cassava), maize, and sugarcane were cultivated along with some tobacco, but to a lesser degree than in the Handei district.

These sources thus appear to demonstrate a well-established predominance of non-African crops in hinterland locations associated with the caravan trade. Such sources nevertheless need to be treated with caution. As an illustration of this, the legendary British explorer, geographer, diplomat, soldier - and occasional spy - Sir Richard Francis Burton, set off on his East African journey in order to make an account of regions previously undocumented. These included the region south of the Pangani river, the source of the White Nile, the vicinityof Lake Nyanza, and the Lunar mountains. The expedition was carried out from 1857 to 1859 under the patronage of the British government and the Royal

Geographical Society. In his 1859 report, Burton described crops and diets in most of the communities he visited, and provides valuable insights regarding the combination of African and non-African crops that might be missed through purely archaeobotanical investigations.

However, there is some ambiguity in his descriptions. For example, the principal cereals of the region are listed as sorghum, *Holcus*, larger and lesser millets, rice, maize, and wheat (Burton 1859). This description creates several interpretative issues. No other sources of this period mention wheat, and no details of where this crop was grown are provided. It is also not clear what Burton means by *Holcus*. This may be *Holcus sorghum,* which is an earlier name for *Sorghum bicolor*, but Burton employs the term sorghum just as often throughout the account, so he could be using the names interchangeably. Similarly, in a section describing sorghum, Burton (1859) notes that 12 varieties of sorghum (*durrah* in Arabic; *mtama* in Kiswahili) were in cultivation, but again without further details. Burton also notes that cereals which he referred to as red and white "millet" were the most common, but it is not clear whether these are varieties of a single species or a distinction between the millet species. Sorghum is said to have been supplanted in some regions by pearl millet (*Penisetum glaucum*), though Burton refers to it by its former taxonomic identifier (*Panicum spicatum*) and notes that the crop was in particular abundance at Ugogo, Unyamwezi, Usukuma, and Ujiji. The information provided by Burton on crops is thus tantalising, and in places seems to refer to recent changes in crop preferences, but this information is sometimes vague, and the nomenclature employed is inexact.

There is, however, perhaps less ambiguity when Burton discusses non-African crops. Rice appears to have been common, albeit sensitive to particular soil characteristics and rainfall regimes. The wild variety of red rice was said to have originated from the coastal hinterland. A variety of rice cultivars were grown on Zanzibar and brought to the interior by “Arab” (i.e. Swahili) traders. The most favoured rice was a lightweight soft white type known as *sena*, closely followed by a longer grain variety, *kinuk’hi* (meaning scented). It was said to closely resemble the musky-flavoured *jira-sal* rice of Western India. *Devu* and *manjano* rice were larger-grained rice varieties, reported by Burton (1859, 399) to be indigestible according to the inhabitants of Zanzibar. He further noted that rice was sown twice a year on Zanzibar, around January or February and again before the *vuli* (little monsoon season in October and November), and once a year in the “interior” (an important if vague distinction) just before the *masika* (big monsoon season in March or April). The rice was harvested after four to six months, and if seedlings grew too dense, too quickly, the rows would be thinned out and the shoots transplanted. Maize (*mahindi*) was known as “the corn of India”, and could be grown in any season in areas of perennial rainfall, just as was the case with rice. Maize was widely preferred in its juvenile state, known variously as green maize or the “*buta* of Western India [i.e. the Americas]” (Burton 1959, 399). Full-grown kernels were praised for being “cool and wholesome” (ibid.) on Zanzibar, but preparation was cumbersome because it involved overnight soaking followed by pounding and drying in the sun.

The mix of introduced crops and African domesticates reported by these 19th-century European sources is perhaps to be expected at a location so close to the coast, but non-African species are also reported by 19th-century European travellers and missionaries in locations far inland. In 1870, A Mombasa-based missionary by the name of T. Wakefield published a journal style account of caravan routes into the East African Interior. The map accompanying this report, *Routes of Native Caravans from the Coast to the Interior of Eastern Africa, Chiefly from Informaion Given by Sádi Bin Ahédi, a Native of a District near Gázi, in Udigo, a Little North of Zanzibar* (Wakefield and Johnston 1870), was the first to locate Ngorogoro and the Serengeti, and provides information on agricultural practices as far inland as the Lake Nyanza. On the basis of the account provided by Sádi Bin Ahédi Wakefield includes information on crops grown, for example noting that at "Chamwáli" on the southeastern shore of lake Nyanza, it is said that a large population was supported by "millet, beans, bananas (the latter in large quantities)" (Wakefield and Johnston 1870, 309) and by a crop for which Wakefield uses only its Kiswahili name: "wimbe" (*Eleusine coracana*). Although a secondary source, this would suggest that African cereals remained economically important inland, though the reference to large quantities of bananas shows the significance of crops of non-African origin. To the south of Chamwáli, but still on the mainland to the immediate southeast of Nyanza, Wakefield reports that the Waukara/Wakara agropastoralists supported large settlements raising cattle and cultivating beans, millet, bananas, cassava, sweet potatoes, as well as "maize, but not much" (Wakefield and Johnston 1870, 311). This quantification of maize cultivation may be vague, and is being reported second-hand, but is nevertheless interesting because it suggests that maize is not yet dominating the grain economy, and instead forms part of a mixed crop repertoire that includes African and non-African domesticates.

The fact that agricultural systems so far inland were prepared to incorporate introduced crops into their economies illustrates an important point raised in the opening section of this chapter: agricultural communities in eastern Africa were clearly not static and were prepared to experiment with and adopt new crops when these became available. Given archaeobotanical assemblages of sufficient chronological depth, I would therefore expect to see changes to crop repertoires over time in inland locations like Engaruka, just as has been seen on the east African coast. There are also suggestions in the historical literature that this process did not always proceed in one direction, with introduced crops being abandoned after their introduction. Burton (1859, 219), for example, reports that in the Ujiji area to the east of Lake Tanganyika "Arabs" once cultivated rice of an excellent quality along the shores of the lake, with this rice reaching heights of 8 to 9 feet, but notes too that the (presumably non-Arab) inhabitants of Ujiji preferred sorghum and, "wearied out by the depredations of the monkey, the elephant, and the hippopotamus (Burton 1859, 219)", abandoned rice cultivation. The story might be apocryphal, but it still highlights the fact that there are many factors that influence crop selection, including cultural dietary preferences, local environmental conditions, resistance to pests and diseases, and storage characteristics, among others.

Even with the reported abandonment of rice cultivation, Burton's account of Ujiji serves to reinforce a central theme of this review, because it highlights the dynamism of local agriculture and describes an economy that incorporated African and non-African domesticates. Burton (1859, 219) named Holcus (see above regarding his confusing use of this term) and *Eleusine coricana* (finger millet) as the principal grains, states that “bajeri” (*Panicum* or millet) was notably absent, and lists non-cereals in cultivation as *Phaseoli* and *Voandzeia* pulses, groundnuts, beans, several species of haricots, manioc, eggplant, sweet potato, yam, cucumber, an underground white fungus, the “Indian variety of the Jerusalem artichoke” (ibid.), and the “guinea palm”. Plantains were named as a staple food. Importantly it is also noted that sugar cane, cotton, and tobacco could be purchased in the “bazaar”, perhaps indicating that they were not grown locally, but also demonstrated that Ujiji was connected to local and long-distance trade via the caravan routes. These networks are sufficient to explain the spread of Asian and new-world crops in to the east African interior, but local conditions and cultural preferences clearly influenced the extent to which they were incorporated into particular farming systems. For a site like Engaruka where we have no information on cultural preferences, it is therefore difficult to confidently predict the extent to which non-African crops were farmed on the basis of the historical accounts alone.

Discussion and Conclusions

Despite their limited sample sizes and the comparatively small number of studies, archaeobotanical residues from East African sites have proved to be invaluable sources of evidence. These residues, especially when securely dated, have the potential to verify, limit, or expand what historical, ethnographic, and oral accounts have reported, but not proven. On the basis of the studies reviewed here the available archaeobotany supports the hypothesis that the three pan-African cereals, cowpea and baobab probably featured prominently in the local agronomy at Engaruka, just as they do now. Maize is a possibility in later contexts, but neither the available archaeobotanical nor historical sources allow us to assess the likelihood of this.

From the review of historical sources, we might also expect that banana was cultivated at Engaruka, and indeed this crop may have been an important feature of the economy from its inception if the linguistic models of its cultivation in the region for at least a thousand years are correct. If so we would need to rely on phytolith analysis to confirm this. As with maize the historical accounts from the 19th century onwards do not allow us to predict the likelihood of banana cultivation, merely its possibility.

The historical sources reviewed here have thus helped in the prediction of crop repertoires at Engaruka, but such sources cannot be interpreted uncritically. The exploration of historical accounts is an enriching, if delicate pursuit, especially once the hazards of relying on travellers' reports of local plant use are acknowledged. The value of the agricultural data originating from such sources must be weighed with regard to the potential for interpretive errors. Factors that contribute to these errors include the difficulty of establishing precise locations, the status of the traveller's host, and inaccurate plant identifications.

First, it can be quite difficult to establish the precise location of places mentioned in the text. Often, the place names provided are quite vague and refer to broad regions dominated by a particular cultural community. For example, the Kiswahili word Ugogo essentially means 'the area where the Gogo live' while Wasambara/Wausambara refers to the 'people from Usambara'. This phenomenon was certainly exacerbated by the fact that travellers often relied on non-local guides prone to the geographic interpretations and perspectives of an outsider. While this naming system was useful at the time to broadly locate places of interest, the cultural distinctions contained therein are themselves fluid and frequently result in shifts in regional demographics. Over time, the broad areas they refer to have undoubtedly experienced dramatic changes resulting in a different name coined by new cultural group that has risen to prominence. Frequently, the name that a place is known by in the present day is one originally employed by early British colonial cartographers, regardless of the level of inaccuracy. Lack of standardised spelling certainly exacerbated such errors. Spelling conventions of foreign place names had not been standardised so phonetic spelling was frequently used, thereby causing confusion. In some instances, it is possible to establish the region based on context and then narrow down the geographic possibilities. However, it is nearly impossible to establish a location based solely on ambiguous landmarks and vague distances (i.e. a day's march from the highest peak). Burton (1859) routinely measured time taken to travel, rather than distance, making it difficult to establish locations based on these measurements, since geographical features and environmental factors can slow the pace of a march.

The next hazard to consider is the potential for the travellers' interpretations to be influenced by the status of his host. As guests of the well-to-do in a given community, travellers are potentially disposed to overemphasise diets that are skewed away from the staples of the majority of the population (Walshaw 2005). Be that as it may, high status foods should not necessarily be ignored, but rather placed in the context of their importance. For instance, in studies of feasting customs, the presentation of high-status foods during feasts is a common component of diplomacy. For example, along the Swahili coast, Arab guests reported that while rice was served preferentially, millet was also a part of the local diet (Walshaw 2005).

Inaccurate and unreliable plant identifications, ranging from incorrect reporting to translation errors, and vague morphological descriptions ((Cappers 2003)), can be quite difficult to correct. Some varieties of millet, for example, can be quite difficult to distinguish from one another, possibly challenging accurate identifications. To this end, it is necessary to confirm the translations of the Kiswahili plant names provided within the accounts. Furthermore, reporting is also subject to the bias of the author. Visitors to the Swahili coast disproportionately report on the abundance and variety of fruits grown or served, because the taxa were exotic to their homeland. Walshaw (2005) cites Ibn Battuta's (Hamdun and King 1994) description of a sweet, stone-centred fruit (jammun) similar to the olive. The shape is consistent with jujube (*Zizyphus*, Rhamnaceae), but the word jammun resembles the Hindi word for the rose apple and clove genus Syzygium (Myrtaceae). This fruit was a curiosity and so Battuta described it dutifully. However, its mere mention should not be inflated with economic significance in the absence of supporting evidence confirming the presence of a major industry relating to the fruit (i.e. a pattern of archaeobotanical residues or historical documentation of trade).

Returning to issues related to cultivation, it is important to note how the nomadic style of European travellers can limit the kinds of information they report. Travellers' accounts of agriculture are dominated by impressive lists of crops, but they make no mention of crop rotation, intercropping strategies, fallowing regimes and other agricultural activities that would only be possible to observe over the course of a longer stay. Clearly, this kind of information was not the focus of the travellers. They were more biased toward information that would promote trade, resource extraction, or exotic encounters. Also missing are detailed explanations of long-distance and long-term trade networks and the motivation for agricultural production. This omission may have been intentional, especially if the travellers were motivated by a desire to be seen as intrepid explorers, rather than foreigners on a guided tour being led by Swahili traders following well-worn trade routes. Many of the locations discussed here are situated along these trade routes, and Håkansson (Håkansson 1998) argues that while caravans may have initially been attracted to any outpost that could supply them, as trade networks improved, caravan size and frequency became linked with a motivation on the part of the farmers to increase production in order to support demand. This could have motivated the farmers to create surpluses of crops preferred by the traders. One way to increase production is to increase labour as a method of intensification. Under certain circumstances, this can lead to the construction of economically (and in this case, agriculturally) significant features, such as terraces and irrigation canals. Håkansson (1998) argues that presence of these features at Engaruka indicate that trade was a motivating factor.

It is important to keep in mind the limitations of ethnographic and historic parallels, when expanding the cultivation possibilities at Engaruka. The fact that a crop was grown in the regional vicinity of Engaruka in the mid-19th century or that the modern Maasai agriculturalists who currently occupy Engaruka grow a specific crop does not necessarily mean that the crop was definitely cultivated during the site's occupation. It does mean that the crop is a likely contender, which merits further inquiry. In which case, it is essential to establish the earliest known occurrence of the crop in this part of the interior through the analysis of archaeological and/or historic records.

If the crop was being cultivated in a historically and ecologically analogous place in the interior, it is possible that it was grown, and consumed, and potentially traded at Engaruka, barring any limitations stemming from food related taboos and cultural preferences (discussed below). Many of the accounts discussed here report that cereal producing areas also grow legumes, bananas, and members of the Cucurbitaceae family. If the Engarukans had the ability to cultivate a variety of crops this would influence both long and short-term resilience. This is particularly relevant in the case of the discovery of rice phytoliths (along with sorghum by Hayley McParland and Carol Lang from the same field contexts sampled during the current study (see chapter 4). It is difficult to distinguish whether the phytoliths in question are associated with wild or domesticated varieties of rice, thus I cannot confidently argue that rice was part of the Engaruka agronomy. The evidence in support of this is that we now know that Engaruka was wetter than it is today, owing to the identification of paddy-like soils (Lang and Stump 2017) that could have supported rice agriculture. Furthermore, we know that specialized rice agriculture was well established along the Swahili coast (Walshaw and Stoetzel 2017) at the Pemban sites of Chwaka and Kaliwa (Walshaw 2015b, 2010) and rice and millets were being cultivated alongside one another at Songo Mnara (Walshaw 2015a). Furthermore, Engaruka was likely to have been connected to networks of trade amongst the pastoralists and agriculturalists of the East African interior as well as to the coastal trade routes which are thought to have supplied the Swahili with goods and slaves for their Indian Ocean trade (Horton 1987).

These issues highlight the importance of corroborating historic accounts with related proxies, including archaeobotany, palaeoecology, and ethnography. These types of data may be used to broaden the interpretation of agricultural practice in the past or to focus in on the circumstances under which specific types of cultivation are possible. The reviews of the historical literature above regarding crop repertoires provides other important lessons, however, including the fact that many dietary preferences are culturally determined and form the bases of dietary taboos, as evidenced by their existence within historic and modern communities. As a result, a crop could be grown in a given area, but not eaten, as is the case with the reportedly 'indigestible' forms of sorghum noted by Burton (1859). Thus, while it is environmentally and historically possible that a crop was grown, there may have been cultural reasons why it was not grown. For example, no game is visible in the faunal assemblage from Engaruka (Thorp 1986), but it would be expected given the site's location and ecology. This suggests either a very strict dietary taboo or some sort of depositional bias. It is important to acknowledge that similar factors could be at play with the archaeobotanical assemblage as well.

The historical accounts also illustrate the diversity of farming practices across the region, and they show too that these were subject to change through time in response to a variety of social and economic factors. The development of the long distance caravan routes from the late first millennium AD no doubt facilitated the spread of non-African domesticates into the interior, and the intensification of this trade through the 19th-century – in part through European influence – has been invoked to explain changes in subsistence practices in areas crossed by these routes, and as an impetus for the development of terraced and irrigated agricultural systems, including at Engaruka (Westerberg et al. 2010). Recognising the possibility of change is important in terms of attempts to predict historic crop repertoires, and means we must be wary of simply projecting historic or ethnographic data into the past.

This recognition that crops may be grown but not eaten also reminds us that trade allows communities to consume plants that they do not cultivate, several examples of which have been highlighted above in reference to goods available in markets compared to crops grown locally. It is thus important that archaeobotanical sampling at both Engaruka and Konso targets locations likely to provide information on crops consumed as well as those that inform us about the cultivation repertoire. This too is likely to miss nuances, for example, whether an edible wild species was regarded locally as a weed or as a component of human diets. It is for this reason that the methodology outlines in the following chapter included the gathering of data on possible uses of plants, including human consumption, as animal fodder, for medicinal purposes, for the manufacture of objects, or as a component of intercropping practices such as green manuring. The combination of archaeobotanical work at Engaruka with archaeobotanical and ethnobotanical work at an analogous community like Konso (or Sonjo) has clear advantages.

In this chapter several types of data sources have been used to reveal what agriculture at Engaruka may have been like during the period relevant to this study, based on what is known about the origin and spread of agriculture throughout the region. With a focus on crop repertoires, archaeobotany has been unable to answer these questions on its own due to issues related to sampling limitations and archaeological visibility. Other types of sources, historical and ethnographic, were therefore reviewed to indicate what might have been happening at the site when archaeological residues are limited, absent or difficult to interpret. Individually sources have their own set of interpretive limits, though when different types of sources are combined the sources can provide significant interpretive benefits.

The sources of evidence presented represent the current state of knowledge derived from archaeobotanical and observational data. The archaeobotanical data is heavily biased towards coastal sites since this is where most previous work has been conducted. This nevertheless demonstrates that African domesticates remain a feature of most economies even after the introduction of Asian and New World species. Historical accounts by 19th century European travellers corroborate this picture and suggest that the three pan-African cereals of sorghum, pearl millet and finger millet likely formed important components of the now abandoned agronomy at Engaruka and were likely intercropped with each other and with *vigna* and baobab. Banana cultivation is possible, but the available sources do not permit quantification of this possibility.

The aim of this review was thus to establish what was known and what was not known at the start of the current study about crop repertoires and locations like Engaruka so that gaps could be addressed through targeted research and through the development of an inclusive fieldwork methodology. The resultant methodology is outlined in the next chapter.

3 Archaeobotanical Methods

Data collection for the study was carried out during two field seasons. Fieldwork at Engaruka in the Arusha District of northern Tanzania took place from September to November 2014. Fieldwork in the Konso region of Southern Ethiopia occurred from September to November 2015. The archaeobotanical programme targeted the archaeological, ethnographic, and ecological evidence for plant use, in general, and crop selection, in particular, using archaeobotanical and ethnobotanical sampling methods. The development of archaeobotanical sampling strategies was based on the potential for an area to yield meaningful plant use data based on the kinds of activity that would have occurred there. A variety of domestic and agricultural activity areas were targeted during the fieldwork: hearths in domestic buildings at the terrace village site at Engaruka, a midden from an abandoned area of the village of Kuile in Konso, and agricultural field sections at the Sahaito River in Konso and along a gully in the South Fields at Engaruka. The current chapter presents descriptions of the archaeobotanical and ethnobotanical field and lab methodologies supported by discussions of the rationale for specific sampling strategies, processing techniques, and methods of analysis.

Notes on Record-keeping in the Field

Throughout the excavations, records were kept of observations involving the analysis, interpretation, and relationship of each depositional or removal event. This included detailed sediment descriptions, stratigraphic interpretations, and references to related records (soil samples, photographs, and drawings). During

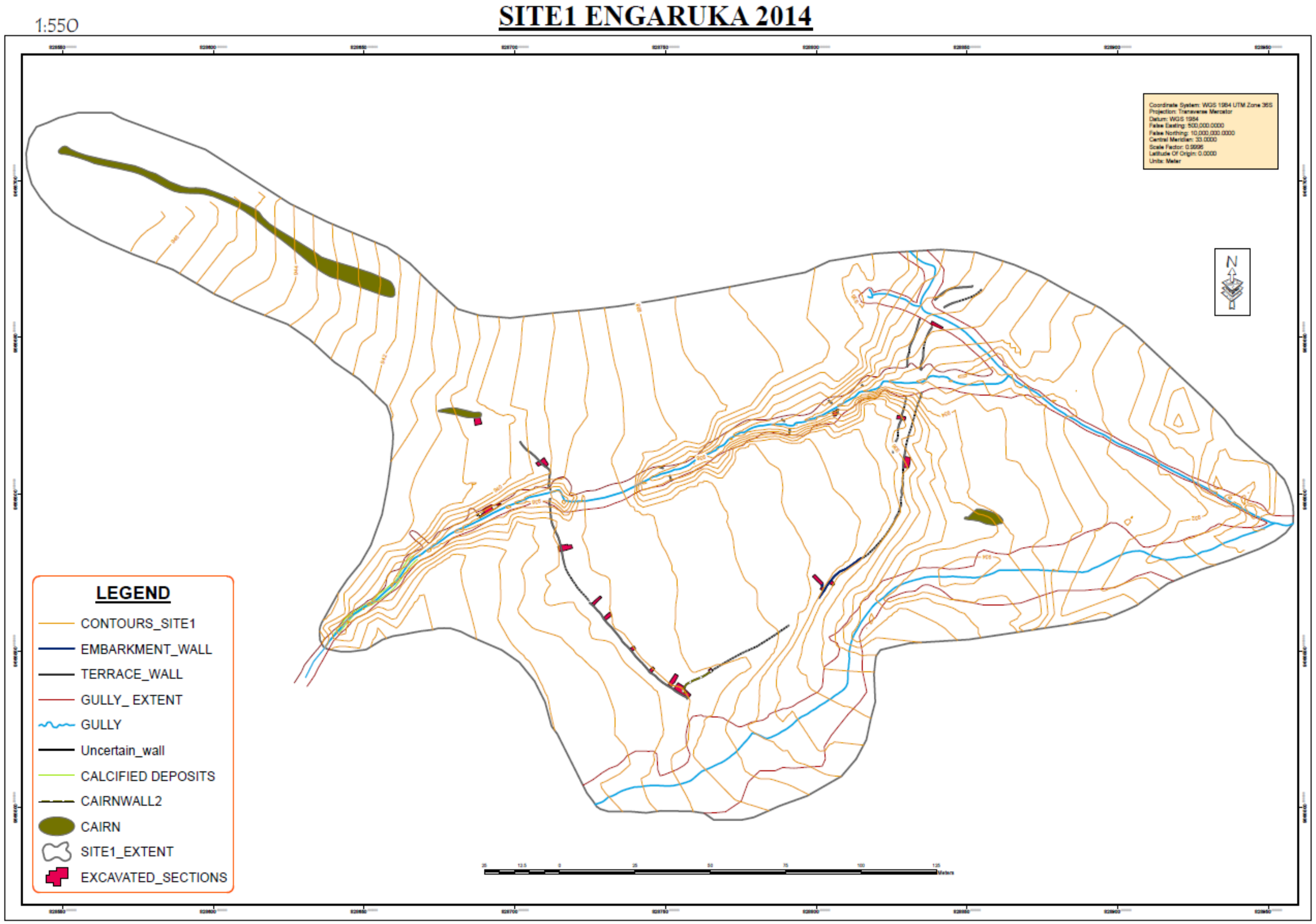


Figure 6. Map of excavations at Site 1.

the excavation, sedimentary layers interpreted as individual depositional or removal events were given a unique record number, referred to as a context. These numbers were also used to identify the provenience of samples and artefacts. Once a section was fully excavated, it was photographed, and profiles were illustrated on waterproof drafting film (scale of 1:10). Plans of overhead views of individual excavated areas were drawn at a scale of 1:20. Each of these excavations was recorded using a GPS (Global Positioning System) or total station theodolite (TST). This process allowed for the reconstruction of the stratigraphic sequence of events resulting in the construction of the terraces and sediment trap fields. This understanding informed the archaeobotanical sampling strategy and played a significant role in the interpretation of the macro-remains recovered from the sites.

Environmental processing registers documenting the details of the flotation samples were established in the field labs and continuously updated as they were processed. They included information about the specific location of the context from which the sediments were sampled, referred to henceforth as provenience following American archaeological convention. Sampling and processing methods were also recorded, including sample volume, processing date, and notes regarding sample contamination, damage, or loss.

