일반논문

인문논총 제77권 제1호 (2020.02.28), pp. 127~165
[DOI] https://doi.org/10.17326/jhsnu.77.1.202002.127

Construction Wood Selection of Prehistoric Hunter-Gatherers/Incipient Agriculturalists:*

An Examination of Carbonised Wood from Chulmun-Period Sites in Korea

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[ABSTRACT]

Although archaeological charcoal fragments retain information on local woodland composition, human decision-which would have filtered and determined the wood taxa brought to the sites-is a primary factor that caused variations in charcoal assemblages. We present anthracological examinations on construction wood of the Chulmun period (8000~1500 BC) in Korea, and examine taxa composition in the retrieved charcoal assemblages.

* This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017S1A5A2A01024541).
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주제어: Charcoal, Wood Selection, Construction, Pit-House, Archaeobotany, Chulmun
목탄, 목재 선택, 조영, 수혈주거지, 식물고고학, 신석기시대

The analyses from five settlements suggest that wood acquisition patterns may vary along a continuum of opportunist-selectivist utilisation and that some archaeological charcoal assemblages are more reflective of human decision than of the locally available wood taxa. Different wood utilisation strategies were undertaken by different prehistoric hunter-gatherer/incipient agriculturalist groups inhabiting the same region with very similar vegetation. The dominance of *Quercus* and *Fraxinus* charcoal in different archaeological sites reflects people's differential preferences of oak wood and ash wood as building materials at different locations.

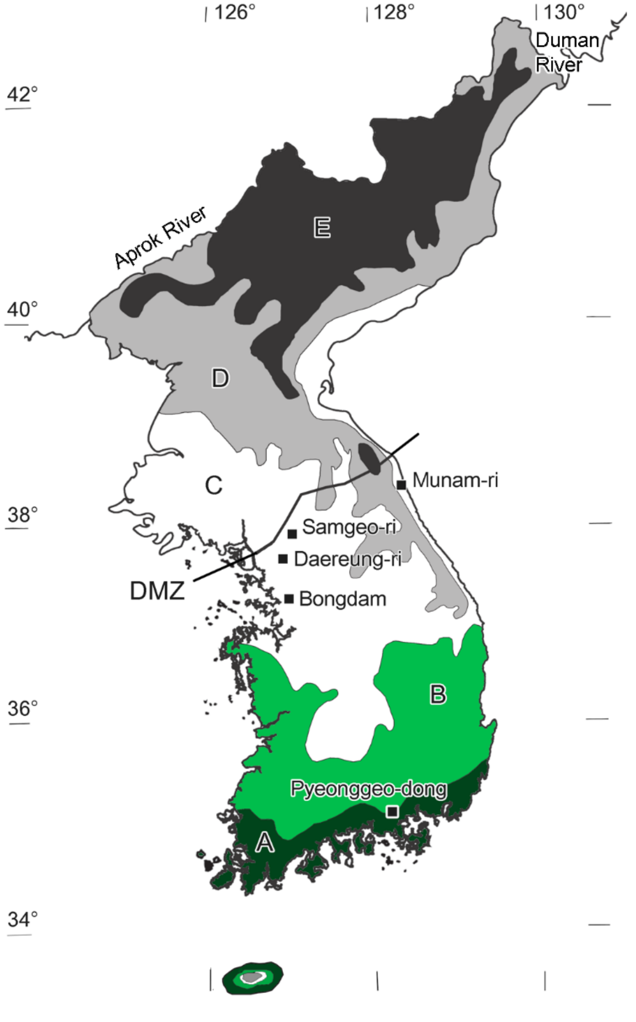
1. Introduction

Wood charcoal remains discovered from archaeological sites represent arboreal resources that were available in the vicinity of the sites, but they are only a partial reflection of local woodland composition. The procurement of wood, just like those of other resources, are subject to human decision-making; only those that were deemed suitable or desirable for the intended purposes would be collected and brought to the sites. Archaeological charcoal remains deliver multi-dimensional information; they provide information on the selection of construction and fuel wood in tandem with information on climatic changes and vegetation composition in the past. People may make selections among different wood taxa based on the physical and biochemical properties of the wood, such as hardness, strength, size, odour, and resistance to degradation, or according to culture-specific criteria and logic (Smart and Hoffman 1988). Although wood charcoal is a type of archaeological remains that is very ubiquitous in prehistoric sites in East Asia, relatively little discussion has been made with regard to purposeful human action in generating variations in charcoal assemblages.

This study focuses on the Chulmun period (ca. 8000~1500 BC) in the Korean Peninsula, during which subsistence economy relied on fishing, gathering, and hunting, with a low degree of plant cultivation (Korean Archaeological Society 2012). Pollen studies have shown that climate during ca. 6000~3000 BC was warm and humid and that a diversity of broad-leaved trees, such as *Acer*, *Alnus*, *Carpinus*, *Fraxinus*, *Juglans*, *Quercus*, *Ulmus*, and *Zelkova*, flourished across the peninsula (Choi et al. 2005; Chung 2011; Yi et al. 2012). These tree taxa produce long and straight timbers; many of them may grow over 20 m high and 1 m wide. They also produce hard, strong, and durable wood that is suitable for a range of purposes (Forestry Research Institute 1994). In this regard, it is natural to expect that people readily incorporated these wood taxa into their life, as these resources became increasingly available in the region. While we acknowledge that the abundance and ease of collection could have automatically led to more intensive utilisation and exploitation, we also consider that people's selection of wood was not random and that they followed a patterned behaviour. The adopted wood exploitation patterns may lead to over- or under-representation of certain wood taxa in archaeological contexts, particularly when people preferred or avoided specific wood types or taxa for explicit purposes.

