CONTEXTUAL ANALYSIS OF PLANT REMAINS AT THE ERLITOU-PERIOD HUIZUI SITE, HENAN, CHINA

Gyoung-Ah LEE[1] and Sheahan Bestel[2]

[1]Dept. of Archaeology and Art History, Seoul National University, Seoul 151-742, South Korea
Email: gyoungahlee@yahoo.com
[2]Archaeology Program, La Trobe University, VIC 3086 Australia
Keywords: China, Henan, Yiluo Project, archaeobotany, cereals

ABSTRACT

This paper examines intrasite distributional patterns of plant remains and their implications for plant use and disposal in the past. We analyzed charred plant remains from various excavated features dating to the Erlitou period at the Huizui regional center, Henan Province, China. The main subsistence strategy of the Erlitou period was dryland farming, as archaeologically evidenced by the dominance of dryland crops such as millet and soybean, and the new incorporation of wheat. However, wetland rice was more in use during the drier and cooler Erlitou than during the wetter and warmer preceding periods, and its regional distribution is restricted to major Erlitou centers. Therefore, rice likely played a primarily social role as a prestige crop and status symbol rather than satisfying basic dietary needs. At Huizui, quantities of plant remains by feature types are not correlated to the functions of the features, as defined by feature shape and size as well as artifact contents. Our quantitative analyses of plant remains suggest that the automatic dismissal of rare taxa as casual intrusions, which is common practice in archaeobotany, may be unwarranted, and that any quantitative classification of feature types by plant content is biased by sample size effects.

INTRODUCTION

Prehistoric agriculture has received increasing attention in Chinese archaeology for the last decade or so. Most research, however, has narrowly focused on the antiquity of domesticated crops, particularly rice. Lately, a few studies have explored the spatial distribution of plant remains on archaeological sites and their social implications, based on thorough archaeobotanical investigations in northern China (e.g. Bestel 2006; Crawford *et al.* 2003; Lee *et al.* 2007; Murowchick and Cohen 2001). Following this line of research, the present paper concentrates on the patterns of intrasite plant distribution from a single cultural period at the Huiziui site. We examine whether and what kind of information they reveal on past activities involving plants, and how post-depositional effects on plant distributions in the archaeological record can be identified.

The Huizui site is located in the Yiluo valley, south of the Yellow River, Henan Province, in northern China (Figure 1). The Yiluo region is known as a birth place of the earliest states of China in the second millennium BC (Liu *et al.* 2002-4). Occupations began in the region from the Early Neolithic period, locally known as the Late Peiligang period (ca. 6000–5000 BC) (Liu *et al.* 2002-4). The cultural chronology of the Yiluo region is well established: the Early (ca. 5000 – 4000 BC), Middle (ca. 4000–3500 BC), and Late (ca. 3500–3000 BC) Yangshao, equivalent to the Middle Neolithic period; the Early (ca. 3000–2500 BC) and Late (ca. 2500–2000 BC) Longshan, equivalent to the Late Neolithic period; Phases I (ca. 1900–1800 BC), II (ca. 1800–1700 BC), III (ca. 1700–1600 BC), and IV (ca. 1600–1500 BC) of the Erlitou, equivalent to the early Bronze Age; the Early Shang (or Erligang, ca. 1600–1300 BC) and Late Shang periods (ca. 1300–1046 BC); and the Western Zhou (1045–771 BC) and Eastern Zhou periods (ca. 770 BC–221).

The Yiluo team has conducted intensive surface survey and excavation at Huizui since 1998, and divided the site into East and West sectors, using a modern gully between them as a boundary (Figure 1). Human occupation of the Huizui site dates from the Middle Yangshao to the Eastern Zhou periods. A total of 665 m^2 of these occupations have been excavated. During the Late Longshan and Erlitou periods Huizui functioned as a regional center and a major lithic production locale (Liu and Chen, this volume). The present paper focuses on the Erlitou occupation of the site, which was uncovered during the 2002 field season. Charred foxtail millet grains from floors, ash-filled ditches, and ash pits were AMS-dated to the first three centuries of the 2nd millennium BC (Table 1). Erlitou remains were mostly preserved in Huizui West, while few were recovered in Huizui East due to historical and modern disturbances. Accordingly, most of our evidence comes from Huizui West.

DATA AND METHODS

During the 2002 field season, eight 5m^2 trenches were opened in Huizui East, revealing numerous ash pits, dwelling floors, and burials, dating to the Yangshao, Longshan, and Erlitou periods. In Huizui West, two terrace cuts were cleaned and features visible here were in

Table 1. AMS dates on foxtail millet seeds at Huizui.

Locality	Provenience	Lab. code	Uncal. BP	Cal BC 1σ	Cal BC 2σ
West	Ter1 Unit12-2A Ash Ditch2	SNU 05131	3590±40	1980-1880	2040-1870
East	T103 F1	BA 06498	3455±55	1830-1730	1890-1660
East	T203H32	BA 06499	3415±35	1760-1660	1780-1620
East	T103 F1 layer 6	BA 06500	3425±35	1780-1680	1830-1620