Sampling Rationale: Aims and Objectives

Despite the low expectation for the recovery of macrobotanical material and the interpretive limitations at open air agricultural sites, archaeobotanical sediment samples were collected from domestic contexts (hearths, middens, and

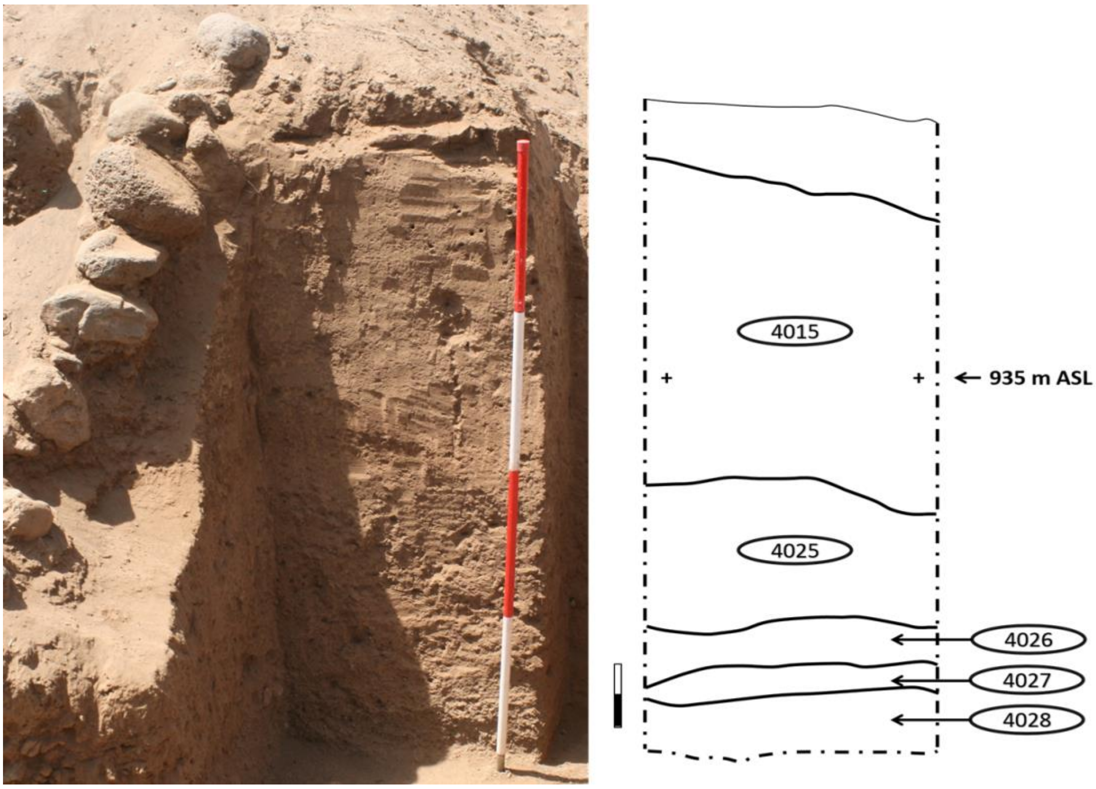


Figure 7. Contexts where samples were taken in the South Fields gully section (Section 4) at Engaruka.

occupation floors) and agricultural field contexts at the gully at Engaruka and at the Sahaito River in Konso, in order to test the following four aims:

1. To test assumptions about agricultural preservation in these specific dryland environments
2. To recover charred wood and seeds suitable for radiocarbon dating well-defined field strata
3. To identify potential weeds of cultivation and irrigation and explore associations with specific cropping repertoires and other sustainable agricultural practices
4. To facilitate an accurate comparison of the sites by identifying the archaeobotanical signatures of each type of domestic or agricultural

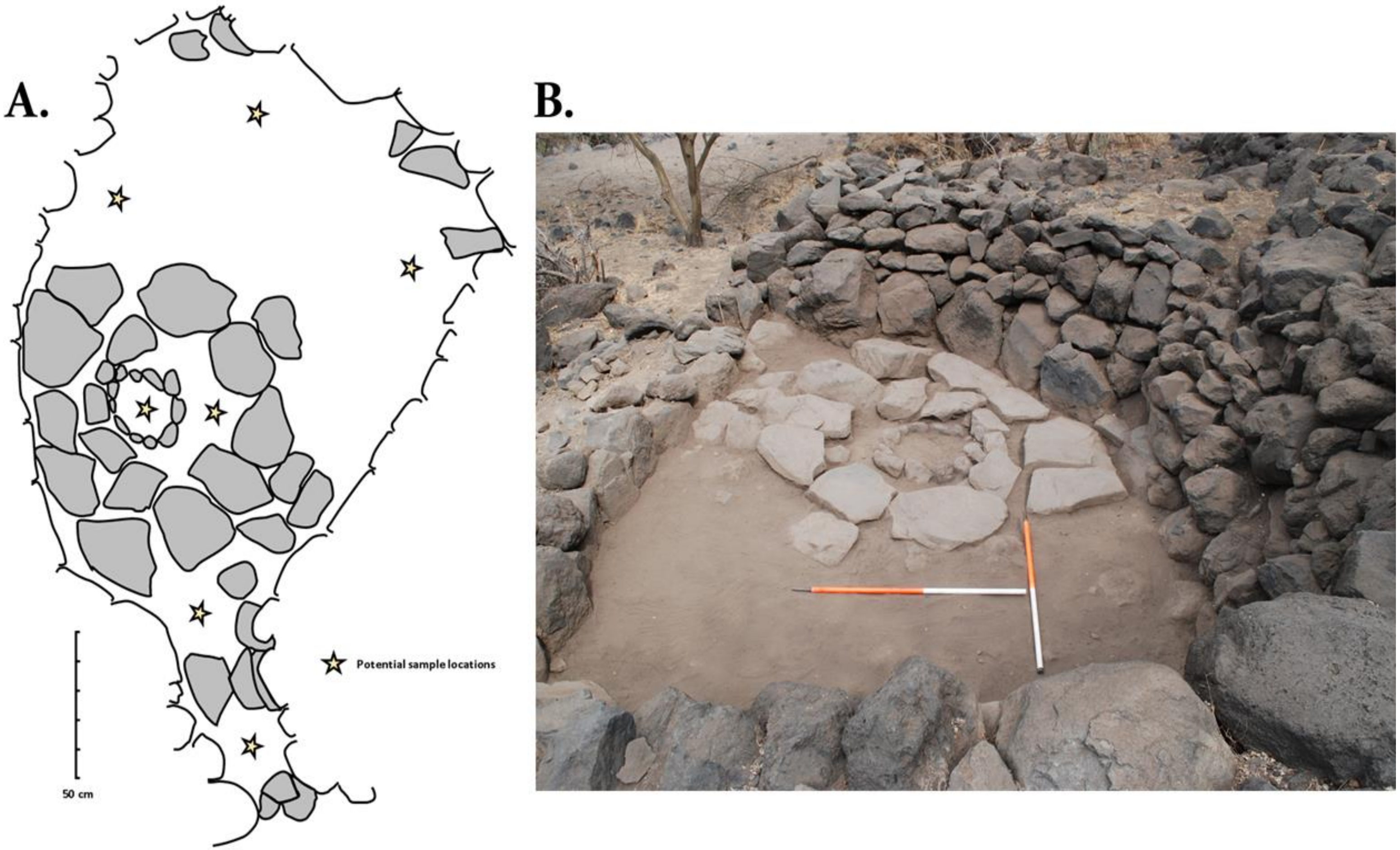


Figure 8. Sampling pattern used for buildings in the terrace village above the South fields at Engaruka.

5. activity area (midden, occupation floors, hearths, and fields) as well as each site

In designing the sampling strategy for the current study, the challenge was to satisfy the aims and objectives of the AAREA project of the archaeobotanical study as well as the AAREA Project. The project objectives (Stump 2013) that were relevant to the archaeobotanical study and thus guided my strategy design were as follows:

1. To break new ground in the study of African intensive agriculture by precisely defining how the agronomy at Engaruka changed through time.
2. To push forward the frontiers of applied archaeological research by critically examining the notion that only archaeological data can provide the long-term social, economic and environmental evidence necessary for sustainability assessments; testing this assertion to breaking point if necessary.

While both objectives relate to archaeobotany, only the first had significant bearing on the sampling strategy. The excavation and sampling strategy had to target those contexts that could provide evidence of change in crop repertoires over time based on archaeobotanical identification of crops and weeds (primarily seeds and charcoal), as well as the recovery of materials for radiocarbon dating. It was not until the laboratory analysis (Chapters 4 and 5) commenced that I began to see that a unique methodology was necessary in to push the data towards finding the limits of what archaeobotany can contribute to resilience and sustainability.

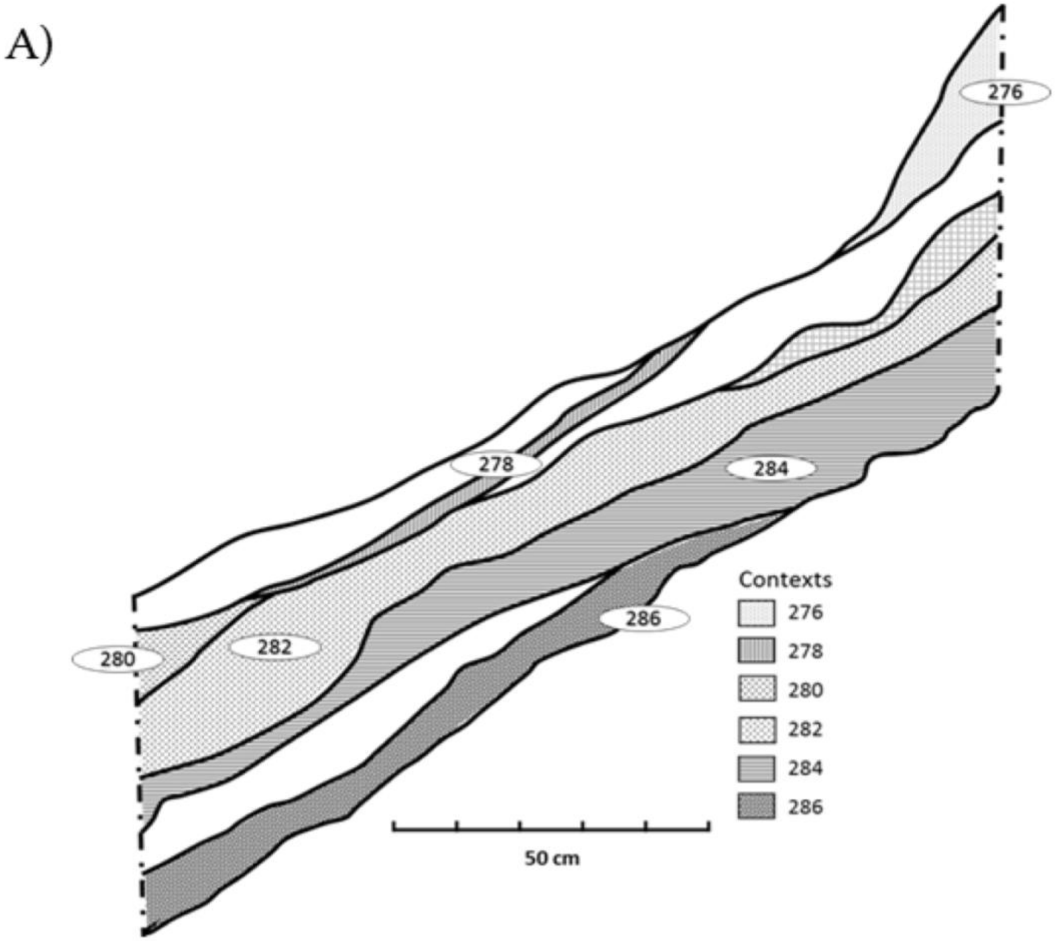


Figure 9. Origin of samples from the upper (A) and lower (B) section of the midden lower and upper sections of the road.

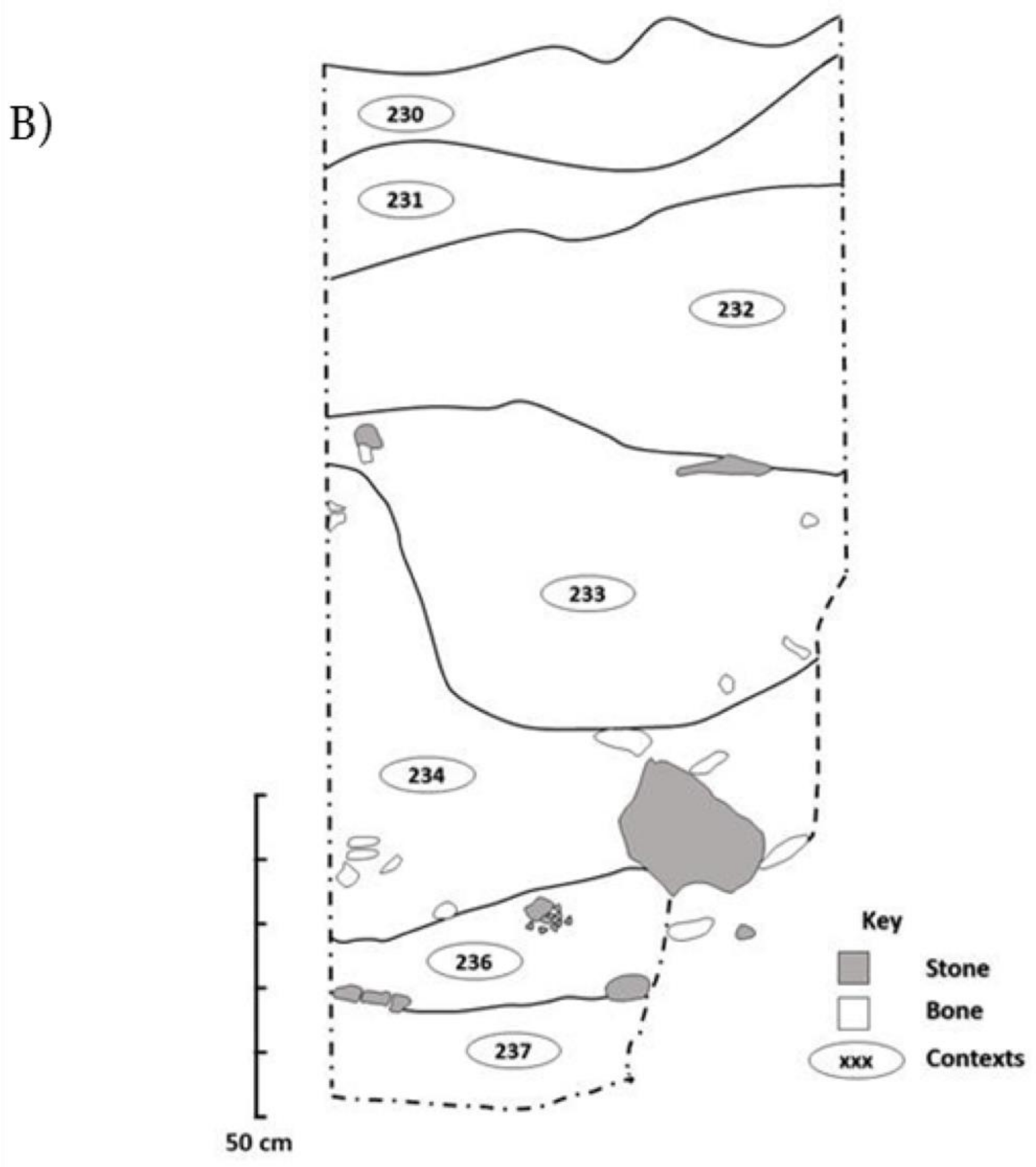


Figure 8. Origin of samples from the upper (A) and lower (B) section of the midden lower and upper sections of the road.

Details of the Sampling Programme

The archaeobotanical sampling at the south fields at Engaruka was carried out during the investigation and subsequent excavation of an agricultural field profile revealed in a gully cross-section (Section 4) at Site 1. A total of eight bulk soil samples (10-20 litres each) were taken from stratigraphic contexts in Section 4 (Figure 7). Four samples were taken from the upper middle and lower sections of context 4015, One sample was taken from each of the remaining

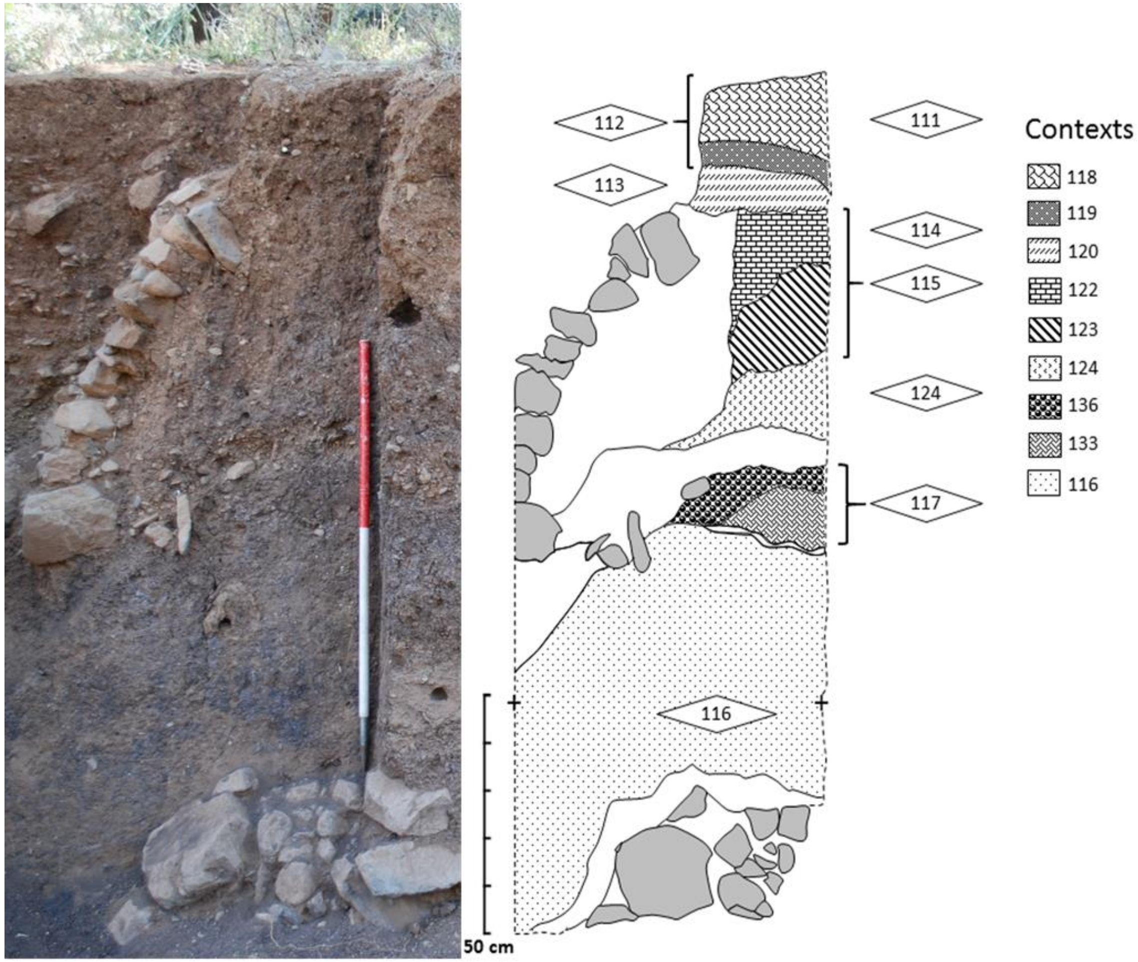


Figure 10. Origin of samples from the Yela, Section 102, at Sahaito.

contexts. Sampling the agricultural fields along the Sahaito river in Konso involved collecting nine bulk soil samples (4.7 to 8.2 litres each) from Section 102 (Figure 10), an exposed gully profile comprised of successive layers of sediment trap fields, known locally as yelas. Each of the field samples from both field sites correspond with micromorphological samples taken by Carol Lang in order improve the comparability of the findings.

Sampling the Village at Engaruka

A total of 89 samples were taken from the excavation of five buildings at the terrace village, referred to as Site 2, situated above the escarpment overlooking the South Fields. Archaeobotanical sampling targeted sediments representing the occupation floors and hearths. Samples taken within and around hearths corresponded with stratigraphically distinctive deposits indicative of the feature’s construction and use. Standard sample size for occupation floor and samples taken from immediately around the hearths was 2 litres, intentionally small so that multiple samples could be taken across the space, given the shallow depth of the floor sediments. Samples originating from within fireplaces were 100% sampled as they were expected to be rich in charred macrobotanical residues. Samples from Building 3 were later excluded from analysis when it was determined that the structure had been previously excavated, so the samples would represent backfilled sediment. We also established that the occupation floors in Building 5 had been excavated by Siiriäinen et al. (2003), but left the hearth intact. In this case, only the hearth samples were subjected to analysis.

Sampling the Midden at Konso

The excavation of the abandoned midden at the village of Kuile in Konso was carried out in two phases because a gravel road had been built on top of the lower section of the midden. Thirteen bulk samples (2.8 to 6 litres each) were taken from contexts in the lower and upper sections of the road (Figure 9). The uppermost contexts of the lower midden (230 and 231) were sampled but expected to have been disturbed by the construction of the road.

Sampling of Agricultural Fields

The agricultural fields at Engaruka and Konso were investigated for evidence of cultivation practices, though only a low density of macrobotanical materials in comparison to the hearth and midden samples, was expected. Agricultural fields are open sites with alternating wet and dry conditions favourable to soil fauna that break down organic matter (Miksicek 1987). Also, farm fields are functionally designed to maximize seed germination, so unless a large-scale agricultural charring event occurs, such as through slash and burn or stubble burning activity, it is unlikely that charred seeds would be encountered. During the excavations at Engaruka, a few discrete charcoal deposits were observed in the field sediments, most likely the result of secondary deposition of charred material from small campfires or remnants of charred trees upslope travelling with the alluvial deposits that were captured within the fields. The isolated nature of these deposits were not indicative of the more large-scale agricultural charring events that would preserve macrobotanical remains en masse. Fields are not usually stratified: the same soils are replanted each year, unless there is a mechanism in place that will build more horizontal deposits. Significantly sediment traps, such as those used by modern Konso farmers and by past farmers at Engaruka, do have their soils replenished resulting in a stratification of field layers over time. Alluvial transport is also a limiting factor when considering the interpretation of archaeobotanical remains from agricultural sites since irrigation, periodic flooding, and sediment trapping can act as agents of depositional transport. The sampling strategy for agricultural field sediments was initially developed at Engaruka and later replicated at Konso. Excavations were initiated in order to better understand how the fields were constructed, maintained, and cultivated. This was achieved through the investigation of agricultural landscape features visible on the ground surface or exposed by gully erosion: dry stone field walls and, at Engaruka, oblong cairn features composed of rock accumulations both enclosed by and filling stone walls.

The investigation of the function of a dry stone wall that formed the upslope side of an irrigation channel led to the identification of well-defined strata within the agricultural field sediments. These deposits preserve a record of how the field walls were repeatedly built up and buried by silt (Lang and Stump 2017). Eight locations were excavated along its extent in order to identify the direction water was flowing through the channel. This resulted in the same sediment deposition events being observed in multiple cross-sections along the length of the terrace wall (Figure 6). It was inferred that the stratigraphic contexts observed in the nearby gully section reflected the same depositional processes and that radiocarbon dating of these sediments could be accurate, despite the mixing which is known to occur within agricultural soils.

Figure 11. The tank flotation system used during fieldwork at Engaruka.

Archaeobotanical samples from the agricultural field sections were taken from the top of the stratigraphic profile to the bottom. This was necessary in order to avoid cross contamination of contexts during sample collection because the friable nature of the sediments meant that the section could collapse if samples were taken from the bottom to the top. As a measure against contamination, at least 15 cm of the exposed sediment from the profile of a context was removed prior to collecting a sample. In order to increase the likelihood of finding macrobotanical remains, the maximum sample volume possible was taken based on the size of the context.

Environmental Processing in the Field

At both Engaruka and Konso, field processing of the archaeobotanical samples was carried out in the field laboratories established at the respective project campsites where water, adequate drainage, and drying space was accessible. The processing method involved the separation of macrobotanical materials from the bulk soil samples involving a flotation system using either a large tank or a collection of buckets. Archaeobotanical flotation systems are based on the principle that in water light materials (light fraction or flot) float and heavier materials (heavy fraction) sink. Soil is immersed in water and agitated so that the light fraction floats to the surface. Heavy fraction is collected in a sieve and sediment smaller than the sieve sinks and is discarded. While there are a variety of techniques, at the most basic level, flotation serves to separate recovered materials into different size categories for analysis (Pearsall 2015).

Method selection depended on an assessment of the size, estimated macrobotanical value, time constraints, and the irregular schedule of camp water allowances. Macrobotanical value was based on the likelihood that charred seeds would be recovered from a given context. In general, tank flotation is more efficient than the bucket method when processing large bulk samples where water is available in good supply. Furthermore, the tank flotation method used at Engaruka was significantly less time consuming, however the chance of losing macrobotanical material was minimised when the bucket flotation is used (Walshaw, pers. comm), because larger, less buoyant seeds could have fallen outside of the heavy fraction mesh basket that was suspended just below the

Figure 12. Bucket flotation at the camp lab in Karat, Konso. The same system was used for hearth samples at Engaruka in order to maximise seed recovery from single session.

water surface. A further drawback of the tank method was that it required a constant flow of water into the tank. This necessity was challenged when the local irrigation schedule diverted the water supply away from the camp. In these instances, water from the tank was used to continue sample processing via bucket flotation, an inexpensive system using supplies that were available locally.

Tank Flotation

Tank flotation was the preferred mode for the majority of samples taken at Engaruka due to the ability to process much larger and/or clay-rich samples in those key contexts. The flotation tank in use was provided by the British Institute in East Africa (BIEA) and constructed according to standards established by English Heritage (2002). The contents of individual sediment samples were added incrementally (to avoid overflow) into water filling an oil drum modified with a run-off spout. A 5-millimetre mesh was set below to catch the heavy fraction (expected to reveal ceramics, lithics, and bone; not analysed herein). A 2 mm mesh is generally preferred for the recovery of heavy fraction materials (Heritage 2002); however, it was only possible to acquire a 5 mm mesh in the field. It should be noted that this meant that there is a reasonable likelihood that some smaller macrobotanical material may have been lost as a result and yet, despite the heavy mesh size being larger than the standard 2 mm, a number of beads and other artefacts smaller than 5 mm were recovered from the heavy fraction. These materials had a greater likelihood than smaller, more buoyant seeds, of being lost through the mesh, suggesting that while seed loss may have occurred, the method was successful to the degree that it was reliable for the recovery of seeds in the samples. Once the material from an individual sample was place in the heavy fraction screen, it was gently agitated by hand, allowing sediment to sink to the bottom of the tank as the flot rose to the surface and poured over the spout into a 0.3 mm sieve positioned below the outtake. The heavy fraction assemblage was catalogued though not analysed for the current study. To avoid cross contamination, the screens/system were rinsed between samples.

Bucket Flotation

I collected samples from hearth features at Engaruka and midden contexts at Konso and used bucket flotation to recover the rich macrobotanical deposits expected from these locations. The hearth samples from Engaruka, at less than 5 litres each, were small enough to be accommodated by bucket flotation without needing to be subdivided. At Konso, bucket flotation was the sole mode of processing used because the water supply was limited to rainwater collection and since bulk samples were small relative to those from Engaruka, maximising recovery of macrobotanical material was a priority.

Bucket flotation can be adapted to recycle water, thereby requiring much less water than needed to implement the tank method. The same water may be reused within the same sample if only a single sieve is available for light fraction collection. In that case, fresh water is obtained for the next sample, and re-used within the flotation of that sample. This avoids cross-sample contamination.

The bucket system I used for the study involved the modification of two 10-litre buckets with one lid that fits onto either bucket. I added individual samples to one of the buckets filled no more than half way with water. The mixture was stirred and agitated gently by hand to release the flot from the sediments. The empty bucket was then fitted with the lid which was modified to support a geological sieve to catch the light fraction. With a 0.300 mm sieve in place, the water containing the flot was decanted through the sieve, taking care not to include the sediment at the bottom of the bucket. This process was repeated at least 3 times (depending on the clay content of the soil), recycling the same water for a single sample, until the sediment ceased production of flot. The sieve containing the flot was rinsed with clean water from a wash bottle. The remaining water and sediment were emptied into a 2mm sieve and rinsed to recover the heavy fraction.

The flot and the heavy fraction were placed in fine mesh bags and dried completely, out of direct sunlight, for at least one day, depending on weather conditions. I packaged the flot for transport to the Archaeobotany Lab at the University of York for subsequent analysis. Heavy fraction, comprised primarily of large stones and gravel, was discarded after being thoroughly scanned for significant archaeological materials (e.g. bone, teeth, ceramics, beads, and large charred macrobotanicals), which were collected and recorded.

Developing Ethnobotanical Objectives

Distinct ethnobotanical methodologies were developed for Engaruka and Konso, based on the cultural relationship of the modern site inhabitants to the historic originators of the field system in question. The Maasai inhabitants of Engaruka neither built the field system and nor are they cultural descendants. They are, however, intimately familiar with the landscape due to herding activities and practice a modern form of irrigated agriculture in the lowlands. At Engaruka, the ethnobotanical component of the study was developed with the aim of understanding the relationship between the modern Maasai inhabitants of Engaruka and the plants of their agricultural landscape and thus to establish a framework for understanding the wild plant resources available to the ancient Engarukans. While these data are informative, they play a minor role in the current study. Future work is planned for Engaruka, focusing on the potential for understanding the cultivation strategies of intensive agriculturalists through ethnobotanical work with local Maasai farmers, as well as Batemi (Sonjo) farmers.

In contrast, the modern inhabitants of Konso are direct descendants of the builders of the field system who carry on the traditional construction and maintenance of the terraces and sediment traps that form the basis of this highly complex system. Investigations at Konso were focused on acquiring the same kind of plant use and ecological data as was done at Engaruka, though the presence of the descendants of the founders of the field system and their continued maintenance and occupation of the landscape meant that the ethnobotanical approach was emphasised to a greater degree. This situation presented the unique opportunity to ask questions that are typically off limits to archaeologists, since traditionally our subjects lived in the distant past, so the ethnobotanical methodology was adapted to maximise this as appropriate.

The ethnobotanical programme at Konso was developed in order to

1. Ascertain the links between modern and historic cropping strategies.
2. Record farmers' accounts of changes of agricultural practice
3. explore the potential for recognising modern practices in archaeobotanical results, especially when supported by stratigraphic interpretations.

I used a several field manuals to identify wild taxa and prepare reference collections for modern plants and seeds. For taxonomic identification of wild vegetation, I referred to Dharani's (2011a) *Trees and Shrubs of East Africa* and *The Kew Tropical Plant Families Identification Handbook* (Utteridge and Bramley 2015). Modern plants were collected as reference specimens according to the Guide to Collecting Herbarium Specimens in the Field (Barber and Galloway 2014) from The Royal Botanical Society Edinburgh and The Herbarium Handbook (Bridson and Forman 2010). Furthermore, Maasai, Kimaa, and Amharic plant names provided by informants were useful in identifying certain plants that where neither flowering nor fruiting at the time of collection, but known locally. Taxonomic identifications were later confirmed, in consultation with botanists, using pressed botanical specimens at the Herbarium at Royal Botanic Gardens, Kew.