Discussion on subsistence-settlement systems of hunter-gatherers illustrates that the degree of selectivity in resource acquisition may be varied along a spectrum (Binford 1980; Bettinger and Baumhoff 1982; Kim 2010; Kelly 2013). We rely on the previous discussion on hunter-gatherer's resource acquisition patterns, and examine wood collection along the opportunist-selectivist continuum. On the one hand, people may use local vegetation in an opportunistic manner, collecting what is readily available in the immediate vicinity of the campsites. In this mode of wood selection, differences in charcoal assemblages will be minimal between different contexts within a site, and the charcoal assemblages would conform closely to the proportions of individual wood taxa in the local woodland vegetation. On the other hand, people may apply very selective criteria in their choices of wood resources, targeting different wood types or taxa depending on their purposes. In this scenario, the charcoal assemblages will be variable across different types of archaeological contexts, being skewed significantly from the frequencies of individual tree taxa in the local woodland.

This paper presents anthracological investigations on five Chulmun-period sites in South Korea — Bongdam, Daereung-ri, Munam-ri, Pyeonggeo-dong, and Samgeo-ri (Fig. 1) — and evaluates the retrieved charcoal assemblages according to the proposed continuum in wood selectivity. These settlements had burnt pit-houses, which preserved the remains of wooden posts, beams, and roofs. The examination of wood charcoal thus provides information on construction wood selection. This research attempts to identify the charcoal fragments down to the genus level, and compares the relationship between richness and sample size in order to evaluate whether the retrieved charcoal assemblages approximate the presumed local vegetation diversity. The investigation then proceeds to compare charcoal assemblages and on- and off-site pollen records in order to assess the degree the charcoal frequencies are correlated with the vegetation composition reflected in the palynological data sets. Finally, the paper



[Fig. 1] Site locations and the vegetation zones of the Korean Peninsula according to Yim (1968) and Yim and Kira (1975): A. Warm Temperate Forest Zone (WT); B. Southern Cool Temperate Forest Zone (SCT); C. Central Cool Temperate Forest Zone (CCT); D. Northern Cool Temperate Forest Zone (NCT); E. Subarctic Forest Zone (S).

addresses the questions of whether trees were selectively exploited for construction, and what were the possible reasons for such selective utilisation.

2. Alternative Modes of Wood Selection

Anthracology, the analysis and interpretation of charcoal remains, is a subdivision in archaeobotanical research, and its primary aims have been to reconstruct past woodland composition, climatic changes, and human exploitation and management of arboreal resources (Smart and Hoffman 1988; Figueiral and Mosbrugger 2000; Asouti and Austin 2005; Kabukcu 2018). An important area of inquiry in this field has been whether the retrieved charcoal assemblages accurately reflect the woodland composition of the past (Salisbury and Jane 1940; Godwin and Tansley 1941; February 1992; Shackleton and Prins 1992). Archaeological charcoal assemblages were often presented to be a reliable proxy for past vegetation, and the foundation for such a viewpoint was the hypothetical wood selection patterns known as the "Principle of Least Effort" (PLE) (Zipf 1949; Prior and Price-Williams 1985; Shackleton and Prins 1992). The assumptions behind this approach are that the collection of fuel-wood occurred in the vicinity of the habitation sites and that the availability of wood taxa was the determining factor in wood selection. Accordingly, different species of woody plants were hypothetically collected in direct proportion to their natural occurrence in the local woodland vegetation. Provided that a large number of samples were analysed, archaeological wood charcoal assemblages were then believed to be a reliable reflection of the arboreal vegetation. The PLE-based approach was most informative in arid environments, where woody plants were scarce, different wood taxa were more or less evenly distributed, and/or pollen records have been poorly preserved (Cartwright and Parkington 1997; Cowling et al. 1999).

Previous studies have nonetheless highlighted that wood materials were not collected at random but rather in response to a number of ecological factors (February 1992; Shackleton and Prins 1992; Buffington and McCorriston 2019). If people actively selected or avoided particular species for certain reasons, the charcoal assemblages would fail to accurately represent the composition and the relative abundance of arboreal taxa in the past. Under the circumstances in which wood is plentiful around villages, people may be highly selective, and the selection, particularly of firewood, may focus only on dry deadwood with desirable density and sizes (Shackleton and Prins 1992). Some trees tend to easily drop their branches, and these taxa may be over-represented in the charcoal assemblages, as people tend to prefer dead branch wood as fuel (Smart and Hoffman 1988). This was a typical situation in temperate regions when a village was newly established in an unexploited habitat. There would likely be plenty of diverse wood resources in the vicinity, and the inhabitants could freely procure desirable wood, acquiring only the wood that was most suitable for their needs with maximal selectivity and the lowest effort. Archaeological wood assemblages are then far from an accurate reflection of woodland composition; rather they convey more information on the preferred wood taxa and types, and the degree of human selectivity among a broad range of arboreal resources.

A model analogous to the prey choice model (or the diet breadth model) has been applied for understanding wood procurement patterns of the past (Marston 2009; Robinson and McKillop 2013). The model predicts that people would rank wood materials by assessing the perceived value and the processing cost. It is assumed that long, straight, and durable trunks would be prised as a construction material while dry deadwood with high heat value would be prised as fuel-wood (Marston 2009). Other commodities being equal, people are expected to always pursue the highest ranked wood; they start to forage for the lower ranked wood only when the higher ranked wood becomes scarce. From this perspective, the three variables that determine the degrees of diversification in wood selection are value, handling cost, and availability of different wood taxa. If higher ranked resources were naturally abundant close to the settlement, people would neglect resources of lower rank, and archaeological charcoal assemblages would be biased towards the preferred taxa and be more reflective of selection behaviour and less of woodland composition.