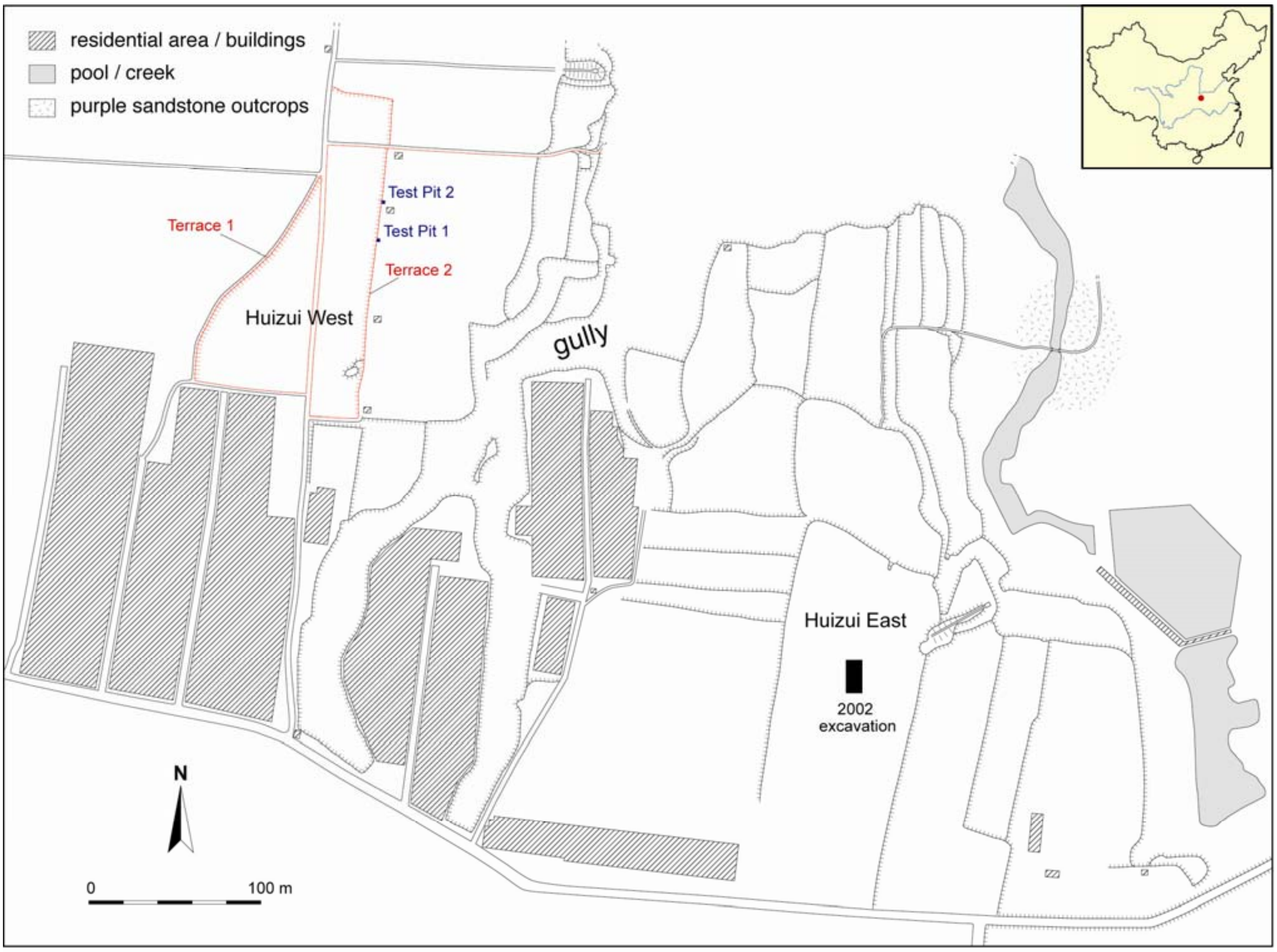

Figure 1. Map of the Huizui site.

vestigated, all dating to the Erlitou period (Figure 1). Over its full length of 67 m, Terrace 1 exposed ash-filled ditches and pits along the north-south axis. Terrace 2, 123 m in length, exposed ash ditches and pits as well as roads. Two 1-m² test pits, 25 m apart from each other in Terrace 2 (Test pits 1 and 2) revealed a lithic workshop and a lithic debris disposal area, respectively (Figure 2). Both features show a high concentration of dolomite and sandstone materials and appear to have been contemporary (Erlitou Phase II) (Webb *et al*., this volume; Liu and Chen, this volume).

Soil samples, varying in size from 1 to 15 liters and totaling 540 l, were collected from 87 separate features and layers. At Huizui East, only samples from the Erlitou-period floors were analyzed. More than two-thirds of samples were recovered from disposal contexts, including a lithic debris area (Test pit 2), ash pits, and ash-filled ditches. The last two types were similar in contents, filled with ash, charcoal, bone remains, and fragmentary artifacts. The difference between them is mainly the size; ditches are usually longer than 4 m (Figure 3). Ash pits excavated during the 2005 field season contained a mixed fill, composed of soil, daub, burned daub, bone, coprolites, and charred and ashed plant materials, mostly wood ash (MacPhail and Crowther, this volume). The lithic debris area in Test pit 2 is characterized by a high concentration of dolomite flakes and potsherds.

Figure 2. Lithic debris disposal area in Test pit 2 at Huizui West.

Figure 3. Ash-filled ditch 2 at Huizui west.

Aside from disposal areas, two other types of contexts were sampled at Huizui: dwelling floors and a lithic workshop floor. Fourteen (80 liter) bulk samples were collected just above dwelling floors, probably representing domestic debris left during the occupations or not long after abandonment. A partial lithic workshop was identified in Test pit 1, revealing a cluster of lithic debitage, including small dolomite flakes and blanks and sandstone fragments. The samples from Test pit 1 reflect the procedures of ground stone tool manufacture (Liu and Chen, this volume). A modified Shell Mound Archaeology Project (SMAP)-style apparatus was used to separate charred organics from soils (see Crawford 1983 for the flotation procedures). Light floated materials were caught with a 0.2 mm-mesh sieve, whereas heavy sunken materials were recovered in a 1 mm mesh. Plant remains larger than 1 mm were sorted thoroughly into their constituent components of charred seeds and nutshells, charcoal, modern plant material such as rootlets, and mineral particles, and their weights were recorded. Only seeds and identifiable vegetative parts were extracted from the fractions smaller than 1 mm. Except for eight samples, only light fractions have been examined.

HISTORY OF PLANT USE IN THE REGION

Recently, the agricultural history of the Yiluo region has been studied in detail through systematic survey and rigorous archaeobotanical research. The survey and excavation collections from 22 sites reflect a 5000-year history of wild plant use and cultivation in the region (Lee *et al.* 2007). The first domesticated plant in the Yiluo valley is foxtail millet, appearing concurrently with the first inhabitation, known as the Late Peiligang culture. Broomcorn millet was available in the neighboring regions along the Yellow River, although this type of millet occurred first in the Middle/Late Yangshao period in the Yiluo region. Both millets remained as the principal crops throughout the region's prehistory and early history. Rice was added by the Late Yangshao period as evidenced by phytoliths (Rosen, this volume). The Yiluo region, however, showed preference for dry crops rather than wet crops like rice for over 5000 years. Wheat has been found at Zaojiashu (Luoyang Relics Team 2002), an Erlitou culture site, 35 km west of Huizui. Our data from Huizui confirm that wheat was used at least from the Erlitou period.

The weed flora diversified through time but was dominated by annual grasses in the Yiluo region (Lee *et al.* 2007). The North China farming tradition emphasizing dry crops with a minor component of rice appears to have been established by the Erlitou period at the latest.

COMPOSITION OF PLANT REMAINS

The Huizui collection contains at least eighteen taxa that can be assigned to the family level or more specific levels, along with several unidentifiable taxa (Table 2). Some seeds of foxtail grass, millet tribe, and rose family show variations in overall shapes and sizes. At the moment, it is not clear whether the variation reflects different species or intraspecific variations. If they are different species, then the total number of species will increase in our collection.

Previous case studies suggest that sample size may affect the number of plant taxa recovered (e.g., Lee *et al.* 2007). However, while the Huizui samples do vary in size from 1 to 15 l, there is no clear correlation of soil volume to the counts (numbers) of charred seeds or the number of taxa (Figure 4). The largest counts of seeds and taxa come from samples of 6 to 10 l, rather than from those with the largest soil volume.

Plant taxa recovered

Domesticated plants in the 2002 Huizui collections include foxtail millet (*Setaria italica* ssp. *italica*), broomcorn millet (*Panicum miliaceum),* rice (*Oryza sativa*), and soybean (*Glycine max*). Evenness of the crops is very low; foxtail millet is the most common single taxon, accounting for 27% of all seeds and 80% of all crops (Table 2, Figure 5). It is ubiquitous in ash ditch samples but is missing in six samples from other feature types. Broomcorn millet, the next most common crop, occurs in much smaller amounts (about 8% of crops) and less frequently than foxtail millet. Slightly more than half of the samples from ash ditches and living floors contained broomcorn

Table 2. Plant taxa and counts identified in each type of features dating to the Erlitou period, Huizui, 2002 field season data.