Crop Seeds and Useful Wild Taxa at Engaruka

I compiled a botanical reference collection of economically significant plants acquired from the markets in the village of Engaruka Chini as well as those harvested during an ethnobotanical vegetation survey. Plants acquired from the market are largely local agricultural food products, while those collected during the vegetation survey are valued primarily as medicines, animal fodder, and for utilitarian purposes (e.g. cordage and thatching material). I used two local interpreters to assist me in communicating with farmers selling food crops in the marketplace.

The interpreter explained to the farmers why we wished to talk to them and helped to negotiate fair compensation. Twelve samples of agricultural food products were acquired from the market. One of the interpreters also served as a primary informant during the ethnobotanical vegetation survey and recruited other local herbalists to assist with collection of samples in isolated locations. Together these informants were able to provide Kiswahili and Kimaa identifiers for the majority of the plants. Twenty-two plant specimens were collected, labelled, photographed, inventoried, pressed and dried.

Interviews and Focus Group Discussions at Konso

At Konso, the ethnobotanical methodology incorporated focus groups with farmers, interviews with herbalists, and ethnobotanical crop and vegetation surveys. I co-led two focus group interviews at the villages of Jaarso and Kuile with Tabitha Kabora. Independently, I carried out an ethnobotanical survey of the plant foods sold in the Karat market, held three semi-formal discussions and four semi-formal interviews with two local herbalists and agriculture experts local to nearby villages. Three of the interviews incorporated participant observation activities related to grain processing, meal preparation, beer-making, and/or distillation of millet-based spirits. One of the discussions and one interview also incorporated useful plant and crop identification walks. Prior to each session I prepared a selection of questions targeting information relating to plant use and agricultural practices, with a particular focus on crop strategies, grain processing and storage, food preparation and discard, and medicinal plant use. The interviews and discussions were recorded using the Voice Memo application on an Iphone 5.

Laboratory Analysis

The dried archaeobotanical samples recovered from Engaruka and Konso were analysed according to the standards of *Paleoethnobotany, Third Edition: A Handbook of Procedures* (Pearsall 2015). Samples were weighed and sorted using the following standard geological sieve sizes (in mm) in order to maximize ease of viewing: 4, 2, 1, and 0.3. Once sieved, the sub-samples were weighed by screen size and examined with a Wild M5A stereoscopic microscope fitted with a Schott KL1500T light source. Materials 2 mm or larger, botanical or otherwise, were sorted into botanical and non-botanical categories, counted and weighed. Fractions smaller than 2 mm were scanned for whole or fragmentary seeds or fruit as opposed to being fully sorted into macrobotanical and non-macrobotanical categories. These data were recorded and entered into a Microsoft Excel spreadsheet for analysis and statistical interrogation.

Macrobotanicals recovered from the samples were initially identified using several seed identification sources under the advisement of Sarah Walshaw (Simon Fraser University). My primary reference guides included the *Digital Atlas of Economic Plants,* Volumes 1-3, (Cappers,Neef and Bekker 2009)*;* the *Digital Atlas of Economic Plants in Archaeology* (Cappers and Neef 2012); *A Manual for the Identification of Plant Seeds and Fruits* (Cappers and Bekker 2013);

Identification of Cereal Remains from Archaeological Sites (Jacomet 2006); and the *Identification Guide for Near Eastern Grasses* (Nesbitt 2006). Identifications were confirmed and corroborated by Dorian Fuller while I accessed the seed reference collection in the Archaeobotany Laboratory at the Institute of Archaeology, University College London. Seeds were also identified through comparison with samples from the Archaeobotany Lab at the Institute of Archaeology at Oxford University and the historic seed reference collection housed in the Millennium Seed Bank at Wakehurst, West Sussex.

Statistical Analysis Methods

After the archaeobotanical assemblage was recorded and the identifications finalised, I used simple statistics to analyse the data for significant relationships between categories of material (e.g. seeds of a specific taxon, chaff, or non-crop seeds) and specific types of contexts (midden, hearth, floor, or field), between sites, and between time periods on the basis of radiocarbon dating. The aim was to identify patterns in the data and hopefully determine whether there was an archaeobotanical signature distinctive to a given area. Statistical methods were applied following a review of statistical methods recommended in Popper (Popper 1988), Miller (Miller 1988), and Marston et al. (2014), as well as consultations with Sarah Walshaw, Dorian Fuller, and Amy Bogaard. Using Microsoft Excel, I manipulated the data from the master seed assemblage catalogue of each site separately using pivot tables to organize the data. In order to interrogate these trends, I explored the ubiquity and relative frequency of materials by where they were recovered and compared a variety of ratio measures (e.g. seeds/litre of soil, grain to chaff). I used the Shannon Index to establish species diversity, particularly as it relates to specific time periods. Species diversity refers to the number and the variety of species in the area of interest, which could relate to a specific region or community. Diversity measures count the number of species within the dataset while also accounting for the evenness of the abundance of species, which establishes how common or uncommon a species is in relation to other species within the same area.

The standard formula for the Shannon index is

$$H = \sum_{i=1}^{s} - (P_i * \ln P_i)$$

where H’ is the negative value results from the formula, pi is the proportion of the species *i*. I applied these techniques to establish whether the data could be queried to confirm or deny a set of hypotheses relating to land use and domestic activity that could, in turn, provide insight into the sustainability of the agronomy. This data analysis is presented in Chapter 4 and 5 and illustrated using pie charts of taxa percentages by context and site, charcoal density by litre of soil, and tables of material count totals.

For the final analysis, I used correspondence analysis (CA), or reciprocal averaging, to identify special patterning of wild and non-wild seeds within each assemblage. This method was selected as it is a standard multivariate tool used by archaeobotanists for its applicability to presence/absence and abundance data and large numbers of taxa, which are common conditions of macrobotanical data sets. CA functions by creating weighted averages of sample data (categories of analysis such as species and/or taxa). In consideration to the parameters laid out by (2014), I used CA to calculate the total variance in species data arranged with taxa/species corresponding with columns and individual samples (referred to as lots) populating the rows. The method uses eigenanalysis to calculate chi-square (X^2) of a given table of data, divided by the table's total (Braak and Smilauer 2002). The process produced bi-plots that were then used to visualize relationships between specific taxa and the contexts in which they were found. Of particular interest was the potential identification of patterns of association amongst weeds and non-weeds and domestic contexts (hearths, floors, and stratigraphic layers within the midden) and agricultural contexts (stratigraphic layers within field sections). The results of these analysis are presented at the end of each of the results chapters (Chapter 4 and Chapter 5) which follow, forming the foundation for summarizing the statistical patterning of each site. Finally, these findings are incorporated into the discussion (Chapter 6) of the use of space and the role of crops and wild taxa in sustainable subsistence strategies.

4 Results of the Analysis of the Engaruka Archaeobotanical Assemblage

In the interest of presenting the archaeobotanical datasets in a methodical and digestible manner, the analysis of the archaeobotanical results from Engaruka is reported in the current chapter, followed by the Konso Results in Chapter 5. The reporting begins with a summary of the excavations that led to the archaeobotanical samples being taken. Included is a discussion of how interpretations of the sites developed over the course of the excavation process. The summary is guided by the priority of interpretations which have the greatest bearing on the interpretation of the archaeobotanical results and future discussion. I present the results of recent radiocarbon dating, shedding new light on the temporal context for the occupation of the village above the South Fields at Engaruka, which was previously investigated by Siiriäinen et al. (2003). I then proceed with reporting the archaeobotanical results including statistical analyses of ubiquity and diversity and briefly discuss the significance of specific plant taxa as they relate to the interpretation of the sites. The primary focus of the analysis is carbonised crop seeds and chaff. Discussion of charred weeds that are economically significant (e.g. wild plant foods, medicine, and building materials) is focused on explanations of context and how they might fit into the Engarukan resilience strategy.

Excavation Summary

The AAREA team carried out excavations at two distinct sites on the Engaruka landscape. My primary role was to lead the archaeobotanical investigation at an

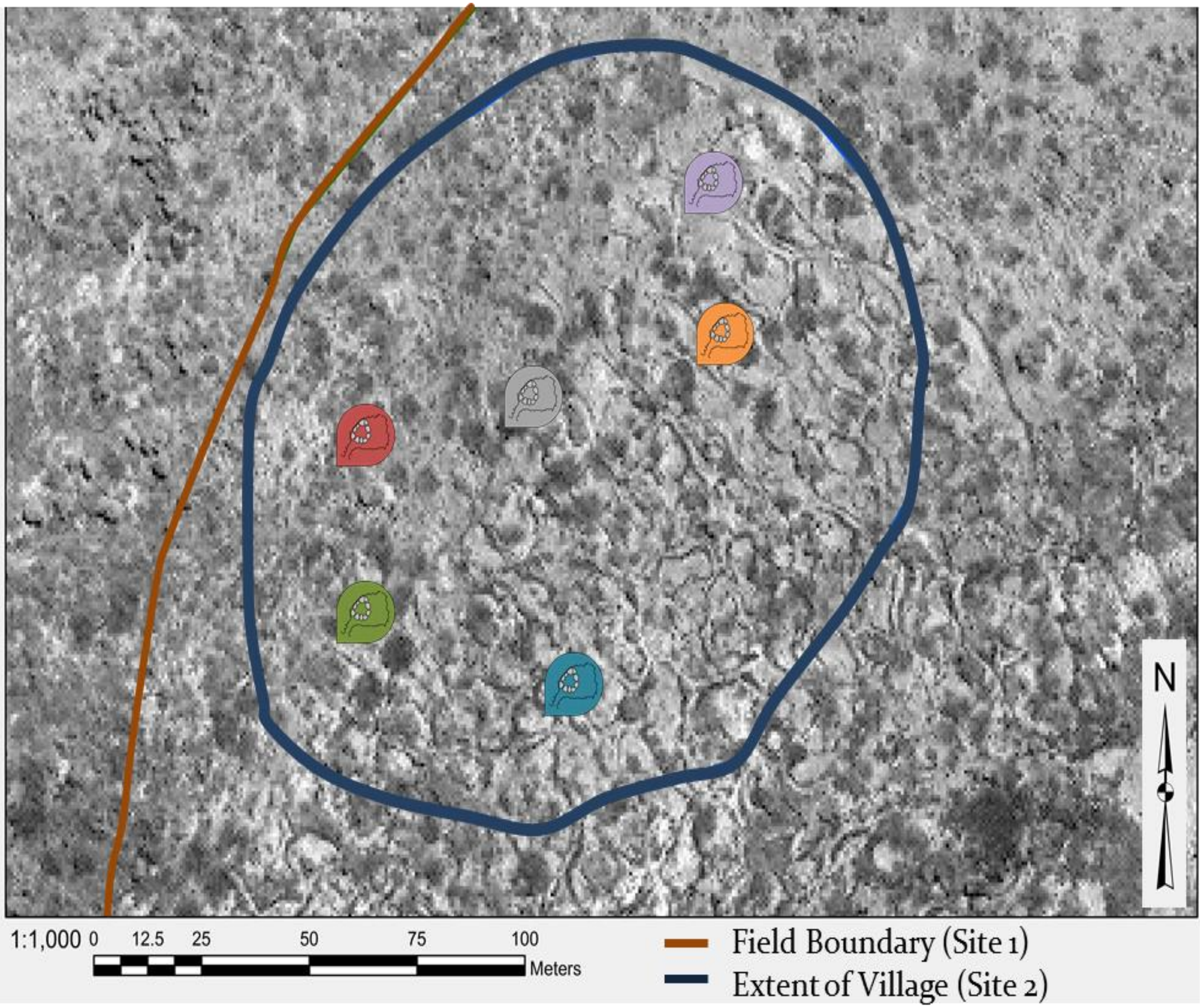


Figure 13. Map of the configuration of buildings at the village, Site 2. Note that while building 6 was excavated, it has been excluded from the current study because it was determined that it had been previously excavated and thus the sediment was disturbed.

agricultural area known as the South Fields (Site 1, see Figure 3 in Chapter 3) and at the village site (Site 2; see Figure 10), which is situated on the escarpment above these fields. Archaeobotanical samples were taken from discrete sedimentary units (contexts) related to agricultural and domestic activities. Domestic activities include those that are centred on the village hearths at Site 2, referred to as buildings in this summary. This encompasses the deposition of material through cooking, discard, and wood burning for heating in addition to removal activity related to hearth cleaning. I collected samples from stratigraphic layers within and around hearths and across (and into) the occupation floor layer.

The analysis of the agricultural contexts in the South Fields represents a methodology that is not often employed by archaeobotanists: sampling field contexts with the aim of finding evidence of cultivation practices, especially for signs of innovation (cropping and irrigation strategies) and environmental changes over the life (i.e. period of use) of the fields. The study also contributed to a broadening of our understanding of natural fluvial processes impacting irrigation, especially regeneration of field soil through sediment trapping. I sampled the profile of a gully section cut during the El Nino of 1998, revealing the stratigraphy created by controlled (irrigation) and non-controlled (flooding) sediment deposition. The motivation for this strategy (detailed in the previous chapter) was to establish the potential for macrobotanical recovery from the fields and to cross-reference these data with results of micromorphological investigations by Carol Lang (Lang and Stump 2017) and a phytolith pilot study (discussed below) by Carol Lang and Hayley McParland, both of whom sampled

Table 1. Count of all material recovered from the South Fields (Site 1) and the village (Site 2) at Engaruka, with the exception of charcoal, which was weighed rather than counted.

Material Type	Fields	Village	Total
Charred Material			
Chaff		6	6
Peduncle		1	1
UNID Rachis		2	2
Sorghum rachis		1	1
Spikelet base		2	2
Spikelet fork		1	1
Sorghum Spikelet base		1	1
Fruit/nut		1	1
Parenchyma		8	8
Crop seeds			
Poaceae		2	2
UNID Family		7	7
UNID Fabaceae		3	3
UNID legume	1	15	16
Vigna sp.		14	14
Vigna unguiculata		2	2
Fabaceae/Poaceae		2	2
Eleusine coricana		3	3
Pennisetum glaucum		3	3
Sorghum bicolor	1	11	12
UNID Millet	1	27	28
Non-crop seeds	12	109	121
Zaleya petandra		4	4
Trianthema/Abelmoschus		5	5
Aizoaceae/ Molluginaceae		1	1
Asteraceae	1	1	2
Caryophyllaceae		1	1
Caryophyllaceae/ Portulacaceae	1	2	3
Chenopodiaceae	1	1	2
Cyperaceae	1		1
Ajuga sp.	1	1	2
Malvaceae		4	4
Molluginaceae/Aizoaceae		1	1
UNID Papaveraceae		1	1
Papaveraceae Type 6		1	1
Typha sp.		2	2
Brachiaria/ Setaria	1	6	7
Digitaria sp.		1	1
UNID Poaceae	1	5	6
Setaria pumila		1	1

Material Type	Fields	Village	Total
UNID seeds	5	72	77
Seed Fragments			
cf. *Elymus* sp.		1	1
UNID Family		2	2
All Uncharred Seeds	19	188	207
Non-botanicals			
Snail Shell	1	6	7
Bone	1	1	2
Dung		48	48
Eggs		1	1
Exoskeleton	1	9	10
Burned clay	2		2
Dung		1	1

the same column of contexts. Excavations revealed the evidence of successive field sedimentation events: the construction of sediment trap fields. Archaeological excavations began at Site 1 with a series of 7 test pits revealing the buried extent of a partially buried irrigation canal. At the same time, a cross-section of the fields (Section 4) was further investigated along a nearby gully, which we later established were akin to the yelas encountered at Konso during fieldwork the following year (2015). Archaeobotanical sampling targeted this profile since it presented the most complete record of the site. For this reason, Section 4 was also subjected to dating via radiocarbon and optically stimulated luminescence (OSL).

The Engaruka results presented below relate to samples taken from the gully section (Section 4), from Site 1 and from the hearths and occupation floors of five domestic buildings in Site 2 on the foothills above the South Fields. These results are derived from the analysis of plant macro remains from flotationTable 1). Interpretations are supported with evidence from preliminary wood charcoal analysis, radiocarbon dating, and a pilot study of phytoliths from the fields. Findings from the collection of seed and pressed plant reference specimens of economic plants as well as consultations with practitioners of the local Maasai agropastoralist plant tradition contribute to furthering the discussion about the significance of certain taxa. This informs the potential for these data to be applied to understanding past plant use in the discussion in Chapter 6.

In order to help contextualise the results, this chapter includes interpretations of possible plant uses and discussion of issues of taphonomy and preservation of macrobotanical material. A discussion of the implications of these results is presented in the following Discussion chapter (Chapter 6), focusing on how these data inform our understanding of Engaruka and Konso, and in particular on how archaeobotanical studies can contribute to studies of sustainability.

Radiocarbon Dating

The radiocarbon dating is presented in order to establish the temporal relationships between the habitation structures in the village (Site 2) and field contexts at Site 1. Whenever possible, charred seeds from the archaeobotanical assemblage were selected for radiocarbon dating; however low levels of carbon in the millets, legumes, and small weed taxa meant that wood charcoal was needed as well. I prioritised the selection of seeds for the purposes of radiocarbon dating since their deposition represents a more refined time frame owing to the seasonality of crops: a tree branch may grow over the course of several years while a seed is produced within a single year. This improves the

Table 2. Radiocarbon results from the South Fields (site 1) at Section 4 and from Buildings 1 to 5 at the Village (Site 2) ordered by date.

Context	Lab No.	Location	Material	Calibrated Ages (95%)	Calibrated Ages (68%)
4015	SUERC-74001	South Fields, Section 4	UNID twig	cal AD 1020–1150*	cal AD 1020–1150*
4025	SUERC-74002	South Fields, Section 4	UNID twig	cal AD 1280–1400*	cal AD 1280–1350*
4126	SUERC-73993	Building 1, Hearth	UNID twig	cal AD 1640–1810*	cal AD 1650–1800*
4131	SUERC-73994	Building 4, Hearth	Moringa sp.	cal AD 1440–1620*	cal AD 1450–1480*
4178	SUERC-73995	Building 4, Hearth	UNID Millet	cal AD 1640–1810*	cal AD 1650–1790*
4174	GrM-12827	Building 3, Hearth	Sorghum bicolor	cal AD 1660-1950**	cal AD 1660-1950**
4174	GrM-13343	Building 3, Hearth	Vigna sp.	cal AD 1660-1950**	cal AD 1670-1940**
4174	GrM-12829	Building 3, Hearth	Sorghum bicolor	cal AD 1690-1920**	cal AD 1700-1920**
4174	GrM-13168	Building 3, Hearth	Vigna sp.	cal AD 1690-1930**	cal AD 1690-1920**
4213	GrM-13171	Building 5, Hearth	Vigna sp.	cal AD 1640-present**	cal AD 1650-1950**
4213	GrM-13172	Building 5, Hearth	Sorghum bicolor	cal AD 1660-present**	cal AD 1660-present**
4213	GrM-13147	Building 5, Hearth	Sorghum bicolor	cal AD 1670-1950**	cal AD 1680-1940**
4213	GrM-13151	Building 5, Hearth	Sorghum bicolor	cal AD 1680-1940**	cal AD 1680-1930**
4200	SUERC-74742	Building 5, Hearth	Sorghum bicolor	cal AD 1660-present**	cal AD 1670-1950**
4183	GrM-12830	Building 5, Floor	UNID millet	cal AD 1660-present**	cal AD 1660-present**
4161	SUERC-73999	Building 2, Hearth	Vigna unguiculata	cal AD 1700–1930*	cal AD 1890–1900*
4174	SUERC-74000	Building 3, Hearth	Sorghum bicolor	cal AD 1670–present*	cal AD 1690–1950*

precision of the dating of the contexts. I selected wood charcoal specimens for those contexts which did not contain seeds suitable for dating. To refine the date range as much as possible, it was necessary to either select samples of young charred twigs or to identify short-lived tree taxa. Identification of woody taxa was carried out by Delphine Jolie at the University of York. Seed and charcoal samples were initially sent to the Scottish Universities Environmental Research Centre (SUERC) for Accelerator Mass Spectrometry (AMS) dating.

Samples were dated from two contexts in the gully section and from each of the five domestic buildings in the village. Many of the original specimens were too small or too poorly preserved to contain enough carbon necessary for secure dating. However, given the importance of establishing clear dates, a subsequent round of specimens were sent to the Centre for Isotope Research (CIO) at the University of Groningen, which is equipped for AMS dating of very small seeds and seeds that contain a low amount of carbon due to relatively poor preservation. Highlighting this issue, charred specimens of *Pennisetum glaucum* (Building 5) and UNID Fabaceae were submitted for dating to SUERC; however both were too fragmentary to contain sufficient carbon. The tendency of millets, in particular, to burst during firing increases the likelihood of this type of damage, thereby compounding the issue of dating these small seeds.

All non-charred wild seeds and the fruit/nut were dated to the modern era (post AD 1950) and thus could not support an argument for the possibility of preservation via desiccation. While desiccation was not deemed a likely course for preservation given the annual succession of seasonal flooding and aridity of the fields, establishing this with more certainty guided the study towards its ultimate focus on the charred seed assemblage. The reader should note that recommendations for the potential application of (non-carbonised) seedbank analysis in future studies of Engaruka are presented in Chapter 7.

The details of the dated taxa and AMS results for Engaruka are presented in Table 2. and discussed throughout the statistical analysis. Charcoal samples were dated from two contexts in the gully section and from each of the five domestic buildings in the, nine total contexts. Seed taxa sent for dating included a charred Fabaceae specimen from Section 104, which was not successfully dated due to its fragmentary nature, discussed above. Seeds from the village included *Sorghum bicolor*, UNID millet, *Vigna unguiculata*, *Vigna* sp., *Ajuga* sp., and unidentified seeds. Five different woody taxa were identified during anthrocological analysis of fuelwood from village hearths; however, just one specimen of *Moringa* sp. and one unidentified twig returned successful dates. The undated wood taxa are discussed in the charred wood discussions below.

The earliest dates were from the field and they were based on specimens charred and likely deposited during a flooding event or during in-situ burning (e.g. such as slash and burn and stubble burning), which might be expected in an agricultural field context. In Section 4, Context 4015 was dated to the 10th to 11th century A.D. and Context 4025 (Table 2) was dated to the late 13th to early 15th century A.D. (Table 2), which is significantly earlier than dates in the village. Both specimens were carbonised, unidentified (UNID) twigs. It is possible that these specimens could have entered the record long before the field system was established, perhaps being deposited on the escarpment above and carried via river channels feeding the irrigation scheme. However, the dates are at least consistent with stratigraphic deposition (4015 is below 4025 in the profile), suggesting that while there was mixing of the sediment within field contexts, once deposited the matrices were largely undisturbed as would be expected with sediment trap soil profiles.

The earliest date in the village, 15th to 17th century A.D., came from a fragment of *Moringa* sp. from Building 4 (Table 2). The Moringa tree is the source of an important leafy edible vegetable and oilseed with 8 species endemic to Eastern Africa. It has a well-documented presence in Tanzanian ethnomedicine for the treatment of conditions such as malaria (Nondo et al. 2015) and respiratory disease (Otieno et al. 2011, 614), but little is known of its pre-modern distribution and use in Tanzania. The greatest genetic diversity in the region is found in Northern Kenya and Ethiopia. Moringa use at Engaruka (beyond its use as fuelwood) could be indicative of an agricultural risk mitigation strategy: it has been widely hailed as a drought resistant tree producing food and valuable oil that lends itself to intercropping with millets and legumes. This is the most popular combination of crops amongst the farmers of Konso today. Seeds were also dated from Building 4 including two *Sorghum bicolor* and two *Vigna* sp. and date to the late 17th century. These will be discussed in the seed discussion below.

Building 5 was dated to the late 17th century (Table 2) based on AMS of sorghum (n=4) and *Vigna* sp. (n=1) from the hearth, and UNID millet (n=1) from the occupation floor. Sorghum and *Vigna* sp. seeds from Buildings 1, 2, and 3 returned equivalent hearth dates, though the UNID twig from Building 1 returned an earlier 17th to early 19th century date range.

Table 3. Shannon diversity indices for Site 1 and Site 2 related to radiocarbon dates. Building diversity is listed in chronological order by earliest date within the range.

Location	Dating	Diversity
Site 1	1020-1400 cal AD	2.30
Site 2	1440-present	2.76
Building 4	1440-1810 cal AD	1.37
Hearth A	1440-1620 cal AD	0.69
Hearth B	1640-1810 cal AD	0.00
Building 1	1640-1810 cal AD	2.62
Building 5	1640-present	2.14
Building 3	1670 cal AD -present	2.32
Building 2	1700-1930 cal AD	2.48

The significance of the dated seed taxa are discussed in the seed results which follow. A key finding of the radiocarbon results from the village is that the ruined fireplaces do not appear to have been in use after the abandonment of the site, from at least the 19th century to the present. Also, the earliest structure, Building 4 (which contained two fireplaces) had the lowest diversity (Table 3), but the highest ratio of crops to weeds. Diversity generally increases from the early 17th century possibly indicating a move toward the use of more wild economic plants over time.

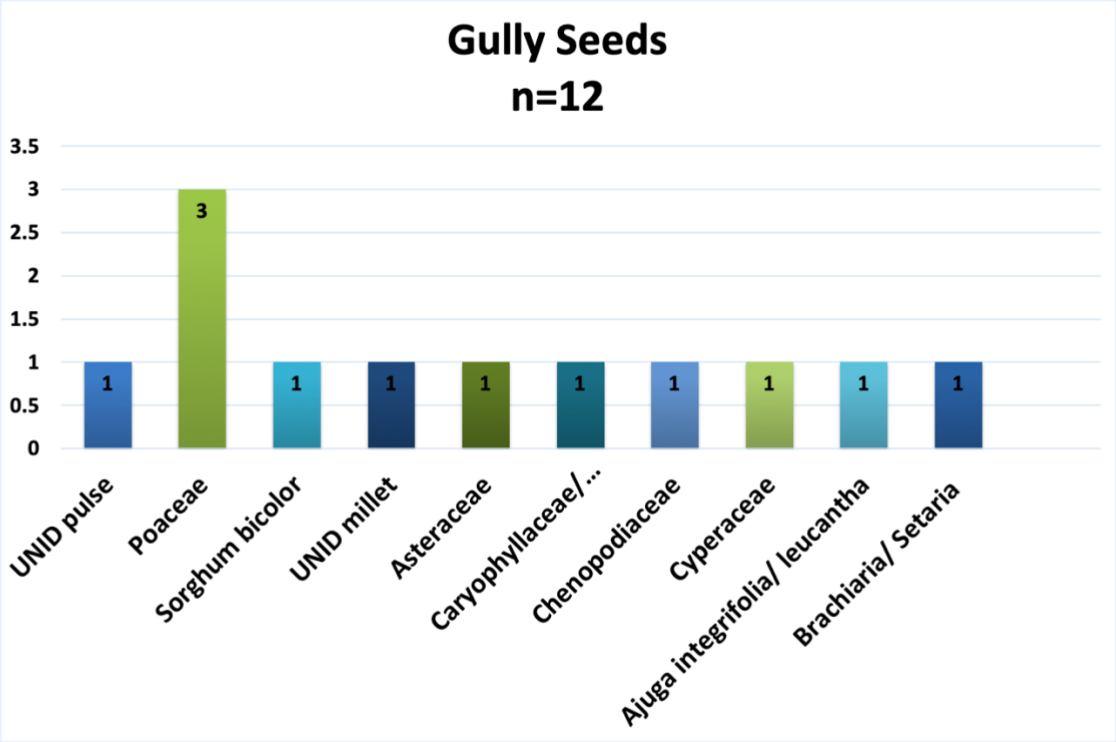


Figure 14. Seed assemblage from Section 4, the gully profile at the South Fields (Site 1) at Engaruka.