Researchers have also highlighted that the practices of wood selection are socially mediated and that archaeological charcoal assemblages are culturally patterned (Godwin and Tansley 1941; Heizer 1963; Ford 1979; Smart and Hoffman 1988; Picornell et al. 2011; Chikumbirike et al. 2016). Ford (1979) and Smart and Hoffman (1988) presented ethnographical and archaeological examples that illustrate that wood materials were selected according to culture-specific criteria and rules. Social status determined access to different fuel-wood types, and oak and pine were exclusively used by the upper class in ancient Mesopotamia (Ford 1979). The Ingalik in Alaska seasonally collected different wood taxa as fuel, but did not collect alder because its red sap was considered offensive. Timbers deemed suitable for construction were carefully curated and/or transported over long distances as illustrated by the Huastec in Mesoamerica and by the people of Chaco Canyon in the American Southwest (Smart and Hoffman 1988). Some ethnographical studies note that people tend to target particular wood species as manufacturing and building materials, but harvest fuel-wood rather indiscriminately with no regard to taxa (Picornell et al. 2011). Cultural values and perceptions partially determine wood taxa brought to the sites, along with a number of other criteria such as physical and biochemical properties, shape and size of the wood, resistance to degradation, and the relative abundance and availability.

Based on the previous discussion, we hypothesise two alternative modes of wood selection patterns and use the model to examine patterns in archaeological charcoal assemblages. The first mode assumes an opportunistic exploitation of arboreal resources. It is expected that people selected wood resources indiscriminately and did not have preference for particular taxa for particular purposes. This mode is similar to the "foragers" in the hunter-gatherer subsistence spectrum, in which people exploited resources available in the immediate vicinity of a campsite in an opportunistic manner (Binford 1980; Asouti and Austin 2005). If this were to be the case, archaeological charcoal assemblages from different contexts (e.g. houses, hearths, or refuse dumps) would be similar in the species composition and they would be congruent with the vegetation structure indicated by other types of palaeo-environmental data (e.g. pollen records). By contrast, the second mode assumes a selective exploitation of arboreal resources. It is expected that people targeted specific wood types or taxa for specific purposes. This mode conforms to the "collectors", as people applied selective criteria in their choice and may have obtained resources from distant locations, possibly by dispatching special task groups (Binford 1980; Asouti and Austin 2005). In this scenario, considerable variations are expected across the charcoal assemblages from different archaeological contexts, and the assemblages would be skewed considerably away from the woodland vegetation composition of the region.

3. Study Region: Environment and Prehistoric Culture

3.1. Climate and Vegetation

The Korean Peninsula, located in the far eastern region of the Eurasian continent, is separated from the continent by the Aprok River and Duman River (Fig. 1). Extending southward from the continent, the peninsula is situated at the temperate latitudes between 34°N and 43°N, thus providing its inhabitants with four distinct seasons. Mean temperatures in the spring (March to May) range between 9 °C and 15 °C with a total seasonal precipitation ranging from 150 to 450 mm. Summer (June to August) is characterised by high mean maximum temperatures in the high 20s °C, with occasional extremes exceeding 30 °C. High volumes of total seasonal precipitation, ranging from 600 to 1,000 mm, are brought by the south-eastern summer monsoon and occasional late summer typhoons from the Pacific Ocean. Mean temperatures in the autumn (September to November) range between 13 °C and 19 °C, with a total seasonal precipitation ranging from 170 to 400 mm. Finally, winter (December to February) is characterised by sub-zero mean minimum temperatures and a low total seasonal precipitation ranging from 60 to 150 mm. Winter weather is largely dominated by cold and dry air masses originating from the Eurasian interior (Korea Meteorological Administration 2011).

According to the vegetation classification of Yim and Kira (1975), the four sites examined in this study (Bongdam, Daereung-ri, Munam-ri, and Samgeo-ri) are located within the "central cool temperate forest zone" (CCT) and the remaining one (Pyeonggeo-dong) is located on the margins between the "southern cool temperate forest zone" (SCT) and the "warm temperate forest zone" (WT) (Fig. 1). The CCT and SCT are sub-zones within the CT, which consists of deciduous broad-leaved forests. Considerable overlap exists between the CCT and SCT in terms of representative arboreal taxa; the most dominant trees are *Pinus densiflora* and various species under the genus *Quercus* (Yim and Yi 2005; Yim 2009). The WT consists of evergreen broad-leaved forests. This forest zone is typically situated in the southern coastal regions with an annual mean temperature above 14 °C and at an altitude below 150 m. Arboreal taxa that are representative of WT include *Camellia japonica*, *Cinnamomum camphora*, *Ilex integra*, and *Quercus myrsinifolia* (Yim and Yi 2005; Yim 2009).

3.2. The Chulmun Period

The Chulmun period, also known as the Korean Neolithic period, lasted from ca. 8000 to 1500 BC (Choe and Bale 2002; Korean Archaeological Society 2012). Although the name of the period derived from the Chulmun pottery, literally meaning the "comb-patterned pottery", not all pottery made during this period was decorated with comb-pattern designs. Rather, there existed a diversity of pottery styles and designs across the peninsula and throughout the period. The pottery designs that predated or postdated the highest popularity of the comb-patterns included raised-clay patterns, nail-shaped patterns, and double-rims (Ahn et al. 2015). Culture that was solely associated with the comb-patterned pottery emerged in central-western Korea around 4000 BC and spread to the southern and eastern regions of the peninsula around 3500 BC (Ahn et al. 2015).