Feature types	Lithic workshop	Lithic diposal area	Ash ditch	Ash pit	Living floor	*Sum*
N of samples	21	5	7	40	14	***87***
Soil vol. L	111	52	34	263	80	***540***
Nutshell	*	*	*	*	*	
DOMESTICATES						
Broomcorn millet	9	5	31	70	18	***133***
Foxtail millet	81	80	157	511	417	***1246***
Rice	1	1	3	11	18	***34***
Wheat		1		23		***24***
Soybean	11	1	19	74	9	***114***
WEEDS						
Grass family						
Barnyard grass	1		5	3	1	***10***
Foxtail grass	46	29	104	172	188	***539***
Panic grass	23	20	28	66	20	***157***
Panic/Manna grass	22	1	3	33	4	***63***
Other Paniceae	114	125	203	495	376	***1313***
Other grass	5	4	3	14		***26***
Bean family						
Wild legume	16	15	11	77	6	***125***
Sedge family						
Sedge	4	1	3	5	4	***17***
Chenopod family						
Chenopod/Amaranth	85	8	21	185	13	***312***
FLESHY FRUITS						
Bramble			1	2		***3***
Plum			1			***1***
Other Rose Family	3	1	2	4		***10***
UNKNOWN						
N	64	31	20	192	64	***371***
Total seed N	***487***	***323***	***615***	***1938***	***1186***	***4549***
Seed density	***4.4***	***6.2***	***18.1***	***7.4***	***14.8***	***8.4***

* Presence

millet, and it is present in other feature types even less frequently. Similar to foxtail millet in the Yiluo region (Lee *et al.* 2007), some seeds of broomcorn millet are quite small for a domesticated millet, but rounder than their wild counterpart. They might have been grains at the tip of ears. It seems that intraspecific size variations of both millets are substantial.

Soybean in the Huizui samples also shows considerable range of variation in size (Figure 6). All soybean seeds at Huizui are smaller than the unquestionable domesticated specimens from the Early Bronze Age (Mumun) sites in Korea that date to 1400–1000 BC (Crawford and Lee 2003). Some seeds of the Erlitou soybean were much larger than the earlier soybean specimens (Late Yangshao and Longshan) in the Yiluo region. As for other domesticated crops, seed size alone is not a safe criterion for distinguishing wild from domesticated soybeans. Given that soybean is as common as broomcorn millet in our collection, it is plausible to assume that soybean had an economic value to the Huizui people. Wheat was evidently introduced to the Central Plains from Southwest Asia. Based on written sources, wheat is commonly believed to have been successfully introduced in Shang times as a third crop to be grown each year during the dry summer months (Keightley 2000). Oracle bone records suggest that there were previously two crops a year, rice and millet (Chang 1980: 141). However, the archaeological records suggest that wheat occurred in China much earlier than the Shang period. Charred wheat grains have been identified from Donghuishan in Gansu (ca. 3000–2500 BC), more than 1000 km west of the Yiluo basin (Li and Mo 2004). Further east, wheat was recovered in small quantities at the Late Longshan Liangchengzhen site (ca. 2600–2000 BC) in Shandong (Crawford *et al.* 2006). Our data from Huizui along with the data from Zaojiaoshu confirm that wheat was used at latest from the Erlitou

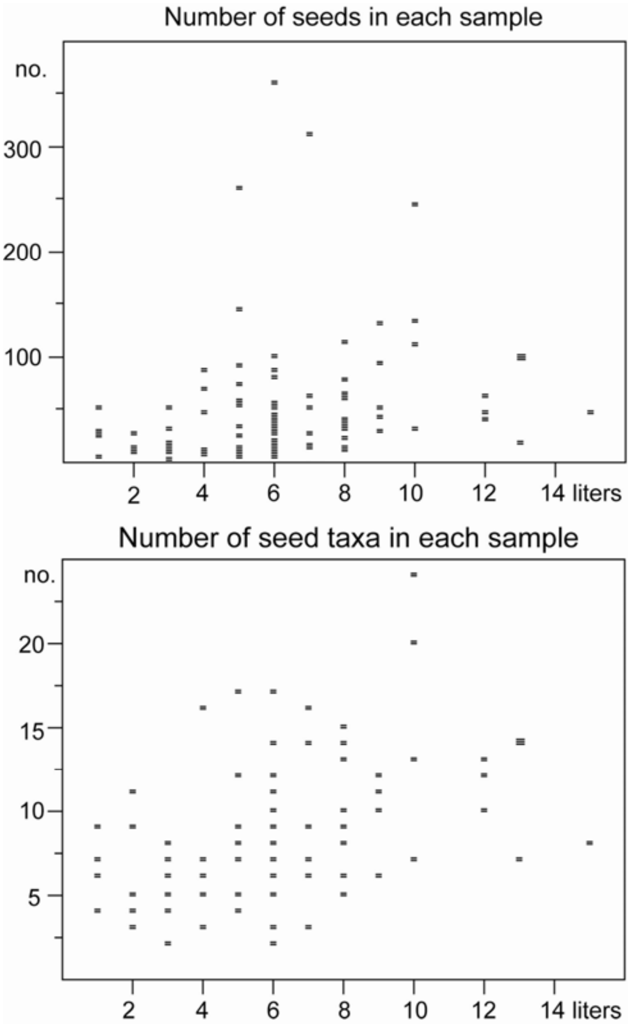

Figure 4. Scatter plot of seed counts and numbers of taxa against soil volume.

Figure 5. Foxtail millet from an ash pit (three on the left) and broomcorn millet from an ash ditch (right). Scale bar, 1 mm.

period in the Yiluo region (Figure 7). Except for one from the lithic debris disposal area, all wheat grains were recovered from ash pits. Wheat grains at Huizui are similar in shape and size to grains from Erligang contexts (ca. 1600–1300 BC) in the Yiluo region (Lee *et al.* 2007) and the Late Longshan Liangchengzhen site in Shandong province (Crawford *et al.* 2005).

The number of rice grains found at Huizui is smaller than that of dry crops. While present in all feature types, rice remains concentrate in ash pits and on living floors (Figure 7). In the Yiluo region, rice was probably available from the Late Yangshao period on, but its use became more frequent during the Erlitou period with its cooler, drier climate. Since these conditions are often regarded as undesirable for rice farming (Rosen, this volume), this unexpected correlation may point to a significance of rice in meeting a social rather than an economic need. Ever increasing political centralization during the Erlitou period might have encouraged the production of rice as a prestigious ritual item. Fermented rice liquor was available from the early Neolithic period in northern China and became an important ritual item in early historical times (McGovern *et al.* 2004; Underhill 1997, 2002). It remains to be investigated, however, whether Erlitou and Huizui people indeed prepared fermented alcoholic beverages from rice.