South Fields

I collected 9 samples from the gully profile (Section 4) which amounted to 225 L of soil, producing 66.4 g of light fraction. Large bulk samples of soil (averaging 25 L each) were taken to investigate the potential evidence of in situ burning. Section 4 was radiocarbon dated to the 11th to early 15th centuries with the later range potentially correlating with the occupation of the village (Table 2). The archaeobotanical assemblage included UNID legume (n=1), Poaceae (n=3), sorghum (1), UNID millet (n=1), comprising the crop seeds, and Asteracea, Caryophyllaceae/Portulacaceae (n=1), Chenopodiaceae (n=1), Cyperaceae (n=1), *Ajuga* sp. (n=1), *Brachiaria/Setaria* (n=1). All of the carbonised seeds (n=12) came from the two dated contexts 4015 and 4025. Despite also being identified as agricultural fields (Lang and Stump 2017, 7), the contexts 4026, 4027, and 4028 contained no carbonised seeds and very little charcoal: 0.02 grams (22% of total charcoal from the gully). These early field deposits may be representative of a management system that did not include stubble burning and thus did not result in the preservation of macrobotanical residues. The practice of stubble burning could have developed over time, with the first archaeobotanical seed and charcoal evidence of burning activity only appearing in the 11th century field deposits (contexts 4015 and 4025). However, the low recovery of burned material could be the result of a secondary deposition of burned vegetation with eroded sediments from the escarpment via controlled flooding.

Charred Wood

A total of 0.87 grams of charcoal was recovered from Section 4. This low density (0.0004 grams/litre of soil floated) is significantly lower than any other site in the study, including the agricultural contexts at Konso. Wood charcoal would not necessarily be expected in a field context unless it was being transported along with sediment eroding from the escarpment above. In addition to the unidentified twigs used to date Contexts 4015 and 4025, charcoal from *Acacia* sp. was identified from context 4015. *Acacia* sp. refers to a large genus of Fabaceae that was sub-divided in 2009 to account for the distance in the lineage between African and Australian Acacias. Despite the original type species, *A. nilotica*, having an African origin, the Australian lineage is much larger, so it was decided that it would be less disruptive to rename the African lineages. Since 2009, *Vachellia* sp. includes the thorn acacias discussed throughout the current study.

Seeds

Charred seed recovery was very low (Figure 11) in comparison to the assemblage at Site 2. Five of the 17 seeds were unidentifiable and the ratio of crop to (identified) weed seeds was 1:1. Crops included UNID legume (n=1), Poaceae (n=3), Sorghum (n=1), UNID millet (n=1). Millets and legumes are known to have formed the basis of numerous modern and ancient regional agronomies as discussed in detail in Chapter 2. Given their prominence in the assemblage they appear to have been just as important to the in the past as they are in the modern farming carried out by local Maasai agropastoralists. Not only were millets and legumes recovered from both the fields and domestic spaces, but sorghum and other grass phytoliths (Figure 15) from either wild or domesticated rice were also identified from the fields as well. The discovery of sorghum seeds in the fields and domestic spaces as well as sorghum phytoliths in the fields confirms that the locally produced crops, were consumed in the village.

Charred seed recovery was very low relative to assemblage at Site 2. The only legume identified from Engaruka (or Konso) was cowpea, but other legumes discussed in Chapter 2 could have been in cultivation, such as *Cajanus cajan* (pigeon pea), *Lablab purpureus* L. Sweet (hyacinth bean), and *Vigna subterranea* (L.) Verdc. (bambara groundnut). These are considered to be contenders for the

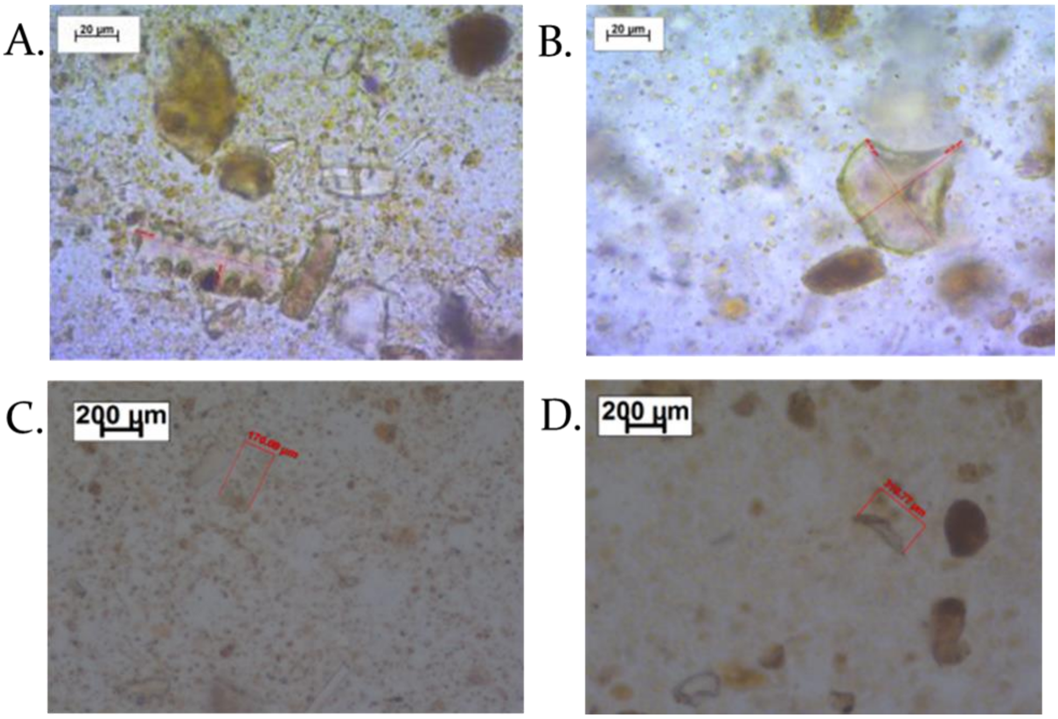


Figure 15. Phytoliths from field contexts at Engaruka, including A). non-articulated sorghum; B). grass bulliform; C). scooped bilobate (wild/domesticated rice); and D). double peaked phytolith (wild/domesticated rice).

UNID legumes found at Engaruka because they are known to have been significant early regional crops that are still in cultivation in Engaruka and more widely across eastern Africa, though the morphology of the UNID seeds is most consistent with cowpea and pigeon pea.

Carbonised weeds included Asteraceae (n=1), Caryophyllaceae/Portulacacea (n=1), Chenopodiaceae (n=1), Cyperaceae (n=1), *Ajuga* sp. (n=1), Brachiaria/Setaria (n=1). Asteraceae is a large family of flowering plants prominently known as a weed of cultivation (Shemdoe et al. 2008) and an ethnomedicinal ingredient (Moshi,Otieno and Weisheit 2012) in Tanzania. The vast diversity of Asters across Eastern Africa limits the interpretation of the potential identity of these taxa, though future studies will investigate their utility as regional weeds of cultivation. Similarly, the other weeds are interpreted to be companion weeds given the low specimen count and their presence in the field context. However, as is the case at Konso and discussed in Chapter 5, the presence of seeds of *Portulaca* sp., a genus which includes edible leafy greens and the sedges of Cyperaceae, often collected as corms, could have been wild food sources as opposed to just being weeds of cultivation.

Terrace Village

The archaeobotanical assemblage from the village (site 2) is based on the analysis of 57 samples taken from across Site 2. The radiocarbon dating discussed above places the start of the occupation of the village to the first half of the 15th century (Table 1). Thirty-one archaeobotanical samples were taken 5 buildings across the site: from 6 hearth contexts, 25 from floor contexts, and 1 from sediment below a hearth (sub-hearth layer). One-hundred and thirty-five litres of sediment were floated from the hearths, 27.8 L from the floors, and 1 L from the sub-hearth layer. After flotation, this produced 504.02 g. of light fraction from the hearths, 411.44 g. of light fraction from the floors, and 89.68 g. of light fraction from the sub-hearth layer. Sample sizes varied significantly based on context. Occupation floor samples averaged 1-2 L, while 100% of hearth contexts were sampled in order maximize recovery of seeds. There was no clear correlation between the density of plant macro-remains and sample size, the recovery of archaeobotanical materials was influenced by factors beyond the amount of sediment processed from given context. Details of the character of each structure are discussed in the following section, however the most significant findings of the analysis are the temporal distribution of specific crops found within the buildings and the revelation that crop:weed ratios correspond with specific contexts of use. A high ratio is associated with hearth contexts while a low ratio is associated with occupation floors, this contrasts with the fields where crop and weed seeds occur in equal numbers.

There are diverse explanations for why non-crop seeds find their way into domestic contexts such as the habitation structures at Engaruka. The key question is whether or not the people who brought them back to the house did so intentionally. Seeds of these wild taxa or weeds of cultivation (defined in Chapter 2) are often accidentally collected during crop harvest, especially if they produce inflorescences at the same height as the crop, or passively carried on the body of people and animals that enter the space. Some are weeds of cultivation or wild taxa known to be collected as economic plants.

In the case of the millet and legume-based agronomy at Engaruka, evidenced by the crop assemblage, the possibility of field weeds being recovered in domestic contexts through accidentally is relatively unlikely because of how these crops are harvested and processed. Legumes grow close to the ground where accidental harvest of wild seeds along with the legume pods would not be unexpected, however the process of dehusking and drying the legumes means that most unwanted seeds (including weeds) would be removed and discarded at the processing site rather than making it back to the domestic space. Meanwhile, sorghum and other millets grow high above most potential weeds of cultivation, with the exception of all but the tallest of wild grasses. The height to which millet seed heads grow and the method by which they are harvested reduces the likelihood that weed seeds would be accidentally collected during harvest, though it could be an explanation for the wild grasses present in the assemblage.

Some weeds enter the domestic archaeological context through natural seed dispersal, known as seed rain. Seeds are transported by wind, water, animal or human transit, and explosive dehiscence, but to be preserved via carbonization they must either be present in the soil around the hearth (having fallen as seed rain), intentionally discarded in the hearth, or accidentally enter the domestic space after being carbonized off site, though Minnis (1981) established that this type of naturally charred seed rain is not common in non-anthropogenic off-site soils. Some weeds are intentionally harvested due to human selection of wild plants and weeds of cultivation. This is evidenced by the presence of edible taxa in the assemblage, including *Portulac*a, *Setaria*, and *Amaranthaceae*.

In the village at Engaruka the collective crop/weed seed ratio in the hearths is 17:21, and across the occupation floors is 5:31. Contrasting this with the fields, where the ratio is 1:1, we begin to see a recognisable pattern of deposition. The charred weed seeds are most common in hearths and least common across floors but make up the majority of the total seeds in both categories. Seed rain and human or animal dispersal explains the presence of non-carbonized weed seeds in the floor sediments, but why are so many charred weeds found in hearths and why do they appear in the floors outside of the fire? The higher density of seeds in the hearth and their more occasional recovery from the floors is likely the result of hearth cleaning. Floor sweepings were discarded in the hearth and carbonised along with fuelwood charcoal and other discarded household waste, then when the hearth was cleaned some charred macrobotanicals could fall and become incorporated into the matrix of the floor.

It should be noted that the final assemblage excludes one building and one occupation floor that were excavated and sampled during fieldwork. A sixth building in the village (Building 6), was excavated and sampled, but later excluded from the analysis when it was determined to have been excavated by Sassoon (1966). Samples from the floor at Building 4 were also taken and analysed, however they were excluded from the current study because they had previously been analysed during 2002 excavations (Siiriäinen et al. 2003), though the hearth had been left intact during those excavations so it was included in the current analysis. The macrobotanical assemblage was comprised of charred seeds (n=115), chaff (n=6), parenchyma (n=8), and charcoal (77 g.). Non-botanical finds include bone (n=1), insect dung (n=48), a small reptile egg, insect exoskeletons (n=9), gastropod shells (n=6).

Crops Seeds The crop seed assemblage (n=77) was dominated by millets (n=43) and legumes (n=34) including Fabaceae (n=3), UNID legume (15), *Vigna* sp. (n=14), *Vigna unguiculata* (L.) Walp. (cowpea, n=2), *Pennisetum glaucum* (L.) R. Br. (pearl millet, n=3), *Sorghum bicolor* (L.) Moench var. *caudatum* (n=11), and UNID millet (n=27). Two seeds were identified as either Poaceae or Fabaceae.

Fabaceae and Poaceae crops seeds were found in all of the habitation structures. The earliest dated crops are early 17th century seeds of UNID millet and *Vigna* sp. from the hearth at Building 5 (Table 2). Other crops recovered from this

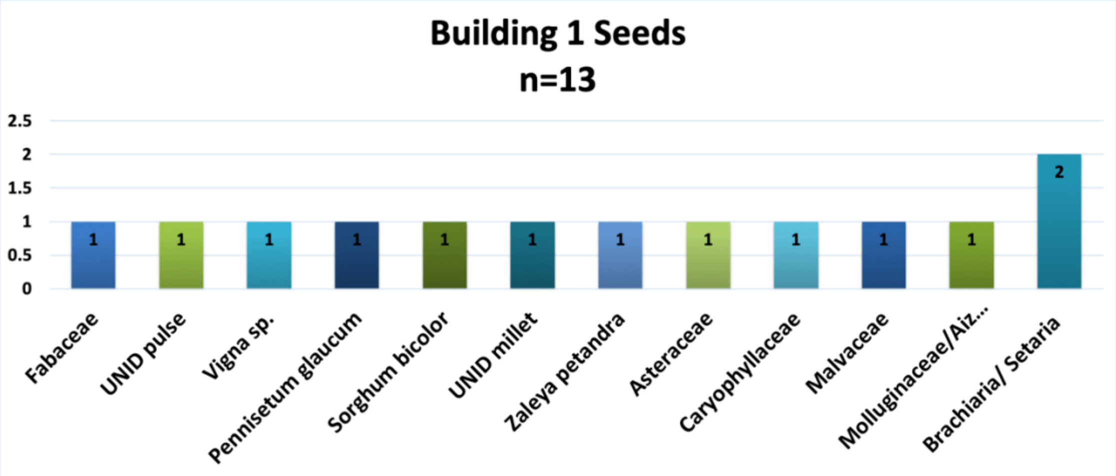


Figure 16. Charred seeds from Building 1. Note that this count excludes UNID seeds (n=14).

context include UNID Fabaceae (n=1) and UNID legume (n=1). This indicates that both legumes and millets appeared at Engaruka at the same time, though it is possible that either of these crops could have been imported, at least initially. The fact that sorghum phytoliths were recovered from the South Fields contexts that predate the earliest occupation of the village suggests that it was being grown locally rather than imported.

Weed Seeds Charred wild seeds included *Zaleya pentandra* (L.) C. Jeffrey (n=4), *Trianthema*/Abelmoschus sp. (n=5), Aizoaceae/Molluginaceae (n=2), Asteraceae (n=1), Caryophyllaceae (n=1), Caryophyllaceae/Portulacaceae (n=2), Chenopodiaceae (n=1), Ajuga sp. (n=1), Malvaceae (n=4), Papaveraceae (n=2), Brachiaria/Setaria sp. (n=7), Digitaria sp. (n=1), Poaceae (n=5), Elysmus sp.(n=1) and UNID fruit/nut (n=1).

Building 1

Building 1 is situated at the lowest terrace in the village and is closest to the South Fields down the slope. The north section of the wall facing the downslope had been damaged causing the floor sediments to erode and impacting the integrity of the occupation floor. A total of seven samples were taken from the hearth (n=5) and floor (n=2). The soil sampled (22.3 L) produced 71.93 g. of light fraction, from which 27 seeds were recovered (Figure 13). The archaeobotanical assemblage was dominated by UNID seeds (n=14) that were too damaged for identification. Identified seeds included Fabaceae (n=1), UNID legume (n=1), *Vigna* sp. (n=1), pearl millet (n=1), sorghum (n=1), UNID millet (n=1), *Z. petandra* (n=1), Asteraceae (n=1), Caryophyllaceae (n-1), Malvaceae (n=1),

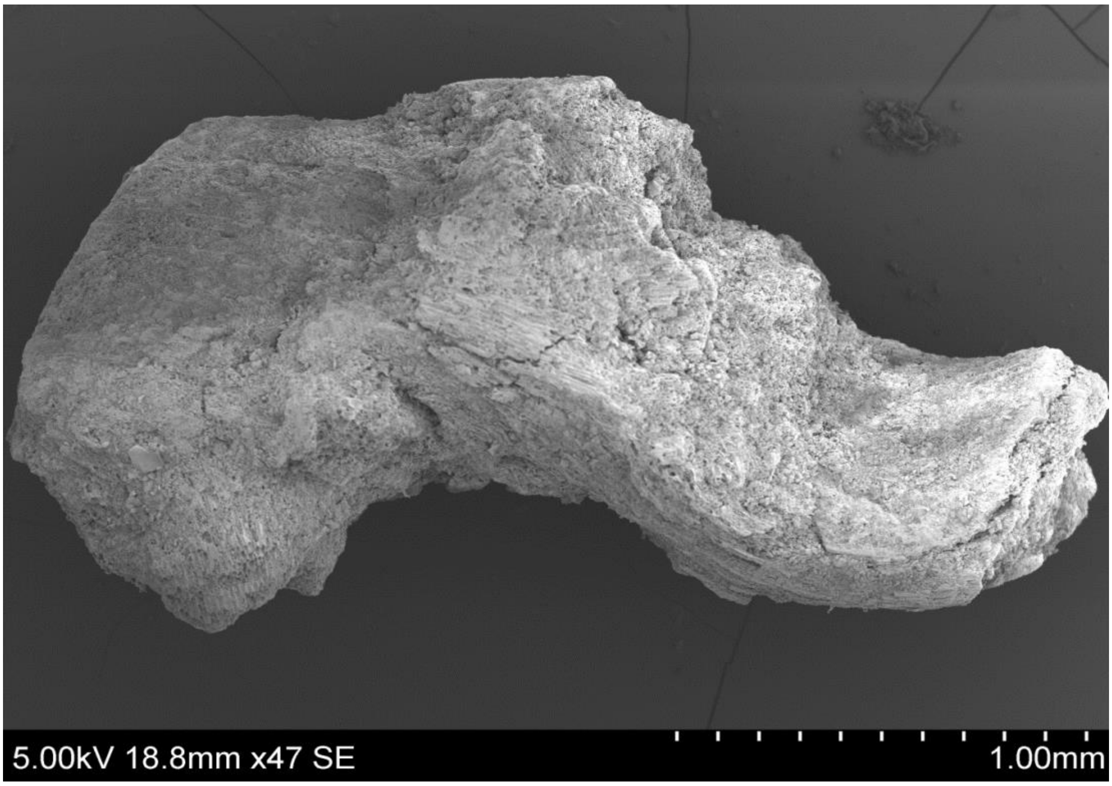


Figure 17. SEM image of a sorghum rachis. Courtesy of Dorian Fuller and Lara Gonzalez Carretero, Institute of Archaeology, University College London.

Brachiaria/Setaria sp. (n=1). Charred seeds were 67% ubiquitous from across the contexts within the structure, with the ratio of crops to non-crops being nearly equal (6:7).

Building 1 contained the largest amount of chaff (n=5) and highest ratio of chaff to millet (5:3) of any of the village structures with a chaff. A rachis of sorghum from context 4126 within the hearth, dating to between the 17th to 19th century AD (Table 1), was identified by Dorian Fuller using SEM imaging (Figure 14). The presence of chaff and grains in the hearth and the low density of wild seeds in the domestic context suggests that stalks of sorghum were harvested and brought back to the village to be processed locally rather than in the field, a practice that is well established ethnographically and discussed further in Chapter 6.

Building 2

Building 2 is situated to the south of Building 1 on the terrace above it (Figure 1). The two structures are separated by a small stone-walled yard next to Building 1 and a wide footpath extending along the terrace through the village. A smaller footpath connects Building 2 to the wider footpath. Since the floors of Building 2 were previously excavated, the current study excludes this context from the results. Contexts within the hearth were excavated and five samples were taken, comprising 26 L of soil, which produced 26.67 g of light fraction. The carbonised seed assemblage from the hearth contained crop seeds including indeterminate Fabaceae (n=1), UNID legume (n=2), *Vigna* sp. (n=2), Cowpea (n=2), Fabaceae/Poaceae (n=1), sorghum (3), and UNID millet (n=3). Carbonized

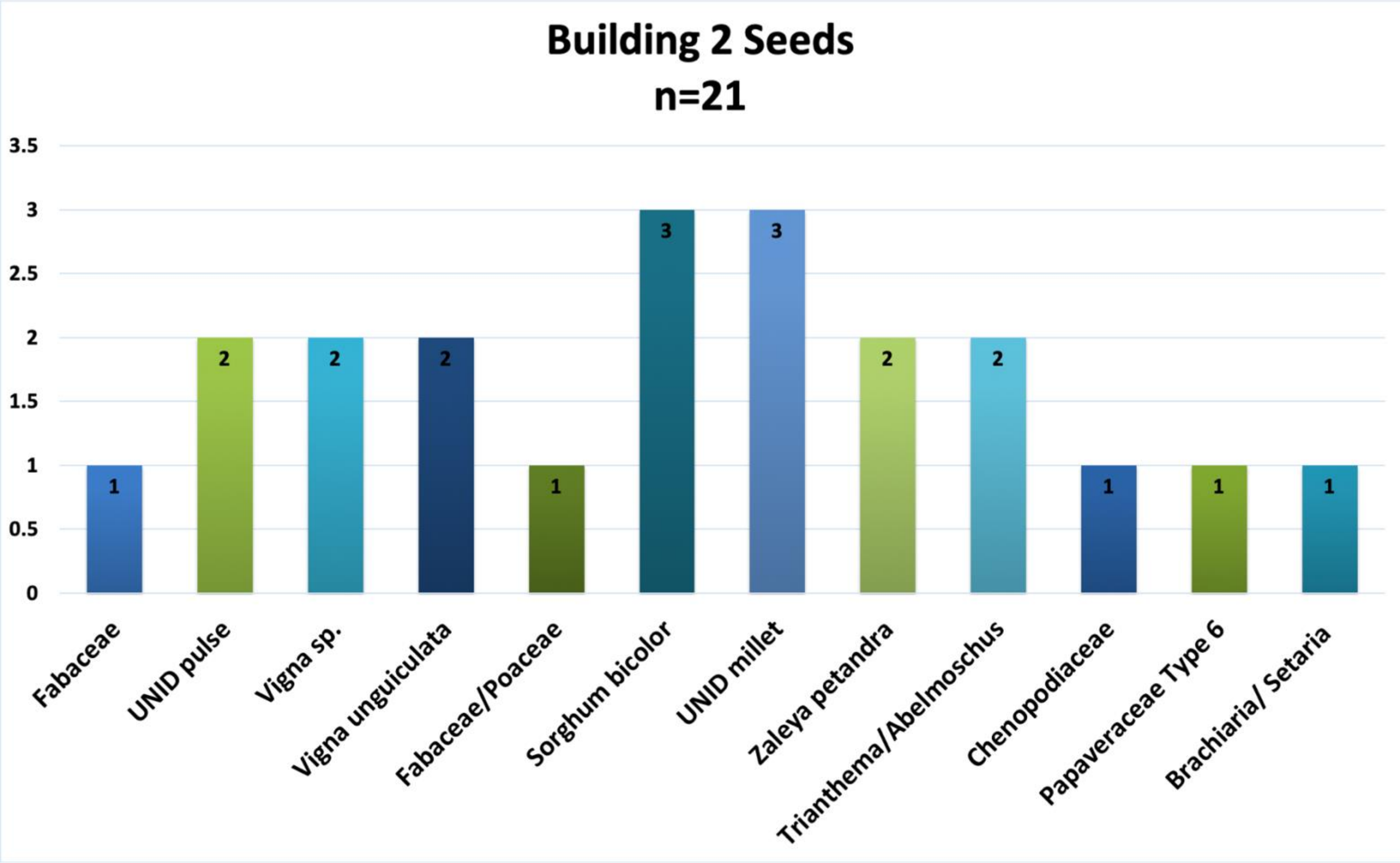


Figure 18. Charred seeds from Building 2. Note that this count excludes UNID seeds (n=18).

weed seeds included *Zaleya pentandra* (n=2), *Trianthema/Abelmoschus* (n=2), Chenopodiaceae (n=1), Papaveraceae (n=1), *Brachiaria/Setaria* (n=1). The ratio of crops to weeds was 2:1.

The highest density of crops came from contexts 4158 and 4161, with each containing four crop seeds, including millets and legumes. Context 4158 was described as habitation fill overlaying the outer hearth deposits, which may have been disturbed during previous excavations. These results are included because of the relationship to the hearth, but interpretation is limited due to the uncertainty about the integrity of the context. A fragment of unidentified Poaceae chaff was recovered from this context, though no grain was found.

One cowpea from Context 4161, the lowest hearth deposit, was dated to between 1700 and 1930 AD (Table 2), and thus contemporary with the occupation of Building 1. It also produced the highest density (n=21) of charred seeds of all of the contexts within the hearth, including 16 weed seeds. The greatest density of weeds also came from 4161. Context 4160 was made up of later hearth fill above 4161 and contained just two UNID millet seeds and no legumes or non-crop seeds.

Building 3

Building 3 is situated to the south of Building 2 and below Building 4 at the same position on the slope as Buildings 3 and 6 (Figure 1). These structures, which are situated at a steeper incline than Buildings 1 and 2, are accessible by way of meandering paths frequently bounded by large stones and punctuated with stone steps. Three contexts within the hearth were excavated with one

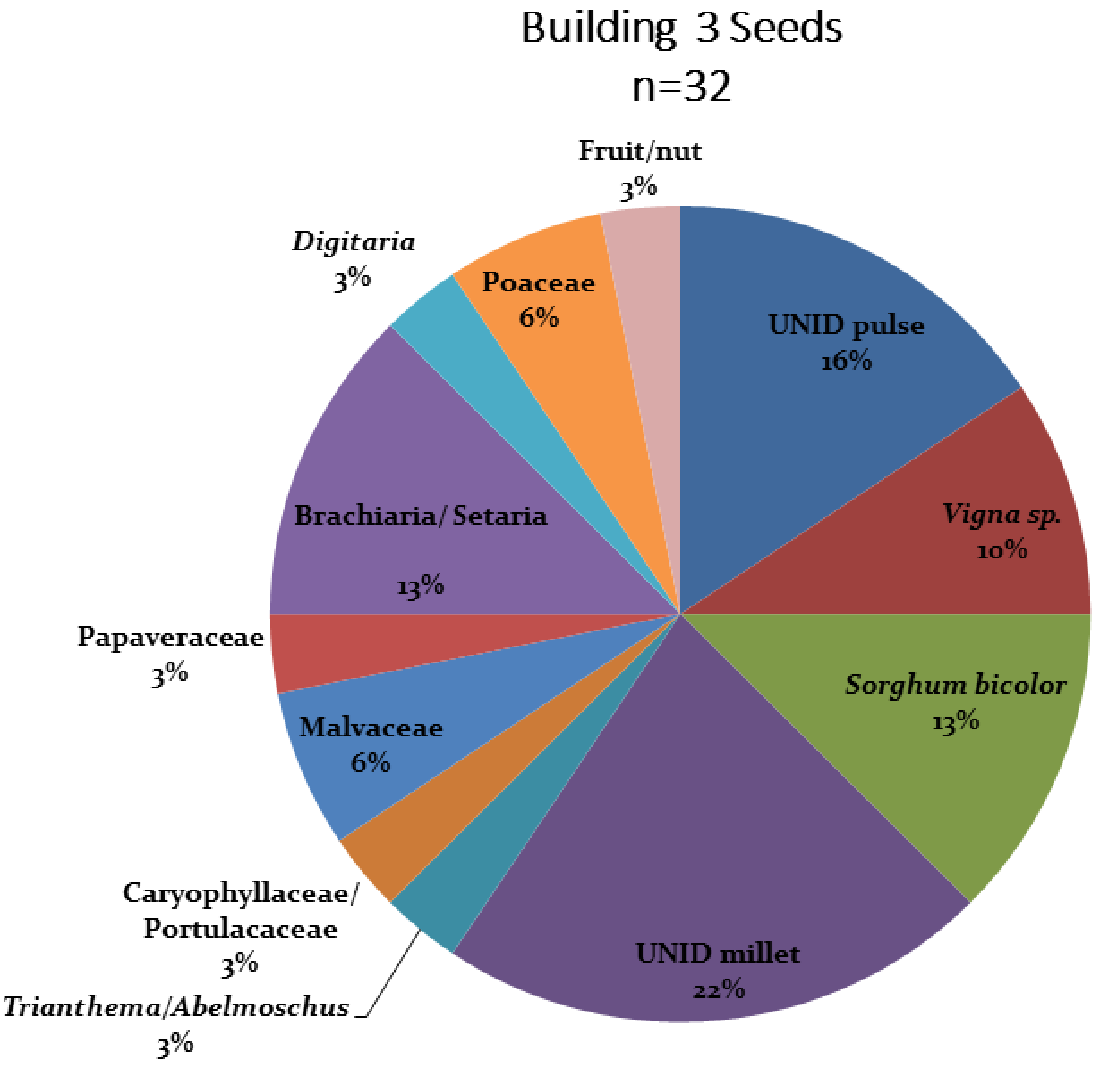


Figure 19. Charred seeds from Building 3. Note that this count excludes UNID seeds (n=19).

sample taken from each. Total soil sampled was 37 L and flotation produced 93.5 g of light fraction. Charcoal recovery (0.1 g) was low, but comparable to Buildings 1 and 2. The carbonised seed assemblage from the hearth contained crop seeds including UNID legume (n=5), *Vigna* sp. (n=3), sorghum (4), and UNID millet (n=7). Crop seeds were relatively evenly distributed within the hearth and floor contexts: 4-5 seeds including millets and legumes. The exception was context 4156 which contained only a single sorghum seed.