Based on the presence of semi-subterranean pit-houses, it is commonly assumed that the Chulmun people had a sedentary life-style (Choe and Bale 2002; Norton 2007; Shin et al. 2012). They relied on hunting, gathering, and fishing as the dominant means of subsistence, and exploited both terrestrial and aquatic resources (Shin et al. 2012). In terms of plant resources, people relied greatly on acorns (*Quercus* spp.) and a variety of fresh fruits (e.g., *Vitis* and *Rubus*), nuts (e.g., *Castanea* and *Juglans*), and roots (e.g., *Allium* and *Pueraria*) (Ahn and Yu 2002; Shin et al. 2012; Ahn et al. 2015). In terms of animal resources, deer (*Hydropotes inermis* and *Cervus* spp.), antelope (Antilopinae), and wild boar (*Sus scrofa*) were hunted on land, while oysters (*Crassostrea gigas*), clams (Venerida), and scallops (Pectinidae) were collected on the coasts and cods (*Gadus* spp.) and mullets (*Mugil* spp.) were fished in the ocean (Choe and Bale 2002; Norton 2007; Shin et al. 2012).

The subsistence activities of the Chulmun people are best illustrated by archaeobotanical and zooarchaeological findings, such as acorns from the sites of Amsa-dong, Daecheon-ri, and Jitap-ri (Ahn and Yu 2002; Ku 2006; Shin et al. 2012), and a variety of animal, fish, and shellfish remains from shell middens of Gonam-ri, Gungsan, Sejuk-ri, and Tongsam-dong (Sample 1974; So 2002; Shin et al. 2012). Archaeobotanical research has demonstrated that people also started to practice cultivation of broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) by ca. 3500 BC (Crawford and Lee 2003; Choi et al. 2005; Ahn 2006). Lee and her co-authors (Lee 2011, 2013; Lee et al. 2011) proposed the possibility that red bean (*Vigna angularis*) and soybean (*Glycine max*) were cultivated by ca. 3000 BC.

The number of settlements reached its highest peak around ca. 3500 BC (Ahn et al. 2015; Ahn and Hwang 2015; Kim et al. 2015). From ca. 2500 BC, settlements started to disappear across the peninsula and only a small number of settlements with no more than three pit-houses were found from the period 2500~1500 BC (Ahn et al. 2015; Ahn and Hwang 2015; Kim et al. 2015). By contrast, the number of outdoor features (e.g., open-air hearths and shell middens) increased during the same period, especially in the coastal and island regions (Ahn et al. 2015; Kim et al. 2015). This change in settlement patterns is considered to reflect reduced sedentism and an increased residential mobility and/or a decrease in population (Ahn et al. 2015; Ahn and Hwang 2015). The pit-houses from the five settlements covered in this study were occupied in 4000~3000 BC, and most of them temporally corresponded to the period of the great expansion of the Chulmun settlements in terms of both settlement and pit-house numbers (Kim et al. 2015).

4. Materials and Methods

Carbonised wood samples were retrieved from five Chulmun-period sites across the Korean Peninsula (Fig. 1). Soil samples for charcoal extraction were collected from the house floors, and carbonised materials were separated from the soil matrix by flotation using a sieve with a 1 mm aperture. The light fractions (i.e., organic and charcoal materials that floated in the water) were transported to the lab and dried at room temperature. Charcoal fragments large enough for identification (typically larger than 5 × 5 × 5 mm) were hand-picked, and three sections (transverse, radial, and tangential) were exposed with a microtome blade and subsequently observed under a stereoscopic microscope (Leica S8APO; up to × 80 magnification) and a metallurgical microscope (Leica DM2500M; up to × 500 magnification) in a sequence. The taxonomic identification was conducted with the help of reference literature and comparative modern specimens (Lee 1994; Itoh 1995, 1996, 1997, 1998, 1999; Lee 1997; Park et al. 2006)

The largest settlement under consideration is Daereung-ri, where a total of 39 pit-houses dated to ca. 3600 BC were found (Fig. 1 and Table 1). The pit-houses were built in five rows along a hill-slope with no overlapping relationship to each other; an orderly arrangement of the pit-houses suggested that they were contemporaneous (Gyeonggi Ceramic Museum 2017). The pit-houses were rectangular, with an average size of 20 m^2. One house could have hosted up to six people, and it is likely that the site was a home to a large group that possibly consisted of more than 200 people. The examination of charcoal remains was not a part of the original site excavation plan. The need for anthracological research was raised during excavation, as eleven charcoal fragments collected from an equal number of burnt pit-houses for the purpose of radiocarbon dating were all identified to be *Quercus* wood and suggested a narrow spectrum in wood selection. A research plan to examine charcoal remains was then implemented and soil samples were systematically collected from five pit-houses (Gyeonggi Ceramic Museum 2017).

Samgeo-ri and Bongdam are located, respectively, 40 km northeast and

〈Table 1〉 AMS Dates from the Five Settlements

	Site	BP	Error	Calibrated BC (95% range)	Feature type	Material	Lab number
1	Daereung-ri (Gyeonggi Ceramic Museum 2017)	4970	40	3930-3650	Pit-house #10	Charcoal	KGM-OTg160353
2		4950	25	3781-3657	Pit-house #34	Carbonised wood (*Quercus*)	PLD-31365
3		4940	40	3800-3640	Pit-house #9	Charcoal	KGM-OTg160352
4		4930	30	3768-3651	Pit-house #36	Carbonised wood (*Quercus*)	PLD-31367
5		4920	40	3780-3640	Pit-house #34	Charcoal	KGM-OTg160359
6		4915	25	3762-3644	Pit-house #37	Carbonised wood (*Quercus*)	PLD-31368
7		4910	50	3800-3540	Pit-house #24	Charcoal	KGM-OTg160357
8		4910	40	3770-3640	Pit-house #36	Charcoal	KGM-OTg160361
9		4900	40	3770-3630	Pit-house #17	Charcoal	KGM-OTg160354
10		4885	25	3702-3640	Pit-house #27	Carbonised wood (*Quercus*)	PLD-31362
11		4875	25	3703-3637	Pit-house #30	Carbonised wood (*Quercus*)	PLD-31363
12		4860	40	3720-3520	Pit-house #23	Charcoal	KGM-OTg160356
13		4860	40	3720-3520	Pit-house #35	Charcoal	KGM-OTg160360
14		4850	25	3699-3537	Pit-house #35	Carbonised wood (*Quercus*)	PLD-31366
15		4840	40	3710-3520	Pit-house #32	Charcoal	KGM-OTg160358
16		4820	25	3656-3527	Pit-house #25	Carbonised wood (*Quercus*)	PLD-31360
17		4810	25	3652-3527	Pit-house #12	Carbonised wood (*Quercus*)	PLD-31358
18		4800	40	3660-3380	Pit-house #22	Charcoal	KGM-OTg160355