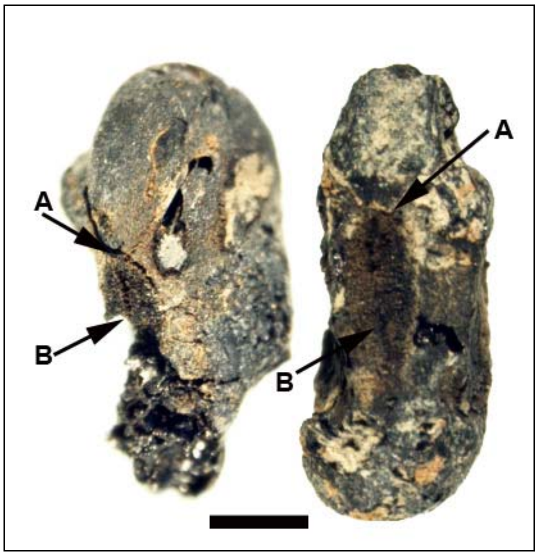

Figure 6. Soybean specimens from ash pits, ventral view. A) hypocotyls-radicle (embryonic stem and root) and B) hilum. Scale bar, 1mm.

Figure 7. Rice (left) and wheat (right) form ash pits. Scale bar, 1 mm.

Non-domesticated seeds include weeds and fleshy fruits. Since they are both anthropogenic flora, and fruit remains are scarce in our collection (a total of 14 seeds), fruits and weeds are pooled into one category in most comparative analyses below. Non-domesticated plants in the Huizui collections belong to the grass, legume, sedge, and chenopod families (Table 2). The grass family is the most common, representing 46% by count of all seeds in the Huizui collection (Figure 8). The most numerous weedy seeds are panicoid (*Panicoidea*), and most of them can be assigned to the millet tribe (*Paniceae*). Some seeds can be identified to the genus or species level, such as barnyard grass (*Echinochloa crusgalli*), foxtail grass (*Setaria italica* ssp. *viridis*), and panic grass (*Panicum* cf. *biscatum*). Some green foxtail seeds are quite similar to small grains of domesticated foxtail, except that green foxtail is rather flat. Some panic grasses also resemble manna grass (*Glyceria* sp.). More than half of the grass seeds are assigned to the millet tribe; any more specific identification based exclusively on charred seeds is hindered by their high plasticity and possible intraspecific variations. Millet-tribe seeds are found at least from the Late Yangshao period in the Yiluo region (Lee *et al.* 2007). Seeds of this type are very thin (less than 0.6 mm) and round (length to width ratio close to one). *Chenopodiaceae* is the next most common family in our samples, representing 7% of all seeds (Figure 9). At least two types can be distinguished by size and shape. Some have ridges around the edge, which is a characteristic of the amaranth family (Amaranthaceae). Without scanning electron microscopic observations of microstructures, it is hard to distinguish amaranth from chenopod (*Chenopodium* sp.). More detailed studies are required to determine whether chenopod in the Yiluo region is the domesticated Asian variety (*C. giganteum*), a variety of common chenopod (*C. album*) (Lee *et al.* 2007). Formosan aboriginal people in the central highlands of Taiwan encouraged weedy chenopod in millet fields and used its grains as a source of starch (Fogg 1983). The frequency and ubiquity of chenopod in the Yiluo region from the Middle/Late Neolithic period suggest that it commonly grew in arable environments after farming was adopted.

Figure 8. Weedy grasses. Upper left, panic grass; the rest three in the upper row, panic or manna grass; the two from the left in the lower row, green foxtail; and the two from the right in the lower row, millet-tribe grass. Scale bar, 1 mm.

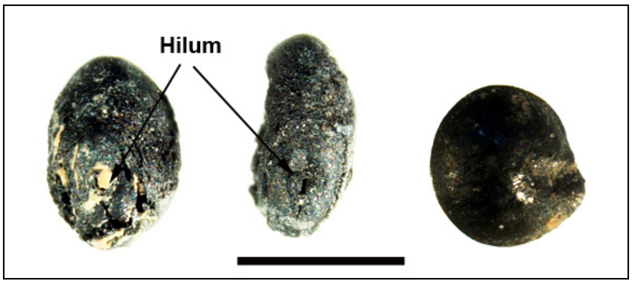

Figure 9. Chenopod (right) from a lithic workshop and wild bean (left and center) from an ash ditch. Scale bar, 1mm.

Wild legumes were found in all feature types, but most of them are from ash pits. They are similar to Asian clover (*Kukumerowia* sp.), sweet clover (*Melilotus* sp.) or lespedeza (*Lespedeza* sp.) (Figure 9). These taxa are common in dry fields throughout East Asia and were used as field fertilizer in northeast China in the early 20th century (King 1901). Wild legumes were found in all types of features, but about two thirds come from ash pits. Achenes of the sedge family (Cyperaceae) are also present in all types of features, but are very rare, with densities of only one per liter except for a single sample from an ash ditch. Sedges are common weeds in modern wet rice fields. They might have accidentally entered the site when rice was brought in from the paddy fields.

All fleshy fruits from Huizui belong to the rose family (Rosaceae). Four seeds of bramble (*Rubus* sp.) and plum (*Prunus* sp.) were only found in ash ditches and pits. Fruits are usually rare in open sites because many taxa of these genera are digestible as raw fruits and consequently have less chance to be cooked and charred. Other seeds of the rose family occur in every type of features in a negligible number. Most of the non-domesticated plants in our Huizui collection are weeds that flourish in agricultural fields. Well-established multiple cropping during the Erlitou period may have encouraged some weeds to mimic crops. Crop mimicry may explain the similarity of some panicoid weeds to domesticated millet.

COMPARING PLANT DISTRIBUTIONS

Variation in the contextual distribution of plant remains has an impact on intersite comparisons as well as on our understanding of the function of structures and plant processing (Crawford *et al.* 2005). In conjunction with other archaeological information, plant distributions may help us identify the functions of features related to plants or post-depositional effects. Therefore, in this section we compare the botanical assemblages from five feature types that were defined on the basis of feature shape and size as well as artifact contents. They include ash ditches, ash pits, a lithic production area (workshop), and a lithic debris disposal area.

At Huizui, numbers of seeds found in each sample vary from less than one to 60 per liter of soil. The average seed density (10 per liter) is lower than at other sites in the Yiluo region dating from the Late Longshan to the Erlitou periods. Previous studies in the Yiluo survey region have shown that charred seed densities are inversely related to site size (Lee *et al.* 2007). Crop remains are mostly responsible for this pattern: crop densities tend to be much higher at smaller sites than at large centers. At the Erlitou components at Huizui, crop densities range from zero to 22 seeds per liter. This is less than half the pooled density range of weeds and fruits (less than one to 44 per liter). Mean density figures are lower for crops (3 per liter) than for weeds and fruits (6 per liter). Similar to other large sites, Huizui shows a smaller seed densities than smaller Erlitou-period sites.