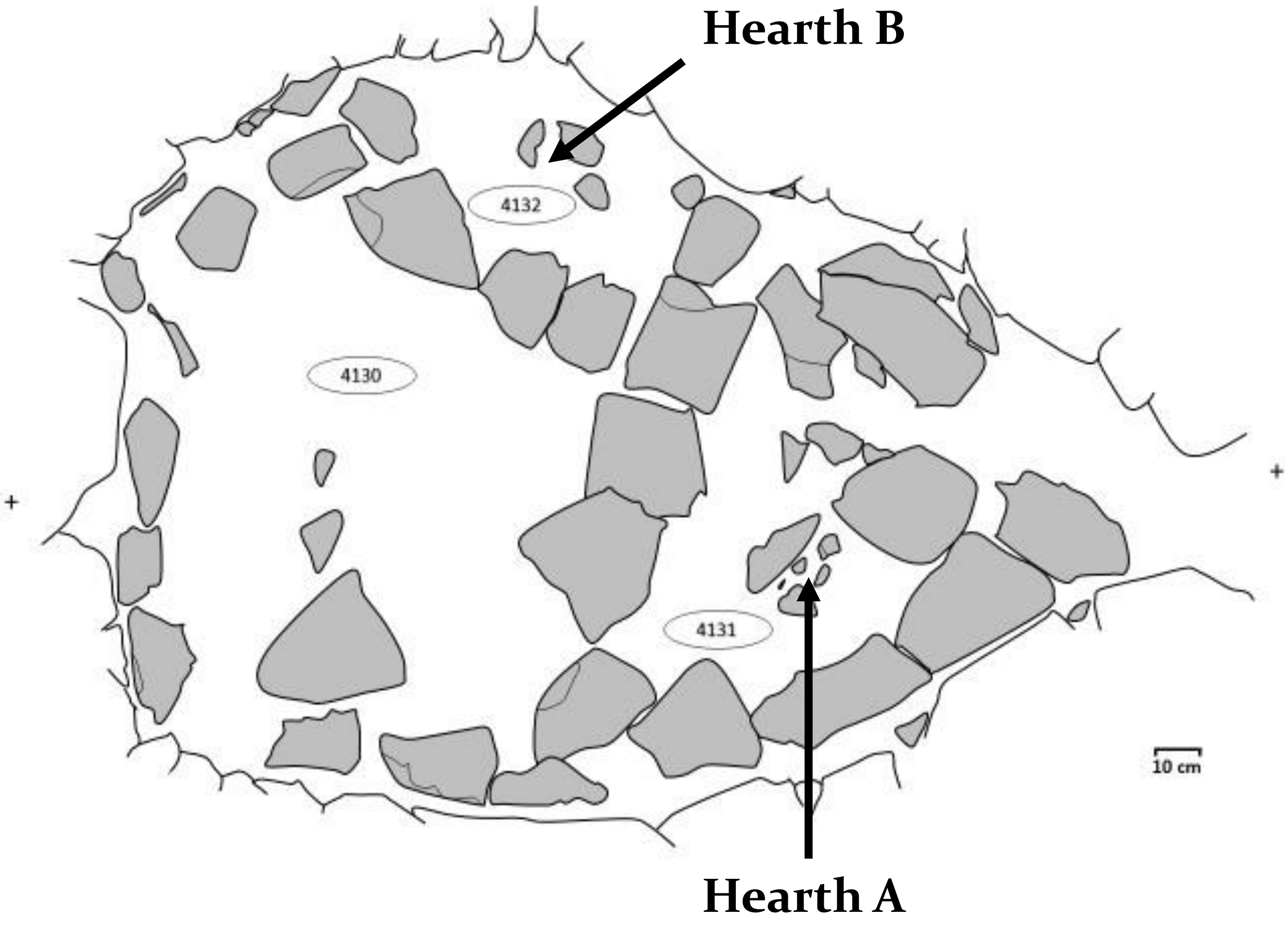


Figure 20. Plan of Building 4 including Hearth A and Hearth B.

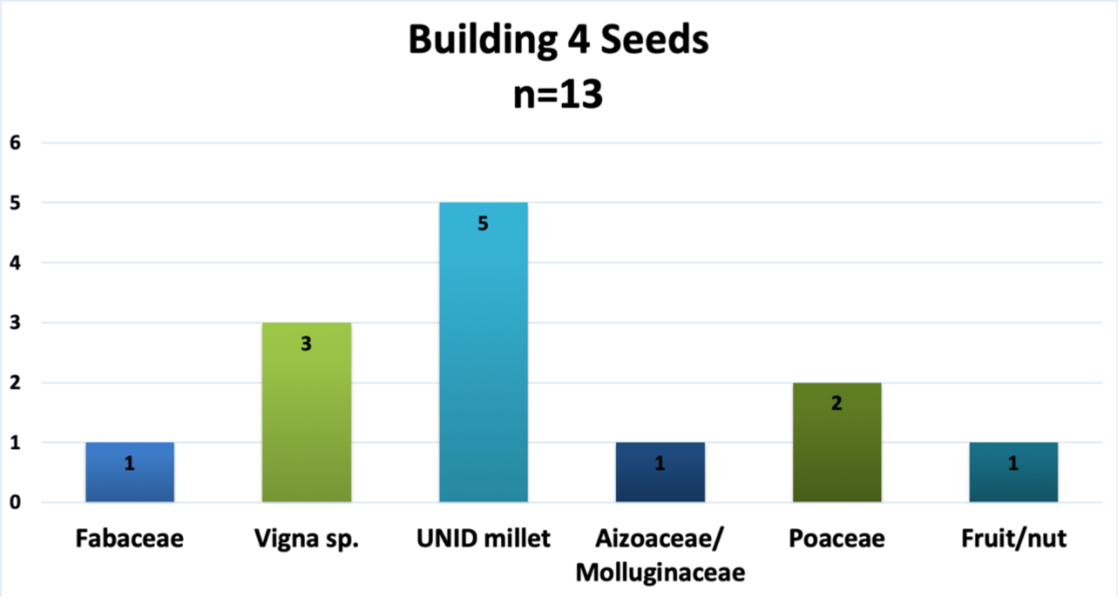


Figure 21. Charred seeds from Building 4. Note that this count excludes UNID seeds (n=8).

Context 4174, the lowest hearth layer, contained the highest number of different crop taxa and a single sorghum seed was dated to the late 17th century. In addition to charred seeds, 5 pieces of millet chaff were recovered from context 4174, including a peduncle and three spikelet bases. Carbonized weed seeds included *Trianthema/Abelmoshcus* (n=1), Caryophyllaceae/Portulacaceae (n=1), Malvaceae (n=2), Papaveraceae (n=1), *Brachiaria/Setaria* (n=4), *Digitaria* (n=1), Poaceae (n=2), and UNID fruit/nut (n=1). The seed ratio of crops to weeds was 19:13.

Building 4

Building 4 is situated to the south of Building 3 and to the West of Building 5 (Figure 10) and is unique because it contains two hearths (Figure 17). Hearth A was located closest to the doorway and predated Hearth B, located in an alcove along the right side of the building. A fragment of *Moringa* sp. from context 4131 in Hearth A placed its use to between the first half of the 15th century AD and the early 17th century A.D., while an UNID millet from context 4178 in Hearth dated to between the first half of the 17th to the early 19th centuries AD (Table 2). The location of Hearth A was unusual because it was so close to the doorway that people entering the structure would have only a narrow passage of about 50 cm to pass through. Its proximity to the door would have facilitated ventilation and allowed someone at the fire to see out the doorway. Assuming that the limited overlap of the radiocarbon dates of the hearths and that the earlier date of Hearth A both indicate that it was abandoned when Hearth B was established, its inner hearth stones would have created an uneven walking surface, which is another characteristic unique to Building 4. The archaeobotanical assemblage was derived from the sampling of five hearth contexts and 2 floor contexts. Sediment amounting to 26 litres was processed and 3.63 grams of charcoal, the second highest concentration in the village after Building 5. The carbonised seed assemblage (Figure 18) was comprised of Fabaceae (n=1), *Vigna* sp.(n=3), UNID millet (n=5), Aizoaceae/ Molluginaceae(n=1), Poaceae (n=2), and UNID fruit/nut (n=1). Building 4 contained the second highest ratio of crop seeds (n=9) indeterminate Fabaceae, *Vigna* sp., and UNID millet) relative to weed seeds (n=4); Aiozoaceae/Molluginaceae, UNID fruit nut, and wild Poaceae). As mentioned above, Building 4 was the earliest and least diverse seed assemblage of any of the buildings (Table 3). It represents the earliest appearance of millets and legumes. The low recovery of weed seeds may indicate a preference for domesticates during the earliest phase of Site 2 occupation, despite the distance of Building 4 from the sediment trap fields at Site 1.

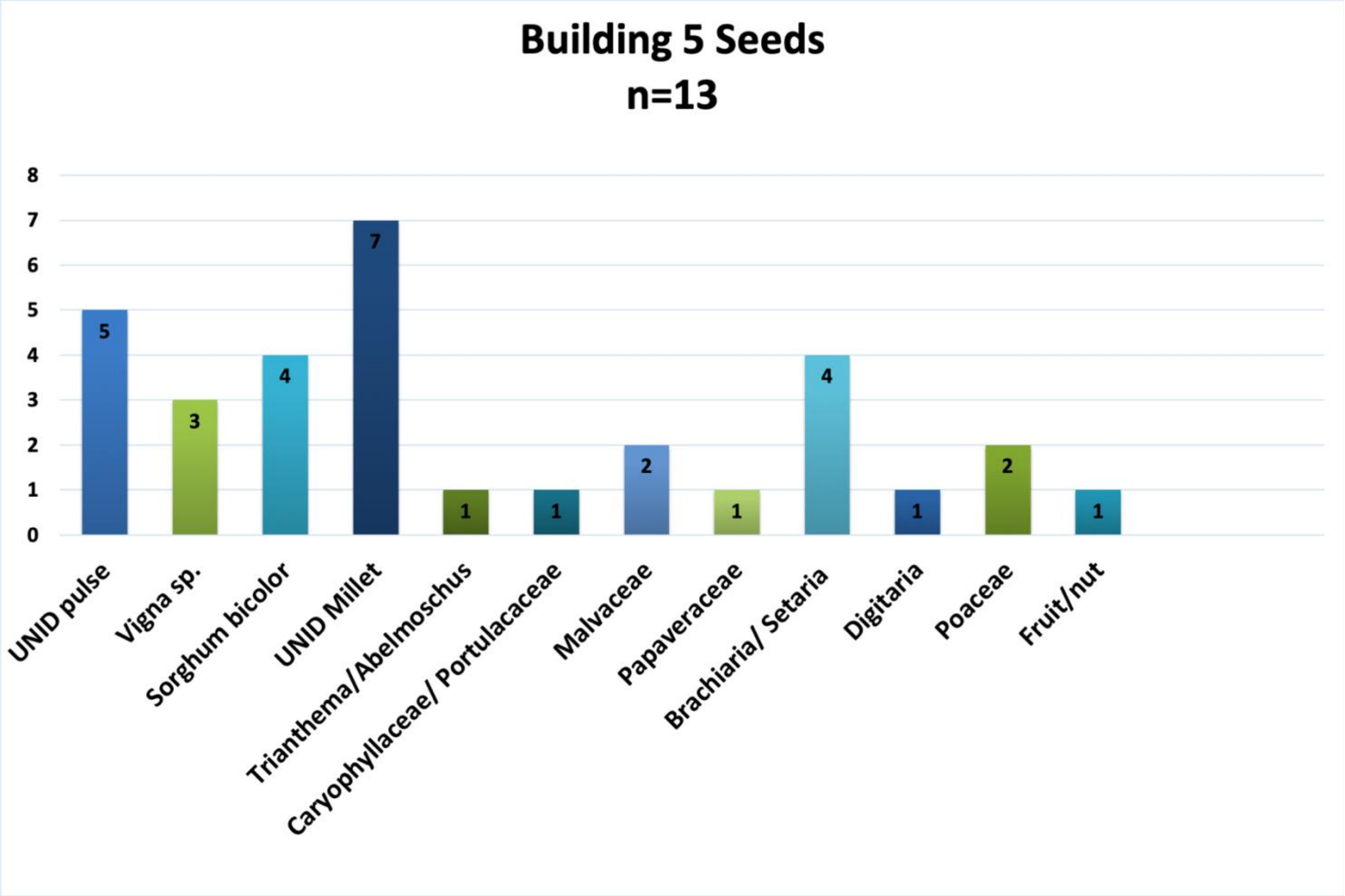


Figure 22. Charred seeds from Building 5. Note that this count excludes UNID seeds (n=13).

Building 5

Building 5 was at the highest elevation, located in the south-central area of Site 2, southeast of the nearest neighbouring structure in the village, Building 4 (Figure 10). The structure dates to between 1640 cal AD and the present (Table 2), placing its earliest occupation within the range of Building 1 and also later phase of Building 4, associated with Hearth B. Sediment amounting to 52.5 L was processed from three hearth contexts, one sub-hearth context (terrace platform sediment), and one occupation floor context. Charcoal recovery (4,74 g) was high relative to the other buildings in the village, with the average recovery being 1.86 grams.

Non-Botanical Categories

The current study does not focus on the non-botanical assemblage, however, these data are partially reported in Table 1. These finds were recovered from light fraction and include snail shell, bone, insect or small rodent dung, small reptile eggs, insect exoskeleton, and burned clay. Though not included here, glass beads and a child’s tooth were found in heavy fraction samples.

Summary Based on Correspondence Analysis.

Correspondence analysis was carried in order to identify the spatial patterning of charred seeds across the three categories of contexts: hearth, floor, and gully. The analysis was focused on the entire sub assemblage of charred seeds and chaff, which originated from 24 different samples. Coincidentally, once outliers were excluded, the number of species was also 24, thus providing a robust ration

Table 3. Contingency table of percentages relating to correspondence of specific taxa to domestic and agricultural contexts.

Taxa	Floor	Field	Hearth	Total
Aizoaceae/ Molluginaceae	0.000	0.000	2.222	1.449
Ajuga integrifolia/ leucantha	2.632	10.000	0.000	1.449
Asteraceae	0.000	10.000	1.111	1.449
Caryophyllaceae/ Portulacaceae	0.000	10.000	2.222	2.174
Chaff	2.632	0.000	14.444	10.145
Chenopodiaceae	0.000	10.000	1.111	1.449
Cowpea	0.000	0.000	2.222	1.449
Cyperaceae	0.000	10.000	0.000	0.725
Fabaceae	0.000	0.000	3.333	2.174
Fabaceae/Poaceae	0.000	0.000	2.222	1.449
Fruit/nut	2.632	0.000	2.222	2.174
Malvaceae	0.000	0.000	4.444	2.899
Millet	31.579	10.000	16.667	20.290
Papaveraceae	0.000	0.000	1.111	0.725
Pearl Millet	0.000	0.000	3.333	2.174
Poaceae	7.895	20.000	10.000	10.145
Pulse	23.684	10.000	6.667	11.594
Sorghum	0.000	10.000	13.333	9.420
Trianthema/Abelmoschus	2.632	0.000	4.444	3.623
Vigna sp.	26.316	0.000	4.444	10.145
Zaleya petandra	0.000	0.000	4.444	2.899
Total	100	100	100	100

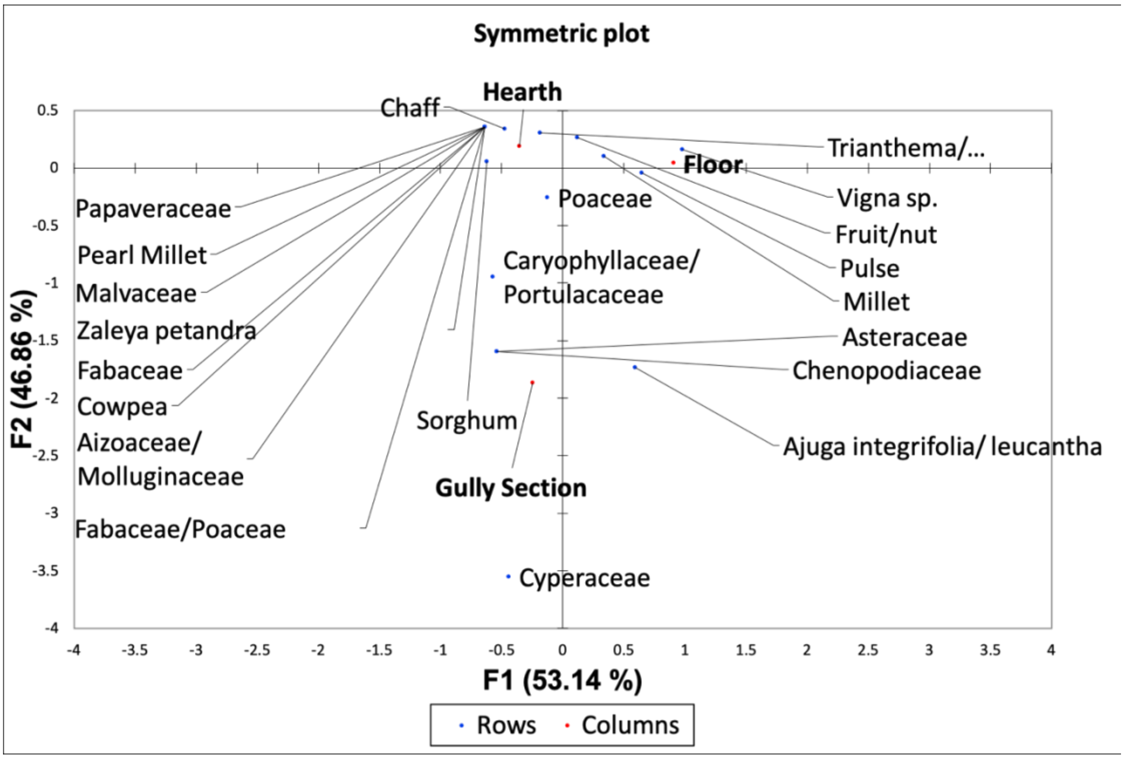


Figure 23. Biplot of spatial analysis of taxa across domestic and agricultural contexts.

for comparison. The data was transformed into a contingency tables and a symmetrical plot (Figure 23), which serve as useful visual tools for analysis of the data. A number of relationships emerged during this exercise. First, floor samples were revealed to have the strongest correlation with crops, including millets, pulses, and *Vigna sp*. Field percentages were quite low (Table 3), however, the correlation with wild grasses and weeds in general can be seen in Figure 23. Meanwhile, hearths have an association with chaff, but lag behind floors where millets and pulses are concerned.

5 Results of the Analysis of the Konso Archaeobotanical Assemblage

In the following chapter, I report the results of the analysis of the archaeobotanical data from Konso. These data are comprised of macroremains from flotation, preliminary wood charcoal analysis, radiocarbon dating, and findings from ethnobotanical activities, including establishing wild plant and crop seed reference collections and conducting interviews.

Archaeological investigations focused on traditional agricultural plots along the Sahaito River as well as excavation of a midden from an abandoned section of Kuile village. Excavations along the river revealed cross-sections of terrace and yela plots (as defined in Chapters 1 and 3). Archaeobotanical sampling was carried out on the Yela profile (Section 102) following column sampling for soil micromorphology, geochemistry and soil organic matter composition. Excavations at Kuile Village were focused on exposing and sampling the upper and lower profiles of an abandoned midden.

Radiocarbon Dating

Radiocarbon samples, both seeds and charred wood, were taken from Sahaito and Kuile contexts. However, low levels of carbon in the very small seeds meant that the only successful results came from charred wood samples from the upper section of the midden, referred to locally as *Kailama*. Table 1 reports the dates that resulted from the successful analysis of three contexts listed in stratigraphic

Table 4. Radiocarbon dates from the upper midden at Kuile village. * uses the mixed calibration curve as per ** Oxcal v4.3.2 (Ramsey 2017) and IntCal13 atmospheric curve as per Crowther et al (2016). ** Oxcal v4.3.2 (Ramsey 2017) and IntCal13 atmospheric curve (Reimer et al. 2013).

Context	Lab no.	Material	Measurement	δ13C	Calibrated	Modelled
286	SUERC-74438	UNID charred twig	298 ±29	-24.2 ‰	cal AD 1510 to 1670	cal AD 1615-1675 (87%)
286	SUERC-74437	Ziziphus sp.	198 ±29	-24.3 ‰	cal AD 1650 to Present	cal AD 1645-1705 (85%)
284	SUERC-74430	UNID charred twig	188±29	-21.4 ‰	cal AD 1660 to Present	cal AD 1660-1815 (95%)
284	SUERC-74432	Ricinus communis/ Calatropis procera	178±29	-24.4 ‰	cal AD 1660 to Present	cal AD 1665-1820 (91%)
284	SUERC-74431	Cadaba sp./ Maerua sp.	125±25	-25.0 ‰	cal AD 1680 to Present	cal AD 1670-1740 (71%)
284	SUERC-74433	UNID charred twig	230±19	-26.1 ‰	cal AD 1640 to 1810	cal AD 1725-1805 (69%)
276	SUERC-74429	Ziziphus sp.	180±29	-26.1 ‰	cal AD 1660 to Present	cal AD 1680-1890 (85%)

order, placing the use of the midden between the early 17th to late 19th century. Identification of woody taxa was carried out by Delphine Jolie at the University of York. Radiocarbon dating was carried out by the Scottish Universities Environmental Research Centre. Bayesian modelling was done by Suzi Richer at the University of York.

The earliest dates were associated with the lowermost context (286), based on dating of an UNID twig and a fragment of *Ziziphus sp*., a genus of spiny shrubs and small trees of the family Rhamnaceae, referred to collectively in Konsogna (the Konso Language) as *kopta*. A number of species have been used as wild food, fodder, and fuelwood throughout Konso. *Ziziphus mucronata* Willd., a preferred fuelwood discussed during the farmer focus group interviews of the ethnobotanical component of the current study, is the most likely identity of the Ziziphus charcoal recovered from the midden. The yellow or brown date-like drupes of *Z. mucronata* and *Z. spina-christi* (L.) Willd. are eaten. These two taxa, in addition to *Ziziphus mauritiana* Lam. are among the foddering species (Hallpike 2008, p 467).

The centre of the midden, (284) was dated to between the second half of the 17th century and the early 19th century, based on radiocarbon samples of *Ricinus communis* L./*Calotropis procera* (Aiton) W.T.Aiton, *Cadaba/Merua sp.*, and charred twig fragments. While it was not possible to distinguish *R. communis* from *C. procera* from an anthrocological perspective, understanding how each taxon is used helps to understand how each taxon could have been preserved via charring in the midden. During analysis, no other charred macrobotanical remains were attributed to these taxa or any of the other identified charcoal samples. *R. communis*, the castor bean, is the source of castor oil which is used widely in manufacturing and as a purgative. This woody herb of the Euphorbiaceae is indigenous to East Africa, the Mediterranean, and India. All parts of the plants are used medicinally, though the seeds are highly toxic as the source of ricin. In Konso the seed oil is heated to remove toxicity and used in several different ways. It is traditionally applied as a leather softener and varnish (Hallpike 1970, 31; Engels and Goettsch 1991, 347). It has also been burned as a lamp oil and used as cooking oil for frying injera, the spongy sourdough flatbread made from teff flour that is a vital part of the Ethiopian diet. However the introduction of teff, and thus injera, to the Konso region occurred in the 1970's and 1980's (Hallpike 2008, 36), a side effect of the influx of Amharic traditions beginning with the region being conquered by the forces of Emperor Menelik II in the late 19th century (Hallpike 2008). The wood may have been discarded in the fireplace or midden as a by-product of oil production or medicinal utilization of the roots, stems and leaves. It may have also been used as a supplementary fuelwood, such as for kindling, though there are no ethnographic accounts of this.

C. procera, the Dead Sea fruit or Sodom's Apple, is a small tree or shrub that bears a characteristic green gourd and a poisonous milky sap. I have not encountered any accounts of its use in Konso, though it is used as a stick for tending fires across Eastern Africa (Dharani 2011, 216), which could account for its preservation through charring in a midden context.

The charred wood specimen identified as *Cadaba/Marua* is discussed here in terms of which local Konso trees could be the source based on fuelwood value and other economic considerations. *Cadaba farinosa (*Forssk.) is an economically significant species that occurs in the Konso region that could be expected in a midden context. *C. farinosa* is a bushy shrub in the Capparaceae family that prefers woodland and wooded deciduous grassland habitats, often near rivers. Known as *luqata sigmama* in *Konsogna*, the fruit are eaten by herders while out grazing their stock. In Ethiopia, it is recognized as a famine food to be exploited during severe droughts and a preferred fuelwood (UN-EUE 2001), potentially explaining its charred recovery in a midden context. *Maerua angolensis* (*alqalta*) is a locally available taxon of *Maerua* also from the family Capparaceae that is known to be used as fuelwood and fodder.

Sahaito River Yela

Nine archaeobotanical samples were taken from yela contexts with two of these being combined following post-excavation analysis, which indicated that the contexts were indistinct from each other. A total of 50.2 litres of sediment were floated, producing 55.4 grams of flot. There was no correlation between the density of macroremains and sample size.

Charred Wood

A total of 0.66 grams of charred wood was recovered from the yela (Figure 1); this is very low density of charcoal relative to the Kuile midden or the hearths in Engaruka, but consistent with the low recovery in the gully at Engaruka.

Agricultural fields are not generally associated with recovery of significant charred botanical remains unless in situ burning has occurred, such as through slash and burn agriculture. Context 116 appeared to contain a higher density of charred material based on visual inspection of the sediments in the field, which initially led us to believe that in situ burning had occurred, however, only 0.05 g of charcoal was found in the flotation sample from that context. Following in depth laboratory analysis, Ferro-Vazquez et al. (2017) later determined that the colour of the soil was caused, in part, by manganese in the sediment, but also due to the comparatively high concentrations of pryogenic material (e.g. Contexts 116 and 157), which is far too small to be collected in a geological seive and too disperesed to be visible in a micromorphological slide. They argue instead that charred wood in these yela fields travelled along with eroded material resulting from slash and burn activities on the hillsides upstream.

Context 118 contained the highest density of charcoal (0.14 g), possibly relating to the presence of the most recent dry stone walls used to trap sediments for yela construction. These sediments would be expected to contain charred wood resulting from erosion activity occurring upstream. The charred wood from context 116 likely originated upstream (the result of natural processes of silt deposition), whereas charred material from context 118 might be indicative of in situ stubble burning due to its relative abundance in the latter context.