	Site	BP	Error	Calibrated BC (95% range)	Feature type	Material	Lab number
19	Daereung-ri (Gyeonggi Ceramic Museum 2017)	4780	25	3641-3521	Pit-house #21	Carbonised wood (*Quercus*)	PLD-31359
20		4770	50	3660-3370	Pit-house #8	Charcoal	KGM-OTg160351
21		4750	25	3636-3383	Pit-house #6	Carbonised wood (*Quercus*)	PLD-31357
22		4725	25	3634-3377	Pit-house #26	Carbonised wood (*Quercus*)	PLD-31361
23	Samgeo-ri (Heegyeong Jang, pers. comm., 2019)	5020	40	3950-3700	Pit-house #1	Charcoal	
24		4860	30	3710-3530	Pit-house #1	Charcoal	
25		4770	30	3650-3380	Pit-house #1	Charcoal	
26	Bongdam (Jungwon Cultural Property Research Center 2018)	4400	40	3330-2900	Pit-house	Charcoal	RPC-180082
27		4330	40	3090-2880	Pit-house	Charcoal	RPC-180081
28	Munam-ri (National Research Institute of Cultural Heritage 2013)	5170	50	4222-3801	Hearth #10	Carbonised wood (*Quercus*)	SNU12-R200
29		4600	50	3520-3106	Pit-house #4	Carbonised wood (*Pinus*)	SNU12-R203
30		4480	40	3349-3026	Pit-house #2	Carbonised wood (*Quercus*)	SNU12-R201
31		4480	50	3359-3013	Pit-house #3	Carbonised wood (*Pinus*)	SNU12-R202
32		4460	50	3348-2938	Hearth #7	Carbonised wood (*Pinus*)	SNU12-R199
33		4440	50	3336-2925	Hearth #12	Carbonised wood (*Quercus*)	SNU12-R197
34	Pyeonggeo-dong (Gyeongnam Development Institute 2012)	4450	50	3340-2920	Pit-house #5	Charcoal	SNU12-R022
35		4370	50	3320-2880	Ctone pile #111	Charcoal	SNU12-R023

90 km south from Daereung-ri (Fig. 1). Samgeo-ri is roughly contemporaneous with Daereung-ri, whereas Bongdam is dated slightly later, at around 3000 BC (Table 1). Samgeo-ri and Bongdam are different from Daereung-ri in that only one pit-house was found from each site despite extensive survey and excavation across a wide area in the vicinity. The Samgeo-ri pit-house is rectangular and measures 5.2 × 4.7 m (24 m^2). The Bongdam pit-house is also rectangular, but measures 12.0 × 8.0 m (96 m^2) and is considerably larger than pit-houses from other Chulmun sites. The pit-house is also distinctive in that it has stepped underground walls and an extruding entrance. The pit-houses from Samgeo-ri and Bongdam both had indoor hearths in the centre, and potsherds, stone arrowheads, and grinding stones were found along with some stone debitage (Baekdu Institute of Cultural Heritage 2017; Jungwon Cultural Property Institute 2018).

Munam-ri is located on the eastern coast of the peninsula (Fig. 1). Seven pit-houses were discovered but not all of them were contemporaneous as indicated by their overlaid relationships (National Research Institute of Cultural Heritage 2013). Radiocarbon dates and pottery styles nonetheless suggested that all pit-houses were occupied in ca. 3500~3000 BC. This site stood out from other Chulmun sites as it had been claimed that a section of an agricultural field, which was allegedly used to cultivate millets, were found at the site. The site excavators argued that traces of furrows discovered at Munam-ri dated to ca. 3000 BC, judging from associated artefacts and OSL dating (Cho 2018). The date of the furrows, however, is debated and has not been agreed upon among researchers. Finally, Pyeonggeo-dong is located in the southern region, and the eight pit-houses were occupied in ca. 3000 BC (Fig. 1 and Table 1) (Gyeongnam

Development Institute 2012).

For all five settlements investigated in this study, the sampled pit-houses were burnt down at the time of abandonment or after, and the charcoal remains from the floors were assumed to have been parts of the upper structures, such as posts, beams, and roofs, that collapsed by fire. The chronology of the pit-houses was determined by AMS dating of charcoal remains recovered from the house floors (Table 1). The dated materials were mostly wood charcoal and included some carbonised seeds. The calendric years were obtained by calibrating the dates using OxCal ver. 4.3 with the IntCal13 calibrated curve (Reimer et al. 2013; Bronk Ramsey 2017).