Plant densities and proportions by feature types

In general, ash ditches and living floors have the highest seed densities, for both crops and weeds (Figure 10). The two feature types also display the widest range of variation between samples. Ash ditches yield both the lowest and highest total seed densities as well as weed and fruit densities. The highest and lowest crop densities come from living floors. Weeds are more abundant than crops in most samples (73 out of 87). On average, living floor assemblages have a higher percentage of crops than other features (Figure 11). Ash ditches and pits also show higher crop percentages than features rich in lithic remains. Crops probably had a higher probability of being left in dwelling areas, where food preparation occurred and food waste was spilt, than in lithic workshops. This Erlitou plant distribution stands in contrast to the pattern observed for Yangshao floors made of tufa slabs at Huizui East (MacPhail and Crowther, this volume).

No Yangshao occupation floor deposits were found (only ground-raising clean loess deposits), suggesting that either floors were swept or mat-covered. We are currently analysing macrobotanical remains from the Yangshao floors that were excavated in 2005 and our findings are consistent with the results of soil micromorphological analyses of these floors. The Yangshao floors show very low total seed and crop densities. Food waste seems to have been cleaned regularly, leaving almost no residue on Yangshao-period floors. In brief, changes in cleaning behaviours affected the plant distribution patterns in dwelling floors through time. Millet (both foxtail and broomcorn) outnumbers other crops such as soybean, rice, and wheat in all feature types, representing between 84 and 97% of all crops (Figure 12A). Other crops are also less ubiquitous in each feature type (Figure 12B). They are present in as little as 33% of all samples from the lithic workshop to as much as 64% of samples from living floors. After millet, soybean is the second most common crop, making up between 1 and 11% of all crops in each feature type (Figure 12C). Most soybean seeds occur in ash ditches, ash pits, and the lithic workshop. Most rice grains occur in domestic activity areas except for two from the lithic workshop and lithic disposal area. All but one wheat grain come from ash pits. Among non-domesticated plants, weedy grass seeds are the most numerous, including several taxa (Table 2). Samples from the lithic workshop contained the smallest proportion of weedy grasses on average (66%), while ash ditches have the most (90%) (Figure 13A). Chenopod is the second most numerous weed (Figure 13B). Most specimens come from ash pits and the lithic workshop, which together account for 87% of chenopod seeds. Wild legumes, possibly clover or lespedeza, are present in all feature types, but about two thirds of their seeds are found in ash pits. Sedge and fruits occur only sporadically.

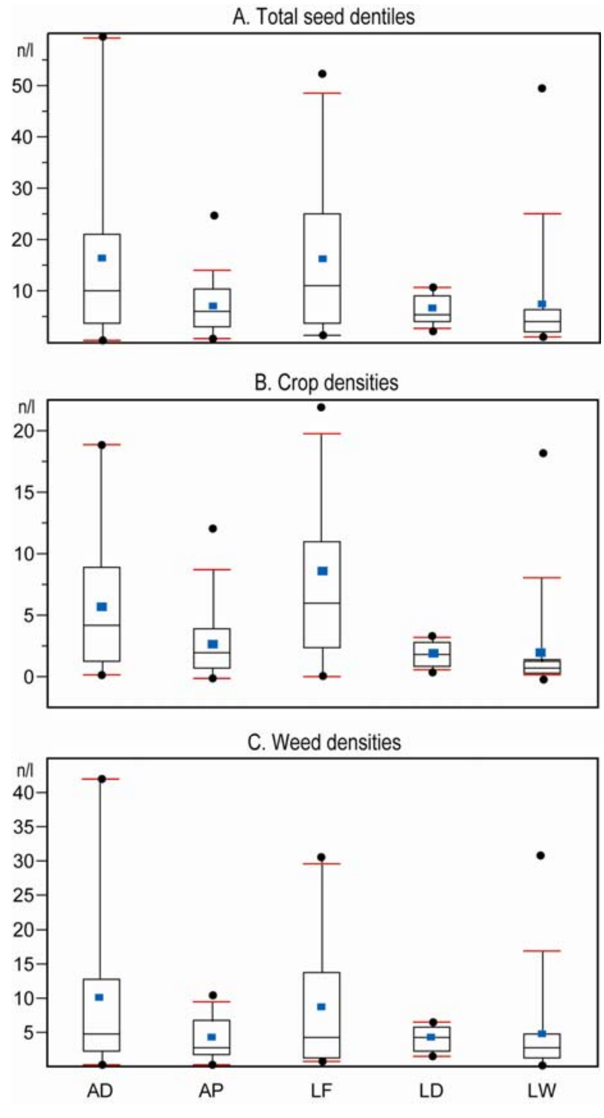

Figure 10. Box plot of charred seed densities by feature types (seed number/liter of soil): A) total seed densities; B) crop densities; and C) weed densities.

Statistical test of differences between features

At first sight, crops seem to be differentially distributed across feature types. For a statistical validation of this impressionistic assessment, we performed a Mann-Whitney test on the plant data. This non-parametric test is

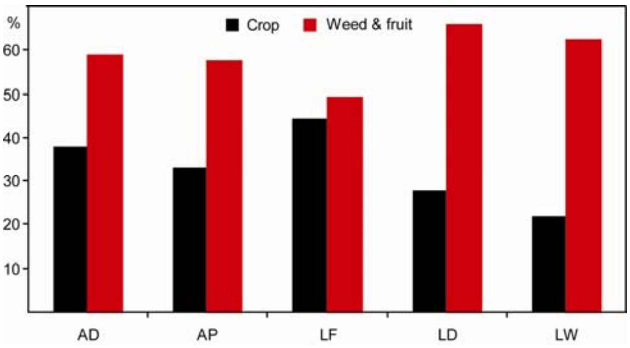

Figure 11. Percentiles of crops and non-domesticated seeds per total number of seeds in each feature.

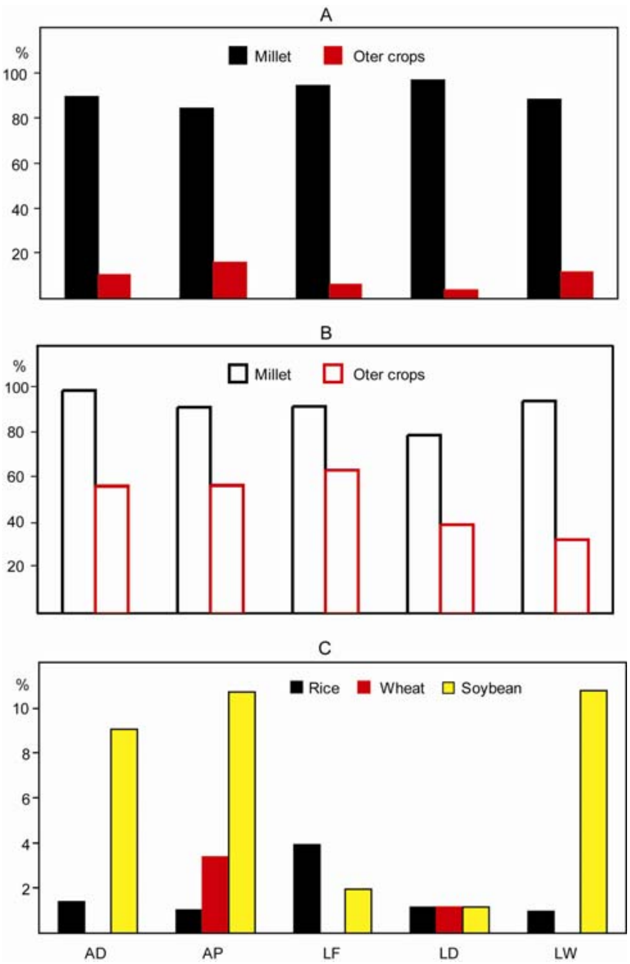

Figure 12. Crop compositions in each feature type: A) percentiles of millet and other crops per total number of crops; B) percentiles of ubiquity of millet and other crops per total number of samples in each feature type; and C) percentiles of rice, wheat, and soybean per total number of crops.