Three types of wood taxa were identified for the purposes of radiocarbon dating: *Ziziphus* sp., *Cadaba/Maerua* sp., *Ricinus communis/Calatropis procera*. These taxa are discussed in the Radiocarbon section above in association with the

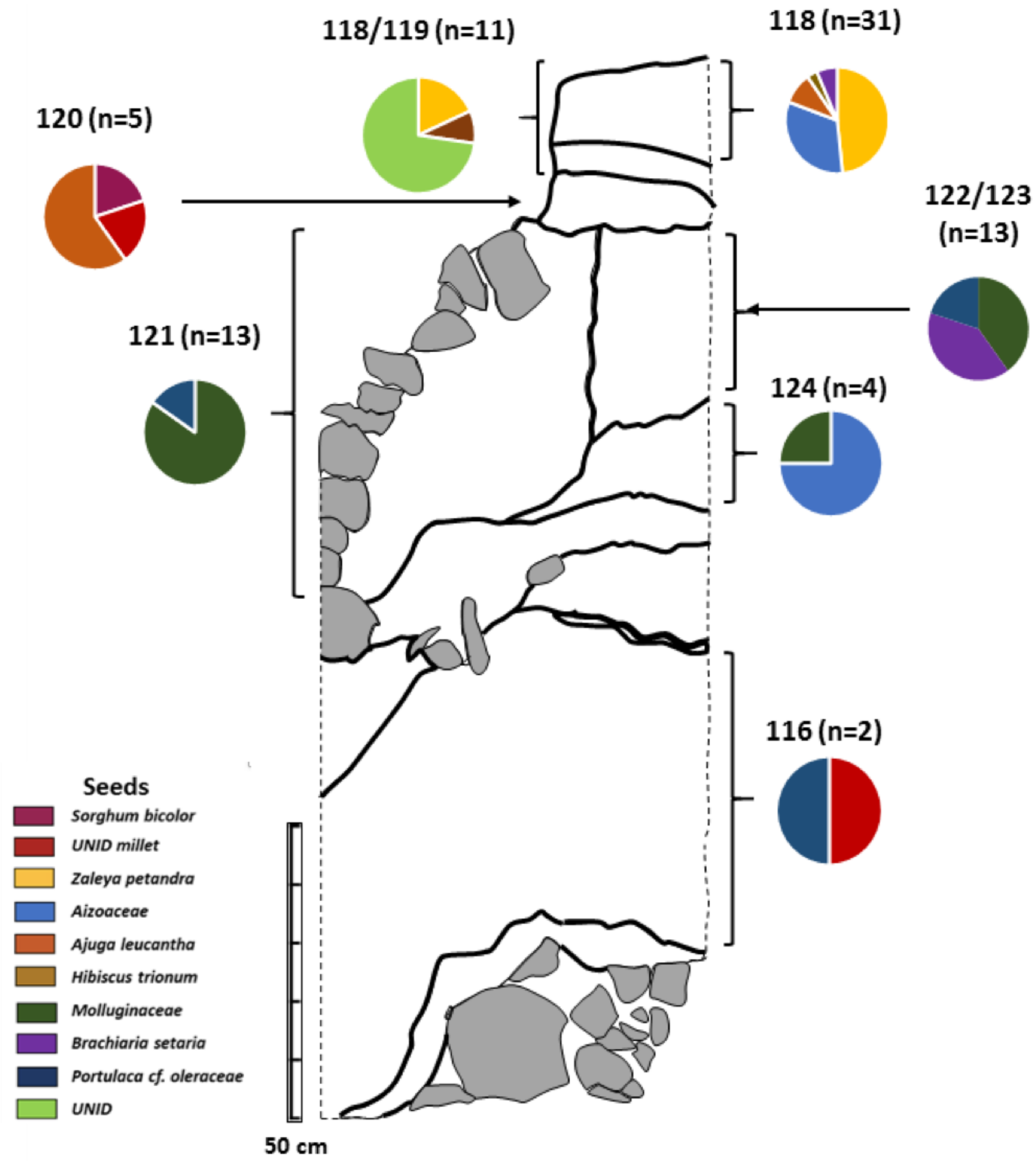


Figure 24. Charcoal and charred seed recovered from yela contexts.

midden. It should be noted that their presence in an agricultural field setting would be appropriate given that they are valuable fodder and/or fuelwood.

Carbonization would have occurred when grazing land was transformed into farm plots through slash and burn activity or by way of wildfires. As fuelwood, they may have been burned in small temporary campfires, which could explain

Table 5. Shannon Diversity Index for the Yela assemblage.

Unit	No. Seed Taxa	Shannon Index
Entire site	33	3.06
Highest diversity context: 118	11	1.81
Lowest diversity context: 121	4	0.93

the low charcoal density. Given the secondary deposition of the yela soils (since it is a sediment trap), charcoal from either category of use could have come from upstream or from the slope above prior to the construction of terraces as erosion

Seeds

The yela was sampled archaeobotanically to establish whether or not there was evidence of in situ burning, such as a significant density of charred macrobotanicals, which could potentially indicate a change in management practices. There is an overall increase in the diversity of taxa and the number of carbonised seeds over time based on the deposition of sediment layers in the yela. However, there was not significant recovery of charred material that would support the in situ burning hypothesis. As expected, there was a greater diversity of wild taxa recovered from agricultural soils in the yela (n=9; Table 1) than from the midden (n=3; Table 2). This is based on the exclusion of UNID seeds, which were too damaged or fragmentary for identification. Readers should note that a large number of UNID seeds were found in these assemblages and sorted by distinct characteristics. If identified at least to the level of family, they might change the number of identified taxa. This avenue of research is being targeted by future research currently under development (see Chapter 7).

Recovery of charred wild seeds in a millet and legume-based agronomy (discussed below), such as Konso, is more likely to be associated with agricultural contexts because harvesting and food exploitation practices minimize the likelihood of weed recovery in domestic spaces. Sorghum is tall relative to other crops and weeds so it is harvested without much risk of accidentally collecting weed seeds. Legumes are harvested within their pods which grow at weed-level, so there are slightly greater chances that weeds seeds could be collected, however there is no guarantee that these seeds would then be preserved via charring and therefore found in archaeobotanical assemblages. Variation in the time when seeds are produced by weed taxa also has implications on whether they will be collected during harvest.

Crops As mentioned previously, recovery of crop seeds was very low at the yela. Context 116, a soil layer captured behind the earliest yela wall, was the earliest context in the sequence from the profile sampled for the current study. Context 116 contained one unidentified (UNID) millet, indicating the earliest cultivation practices. Seeds in the UNID millet category have distinctive characteristics associated with the diverse millets of the Konso agronomy, which in modern times includes sorghum and finger millet. The UNID millet designation was made when the seed was clearly a millet, but the characteristics features which distinguish them from one another were too ambiguous for a more refined identification.

A single sorghum seed from the yela came from Context 120, which was deposited after the construction of the earliest courses of the dry-stone wall associated with the yela. This suggests that millet agriculture was occurring at the site before and after the construction of the yela on the current site, though *yelas* may have been in use on other farmland in the vicinity before they were established here. Yela construction was clearly an innovation to agricultural landscape management rather than the initial/original management practice on the site.

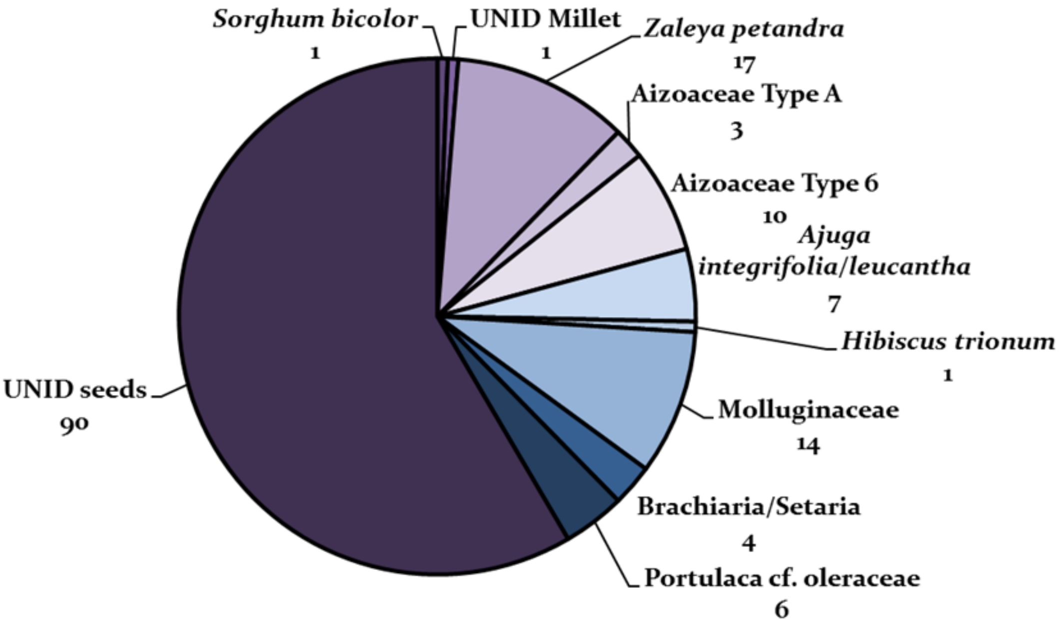


Figure 25. Charred seeds from the yela.

Wild Economic Plant Seeds Within the context of the current study, an identified wild seed is considered to be an economic plant if it is a taxon known to be used in an economically significant way (e.g. food, fodder, fuelwood, and medicine) based on interviews with individual farmers and focus groups discussions conducted for the current research as well as through literature

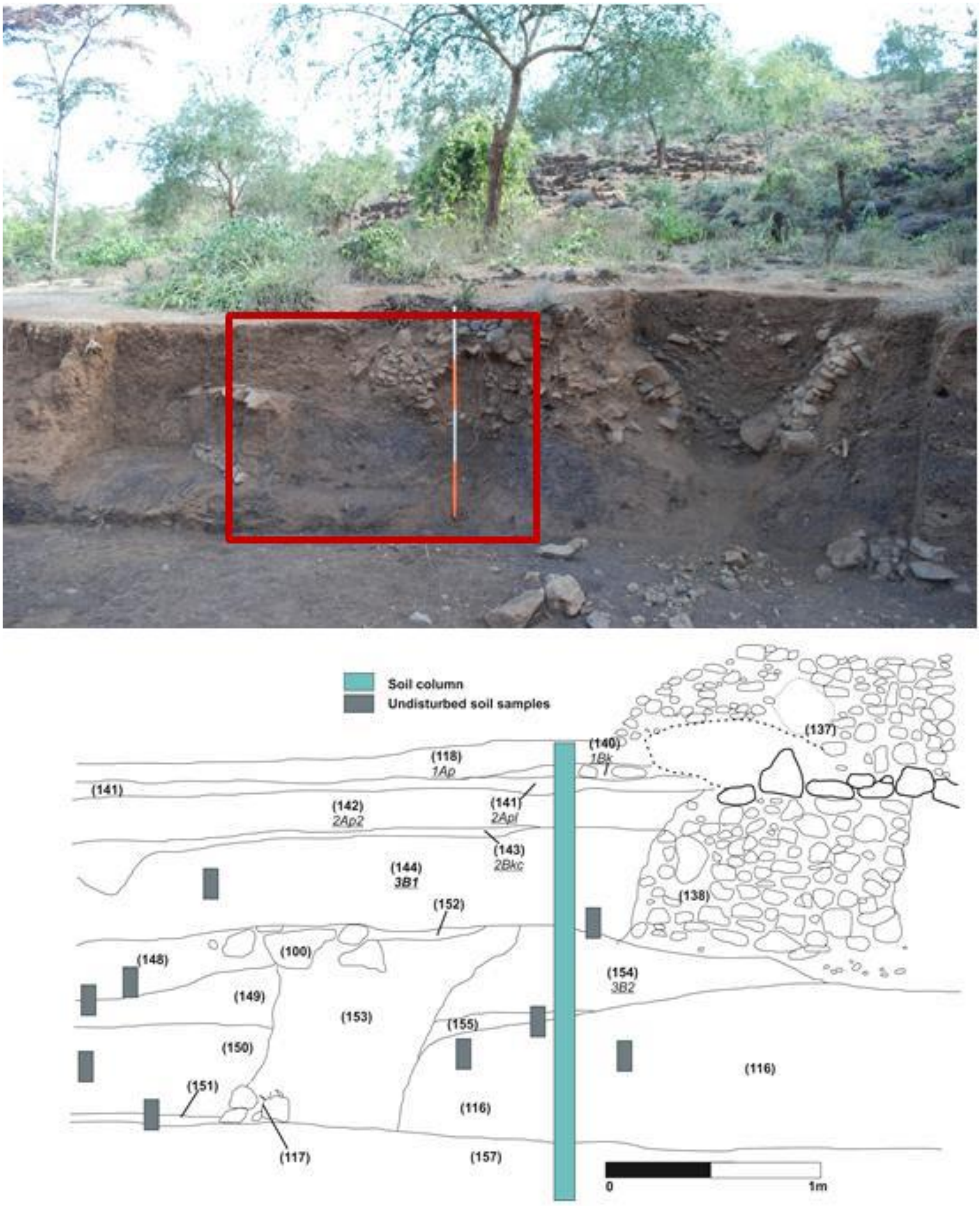


Figure 22. Photograph and drawing of Section 102, depicting the contexts relating to the construction of yela at the site (from Ferro-Vázquez et al. 2017, 8).

surveys. Context 116 contained one seed of *Portulaca cf. oleraceae,* a leafy succulent and beneficial weed of cultivation often exploited as a wild plant food. The roots of *P. oleraceae,* known in the west as purslane and in Konsogna as *marayta*, break up dense clay soils, improving permeability for nutrient uptake in crop plants. The entire plant is cooked and eaten whole in Konso, though in modern times it is recognized as a famine food and as a result its use is stigmatized based on economic status.

Other taxa from the yela include: *Zaleya petandra* (n=17), Aizoaceae (n=13), *Ajuga leucantha* (n=7), *Hibiscus trionum* (n=1), Molluginaceae (14), *Brachiaria/Setaria* (n=2), and two distinctive types of UNID seeds. Context 118 had the highest density and diversity of non-economic weed seeds (n=31) followed by context 118/119. Given that context 118 and context 118/119 represent the uppermost soil layers in the midden (below the modern O horizon), the relative density and diversity of weedy non-economic taxa is likely associated with seed rain. The fact that these seeds are charred would suggest that burning activity had occurred in the field after they were deposited, but before they had time to germinate. Future research will seek to understand germination seasonality for each taxa. It will then be possible to compare the timing of germination with millet and legume cultivation schedules. It may be possible to determine whether the timing of stubble burning was timed to coincide with weed germination, reducing the impact of harmful crop weeds. A key question will involve establishing whether those taxa that benefit from fire action are represented disproportionately since they would have been able to reach full germination. It is at this point that the data relating to the modern seed assemblage from the midden will provide meaningful information about what happens to the diversity of weed taxa when they are not disturbed by farming activity.

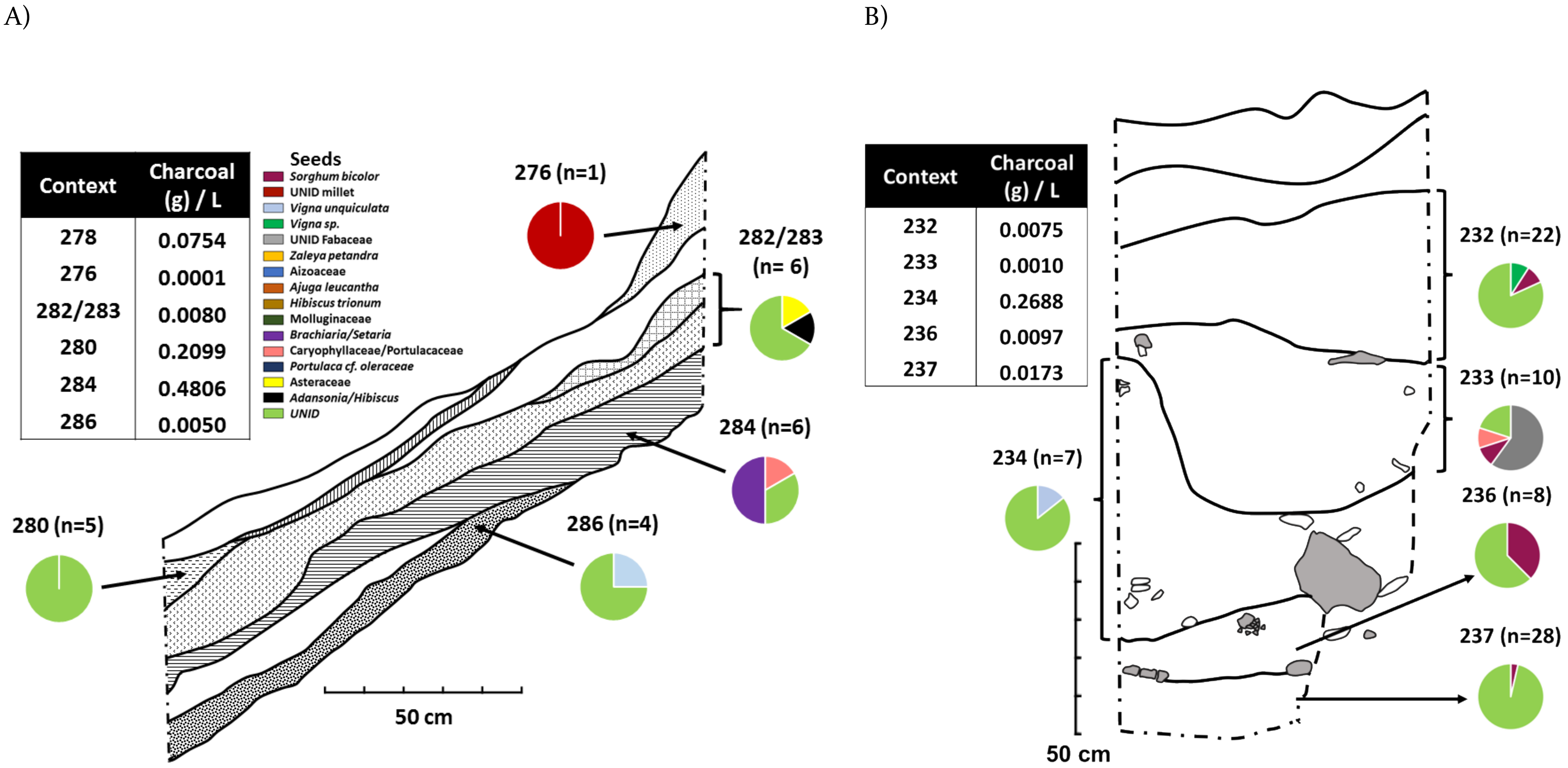
Weed Seeds Seeds for which there is currently no known economic value among the Konso people were place in the weed category. Charred weed seeds were ubiquitous throughout the yela profile and came from 6 different wild Of the 30 charred seeds of Aizoaceae recovered from the yela, (including *Z. petandra)*, 25 were found in context 118. Aizoaceae is a family of 135 genera concentrated in Southern Africa, just 4% occurring outside this centre of genetic diversity. *Z. petandra* is a widespread weed of cultivation found from northern South Africa to North Africa and Madagascar.

The Midden at Kuile Village

The midden at Kuile was located on the downslope of a hill below the abandoned section of the ancient extent of the village. The midden formed as refuse was discarded by the people occupying the hilltop. There are no buildings left standing from that period of occupation. Other than the midden itself, the only visible traces of human habitation that remain are the stands of Dracaena indicative of landscaping around the footprints of buildings. A local farmer reported that the midden was abandoned during his grandfather's time due to drought (see ethnobotany section below). This was interpreted to mean that people were moving away in response to the drought and the midden was no longer needed. In the relatively recent past, a path was built across the midsection of the midden in order to provide access to the fields below the village. During excavation, contexts that were impacted by the path construction were avoided. The exception was the uppermost layers of the lower midden. These contexts were visibly disturbed by the path, but were minimally excavated along with the lower contexts to reveal the midden profile. The disturbed contexts were not sampled for flotation. In total, 11 samples (2.8-7.6 litres each) were taken from the midden, comprising 50.4 litres of soil in total. The average sample size was 4.58 litres. Sample size did not impact the amount of light fraction recovered since the range in size of the light fraction (LF) produced did not reflect significant variation in the amount of soil processed. The LF range of the 5 samples closest in size (4-5 litres of soil) to the average was 66.7, which is quite a large spread given the relative consistency of the sample size. Furthermore, context 232 produced the most LF, while being one of the smallest flotation samples (3.6 litres). Meanwhile, the largest flotation sample (7.6 litres) was from context 282 and it produced the 3rd smallest light fraction sample.

Charred Wood

Wood was present in nearly all of the samples at a mean density of 1.0g/L; ubiquity was 89%, and only context 279 lacked charcoal. Identification of the charred wood from the midden by Delphine Joly helped to link ancient and modern wood charcoal preferences (Table 1). The wood charcoal assemblage of the midden is representative of secondary deposition of material cleaned from fireplaces, rather than wood being burned in situ. This is because of context, rather than content: wood fires would not have been made in the midden.



A)

Context	Charcoal (g) / L
278	0.0754
276	0.0001
282/283	0.0080
280	0.2099
284	0.4806
286	0.0050

B)

Context	Charcoal (g) / L
232	0.0075
233	0.0010
234	0.2688
236	0.0097
237	0.0173

Figure 23. Charred seeds and charcoal density in the A) upper section of the midden and B) lower section of the midden.

However, despite the lack of any evidence of systematic in situ burning of wood or discarded domestic waste, it is likely that the latter was a common practice. I observed modern residents of Konso villages tending midden fires, though I was not able to conclude whether this was done to simple reduce the amount of bulk as a waste management practice or if the product of the burning was to be used as fertilizer. The charcoal from the lower midden was found to be exclusively *Acacia* sp. Taxa recovered from the upper midden include *Ziziphus* sp., *Cadaba/Merua*, *Ricinus communis/Calotropis procera*, which were discussedpreviously. *Acacia* sp., *Balanites aegyptiaca (L.) Delile, 1812*, and *Combretum* sp. were also recovered and are discussed below.

Balanites aegyptiaca, the desert date, is a tree of family Zygophyllaceae that is indigenous to Africa and the Middle East. In Konso, it is a valuable multipurpose tree (De Vletter 1991, 95) that is planted on the terraces amongst the crops to reduce soil erosion. It highly ranked wild plant food, locally known as *hankalta* (Addis,Asfaw and Woldu 2013b, 131). Its flowers, fruits, and leaves are eaten by people and it also serves as a fodder and firewood. As a fuelwood it would be expected to be recovered in a midden.

In Konso, the genus *Combretum* (the bushwillows of the Combretaceae) is represented by *Combretum aculeatum* Vent., found growing across woodland savannahs and bushlands that characterize the landscape. In Konsogna it is called *kignfirda* and valued for its edible seeds, which are eaten raw (Addis, Asfaw and Woldu 2013b, 127). Across Ethiopia, the leaves and roots are used medicinally. The wood is used as fuelwood and the leaves are a common fodder (Azene Bekele-Tesemma. and Tengnäs 2007, 182).

Seeds

Crops recovered from the midden include cowpea, unidentified Fabaceae, Sorghum and UNID Millet (Figure 4). The millets have been described in the context of the Yela above. The midden was the first location in which the legumes were encountered. They are detailed below along with newly encountered wild taxa. Wild and weedy taxa include Asteraceae, Caryophylaceae/Portulacaceae, *Adansonia/Hibiscus*, and UNID Seeds. The midden had a greater diversity of crops (1.90) than the yela (0.02), but a lower diversity of charred wild taxa. Though not detailed here, the diversity of non-charred crops at both sites was quite close to one another.

Crops Crops were 57% ubiquitous in midden contexts. Sorghum was recovered exclusively from lower midden contexts. The only context sampled from this lower section that did not contain sorghum was context 234, which coincidentally also contained the only cowpea (n=1) in that lower section. Cowpea (n=1) was also found in the lowest layer (286) of the upper midden. Cowpea (Vigna unguiculata (L.) Walp.) is one of the most popular indigenous legumes in Konso. It is commonly intercropped with millets and valued as a staple food. I also identified two additional, more ambiguous seeds of Fabaceae, one of which was clearly a domesticated Vigna (n=1) while the other was an unknown legume (categorized as UNID Fabaceae).

Wild Edible seeds and Weed Seeds Charred wild taxa were found in in 64% of the contexts. No charred wild seeds were found in contexts 276, 278, and 281. Asteraceae is the second largest taxonomic family in the world. *Launaea*

Table 6. Shannon Diversity Index for the Kuile village midden

Time Period	Unit	No. Taxa	Shannon Index
	Entire Site	25	2.75
	Dated contexts (in stratigraphic order)		
Late 17th to early 19th century	284	6	1.95
	AD 1660-1820		
	Highest diversity: 286	8	2.1
	AD 1615-1705		
	Lowest diversity: 237	4	.79

intybacea (Jacq.) Beauverd is an edible Aster native to Konso, known locally as *hankolayta* (Addis, Asfaw and Woldu 2013b, 126). The leaves of this herb are boiled and eaten. The presence of just one seed in the midden from context 282/283 is not a sure indication that edible Asters were being exploited (it could be a product of seed rain), but it is worth mentioning that there is potential for this to be the case.

Seeds of Caryophyllaceae/Portulacacea (n=2) were recovered from the midden, one each from context 284 in the upper midden section and in the lower midden section from context 233. Portulacaceae was discussed in detail in the yela seed discussion above, however these seeds are distinctive from *P. oleracea*, which is commonly eaten in Konso. *P. quadrifida* L., is another edible taxon eaten in the same way as *P. oleraceae*. However, since the seeds would not be expected to be carbonized during the cooking process since they are not eaten, they might have found their way into a hearth or midden context through natural or anthropogenic deposition. Members of the Caryophyllaceae, the pink family, are not known to be eaten in Konso, so it is likely that if these seeds are of this family, they were present in the soil prior to charring either in the midden (e.g. through household waste burning for fertilizer) or in a household hearth.

Table 7. Percentages derived from the correspondence analysis of weeds and crops from midden and field contexts at Konso.

	Field	Midden	Total
Aizoaceae	4.545	0.000	2.703
Ajuga sp.	13.636	0.000	8.108
Caryophylaceae/ Portulacaceae	4.545	13.333	8.108
Cowpea	0.000	13.333	5.405
Millet	4.545	33.333	16.216
Molluginaceae	13.636	0.000	8.108
Poaceae	13.636	6.667	10.811
Portulaca cf. oleraceae	22.727	0.000	13.514
Setaria sp.	0.000	6.667	2.703
Sorghum	4.545	26.667	13.514
Zaleya petandra	18.182	0.000	10.811
Total	100	100	100

Adansonia/Hibiscus (n=1), a member of Malvaceae, was found in context 282/283. Adansonia, the baobabs, is not native to Konso, though it is traded. In Konsogna, *Hibiscus* sp. is known as *oranna keltyta* (Hallpike 2008, 469), but is apparently not eaten. The leaves of certain species of Hibiscus are eaten in other regions of Ethiopia (Molla et al. 2011, 106).

Non-Botanical Categories

While not a focus of the current study, a number of non-botanical macroremains were identified from the heavy fraction and the light fraction.