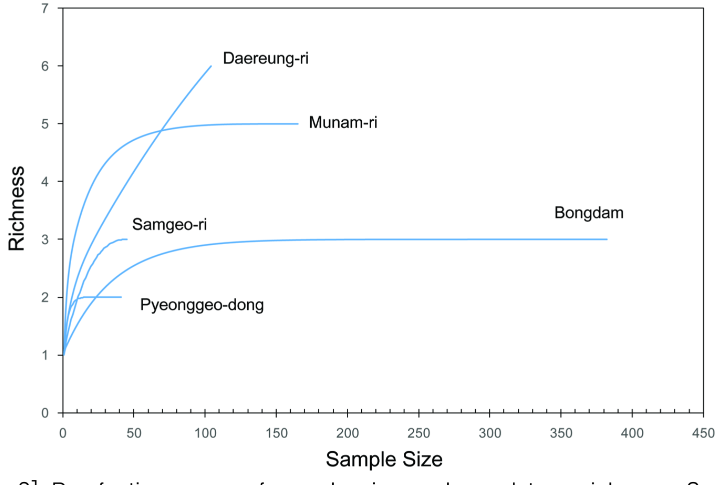
5. Results

Carbonised arboreal taxa recovered and identified from the five settlements are summarised in Table 2. Charcoal of *Quercus* wood was discovered from all five sites, and oak is the most dominant tree taxon based on the sheer number of discovered fragments. The *Quercus* wood is ring-porous and characterised by the presence of homogeneous uniseriate and compound rays. Relatively large amounts of *Fraxinus* and *Pinus* charcoal were also found, although they mainly appeared in Samgeo-ri and Munam-ri. Other minor components in the charcoal assemblages included *Acer*, *Celtis*, *Cornus*, *Platycarya*, and *Prunus* (Table 2).

Fig. 2 presents the individual-based rarefaction curves of the five charcoal assemblages retrieved from the settlements. The x-axis is the number of examined charcoal fragments and the y-axis is the species richness in the samples (i.e., the number of discovered taxa). The inherent difficulty

〈Table 2〉 Wood Identification Results

	Daereung-ri	Samgeo-ri	Bongdam	Munam-ri	Pyeonggeo-dong
Acer	1				
Betula		2			
Castanea	2			9	
Celtis					
Cornus	1				
Fraxinus	16	40			
Pinus				59	
Platycarya					10
Prunus	1				
Quercus	83	3	360	81	31
Ring porous			8	12	
Diffuse porous			14	4	
Indeterminate		2	16	2	
No. of sampled pit-houses	5	1	1	5	5
Total	104	47	398	167	41



[Fig. 2] Rarefaction curve of sample size and wood taxa richness. Species richness for a given sample size was calculated using PAST ver. 3.26.

in comparing richness in multiple assemblages is that sample sizes are related with species richness; the larger the sample the more the taxa (Leonard and Jones 1989). The rarefaction method enables easy comparisons to be conducted amongst samples with different sample sizes retrieved from different environments, relying on the reasoning that new taxa tend to be encountered at a continuously decreasing rate with an increase in sample sizes. The rarefaction curve is generated by keeping the percentage composition of the component species constant and artificially creating samples with smaller sizes (Sanders 1968; Gotelli and Colwell 2011). The curves tend to be curvilinear, as the number of individuals increases at an arithmetic rate but the number of taxa increases at a decreasing logarithmic rate.

Fig. 2 shows the curves of the interpolated taxa numbers at different population levels up to the total number of individuals for the assemblages. The figure indicates that — except for the assemblage from Daereung-ri — all charcoal assemblages reached asymptotes; we are unlikely to discover more taxa even with larger sample sizes. The curves demonstrate an intriguing pattern as they show that each settlement had its own characteristic rate of species increment. The fewest number of wood taxa per unit number of identified wood specimens was found in Pyeonggeo-dong, while somewhat higher but modest richness values of three to five occurred in Bongdam, Munam-ri, and Samgeo-ri. The Daereung-ri assemblage did not reach a plateau and was distinctive from other assemblages. We expect to find more arboreal taxa from the Daereung-ri pit-houses as we continue examination, although it is difficult to assess how diverse the collected wood would have been due to the limited number of available samples.

6. Discussion

This study sheds light on wood utilisation practices of the hunter-gatherers/incipient agriculturalists who inhabited the Korean peninsula during the Chulmun period. The results enable us to evaluate whether the charcoal frequencies are correlated with the arboreal vegetation composition reflected in the palynological data sets by comparing taxa richness of both charcoal assemblages and on- and off-site pollen records. Three possible outcomes are 1) opportunistic wood utilisation pattern, 2) selective wood utilisation pattern, and 3) indeterminate pattern caused by inadequacy of evidences and/or characteristics of local vegetation composition.

6.1. Opportunistic Wood Utilisation

An indication of opportunistic wood utilisation is that charcoal taxa frequencies are generally congruent with the woodland vegetation composition in the vicinity and both are high in taxa richness. In other words, a multitude of arboreal taxa were utilised with little or no selection with regard to wood properties and purposes. Out of the five sites, Daereung-ri fits the criteria for opportunistic wood utilisation.

The period of ca. 6000~3000 BC, which temporally covers the occupation of all five sites in this study, is considered mid-Holocene climatic optimum; the central-western region of the Korean Peninsula during this period is characterised by a warm and wet climate, high sea-level rise, and the expansion of deciduous broad-leaved forests (Yi et al. 2012; Nahm et al. 2013). Pollen records have suggested that, with some local variations, the central-western region was covered by *Quercus*-dominated forests, while other hardwood trees such as *Alnus*, *Betula*, *Castanea*, *Fraxinus*, *Salix*, *Ulmus*, and *Zelkova* also flourished (Jun et al. 2010; Yi et al. 2012; Song et al. 2018). Arboreal taxa recovered from the charcoal assemblage of Daereung-ri shows high taxa richness, as presented in Fig. 2. The rarefaction curve for Daereung-ri strongly indicates that more arboreal taxa are likely to be recovered from the charcoal assemblage should a larger quantity of charcoal samples be collected for analysis. The potential recovery of even more taxa and the confirmed taxa richness from the charcoal assemblage suggest that it is very likely that Chulmun inhabitants of Daereung-ri exploited and utilised diverse arboreal taxa available in their environs in an opportunistic manner for construction purposes.