appropriate given the strongly non-normal distribution of seed densities by feature types.

In terms of crop distributions, the lithic workshop in Test pit 1 is the most distinctive feature type, statistically distinguishable from all other feature types except the litchis debris area in Test pit 2 at 95 % confidence level (Table 3A). Living floors are also distinguishable from ash pits and the lithic workshop. Weed distributions do not significantly differ between feature types. Seed remains in ash pits, ash ditches and the lithic debris area likely entered the archaeological record through day-to-day waste discard behavior. Thus, multiple dumping episodes may be expected to produce a mixing effect, homogenizing seed deposits in waste disposal contexts. A Kruskal-Wallis t-test confirms that the seed distributions in all three waste-disposal feature types are statistically indistinguishable (Table 3B). In contrast, plant distributions in non-discard contexts such as living floors and the lithic workshop may have preserved more or less distinctive signatures of activities involving crops.

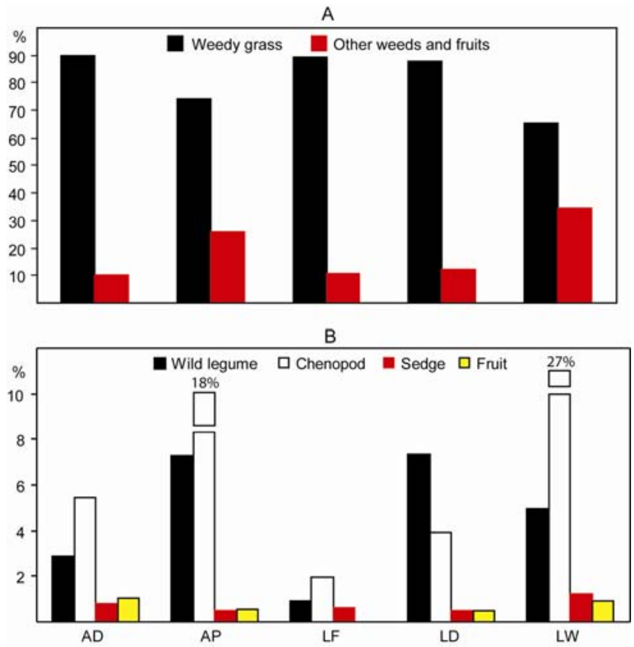

Figure 13. Weed compositions in each feature type: A) percentiles of grass weeds and other weeds per total number of non-domesticated seeds; and B) percentiles of wild legume, chenopod, sedge, and fruits per total number of non-domesticated seeds. Numbers above the bars are percentages.

Discriminant analysis

Given the patterns described in the previous section, there was possibility that seed distribution patterns might replicate the archaeological feature typology. We explored this possibility through a series of discriminant analyses applied to three separate sets of variables (Table 4). The first set includes pooled densities of crops and of non-domesticated seeds (weeds and fruits); the second set densities of millet, other crops (soybean, rice, and wheat), weedy grass, and other weeds and fruits; and the third set densities of almost all individual taxa. Given a number of quantitative variables (plant densities) describing a set of samples (features) and a categorical classification of the same samples (the feature typology), discriminant analysis attempts to reproduce the categorical classification through a linear discriminant function built from the quantitative variables. If the discriminant function assigns

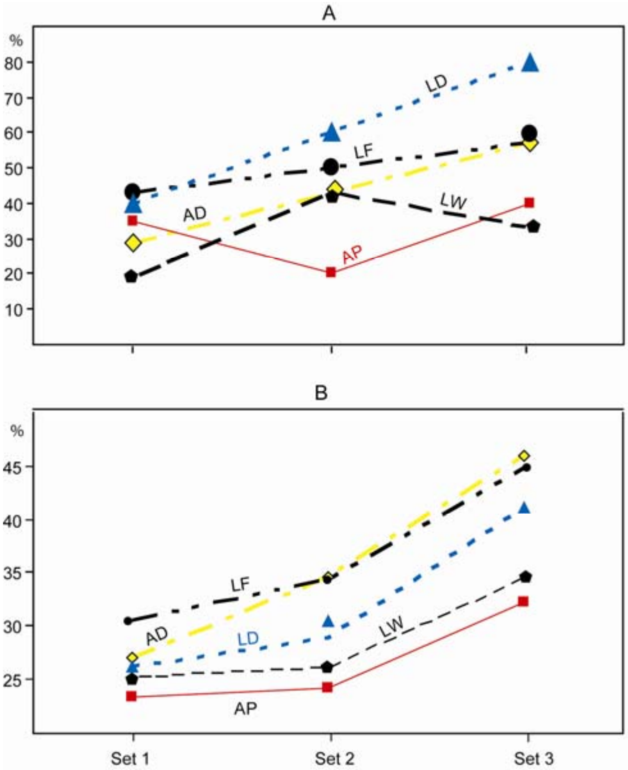

Figure 14. Discriminant analysis: average prediction frequencies (A) and posterior probabilities (B) of assigning each sample to the correct feature type. Variables are seed densities. Each set of discriminant analyses used the following variations: Set 1) densities of crops and non-domesticated seeds; Set 2) densities of millet, other crops, weedy grasses, and other taxa of weeds; and Set 3) densities of millet, rice, wheat, soybean, weedy grass, chenopod, wild bean, sedge, and other taxa.

a large proportion of samples to the same ("correct") category as the categorical classification (feature typology), and posterior probabilities of membership in that category are distinctly higher than for any other category, the quantitative variables do allow us to distinguish the categories of the categorical classification. In the present case, plant densities would reproduce the archaeological feature typology based on feature size and shape and artifact contents.

Using the first set of variables, the average probability of assigning each sample to the correct feature type is low for all feature types (Table 4). What is more, not even half of the samples are assigned to the correct feature type. Clearly, then, two plant-density variables are insufficient to distinguish archaeological feature types. As more variables are included in the analysis, the proportions of correctly classified samples increase (Figure 14A). For example, a discriminant function based on the third set of variables assigns about half of the ash ditch and pit samples and 80% of the samples from the lithic disposal area to the correct feature type. Average posterior probabilities of membership also increase for all feature types (Figure 14B). However, for all feature types predicted membership probabilities are typically less than 50% and com monly are almost equal for two or even three feature types. In summary, we may conclude that variations in densities of various plant taxa do not distinguish archaeological feature types defined as their shape, size, and artifact contents at Huizui.