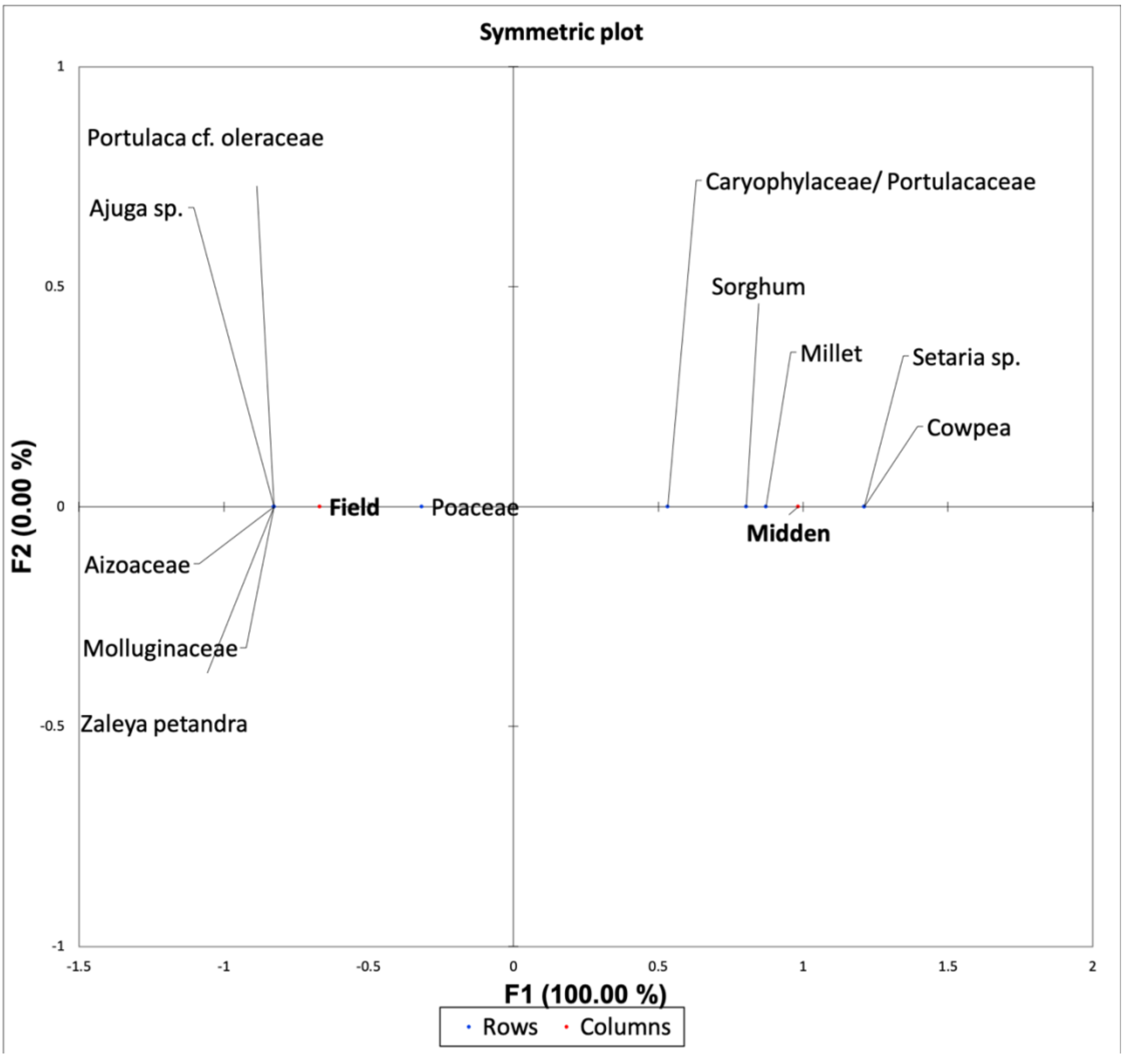


Figure 26. Symmetrical plot representing the correspondence analysis of weeds

and crops with middens and fields at Konso.

These included tooth and bone, beads and fragments of Ostrich eggshell and Ostrich eggshell beads, ceramic fragments, lithic debitage, and grinding stone fragments.

Summary Based on Correspondence Analysis.

As was done with the final Engaruka data, correspondence analysis was used to establish correlations between charred seeds and chaff from two distinct agricultural and domestic contexts. The analysis was focused on 11 taxa, which originated from 16 samples. Table 7. Percentages derived from the correspondence analysis of weeds and crops from midden and field contexts at Konso. Table 7 is highlighted to identify where the strongest relationships are to be found, while Figure 26. Symmetrical plot representing the correspondence analysis of weeds and crops with middens and fields at Konso. presents this patterning visually with a display of each of the points clustering along the horizontal axis. These data express a strong correlation between wild taxa and fields and a similar pattern of crops within the midden.

6 Discussion

In the last five chapters, I have explored the application of a novel suite of archaeobotanical techniques to sites of intensive agriculture in Eastern Africa with the aim of answering two versions of the same question, introduced in Chapter 1.

1. What is needed in order to *relate* archaeobotany to discussions of sustainability?
2. What can archaeobotany *contribute* to discussions of resilience and sustainability?

Addressing concerns about both the potential and very tangible relevance of archaeobotanical findings has been the guiding principal of the study, with a particular focus on updating the narrative to include those previously invisible factors that impacted the sustainability of the agricultural system at Engaruka. The data recovered from Konso was pivotal in helping to identifying the strengths and weaknesses of the purely archaeobotanical approach taken to Engaruka, because I was also able to talk to modern farmers and review existing literature about the rationale and outcome of specific agricultural strategies in a geographically and economically analogous region.

Through the interpretation of the archaeobotanical and ethnobotanical results I was able to establish a more refined baseline of knowledge of the agronomies of both sites. The presence of crop residues and edible weeds, when related to dated contexts, helped to determine when certain foods may have been in use. At Engaruka, where previously only sorghum had been found archaeologically, the discovery of pearl millet, finger millet, and cowpea, has paved the way for discussions of the particular crop repertoires and the management strategies needed to support them. Sampling the same sediment trap field contexts targeted by the phytolith pilot study allowed for cross referencing of the results, revealing that sorghum was being cultivated in the fields and eaten locally in the

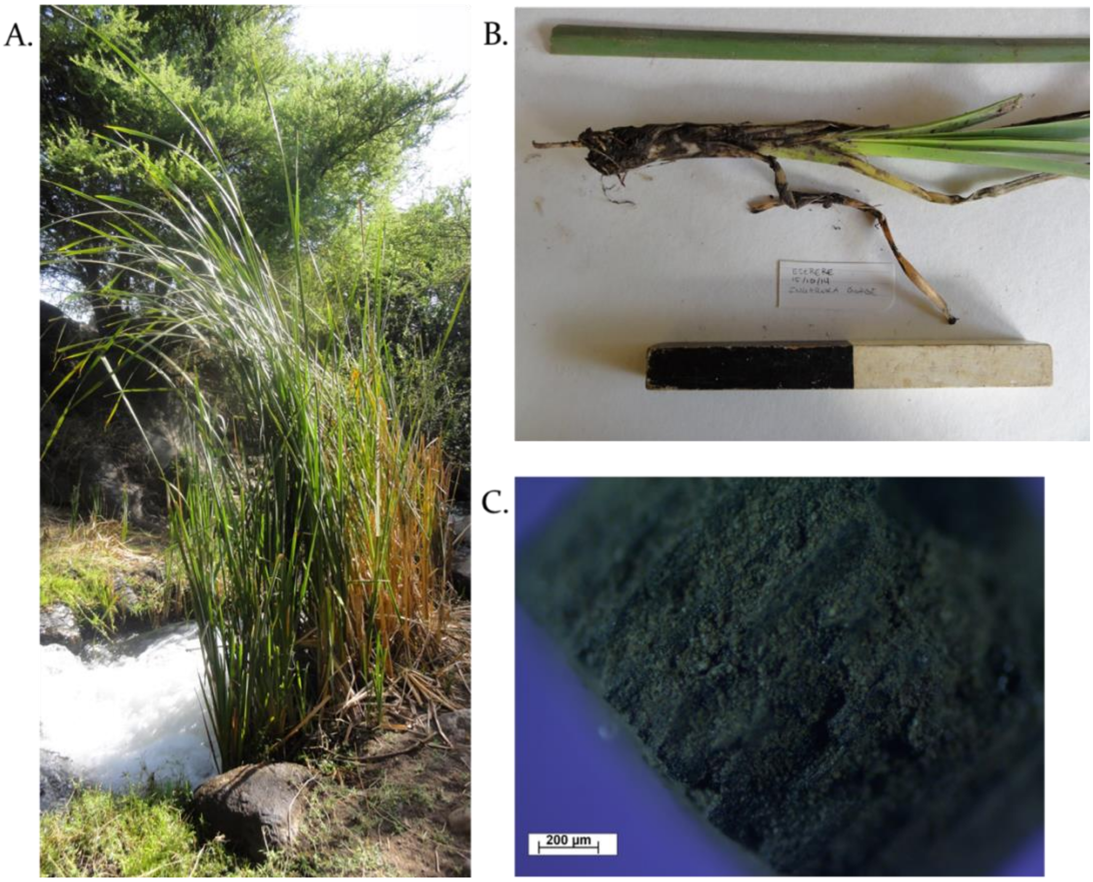


Figure 27. *Typha* sp. is suspected to have been used as thatching material for the buildings in the village at Engaruka. It was found growing along the Engaruka River Gorge(A) during and ethnobotanical hike, a specimen was photographed and pressed (B), and during analysis of the archaeobotanical assemblage it was identified (C) in a hearth context from Building 1 in the village.

village. While this might seem like a logical assumption, it was an important (if basic) notion to confirm. In some cases, and despite very palpable threat of food insecurity, locally grown crops are not always eaten by the farmers who cultivate them, often because it makes more economic sense to sell that particular crop than to eat it, but also due to social conventions associating food with class. For example, conversations with some local farmers at Engaruka revealed an avoidance of lablab by some (despite its nutritional value and suitability to the local climate), because it is a food for the poor. Though it was grown locally, it was largely reported to be an export product for other nearby markets with only a few families admitting to its consumption.

While at Engaruka more crops were recovered than expected, at Konso, only a small fraction of the total number of the potential variety of crops (Figure 25, A) were recovered from the fields and the midden. Modern Konso agriculture involves complex intercropping of staple grains, legumes, vegetables, and trees in on the outfield *yelas*, and cultivation of more valuable economic crops in the home gardens within the villages, such as tobacco, coffee, and cotton; a situation analogous to that described by González Jácome (1985).

Trees of more ritual and utilitarian significance are also planted within the walled communities, such as juniper and myrrh. Despite this diversity of crops that probably would have been available to the villagers who worked the land and discarded household waste in the midden, only grains and legumes were recovered from the archaeobotanical assemblage, thus exemplifying the value of the ethnobotanical approach. This is especially significant when robust cultural and subsistence connections exist between the ancient inhabitants of the landscape and the modern farmers who are still cultivating the land.

At Engaruka, ethnobotanical hikes and consultations with local Maasai plant experts were helpful for the identification of wild economic taxa. However, Maasai agropastoralist tradition at the very least de-emphasizes the value of wild plant foods, and at the most extreme, completely avoids it, since Maasai cultural identity features a dichotomy whereby domestication is associated with civilisation and ‘being Maasai’, while and wild foods are linked with non-Maasai communities (Spear and Waller 1993). As a result, the data collected were biased towards plants used for medicine, fodder, and for utilitarian purposes, such as thatching in the case of *Typha* sp., which was also identified in the archaeobotanical assemblage of Building 1 (Figure 24).

During the analysis, a number of common themes relating to both sites began to emerge. The shared climate features, crop repertoires (sorghum, millet, and legumes), and land management strategies (irrigation and terracing) are reflected in the archaeobotany. As a result, it was often possible to relate Engaruka and Konso to one another. The identification of the macrobotanical assemblages of distinct areas of activity (fields, domestic buildings, and a midden) revealed patterns of consumption and discard on a temporal scale. The analysis of charred material density in the fields was used to explore the differential impact of agricultural fire management practices (i.e. stubble burning) versus wildfires. These considerations are part of a broader exploration of the health of the landscape and the sustainable management of the

Figure 28. Process of grain preparation for the production of local beer at Konso. A). Selection of preferred grains: sorghum, millet, and maize cultivated in nearby fields. B). Traditional ground stone processing. C). Dicard of chaff as a supplement to fodder.

agronomies at different points in time. Recovery of chaff was low at both locations but the contexts in which it was found (buildings vs. midden) helped to reveal evidence of crop processing in the villages rather than in the fields, a finding that echoes the patterns of crop processing at Konso. Charred weed seeds had different implications based on context. In the fields they helped to facilitate analysis of fire management as an agent of preservation for weeds of cultivation (companion weeds). Below I expand this discussion to explore the implication of irrigation weeds as well. Weeds in the midden provided evidence of discarded household waste, beyond foodstuffs, which could then be used as a soil amendment. Weeds recovered in the buildings were broken down into floor weeds and hearth weeds, recognising that weeds in the hearth may have been floor sweepings discarded in the hearth fire, and carbonised weeds in floor contexts weeds may have been inadvertently deposited when the hearth was cleaned.

In the remainder of this chapter, the themes summarised above are discussed within the context of specific activity areas and later integrated into a detailed discussion of the sustainability implications of the analysis. The results are related to the original research expectations, as a point of context, forming the basis of the discussion about conformities and distinctions and how this information moves forward the discussion regarding sustainable systems. Lastly, I identify where there is scope for future research related to the current archaeobotanical assemblages, with particular emphasis placed on the novel application of archaeobotanical, ecological, palaeoenvironmental, and ethnographic techniques.

Interpreting the Sediment Trap Fields

One of the most significant outcomes of the AAREA Project was the revelation that the stratigraphic sediment in the riverside fields, known as *yela*, in Konso, was deposited and intentionally controlled using the same mechanisms as at Engaruka. Stone wall embankments were excavated at both sites, however the discovery of a succession of these buried sediment trap features at Konso provided the most comparable archaeological evidence and it was supported by the interviews and focus group discussions outlined above.

The archaeobotanical methodology was designed to contribute to a better understanding of the contruction and use of the fields. The effort what made worthwhile when I discovered the charred remains of weeds and crops in the field sediments. This is significant because fields are often excluded from archaeobotanical sampling strategies, because of concerns about preservation and disturbance. However, in the case studies presented here, testing the assumptions that drive that avoidance has helped to refine plans for future sampling.

Interpretation of the results of the excavation of terraces and *yelas* along the Sahaito River (Ferro-Vázquez et al. 2017) corroborated the narrative of landscape development detailed by modern farmers during project interviews. Construction of agricultural plots began at the river with sediments captured to form *yelas*, then extended up the slope with the terraces built to control erosion that could potentially bury these agriculturally productive sediment traps. Excavation of Section 118 revealed unambiguous evidence of 3 to 4 earlier hillside terraces buried beneath the currently visible terrace walls at the ground surface. The earliest phases of the dry stone wall were placed upon the exposed bedrock/relic saprolite after the original topsoil and subsoil had already eroded off. The *yela* soil contained by the dry stone wall in which crops were planted had accumulated through fluvial deposition of upstream slope erosion rather than developing in situ (Ferro-Vázquez et al. 2017, 5). Hillside terrace stratigraphy revealed the deposition of alternating layers of fine and stone-rich sediments, which reflects the same natural and/or anthropogenic pre-depositional sediment sorting encountered during the excavation of the habitation terraces at Engaruka and discussed in Chapter 4.

Carbonised seeds would not normally be expected in the fields and even when archaeobotanists do encounter them, interpreting proves to be a complex task. Given the sedimentation patterns of the soils in the fields, which involves the transportation of eroded material, there is no certainty that seeds were first deposited locally before being redeposited in their context of recovery. The deposition of seeds through sediment capture is evidenced by the presence of non-charred crops suggesting that seeds could have travelled from upstream contexts. For this reason, it was important for me to understand each of the scenarios that might explain their presence in these agricultural contexts.

Despite accepting that secondary deposition of seeds is highly likely, it is also possible that some charred seeds were recovered from primary contexts due to in situ intentional burning or wildfire. The presence of charred crop seeds - especially sorghum - in the fields at Engaruka, from contexts also containing sorghum phytoliths, suggests that the seeds were charred in situ. Some of the charred non-crop seeds found in fields may have also been burned in the fields along with the crop seeds as a result of fire management practices. However, this is difficult to distinguish from seeds charred upstream due to wildfire activity or off-site anthropogenic burning. Future analysis of the assemblage should pursue the identification of those weeds of cultivation/irrigation whose germination is dependent upon fire and compare relative abundance between field and settlement.

A different suite of crops was encountered in the field than that which was recovered in the domestic contexts. The phytolith evidence (see Chapters 2 and 4, Figure 15) combined with the crop macrofossil assemblage indicate that local people were eating what they were growing because some of the crops found in the fields, sorghum and cowpea, were also found in the kitchens. Some of the crops being eaten may have been sourced from other local field areas. For example, no evidence of millets was found in the field contexts sampled, despite the recovery of pearl millet and finger millet from the village, but they still could have been grown on other plots and traded amongst nearby farmers. Furthermore, it is possible that those crops that are invisible in field contexts could have been imported as a result of trade along the norther caravan route, however, no definitive evidence exists for this participation. The identification of likely trading partners and cross-referencing the Engaruka crops with the assemblages of sites along the caravan routes (Biginagwa 2009, 2012) would be a significant benefit to this argument that has very real implications for supporting sustainability strategies.

Returning to the original discussion of why fields are not often the target of archaeobotanical studies, an explanation for the discrepancy between the field and domestic assemblages could be a function of the very low recovery of crops in the fields because the agent of preservation (fire) is not active enough in

Figure 29. Stock keeping beneath granaries in a Konso home garden.

removed from fields before introduction of fire. Indeed, the fact that they are present at all was unexpected.

fields to provide a representative sample. While sorghum and cowpea were recovered from the fields, preservation and recovery of crop seeds from field contexts is not common or expected because most crop seeds are harvested and

The Development and Varied Use of Domestic Space

Villages are multi-use areas where people socialise and ritualise, sleep and co-habitate, prepare and share meals, and participate in crafting and construction activities. Each of these activities impacts subsistence (Ortiz-Sánchez et al. 2015), and as a result, they also have the potential to leave behind archaeobotanically visible traces. However, the current study found distinctive biases in the preservation and recovery of materials associated with specific activity. Proximity to or association with areas that are subjected to burning activity, meant that interpretations are primarily based on carbonised seeds and charred wood taken directly from the buildings at Engaruka and the midden at Konso. While it was not possible to sample congruous areas at each location, we can begin to push interpretations of the data. Potential patterns of use were identified through observations of village life at Konso and in the modern Engaruka settlements, as well as through conventional lines of enquiry from archaeology, ethnography, and human geography. The former two fields of study have been discussed in Chapters 1 and 2, because their applicability was identified at the start of the research, but insights derived from human geography has become more relevant in light of the findings of the midden and building sampling.

A particularly compelling way of thinking about the midden and habitation structures is to consider how they relate to one another, how that relationship provides evidence of home gardens, and the role that home gardens play in subsistence. This analysis of the potential for home gardens corresponding with middens is presented as a hypothesis based on Doolittle's (2004) argument that some of the earliest home gardens were the result of residents discarding plant materials in the outdoor vicinity of houses in either scattered or discrete middens. This pattern of discard is relevant because the midden at Konso is situated just downslope from the abandoned section of Kuile village. It is not clear that the midden was a formally established home garden, but home gardens are a significant feature of all of the Konso villages.

The stone-bound terrace platforms adjacent to the buildings at Engaruka strongly resemble the Konso home garden areas. To be clear, these areas have not been identified as either middens or gardens, but questions have arisen about the purpose of these platforms, the distance of the fields from the village, and the fact that no middens have been found at Engaruka. The platforms might have been used for a number of purposes including craft production (e.g. weaving areas at Konso), crop storage, stock keeping, market activities, as well as public space.

Establishing an archaeobotanical argument for the identification of visible features of a home garden overlaying a midden is complex. However, it may be possible to identify middens at Engaruka by identifying areas of dense vegetation on the village platforms and taking soil cores (augering) in hopes of finding concentrations of charred organic material that might hint at human discard activity. In order to confirm the presence of home gardens, as opposed to just middens, a programme of archaeobotanical sampling for plant macro fossils and phytoliths should be carried out.

This combination of techniques could reveal seeds and phytoliths of domesticated crops that are known to be cultivated in a home garden setting.

These include crops that

- Are valuable and thus planted close to the home for commodity protection, such as is the case with medicinal species and spices, in general, as well as coffee and cotton in Konso
- Require regular tending and management, such as leafy vegetables that are vulnerable to pests.
- Serve as fodder for penned animals and raw materials for crafting activities.
- Provide shade cover for social gatherings and outdoor labour, in addition to the economic contributions of their leaves, fruits, seeds, flowers, roots, and bark.

I make the argument that there is a strong case to be made that the Engaruka village platforms were used for local gardening activities and that this use would not have prohibited any of the other activities, other than stock keeping, from occurring amongst the crops at the same time. At Konso, animals are often housed beneath granaries within household compounds (see Figure 26), where their fodder is supplemented with chaff from crop processing (see Figure 25). Wooden fencing restricts them from grazing on home garden crops. A similar method may have been used at Engaruka, though the necessary evidence, such as postholes and granary features, has not yet been identified.

Middens are ubiquitous features of dense human settlement sites and cultivation of economically valuable crops in protected space near the home is an equally common practice. The pattern of discarding biological household waste, particularly foodstuffs and human waste, near the house feeds the soil, creating a substrate in which discarded viable seeds are able to germinate (Doolittle 2004, citing Anderson 1952,136-150). Also, seeds lying dormant in middens situated downslope from dwellings benefit from water runoff; a pattern identified in Doolittle (1994) and also observed at Konso. The combination of "compost" and "irrigation" provide favourable conditions for opportunist crops and weeds to become established. Whether the gardens are initially established on purpose is an important line of enquiry to follow given the recovery of economic wild taxa and the lack of evidence of valuable non-staple plants that might be expected to have been planted near the house. Given the period of occupation, cotton would have been a likely crop and home garden cultivation of cotton is undertaken by the modern residents of Konso, and yet seeds have not yet been found at either site. Wild economic plants may have been allowed to grow in these areas at first, and then later intentionally planted once reliance on the outcropping was identified as a convenience benefitting the inhabitants in some way.

Contrasting Assemblages

The key takeaways of the Konso results are based upon comparability of the archaeobotanical assemblage with that of Enagaruka and the insights and gaps contributed by the ethnographic data that exists. Radiocarbon dating demonstrates that non-charred wild seeds represent intrusion of modern wild taxa into midden and *yela* contexts. There is a higher diversity of crops in the Engaruka assemblage, but Konso has more known diversity in the number of modern crops in the subsistance package. It is therefore possible that the crop repertoire at Engaruka could have been more in keeping with the diversity seen at Konso. Similarly, weed diversity is roughly equivalent at both sites, but the ethnographic baseline at Konso allows for more robust interpretation of economic use.

As concentrated areas of human agricultural and domestic activity, the archaeobotanical assemblages of Engaruka and Konso contain a broad suite of crop and non-crop seeds. More crop and non-crop plant use activity was occurring in the villages than in the fields, where farmers were promoting the growth of a reduced number of taxa, especially specific crops and some edible/beneficial/tolerated weeds. This process encouraged the deposition of diverse plant types in the domestic sphere and reduced diversity in the fields. Meanwhile, hearths in domestic buildings act as the agents of seed preservation. Carbonised seeds area much more commonly preserved and recovered from hearths and floors, than from wildfire or anthropogenic burning in the fields.

The abundance of fireplaces in villages coupled with the common practice of disposing of rubbish in hearths increases the likelihood of all types of seed preservation in domestic contexts. Charred wild and crop seeds were more likely

Figure 30. Konso woman carrying maize stalks from the fields. Women are responsible for a disproportionately large portion of domestic and agricultural labour.

to be found in domestic contexts. Crop seeds may be intentionally discarded directly into the hearth if found to be damaged just prior to cooking in the case of grains, and/or during the early stages of the cooking process as occurs with legumes. Furthermore, abundance of charred seeds from hearths is greater than from occupation floors even within the same structures, as is to be expected. The current study was not able to definitively distinguish charred weeds of cultivation (or weeds of irrigation) from other wild economic plant seeds at Engaruka, but the concluding chapter presents recommendations for how this might be achieved in the future.

Pushing the Results

At the start of the current study, the narrative permeating some archaeological and development discussions about Engaruka was based on the argument that abandonment was equal to failure and that failure was a result of agricultural mismanagement (e.g. Conte 2004). By the end of the study, the AAREA project has shifted this discussion to focus on the fact that not enough data exists to make such an argument, and that new data suggest that the interplay of variables impacting assessments of resilience and sustainability are more complex than the success-failure binary narrative can illustrate. This realization has been integral to the development of the unique methodology applied in the current study. The above variables have been discussed in previous chapters and are discussed further below. In summary, these success-failure narratives do not focus enough on the success of the system through periods of intense climatic shifts (Westerberg et al. 2010) that would have made farming a very unpredictable subsistence strategy requiring adaptation through intensification and diversification strategies, detailed below. Drought resistant crop management would have been an important feature of such systems, including the selection, and plausible intercropping and rotation of sorghum, millets, legumes and perhaps other crops that are not yet archaeobotanically visible.

The problems with assuming failure is that this assessment classifies the site based on a static snapshot of the end result rather than recognising the dynamic adaptations that would have occurred during the lifetime of the agronomy. It overlooks the inevitability that livelihoods can change both subtly and drastically in response to a variety of stimuli, but do not always or only change in response to climatic shifts or to failures in the management of the system. External factors are important to consider. The politics of changing power dynamics impact trade and make a differentiation between what is needed and what is allowed. Shifts in political will also affect the availability of natural resources (water and land), labour provisions and social factors impacting the composition of the labour matrix. These issues are exemplified by modern farming families in Konso and Engaruka assessing the cost-benefit of educating young women, who traditionally are responsible for a disproportionately high level of domestic and agricultural subsistence activities (Figure 27), including, but not limited to crop processing, food preparation, hauling water, planting, weeding, and caring for children and the elderly.

Responses to these changes are dependent on numerous factors, but here I discuss those that are known to have relevance to this landscape and provide examples of how these manifest archaeologically. In times of economic uncertainty migrant farming can help to provide stability during short term gaps in production. Migrant farming is a mode of diversification within an intensive system that could be viewed archaeologically in the seasonal/temporary occupation of agricultural settlements. Leaving for greener pastures on a permanent basis may have occurred if the new areas visited during seasonal migration prove to be more reliable due to climate conditions or management innovations. If Engaruka's farmers participated in the Northern Caravan trade, individuals may have heard the call of the import/export economy and decided to pursue work as traders at urban markets and smaller rural outposts. Evidence of this should arise in an expansion of exotic goods, including crops, pottery, textiles, and beads. Of these, only the latter have been recovered from the site, though analysis has not been carried out on the origin of the very scant bead specimens. Another option is to avoid overreliance on a single subsistence strategy through economic multitasking. This is a more complex strategy to identify archaeologically, though in-depth spatial analysis of activity areas for the identification of specific economic residues is potential a fruitful method to employ.

The Archaeobotanical Evidence of Risk Management at Engaruka

In the section that follows, I set aside the traditional classification of Engaruka as a system of intensive agriculture on the basis of the presence of terraces and irrigation features (e.g. Widgren and Sutton 2004), to present the evidence of diversification as well as that of intensification based on the findings of the analysis of the archaeobotanical assemblage. In focusing on field contexts and weed assemblages, I was able to set the stage for more advanced studies of agricultural biodiversity, weed ecology, and functional ecology at Engaruka, as well as other proxy sites in the Sonjo region.

Proxy data from the analysis of the Konso study, which critically includes the ethnographic component, is incorporated into the discussion to assist in pushing interpretations as far as possible. However, do note that these arguments are not meant to serve as speculations, but rather they are presented to help identify exactly what types of future investigations are necessary in order to further explore the evidence of sustainability in the Engaruka system.

The Engaruka system either developed as a response to the challenges presented by a dry environment, or to capitalise on the opportunities for irrigation provided by the permanent and seasonal streams, or a combination of both over time. The severe seasonal concentration of rainfall meant that if farming was to support a growing community water was going to need to be channelled to reach the entire network of fields. Prior to the AAREA Project investigations, it was assumed that water was the primary resource transported via the irrigation channels to the fields. The revelation that the gently terraced fields at Engaruka were deposited in the same way as the sediment trap fields, known as *yela* at Konso, immediately refined the definition of intensification to include the transportation of water and soil, both of which are pivotal to the goal of overproduction.

The earliest radiocarbon dates were associated with weed seed specimens charred and likely deposited during a flooding event or during in-situ burning (e.g. such as slash and burn and stubble burning) in the 10th to 11th century A.D. Both of these modes of deposition represent the earliest evidence of intensification. Irrigation brought in soil and water to support the cultivation of crop surplus, and anthropogenic burning returns nutrients to the soil and reduces crop pests.