6.2. Selective Wood Utilisation

An indication of selective wood utilisation is that charcoal taxa frequencies are not congruent with the arboreal vegetation structure in the vicinity and that charcoal fragments are low in species richness. In other words, a limited number of wood taxa were utilised amongst the available resources in the vicinity. Out of the five sites, Bongdam and Samgeo-ri fit the criteria of selective wood utilisation.

Bongdam, Daereung-ri, and Samgeo-ri are located in the central-western region and presumably had similar vegetation structures. Nevertheless, the taxa richness of the Samgeo-ri charcoal assemblages displays a very different pattern from that of Daereung-ri. The rarefaction curve of Samgeo-ri suggests that it is unlikely that more arboreal taxa would be recovered, even if a larger quantity of charcoal samples is analysed. Taxa richness of the charcoal assemblages from Samgeo-ri is rather low when compared with the potentially high taxa richness of the surrounding woodland vegetation. Moreover, the dominant taxon of the charcoal assemblages from this site is *Fraxinus*, which presumably was only a minor forest element in the area (Yi and Kim 2012). These indications suggest that the Samgeo-ri inhabitants heavily utilised a minor arboreal taxon as construction material, although a much wider range of options were available in the vicinity. It is likely that the inhabitants exploited and utilised the arboreal vegetation in a selective manner for construction purposes.

The fact that *Fraxinus* was the most dominant wood taxon and far outnumbered *Quercus* in Samgeo-ri is noteworthy because in some other sites, *Quercus*, either by targeted or opportunistic selection, was the most abundant. Wood under the *Quercus* and *Fraxinus* genera possess similar mechanical properties to be used as construction materials (Forestry Research Institute 1994; Ross 2010). The *Fraxinus* wood is known for its high resistance to shock as well as high flexibility and elasticity, which make it a strong and versatile wood for construction (Ross 2010).

We note that some ethnographical records from East Asia documented that people utilised *Fraxinus* as the preferred construction wood. For example, the Ainu in Hokkaido, Japan, is known to have preferentially utilised species from the genus *Fraxinus* to build permanent houses (*chise*) and structures for seasonal hunting-gathering stations (*kucha*) (The Foundation for Ainu Culture 2010; Hokkaido Museum 2017). Archaeobotanical research in Hokkaido has confirmed that the practice of preferential selection of *Fraxinus* has a long history that started as early as 2000 BP during the Epi-Jomon period (Watanabe et al. 2008, 2017; Moriya 2015). This demonstrates that both in prehistoric Korea and Japan, some people targeted *Fraxinus* as a construction wood, although there were presumably other tree species available that were comparable for the same purposes. In addition to possessing some similarly desirable qualities as *Quercus*, *Fraxinus* might also have been chosen as a preferred wood for construction purposes due to yet unknown cultural reasons that were specific to the inhabitants in Samgeo-ri.

Another site that suggests the operation of selective wood utilisation is Bongdam (Fig. 2). Although *Quercus* was presumably the most abundant arboreal taxon in the surrounding vegetation, an overwhelming dominance of *Quercus* charcoal despite a relatively large sample size is not congruent with the natural woodland diversity in the vicinity. The inhabitants of Bongdam practised a selective utilisation pattern in building their pit-house, targeting *Quercus* almost exclusively for construction.

The preferential exploitation of *Quercus* as construction wood is attributable to the physical and biochemical properties of its wood. Taxa within the genus *Quercus* are known for their high durability and strength (Ross 2010). They produce dense wood that possesses strong tensile and compression strengths. They are also characterised by high decay resistance to fungi and bacteria due to the high tannin content, especially in the heartwood (Ross 2010). Although other hardwood taxa in the region may provide similarly dense and strong wood, they rarely possess high tannin contents and show poorer resistance to degradation caused by fungi and bacteria. Softwood taxa such as *Pinus* are vulnerable to degradation caused by white rot and soft rot fungal infection (Duncan 1965; Takahashi and Nishimoto 1973; Enoki et al. 1988; Goodell et al. 2008). Moreover, softwood taxa generally have lower density, and thus lower strength, than hardwood taxa such as *Quercus*. The physical and biochemical properties of *Quercus* wood make it an ideal wood for pit-house construction, and the people in Bongdam appear to have targeted this tree species regardless of the presence of other wood types in the area.

6.3. Indeterminate Pattern

In some cases, it was difficult for us to determine whether the site inhabitants were practising selective or opportunistic wood utilisation. This was due to either the dominance of only a few taxa both in the local vegetation and in the charcoal assemblages, or the insufficient number of identifiable charcoal specimens. Under such circumstances, it was not clear whether the presence of only a few taxa in the charcoal assemblage was a result of the opportunistic wood selection or whether it was a result of targeted selection towards specific taxa that dominated the landscape. Among the studied sites, Munam-ri and Pyeonggeo-dong may fall under this category.

Palynological research in the central-eastern coastal region of the Korean Peninsula has a long history (Jo 1979; Yoon 1998; Fujiki and Yasuda 2004; Yoon et al. 2008; Park et al. 2012; Evstigneeva and Naryshkina 2013; Song et al. 2018). The pollen record from Songjiho Lagoon, which is located 4 km north of Munam-ri, well represents the regional vegetation change from ca. 7000 BP to the present (Song et al. 2018). The research suggested that during the period of Munam-ri, *Quercus* and *Pinus* dominated the landscape, respectively representing more than 45% and 30% of the total pollen counts. The co-dominance of *Pinus* and *Quercus* along the central-eastern coast during the Chulmun period is also confirmed by other palynological research across the region (Jo 1979; Fujiki and Yasuda 2004; Evstigneeva and Naryshkina 2013).