DISCUSSION AND CONCLUSION

Our in-depth analysis of plant remains from the Huizui site confirms some predictions put forward in a previous study of survey samples from the Yiluo region (Lee *et al.* 2007). Moreover, our research adds new insights on plant use during the Erlitou period and the contextual distribution of plant remains. At Huizui, dry crops were the major staples, but wet rice was still grown during the Erlitou period, although the climate became drier and cooler. Thus, rice was probably not a major source of calories, but rather held symbolic value as a prestige crop in Erlitou-period regional centers like Huizui. Non-indigenous wheat was incorporated into the local assemblage of dry crops during the Erlitou period at the latest. Wheat may have been an exotic or luxury food initially consumed by the elite (Keightley 2000), and its introduction to the Yiluo basin seems to reflect an 'increased level of interregional interaction during the period of state formation' (Liu *et al.* 2002-4).

Considering its ubiquity and quantity, millet probably was still the dominant staple crop during the Erlitou period. Rice and wheat were only found at larger Erlitou-period centers in the Yiluo region, whereas all other seeds were much more abundant at smaller settlements (Lee *et al.* 2007). This pattern again suggests that both rice and wheat met elite demands for luxury food items in a period of intensifying social competition and stratification, rather than calorific needs as major staples. One of the distinctive characteristics of plant distributions at Huizui is low seed densities, relative to other contemporaneous sites — both large centers and small settlements— in the Yiluo region (Table 5). Twenty-two sites dating from the Late Peiligang to the Erligang periods in the Yiluo region show much higher crop than weed densities (see Table1 in Lee *et al.* 2007). This pattern suggests that crop use at Huizui was less intense than at other sites. Given its occupation size and duration, the population of Huizui could not have been smaller than that of smaller settlements, and there must have been commensurate demand for crops. Crop remains in the archaeological record, however, do not necessarily represent what was consumed *in situ*, but merely what is left after processing, consumption, and filtering through postdepositional processes. Since the sites discussed here are located in broadly similar environments and comparisons were drawn strictly between equivalent feature types, (ash pits) preservation conditions are unlikely to differ greatly between sites.

What cultural activities, then, might account for the low densities of crop remains at Huizui? According to soil micromorphology evidence, the Yangshao floors at Huizui were regularly cleaned or covered with mats, and as a result are virtually devoid of dwelling residues (MacPhail and Crowther, this volume). Our ongoing archaeobotanical analysis also found almost no seeds remaining on Yangshao living floors, but more in ash pits from the

Table 3. Non-parametric difference test results.

A. Mann-Whitney test results and |z| scores, α=0.05.

	Living floor	**Lithic workshop**
Ash ditch		difference 2.1
Ash pit	difference 2.9	difference 2.2
Lithic disposal area	difference 2.1	
Lithic workshop	difference 3.0	

B. Kruskal-Wallist test among ash pits, ash ditches, and lithic debris area. α=0.05, DF=2

	Total density	**Crop density**	**Weed density**
χ^2	1.1	1.1	2.6
Result	no difference	no difference	no difference

Table 4. Discriminant analysis results: average prediction frequency and posterior probabilities of assigning each sample to the correct feature type. Variables are seed densities.

Variables compared	**Feature types**	**Prediction frequency%**	**Posterior probability %**				
			Mean	**Std**	**Minimum**	**Median**	**Maximum**
Set 1	Ash ditch	28.6	27.1	26.2	11.1	15.4	84.5
crops;	As pit	35.0	23.3	4.6	5.9	24.95	27.9
weeds+fruits	Living floor	42.9	32.0	27.3	6.1	25.4	94.1
	Lithic disposal	40.0	26.2	2.5	22.8	25.4	29.5
	Lithic workshop	19.1	25.1	6.7	1.6	26.6	34.1
Set 2	Ash ditch	42.9	34.6	35.2	6.2	17.0	99.2
millet; other crops	As pit	20.0	24.1	4.1	12.3	25.1	33.4
weedy grass; other	Living floor	50.0	34.4	34.8	5.0	21.9	99.8
weeds+fruits	Lithic disposal	60.0	28.9	4.3	23.8	29.2	35.3
	Lithic workshop	42.9	26.0	7.7	2.1	28.9	31.0
Set 3	Ash ditch	57.1	45.9	38.6	3.0	43.2	99.9
millet; rice; wheat;	As pit	40.0	32.2	17.9	9.5	27.6	88.1
soybean;chenopod;	Living floor	57.1	44.9	38.2	3.9	31.0	99.9
wild bean; sedge;	Lithic disposal	80.0	41.1	18.5	22.9	32.6	67.4
other weeds+fruits	Lithic workshop	33.3	34.4	22.1	0.9	29.0	97.4

Table 5. Seed densities of the Erlitou-period sites in the Yiluo region. Data other than the Huizui site are quoted from Lee *et al.* 2007.

Site	Small		Large			
	Huilongwan East	Xinhougou-Yaochang E	**Huizui** all features	**Huizui** ash pits	Luokou Northeast	Shaochai
Sample N.	1	2	**87**	**40**	4	7
Soil V. (liter)	7.0	25.0	**263.0**	**540.0**	8.0	72.2
Total seed density	71.0	71.3	**8.4**	**7.3**	66.6	47.9
Crop density	62.7	37.4	**2.9**	**2.7**	33.4	27.5
Weed density	7.9	33.0	**4.8**	**4.1**	32.9	19.9

* Data other than the Huizui site are quoted from Lee *et al.* 2007.

Yangshao period. This trend is reversed for the Erlitou components. Erlitou living floors produce more than or at least as many seeds as dumping contexts (ash pits and ash ditches). Soil micromorphology indicates that ash pits served as domestic waste dumps (MacPhail and Crowther, this volume). Thus, the Erlitou residents of Huizui may not have cleaned floors as intensely as the Yangshao occupants and may not have covered their floors with mats, allowing the deposition of food wastes (crop remains). Still, they continued to dump their daily refuse into ash pits and ditches as previous occupants had. Changes in maintenance practice still cannot explain fully lower overall seed densities in ash pits and other features at Huizui than at other contemporaneous sites. Lower crop densities at Huizui may reflect different crop processing and food preparation strategies. Food processing methods, such as boiling, steaming, or parching, probably affect the chance of cereals to be charred and consequently the amounts that are preserved in the archaeological record.