Evidence of diversification arrived with the recovery of a fragment of Moringa charcoal dating the earliest phase of the village to the 15th to 17th century AD. Moringa is a leafy vegetable, fuelwood, and medicinal taxa that would have been a useful risk management tool. Use of Moringa and other wild taxa may have been a holdover from pre-agricultural occupation of Engaruka and it is important to view diversification and intensification as a mosaic of strategies embedded in the agronomy from the time of its inception. Furthermore, Moringa is often intercropped with sorghum, millets, and pulses, throughout the region including at Konso, providing evidence of domestication of wild taxa to support sustainable livelihoods. Sorghum and *Vigna* sp. seeds dating to the 17th century represent the earliest dated crops recovered from buildings high up the slope, while lower structures dated to the late 17th century, suggesting that village expansion developed down the slope, moving toward the sediment trap fields below. This could be representative of an increasing reliance on intensive modes of staple crop production as the settlement grew.

Recovery of a variety of charcoal types and wild seeds in the village suggest that economic plant use may have impacted the biodiversity of the vegetation at least in the proximity of the village. However, a larger sample cross-referenced with existing palaeoenvironmental data is needed to refine this hypothesis.

What is Still Unknown About the Sustainability Strategy at Engaruka?

The study revealed a number of significant results that have contributed to an expansion of what is known about pre-colonial agriculture in the Eastern African interior and it has also shed light upon possible strategies of subsistence that contributed to the long-term stability of the Engaruka agronomy. However, there are some issues that remain to be addressed either because the material evidence needed lies outside the scope of the current study, or because archaeobotanical analysis alone cannot resolve the mysteries of Engaruka's eventual abandonment, and, lastly, because the identification of the archaeobotanical markers of sustainability is at a preliminary stage.

Comparison of the archaeobotanical and ethnographic data from Konso to the Engaruka analysis has identified a number of gaps. We still do not have a refined understanding of how the ancient subsistence strategy differs from that of modern tradition-style farmers living in comparable conditions across Eastern Africa. Also necessary is further recovery and identification of economic seeds so that a more complete cross-section of the agricultural practices can been explored. For instance, it is known that economic weeds of cultivation and irrigation play an important role in food security, maintaining health, and supporting the microfauna and macrofauna of the agroecosystem in the arable drylands of Central Tanzania (Shemdoe et al. 2008). There is not currently sufficient understanding of past crop weeds, and thus integration of knowledge about Engaruka's present economic field weeds is not possible. The increased base-line knowledge about economic weeds at Konso significantly expanded my ability to interpret the value of specific economic plants.

Establishing whether the cropping regime involved intercropping, crop rotation, and the use of home gardens has a significant impact on assessments of sustainable subsistence. Dating fluctuations in these practices is vital. It is also important to better understand the degree of reliance on wild economic plants over the course of the life of the system.

Wild plants as food, medicine, and building/craft material make subsistence more robust through diversification, but their widespread harvest impacts the landscape. Overharvesting leads to depletion and this becomes problematic if the community has become reliant on a particular plant to serve a purpose, especially if the plant in question is a popular trade commodity or a famine food. Furthermore, overharvesting vegetation on the hillslope can also lead to soil erosion, which has both benefits and serious drawbacks. At Engaruka and Konso, erosion frees the sediment that feeds the sediment trap fields, which can free up space for expansion of the settlement, including clearing land for cultivation. Conversely, soil erosion close to dwelling platforms can put the inhabitants at risk of their homes sliding down the slope. If overharvesting becomes severe enough over a large enough area, functional biodiversity also becomes depleted. For example, this type of land clearance impacts the abundance of predator and pollinator insects and spiders that are vital to the agricultural biodiversity of the cropping system (Tscharntke et al. 2012, 56). Depletion of wild plants can leave the community open to risk. Agroecosystems that preserve biodiversity experience lower rates of damaging herbivory than less diverse systems of intensification because herbivores are kept in check by their natural predators (Letourneau et al. 2011).

The question that most directly relates to dating and system stability is how to identify the tipping point that motivated Engaruka's farmers to adopt a new strategy and to leave the old system behind, thus moving the discussion closer to the issues around the abandonment of the farming landscape. Petek's recent thesis (Petek 2018) puts forth a compelling argument for combining the concepts of community resilience and risk spirals into a framework for the assessment of whether communities were "just surviving" or "thriving" in a particular landscape at specific points in time (Petek 2018, 22).

The concept of risk spirals was coined by historical ecologist Rolf Sieferle to describe how: the reduction of a particular risk leads to new types of uncertainty which in turn requires further (risky) innovations. This mechanism creates a permanent innovation pressure responsible for the restless transformations in complex societies (Sieferle and Müller-Herold 1996).

The authors recommended that adaptations to these fluctuations are the best ways for societies to cope. Petek relates this to Magis' (Magis 2010) emergent definition of community resilience whereby members of the group "intentionally develop personal and collective capacity that they engage to respond to and influence change, to sustain and renew the community, and to develop new trajectories for the communities' future." In a discussion with a great deal of relevance to the current study, Petek argues that the framework resulting from the integration of these concepts can be applied to existing data. At Engaruka, archaeobotany has helped to identify features of the agronomy that must be known in order to begin such an assessment though future, more interdisciplinary studies of the intensive and diversification practice that support community resilience and the overall sustainability of the system.

Future Studies of the Existing Assemblage

Further analysis of the existing assemblage (as a component of a broader regional project) is needed in order to push the arguments for why Engaruka was sustained for so long despite climate shocks. This research should target the identification of the weed seeds through detailed studies of local vegetation and local paleoenvironmental shifts, combined with analysis of African seed reference collections. This work will facilitate a better understanding of local weed ecology and the economic significance of wild and weedy taxa that can engage with ecological studies of agricultural biodiversity (Stoop 2017; Chaplin-Kramer et al. 2015; Tscharntke et al. 2012) and archaeological investigations of functional ecology at other sites of agricultural intensification (Bogaard et al. 2016b, 2016c, 2017; Fraser et al. 2011; Bogaard et al. 2001; Jones 1992; Jones et al. 2005, 2010).

With regard to the Konso study, during the 2015 field season samples were taken from a domestic compound abandoned in the mid-20th century, but have yet to be analysed and thus are not presented in the results above. However, the planned future analysis of this historic archaeobotanical assemblage, comprised of charred seeds originating from a hearth, as well as desiccated seeds from contexts below granaries, should reveal the preservation of a greater number of crops than the midden, especially those grown in the home garden. This could result in an expansion of the known exotic crop repertoire at the time of occupation and presents an opportunity for corroboration with ethnographic accounts. The guaranteed recovery of chaff (it was visible in the samples during collection), particularly from the granary samples, will be useful for understanding crop processing practices. These results will be crucial data points for comparison with future archaeological studies of sustainability and will continue to expand the archaeobotanical base-line of knowledge at Konso. The research comprising the current study is relevant and timely because in theory archaeobotany can help seal these data gaps, but the question that needs to be answered now is whether archaeobotany can do this in practice. If no attempt is made to fill in these gaps, then progress towards understanding the markers of sustainability, evidence of trade and regional cultural relationships, and impacts of the historic environment, will remain highly speculative. These components are key to modelling the system, as exemplified by the work of Kabora (2018), and details must be refined in order to ensure the accuracy for the variables. This has broader implications when Engaruka is cast as a case study for broader debates about the kind of advice that should be promoted by policy-makers to farmers in Eastern African facing climate change threats to their subsistence.

7 Conclusion

Farming is a risky endeavour even in the most idealised conditions. When landscape and climate features are less than ideal, or become so over time due to social, economic, and environmental factors, the decision about whether farmers persist or change course relates to perceptions of resilience at that moment in time.

Assessing the sustainability of historic agricultural systems requires comprehensive information on plant cultivation, collection, and exploitation. To achieve this, archaeobotany has traditionally prioritised the identification of preserved crops and 'useful' wild plants. Archaeobotanical studies have long been employed to address these questions by identifying and quantifying the preserved remains of crops and gathered plants (Fuller 2007; Neumann 2003). Recent advances have expanded this methodology by also studying the role of weeds, thereby providing information on a range of issues including cultivation intensity, harvesting techniques, and the and the nature of the local environment (Bogaard et al. 2016; Cappers 2017)

The current study applied this approach at sites of intensive agriculture in Sub-Saharan Africa, focusing on the well-known abandoned irrigated and terraced site of Engaruka, Tanzania, and on the comparable, but still cultivated terraced landscape at Konso, Ethiopia. The aim of the study was to assess the potential for archaeobotany to contribute to debates about resilience and long-term sustainability through an interrogation of the different kinds of results produced by methodologies based on different levels of ethnographic analysis. At

Engaruka, the approach was dominated by archaeobotanical sampling which allowed the macrobotanical data to speak for itself. While there was an ethnographic component to the study focused on the modern Maasai residents of the landscape, I had to fully engage with the caveat that that as 21st century agro-pastoralists, this population has taken quite a different approach to subsistence than the people who originally built the system of agricultural terraces and sediment traps. This highlights the importance of the Konso case study. The modern participants in the local agronomy are still applying what is accepted to be traditional agricultural risk mitigation strategies to semi-arid hill slope and riverbank farming, while living in the same hilltop villages occupied by the ancestors that built the system. These key factors presented the opportunity to compare how differing degrees of ethnobotanical data integrated with archaeobotanical analysis can impact the interpretation of coping strategies and long-term sustainability from an archaeological perspective.

The common starting point for both case studies was to identify the crops that were grown in order to establish key variables influencing risk mitigation. At Engaruka, this information was established through the identification of carbonised millets and legumes, dramatically increasing our knowledge of the crops grown from just one confirmed species, sorghum, to include pearl millet, cowpea, and finger millet. Meanwhile at Konso, it is now know that sorghum, millet, cowpea and a further legume identified only to the family Fabaceae where grown and consumed at least 300 years ago, with millets of unidentified species grown at least 600 years ago. Importantly, the combination of archaeobotanical sampling with interviews on farming practices at Konso also identified a disconnect between the archaeobotanical assemblage (dominated by wild and economic weed taxa with relatively few millet and legume seeds) and information provided by modern farmers and plant specialists who reported a diverse and dynamic array of cultivated and wild taxa that play important roles in the modern incarnation of the traditional agronomy. This disconnect demonstrates that purely archaeobotanical studies like that reported here for Engaruka will miss important details regarding the range of plants exploited, in part due to preservational biases created by factors such as whether cooking or land management techniques lead to the carbonisation of macrobotanical remains. Of equal importance in terms of an archaeobotanical contribution to sustainability assessments, the inclusion of observational and interview data from Konso also emphasized the value of intercropping as a risk mitigation technique, demonstrating that at present at least, the 'intensive' agricultural landscape at Konso does not function to intensify production through maximising yields but rather lessens the risks of bad years and the failure of specific crops by diversifying production both within individual plots and across different landscape niches; the latter created or artificially augmented by the construction of hillside terraces, riverside sediment traps and irrigation structures. It is the contention here that risk mitigation through niche construction and intercropping was likely to have also been a factor at Engaruka, and that this increased the community's environmental resilience, but it must be stressed that this is an inference drawn from the combined archaeobotanical and ethnographic results from Konso compared with the

Engaruka results, rather than on the archaeobotany from Engaruka alone. Marston (2011, 2015) might be right, therefore, in arguing that archaeobotanical research can distinguish agricultural intensification from agricultural diversification (as discussed above on page 132), but the research results reported here have highlighted the strengths of a multi-disciplinary approach that combines archaeobotany with ethnobotany, and which reveal that agricultural sustainability is a more complex process than a purely archaeobotanical approach can hope to interrogate (see also Ferro-Vázquez et al. 2017).

Future Research at Engaruka

The revelations of the current study have identified a new set of questions, which require an increasingly multidisciplinary approach. Primary among these questions is how have human-environment interactions and climate change impacted system sustainability and the resilience of farming populations as a whole. In order to better understand the crop-weed ratios recorded by the current study at Engaruka it is recommended that future research leading on from the results of the current study focusing on weed ecology and crop selection based on ethnobotany and application of an ecological technique known as soil seed bank analysis. In order to understand the complex interplay of farmers and their dynamic dry land environments, the current study has highlighted the importance of better knowing the local vegetation and its potential economic value. It has also established the importance of further ethnographic work with the local Maasai agropastoralists currently subsisting in the Engaruka landscape.

The primary goal would be to identify crop repertoires and weed ecologies and to compare these data with historic vegetation changes and use patterns in order to understand how farmers have impacted their local ecologies, and vice versa. The broad objective of future work at Engaruka should explore crop and weed relationships at both ancient and modern sites of intensive agriculture with varying levels of market vs. subsistence orientation in order to better understand the relationship between plant exploitation, agricultural sustainability, and climate resilient agriculture. The recovery of crop and weed taxa coupled with knowledge of the composition of modern vegetation presents the opportunity to compare changes in wild plant communities over time and to explore the ways in which wild seeds enter the archaeological record. This research has the potential to provide a quantitative basis to compare the biodiversity impact of specific farming methods, which is essential to achieve the fullest possible interpretation of the existing Engaruka assemblage and necessary since no previous comparable crop/wild vegetation studies exist.

With East Africa poised to experience severe impacts from future climate change, the fact that the modern agronomy at Engaruka is heavily reliant upon the reliability of the bimodal rainfall pattern is cause for concern. In recent years, farmers report that these conditions have become less predictable resulting in weaker yields. Critically, the current research, as well as the potential future research recommended here, is intended to refine our understanding of modern agricultural coping strategies through the quantification of biodiversity impacts, which are relevant to non-academic stakeholders, including capacity-building organizations in particular, potentially making the research results meaningful for the current inhabitants of these landscapes.

Appendix A. Engaruka Seed Count by Site

Table 8. Count of seeds by site.

Site	All Seed Ct.
Village	1223
Fields	98
Total Seeds	1323

Table 9. Charred Seed count by building in village.

Location	Charred Seed Ct.
All Total	495
All Village	474
CK1	94
CK2	83
HJ	35
MG	101
Senna	161
Fields	21

Appendix B. Engaruka Taxa Count by Site

Table 10. Count of charred seeds of specific taxa from the agricultural terrace (fields) and the habitation terrace (village).

Taxa	Agricultural Terrace	Habitation Terrace
Aizoaceae		4
Zaleya		2
Aizoaceae/Malvaceae		25
Trianthema/ Abelmoschus		25
Amaranthaceae		2
Amaranthus		2
Caryophyllaceae/ Portulacaceae		3
cf. Asteraceae	1	2
cf. Caryophyllaceae	1	9
cf. Chenopodiaceae	11	4
cf. Cyperaceae	1	
Fabaceae/poaceae		2
cf. Molluginaceae (Aizoaceae)		4
Fabaceae	1	89
cf. mimosoideae		27
cf. Medicago		2
UNID pulse		3
Vigna		4
Vigna Unguiculata		6
UNID Fabaceae		52
Malvaceae		8
Papaveraceae		4
Poaceae	14	277
cf. *Digitaria*		2
Setaria pumila		2
Panicum		4
milliaceum		4
Pennisetum		5
glaucum		5
Setaria	9	224
Setaria/Brachiaria		1

Taxa	Agricultural Terrace	Habitation Terrace
Setaria/Brachiaria/ Echinocloa	3	
Sorghum	1	17
bicolor	1	6
Tragus		1
racemosus		1
Typha		2
Unid Millet		2
UNID Poaceae	1	22
Portulacaceae		11
Montia		6
Fontana		6
UNID Portulacaceae		2
UNID		5
UNID	51	699
Grand Total	80	1150

Table 11. Count of seeds of wild and weedy taxa from agricultural terrace (fields) and habitation terrace (village).

Wild and Weedy	Agricultural Terrace	Habitation Terrace
Aizoaceae		
Zaleya		2
Aizoaceae/Malvaceae		
Trianthema/Abelmoschus		25
Amaranthaceae		
Amaranthus		2
Caryophyllaceae/ Portulacaceae		3
cf. Asteraceae	1	2
cf. Caryophyllaceae	1	9
cf. Chenopodiaceae	11	4
cf. Cyperaceae	1	
Fabaceae/poaceae		2
cf. Molluginaceae (Aizoaceae)		4
Fabaceae	1	
cf. mimosoideae		27
cf. Medicago		2

Appendix B

Wild and Weedy	Agricultural Terrace	Habitation Terrace
UNID Fabaceae		52
Malvaceae		8
Papaveraceae		4
Poaceae	14	
cf. Digitaria		2
pumila		2
Setaria	9	224
Setaria/Brachiaria		1
Setaria/brachiaria/echinocloa	3	
Tragus		1
racemosus		1
Typha		2
UNID Poaceae	1	22
Portulacaceae		
Montia		6
Fontana		6
UNID Portulacaceae		2
UNID		704
Grand Total	42	1119

Crops	Agricultural Terrace	Habitation Terrace
Fabaceae		
UNID pulse		3
Vigna unguiculata		10
Poaceae		
UNID millet		4
Pennisetum glaucum		5
Sorghum bicolor	1	17
Grand Total	1	39

Appendix C. Konso Archaeobotanical Sample Data

Table 12. Archaeobotanical sample data for the yela contexts at Konso.

	116	118	118/119	133/136	122/123	124	121	120	Total
Litres of Sediment Floated	7.20	5.40	8.20	4.80	4.80	4.70	7.80	7.30	50.20
Flot size wt. (g)	7.91	3.68	19.59	3.68	8.34	4.35	4.05	3.78	55.38
Flot(g)/ Litre soil	1.10	0.68	2.39	0.77	1.74	0.93	0.52	0.52	1.10
Seeds/ litre soil	1.94	29.44	10.85	2.50	2.29	1.06	2.95	1.23	6.41
charred seeds/ liter soil	1.25	10.74	5.61	0.00	1.46	1.06	2.95	0.55	3.03
non-charred seeds/ litre soil	0.69	18.70	5.24	2.50	0.83	0.00	0.00	0.68	3.39
Seeds/g of flot	1.94	29.44	10.85	2.50	2.29	1.06	2.95	1.23	6.41
charred seeds/g (flot)	1.14	3.68	2.35	n/a	8.34	1.15	5.68	1.06	2.74
Non-charred seed/ g (flot)	0.63	27.45	2.19	3.26	0.48	n/a	n/a	1.32	3.07
Charred wood wt.	0.05	0.14	0.01	0.01	0.01	0.32	0.03	0.09	0.66
No. samples	1	1	1	1	1	1	1	1	8

Table 13. Archaeobotanical sample data for the midden contexts at Konso.

	232	233	234	236	237	276	278	280	284	286	282/283	Total
Litres floated	3.6	6	3.4	2.8	4.4	4	4.2	4	5	5.4	7.6	50.4
No. Samples	1	1	1	1	1	1	1	1	1	1	1	10
Flot size wt.	112.56	23.74	35.16	16.38	6.43	62.90	13.41	19.91	73.73	7.06	13.02	384.30
Flot(g)/ Litre soil	31.27	3.96	10.34	5.85	1.46	15.73	3.19	4.98	14.75	1.31	1.71	7.63
Seeds/ litre of soil	22.22	2.00	2.06	2.86	6.36	0.25	2.14	2.00	4.60	3.15	1.84	4.11
charred seeds/ liter of soil	6.94	1.67	2.06	2.86	6.36	0.25	0.00	1.25	1.20	0.74	0.79	1.98
non-charred seeds/ litre of soil	15.28	0.33	0.00	0.00	0.00	0.00	2.14	0.75	3.40	2.41	1.05	2.12
Seeds/g of flot	0.71	0.51	0.20	0.49	4.35	0.02	0.67	0.40	0.31	2.41	1.08	0.54

	232	233	234	236	237	276	278	280	284	286	282/283	Total
charred seeds/g (flot)	0.22	0.42	0.20	0.49	4.35	0.02	0.00	0.25	0.08	0.57	0.46	0.26
Non-charred seed/g (flot)	15.28	0.33	0.00	0.00	0.00	0.00	2.14	0.75	3.40	2.41	1.05	0.28
Charred wood wt.	0.38	0.05	13.55	0.49	0.87	0.00	3.80	10.58	24.22	0.25	0.40	54.60

Appendix C

Table 14. Count of charred crop and weed taxa the yela at Sahaito in Konso.

Crops	116	118	118/119	133/136	122/123	124	121	120	Total Seeds
Poaceae									
Sorghum bicolor								1	1
UNID Millet	1							1	1
Total	1							1	2
Non-crops, charred	**116**	**118**	**118/119**	**133/136**	**122/123**	**124**	**121**	**120**	**Total Seeds**
Aizoaceae									
Zaleya petandra		15	2						17
Type A						3			3
Type 6		10							10
Lamiaceae									
Ajuga integrifolia/ leucantha		3	1					3	7
Malvaceae									
Hibiscus trionum		1							1
Molluginaceae					2	1	11		14
Poaceae									
Non-crops, charred	**116**	**118**	**118/119**	**133/136**	**122/123**	**124**	**121**	**120**	**Total Seeds**
Brachiaria/Setaria		2			2				4
Portulacaceae									
Portulaca cf. oleraceae	1		2		1		2		6
UNID									
Indet E3			1						1

Table 15. Count of charred crop and weed taxa the yela at Sahaito in Konso.

Context	232	233	234	236	237	276	280	284	286	282/ 283	Total Seeds
Crops											
Fabaceae											
Vigna unguiculata			1						1		2
Vigna sp.	2										2
Indet Fabaceae		6									6
Poaceae											
Sorghum bicolor	2	1		3	1						7
UNID millet						1					1
Non-crops charred											
Asteraceae										1	1
Caryophylaceae/ Portulacaceae											
Type 37		1									1
Type A								1			1
Malvaceae											
Adansonia/ Hibiscus										1	1
UNID											
Indet B	16			3	17						36
Indet C									1		1
Indet Damaged		2	6	2	10		5	2		3	30
Indet-144										1	1
Indet-159									2		2
Indet-44	2										2
Poaceae											
Brachiaria/ Setaria								3			3

Appendix D. Konso Ratios of Material Categories by Site

Table 16. Ratios of specific material categories by site at Konso.

	Charred Count	Non-Charred Count	Charred: Non-charred	Crops Count	Non-Crops Count	Crops: Non-Crops	Charred Non-Crops	Crops: Charred Non-Crops
Midden	103.00	107.00	0.96	22.00	188.00	0.12	81.00	0.27
Yela	155.00	189.00	0.82	2.00	341.00	0.01	153.00	0.01
All Konso	258.00	296.00	0.87	24.00	529.00	0.05	234.00	0.10

	Chaff Count	Grain Count	Chaff: Grain	Sorghum Count	Non-sorghum crops
Midden	4.00	12.00	0.33	7.00	15.00
Yela	0.00	2.00	0/2	1.00	1.00
All Konso	4.00	14.00	0.29	8.00	16.00

	Cowpea Count	Sorghum: Cowpea	Millet Count	Legume Count	Millet: Legume
Midden	2.00	7/2	12.00	10.00	6/5
Yela	0.00	1/0	2.00	0.00	2/0
All Konso	2.00	4/1	2.00	10.00	1/5

	Charcoal wt.	Charcoal: Charred	Charcoal: Crops	Charcoal: Millets
Midden	54.60	0.53	2.48	4.55
Yela	0.74	0.00	0.37	0.37
All Konso	55.34	0.21	2.31	27.67

	Charcoal: Sorghum	Charcoal: Legumes	Charcoal: Non-Sorghum
Midden	7.8	5.46	3.64
Yela	0.74	n/a	0.74
All Konso	6.91	5.53	3.45

	Charcoal: Charred	Charcoal: Crops	Charcoal: Millets	Charcoal: Sorghum	Charcoal: Legumes	Charcoal: Non-Sorghum
Midden	0.53	2.48	4.55	7.80	5.46	3.64
Yela	0.00	0.37	0.37	0.74	n/a	0.74
All Konso	0.21	2.31	27.67	6.92	5.53	3.46

	Crops Count	Charred Non-Crops
Midden	22	81
Yela	2	153

Appendix E. Konso Taxa and Material Category Ubiquity by Site

Table 17. Frequency and ubiquity of taxa and material categories at the midden at Kuile in Konso.

Midden Material Categories	Count of Frequency	Ubiquity
Charred Material	11	79%
Crop	8	57%
Fabaceae	4	29%
Vigna unguiculata	2	14%
Vigna sp.	1	7%
Indet Fabaceae	1	7%
Poaceae	5	36%
Sorghum bicolor	4	29%
UNID millet	4	29%
Non-crop	9	64%
Asteraceae	1	7%
Caryophylaceae/ Portulacaceae	2	14%
Type 37	1	7%
Type A	1	7%
Malvaceae	1	7%
Adansonia/ Hibiscus	1	7%
UNID	9	64%
Indet B	3	21%
Indet C	1	7%
Indet Damaged	7	50%
Indet-144	1	7%
Indet-159	1	7%
Indet-44	1	7%
Poaceae	2	14%
Brachiaria/Setaria	1	7%
Setaria sp.	1	7%
Charred wood	11	79%
UNID parenchyma	7	50%
UNID fruit/ nut	1	7%
Non-Botanical	11	79%

Appendix E

Midden Material Categories	Count of Frequency	Ubiquity
Bone	9	64%
Ostrich eggshell fragment	5	36%
Lithic debitage	2	14%
Tooth	4	29%
Ostrich egsshell bead	2	14%
Ceramic body sherd	4	29%
Ceramic rim sherd	1	7%
Ceramic body sherd decorated	1	7%
Ceramic rim sherd decorated	1	7%
Grinding Stone fragment	1	7%
Ceramic handle sherd decorated	1	7%
Uncharred	9	64%
UNID leaves and roots	1	7%
UNID fruit/ nut	2	14%
Non-crop	7	50%
Aizoaceae	1	7%
Amaranthaceae/ Chenopodiaceae	4	29%
Brassicaceae	1	7%
Caryophylaceae/ Portulacaceae	4	29%
Type 37	1	7%
Type 53	1	7%
Type 6	1	7%
Type A	1	7%
UNID	3	21%
Indet Damaged	1	7%
Indet E	1	7%
Indet-144	1	7%
Indet-4	1	7%
Indet-75	2	14%
Portulacaceae	2	14%
Portulaca cf. oleraceae	2	14%

Appendix E

Table 18. Frequency and ubiquity of taxa and material categories at the Konso yela.

Yela Material Categories	Count of Frequency	Ubiquity
Charred	7	88%
Crop	2	25%
Poaceae	2	25%
Sorghum bicolor	1	13%
UNID millet	1	13%
Non-crop	7	88%
Aizoaceae	3	38%
Indet	1	13%
Zaleya petandra	2	25%
Caryophylaceae/ Portulacaceae	1	13%
Type 6	1	13%
Lamiaceae	3	38%
Ajuga integrifolia/ leucantha	3	38%
Malvaceae	1	13%
Hibiscus trionum	1	13%
Molluginaceae	3	38%
Poaceae	3	38%
Brachiaria/ Setaria	3	38%
Portulacaceae	4	50%
Portulaca cf. oleraceae	4	50%
UNID	7	88%
Indet Damaged	4	50%
Indet-111	1	13%
Indet-170	1	13%
Indet-171	1	13%
Indet-184	1	13%
Indet-192	2	25%
Indet-E11	1	13%
Indet-E3	1	13%
Indet-E6	1	13%
thorn	1	13%

Charred wood	7	88%
Uncharred	6	75%
Yela Material Categories	Count of Frequency	Ubiquity
Non-crop	6	75%
Aizoaceae	3	38%
Indet	2	25%
Zaleya petandra	1	13%
Amaranthaceae/ Chenopodiaceae	4	50%
Caryophylaceae/ Portulacaceae	2	25%
Type 6	1	13%
Type A	1	13%
Lamiaceae	1	13%
Ajuga integrifolia/ leucantha	1	13%
Malvaceae	1	13%
Molluginaceae	1	13%
Poaceae	1	13%
Brachiaria/ Setaria	1	13%
Portulacaceae	2	25%
Portulaca cf. oleraceae	2	25%
UNID	4	50%
Indet A	2	25%
Indet B	2	25%
Indet Damaged	2	25%
Indet F	1	13%
Indet-118	1	13%
UNID parenchyma	1	13%
Leaves and roots	1	13%

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