In Munam-ri, the most abundant wood specimens were *Quercus* and *Pinus*, and they accounted for approximately 50% and 35% of the total charcoal fragment counts. Accordingly, two alternative scenarios are possible. First, people preferred *Quercus* and *Pinus* as building materials, and as a result, these two tree taxa dominated the charcoal assemblage. Second, people were rather indiscriminate in selecting wood resources, but the prevalence of only a few wood types in the surrounding vegetation created a pattern that resembled the operation of targeted wood selection. In this regard, it is important to note that there were some ring-porous and diffuse-porous wood fragments that we could not identify down to the genus level. It is possible that these categories included some hardwood species that were minor components in the local vegetation. If these wood specimens all originated from different wood taxa, the Munam-ri charcoal assemblage may have relatively high species richness for its sample size. Accordingly, it is rather difficult to determine whether the dominance of *Quercus* and *Pinus* in the Munam-ri charcoal assemblage resulted from an opportunistic wood collection or whether it was a result of deliberate selection of *Quercus* and *Pinus*, which were abundant in the local vegetation.

An on-site pollen study on 3 m sediment at Pyeonggeo-dong reported the presence of a barren zone with no pollen preservation between ca. 9200 and 2700 BC, which temporally covered the period of the Pyeonggeo-dong occupation (Chung et al. 2006). Linear extrapolation in the pollen diagram nonetheless suggested that *Quercus* dominated the area. Two wood taxa that appeared in the charcoal assemblage were *Quercus* and *Platycarya*. Only one species in the *Platycarya* genera, i.e., *Platycarya strobilacea*, is indigenous to the Korean Peninsula; this tree is a pioneering tree species in disturbed habitats and grows easily in the clearings of oak forests (Lee et al. 2003; Bae 2005). It is likely that both *Quercus* and *Platycarya* were available to the Pyeonggeo-dong inhabitants in the nearby forests, while a relatively small sample size of 41 charcoal pieces makes it difficult to determine whether the sole presence of two taxa in the charcoal assemblage reflects either of the two wood selection strategies.

7. Conclusion

This article examined wood utilisation patterns of Chulmun hunter-gatherers/incipient agriculturalists using charcoal remains recovered from five archaeological sites across the Korean Peninsula. This work adds alternative perspective to the previous observation that oak wood was the most commonly used construction material in prehistoric Korea (Park et al. 2001; Yoon 2003; Park and Lee 2007). The warm and humid climatic trend during the Chulmun period is known to have fostered the proliferation of broadleaved forests, in which *Quercus* genera were a dominant element (Kang 1994; Park and Lee 2008; Choi et al. 2005). The discovery of carbonised acorns and acorn storage pits in many archaeological sites suggests that acorns were the main source of carbohydrates despite the practice of incipient plant cultivation (Ahn 2012). Considering the importance of acorns in the Chulmun diet, it is very likely that people also used oak wood for construction purposes. It is presumed that people determined their settlement locations in relation to forest resources and that there were abundant oak trees accessible within the foraging radius.

Although warmer/wetter climate, subsistence activities, and oak wood utilisation may be closely related, the current investigation demonstrates that *Quercus* was not the only wood resource selected by the Chulmun people, but more importantly, that human decisions determined wood taxa brought to the sites and thus created variations in charcoal assemblages. The study demonstrated that people were not entirely opportunistic nor selective when it came to sourcing construction wood. The occupants of Bongdam and Samgeo-ri appear to have targeted particular wood species, *Quercus* and *Fraxinus*, for construction. By contrast, we could not find any indication that people at Daereung-ri opted for specific wood taxa. They were less selective by collecting wood that was available in the vicinity in a rather opportunistic manner. The so-called “Principle of Least Effort” must be applied with caution when it comes to the question of selecting construction wood, as the study illustrated that different wood utilisation strategies were undertaken by different groups inhabiting similar vegetation. In this regard, anthracological analysis allows us to attain a more comprehensive understanding of resource procurement and human-plant interactions in the past.

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원고 접수일: 2020년 1월 1일
심사 완료일: 2020년 2월 14일
게재 확정일: 2020년 2월 14일

초 록

목탄분석을 통한 신석기시대 주거지 조영목재 선별의 모델화

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선사유적에 잔존한 목탄은 유적 점유 당시의 주변 식생과 인간에 의한 목재 선별 양식을 동시에 반영한다. 본고에서는 신석기 유적 5개소(봉담, 대능리, 문암리, 평거동, 삼거리)에서 수습된 목탄편에 대한 분석을 통해 신석기시대(8000~1500 BC) 수혈주거지 조영에 사용된 목재의 선별 양식을 고찰하였다. 분석 결과를 통해 볼 때, 신석기시대 주민의 목재 선별은 선별 기준의 유무와 엄격성에 따라 기회주의적(opportunistic) 이용과 선별주의적(selectivistic) 이용의 연장선으로 모델화할 수 있다. 대능리 유적에서는 주변 식생과 유사한 다종다양한 수목이 확인되어 기회주의적인 목재 이용 방법에 부합한다. 반면 봉담과 삼거리 유적에서는 참나무나 물푸레나무 등 소수의 수종만을 선별적으로 이용한 것을 알 수 있었다. 동일한 식생을 점유하고 있었던 신석기시대 집단들이 상이한 선택 전략을 취했음을 볼 때, 목재 선별에는 환경적인 요인와 함께 문화적 요인이 동시에 작용한 것으로 판단된다.

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