Although the Erlitou component of Huizui contains more weeds than crops (Figure 11), weed densities at Huizui are much lower than those at other contemporaneous sites in the Yiluo region (Table 5). Overall lower weed densities at Huizui may be due to differences in site functions. It is common knowledge in archaeobotany that agricultural settlements produce more diverse, dense weed assemblages than consumption sites (e.g., Hillman 1981; Jones 1984; Reddy 1997, 2003). This argument is based on two premises. Crop processing *in situ* increases the chances of weeds to be left behind in production sites, while weeds are missing from consumption sites because only clean crops were shipped there. Previous research indicates that smaller sites in the Yiluo Valley probably functioned as farming villages throughout the Neolithic and Bronze periods (Lee *et al.* 2007). Conversely, low overall seed densities at Huizui may suggest that farming was not a major activity there. Nevertheless, both crop and weed densities at Huizui are lower than at other regional centers such as Luokou NE and Shaochai (Table 5). Thus, differences in sample sizes may affect the results, as samples from the other Erlitou-period sites are much smaller than those from Huizui. Consequently, all of these hypotheses will have to be reexamined based on samples of equivalent size from all sites.

One of the characteristics of the Huizui plant assemblage is that weeds are more abundant than crops in all feature types. Huizui inhabitants may have harvested weedy grasses, possibly for fodder. Indeed, the Huizui occupation has significant evidence of livestock, primarily pigs, but also cattle and sheep/goat (Li Liu, pers. comm., 2004).

Feature shape and size as well as associated artifacts define the various feature types distinguished at Huizui. Discriminant analysis shows that feature types based on these archaeological criteria do not necessarily match a classification of features based on plant data. In other words, plant remains were not left differently according to the feature types. Since a majority of samples in our collection represent dumping areas, repetitive disposal episodes may have created a blending effect that blurred any originally distinctive patterns of plant deposition. Since the lithic disposal area (Test pit 2) has outstanding density of lithic debris, it is believed to have been a refuse disposal areas associated with a lithic workshop (Test pit 1). Nevertheless, the plant distributions in the lithic disposal area are no different from those of domestic waste disposal areas such as ash pits and ditches. This suggests that Huizui residents may have indistinctly dumped wastes from both domestic and specialized production areas in the same disposal areas. A concentration of lithic debris mixed with potsherds in Test pit 2 exemplifies this disposal behavior. Interestingly, individual plant taxa used as separate variables have greater discriminant power in distinguishing feature types than pooled variables combining all crops and weeds. Rare taxa are often dismissed as insignificant background noise that accidentally entered a site. In contrast, this analysis indicates that rare taxa may be as useful as abundant taxa in detecting differences in distributional patterns across feature types. That is, rare taxa may not have been deposited by accident but for some reason systematically related to the features' functions. Our current collection is still small, and the sizes of samples from each feature type vary. In the future, we will increase the numbers of the analyzed samples as well as equalize sample sizes across feature types. This will put us in a position to determine to what extent our observations and interpretations reflect actual patterns of prehistoric plant use or samples and post-depositional biases.

ACKNOWLEDGEMENTS

This research was funded by an Australian Research Council grant (DP 0450025) to Li Liu and a La Trobe University postdoctoral fellowship to Gyoung-Ah Lee. We appreciate the insights and help of the following individuals: Xingcan Chen, Yongjiang Li, Liye Xie, Facheng Wang, Junfeng Yang, and Hongzhang Wang from the Institute of Archaeology, Chinese Institute of Social Sciences; Arlene Rosen of University College London; Li Liu, Ming Wei, and Hongli Zheng of La Trobe University; and Hartmut Tschauner of the Seoul National University.

REFERENCES

Bestel, S. 2006. *Paleoethnobotanical Analysis of Huizui West, China, during the Erlitou Period*, Unpublished Honours dissertation, La Trobe University, Melbourne, Australia.

Crawford, G.W. and G.-A. Lee. 2003. Agricultural origins in Korea. *Antiquity* 77(295):87-95.

Crawford, G. W., A.P. Underhill, Z. Zhao, G.-A. Lee, G. Feinman, L. Nicholas and F. Luan. 2005. Late Neolithic plant remains from northern China: preliminary results from Liangchengzhen, Shandong. *Current Anthropology* 46(2):309-346.

Crawford, G., X. Chen and J. Wang, 2006. Shandong Jinan Changqingqu Yuezhuang faxian Houli wenhua shiqi de tanhuadao (Houli culture rice from the Yuezhuang site, Jinan, Shandong). *Dongfang Kaogu* (East Asian Archaeology) 3: 247-251.

Fogg, W.H. 1983. Swidden cultivation of foxtail millet by Taiwan aborigines: a cultural analogue of the domestication of *Setaria italica* in China. In D.N. Keightley (ed.), *The Origins of Chinese Civilization*, pp. 95-115. Berkeley: University of California Press.

Hillman, G.C. 1981. Reconstructing crop husbandry practices from charred remains of crops. In R. Mercer (ed.), *Farming Practice in British Prehistory*, pp. 123-62. Edinburgh: Edinburgh University Press.

Jones, G.E.M. 1984. Interpretation of archaeological plant assemblages: ethnographic models from Greece. In W. van

Zeist and W. A. Casparie (eds.), *Plants and Ancient Man: Studies in Palaeoethnobotany*, pp. 43-61. Rotterdam: Balkema.

King, F.H. 1901. *Farmers of Forty Centuries: Permanent Agriculture in China, Korea, and Japan*. Madison: Mrs. F. H. King.

Lee, G.-A., G.W. Crawford, L. Liu and X. Chen. 2007. Plants and people from the Early Neolithic to Shang periods in North China. *PNAS* 104(3):1987-1902.

Li, S. and D. Mo. 2004. Donghuishan yizhi tanhua xiaomai niandai kao. *Kaogu yu Wenwu* 6: 51-60.

Liu, L., X. Chen, Y.K. Lee, H. Wright and A. Rosen. 2002-2004. Settlement patterns and development of social complexity in the Yiluo region, north China. *Journal of Field Archaeology* 29(1-2):75-100.

Luoyang Relics Team. 2002. *Luoyang Zaojiaoshu.* Beijing: Wenwu Press.

McGovern, P.E., J. Zhang, J. Tang, Z. Zhang, G.R. Hall, R.A. Moreau, A. Nunez, E.D. Butrym, M.P. Richards, C.-s. Wang, G. Cheng, Z. Zhao and C. Wang. 2004. Fermented beverages of pre-and proto-historic China. *PNAS* 101(51):17593-17598.

Murowchick, R E. and D.J. Cohen. 2001. Searching for Shang's beginnings: Great City Shang, City Song and collaborative archaeology in Shangqiu, Henan. *The Review of Archaeology* 22(2):47-61.

Reddy, S.N. 1997. If the threshing floor could talk: integration of agriculture and pastoralism during the Late Harappan in Gujarat, India. *Journal of Anthropological Archaeology* 16:162-187.

Reddy, S.N. 2003. *Discerning Palates of the Past: an Ethnoarchaeological Study of Crop Cultivation and Plant Use in India*. International Monographs in Prehistory. Ann Arbor: University of Michigan.

Underhill, A.P. 1997. Current Issues in Chinese Neolithic archaeology. *Journal of World Prehistory* 11(2):103-160.

Underhill, A.P. 2002. *Craft production and social change in northern China*. New York: Kluwer Academic Press.