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The Vegetational History of Korea During the Holocene Period

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ABSTRACT

The vegetational and environmental history of Korea during the Holocene period has reconstructed by the use of floral, palaeoclimatological, archaeological data and written records.

From 10,000 to 6,700 year B.P. in mid−eastern Korea, deciduous broadleaved trees gradually increased in numbers, contemporaneously with the disappearance of cryophilous trees, notably at *c.*8,000 years B.P. From 6,700 to 4,500 years B.P., the vegetation remained dominated by *Quercus* and *Pinus*(Diploxylon). Vegetational informations suggest the postglacial hypsithermal from *c.*8,000 to 4,500 years B.P. After 4,500 until 1,400 years B.P., the admixture of cryophilous trees in midland and thermophilous trees in south seems to imply the latitudinal divisions of vegetation and climate. The presence of cultivated rice pollen as well as non−arboreal pollen and spores indicates an increased rate of deforestation. From 1,400 years B.P., there was a sharp decrease in the representation of temperate trees, but the presence of the cryophilous genera *Abies* and *Pinus* (Haploxylon) is noticeable and might be related to the occurrence of Little Ice Age.

Fossil pollen diagram from western Korea and eastern Korea since 6,250 and 10,000 years B.P., respectively have enabled to compare vegetational dis-

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tribution patterns and changes in the Holocene period. In western Korea, *Alnus*–dominated vegetation continued from 6,250 to 1,500 years B.P., but *Pinus* took over *Alnus* from 1,500 years B.P. In eastern Korea, however, *Quercus* and *Pinus* dominated from 10,000 to 2,000 years B.P., but *Pinus* became predominant from 2,000 years B.P. On a time–spatial basis, different vegetational distribution pattern can be recognised between western and eastern Korea.

The use of seven historical records which is unique to Korea also enabled to reconstruct the distributional pattern and temporal change of vegetation from 1425 to 1928.

Key words ; Vegetational history, Holocene, Postglacial hypsithermal, Deforestation

요 약

홀로세 동안의 한반도 식생사와 환경변천사를 고식물상, 고기후, 고고학, 고문헌 등 다양한 자료를 활용하여 복원하였다.

10,000년 전부터 6,700년 전까지 중부 동해안 지방에는 온대성 낙엽 활엽수가 점차 증가하였으며 이에 따라 서늘한 기후를 선호하는 나무들은 8,000년 전을 기점으로 급격히 감소하였다. 6,700년 전부터 4,500년 전에는 비교적 온난한 기후를 반영하는 참나무류와 잎이 2개인 소나무류 등이 번성하여 약 8,000년 전부터 4,500년 전까지가 후빙기에 들어서 가장 따뜻했던 시기로 추측된다. 4,500년 전부터 1,400년 전까지 중부 지방에는 서늘한 기후를 선호하는 식물들이 그리고 남부 지방에는 온난한 기후를 좋아하는 식물들이 각각 분포하여 식생과 기후의 남북차가 뚜렷했음을 알 수 있다. 재배되는 벼의 화분과 초본식물의 꽃가루 및 포자의 출현은 인위적인 삼림 파괴가 커져감을 나타낸다. 1,400년 전부터는 온대성 나무들이 급격히 감소하는 반면 서늘한 기후를 선호하는 전나무속이나 잎이 5개인 소나무 등이 출현하여 기후가 한랭해졌음을 나타내며 이는 아마도 소빙기의 출현과도 연관되어 있을 것으로 본다.

한반도 중부 이남 지방의 서해안과 동해안의 식생을 시, 공간적 측면에서 복원한 후 비교 검토하였다. 한반도 서해안의 경우 6,250년 전부터 1,500년 전까지 오리나무속이 우점하는 식생이 지속되었으나 1,500년 전부터는 소나무속이 이를 대치하였다. 반면에 동해안에서는 10,000년 전에서 2,000년 전까지 참나무속과 소나무속이 주로 분포하였으나 2,000년 전부터는 소나무속이 우점하였다.

1425년 이래 기록된 고문헌들을 활용하여 역사 시대 동안의 산지 식물과 재배 식물의 분포역 그리고 분포의 시대적 변천과정을 파악할 수 있었다.

1. AIMS, METHODS and DATA

The study aims to reconstruct the vegetational and environmental history of Korea during the Holocene period. For the reconstruction and interpretation of past vegetational patterns, numerous floral fossil data have been collated and presented. Other formative indirect evidences of vegetation change, such as palaeoclimatology and archaeology also are em ployed where appropriate. For the reconstruction of historic vegetational changes, written records of past vegetation are employed from *c.*1425. About 778 plant species have been utilised to reconstruct the vegetational history. The boundary between the Pleistocene and the Holocene has been placed *c.*10,000 years B.P. for most parts of the world (Godwin, 1966 ; Wendland and Bryson, 1974 ; Bowen,

Table 1. Tentative Vegetation History since 17000 years B.P. in Korea.

Dating	Vegetation			Archaeology		Human		Climate			Geology
(B.P.)	Pollen zone	AP	NAP	Cultural age	Agriculture	Habitation	Deforestation	Temperature	Humidity	Period	Sea level
Present 1000	VI	Pinus Quercus Alnus Corylus	Artemisia Gramineae Chenopodiaceae Oryza	Iron				Cool	? Humid	Post Glacial	+0.426 mm/yr.
3000	V	Quercus Pinus Carpinus Corylus Alnus Ulmus Juglans	Artemisia Oleaceae Gramineae Spore	Bronze Neolithic				Mild	? Dry		
5000	IV	Pinus Quercus Carpinus	Artemisia Oleaceae Gramineae					Warm	Dry		-1 m (Korea) +1.4 mm/yr.
7000 10000	III	Quercus Pinus Carpinus	Gramineae Spore Artemisia Cyperaceae	?				Mild	Dry		-10 m (Korea) -25 m (Korea)
13000	II	Quercus	Cyperaceae Spore Gramineae Artemisia	Palaeolithic				? Cold	Dry	Late Glacial	-40 m (E.China) -70 m (E.China)
17000	I	Picea Larix Abies Pinus (Haploxylon)	Cyperaceae Artemisia Spore					Cool	? Dry		-80 m (Japan)

(Compiled from Chard, 1960a; Sample, 1974; Oh, 1976; Park, 1977; Kim 1980; Jo, 1980a,b; Seoul National University, 1980; Yasuda *et al.*, 1980; Nelson, 1982; Kim 1985; Kang, 1987)

1978 ; Nilsson, 1982) and the same division is employed in this work.

2. VEGETATION OF THE HOLOCENE PERIOD

1) Microfossil Data of Lake Younglang

Microfossil (pollen) evidence from Lake Younglang(Yasuda *et al*, 1980) indicates that along the lowland central east coast region, deciduous broadleaved trees (*e.g. Quercus, Juglans, Carpinus, Alnus, Ulmus,* and *Celtis*)gradually increased in numbers from 10,000 to 6,700 years B.P., contemporaneously with the disappearance of cryophilous trees, such as *Picea, Larix* and *Betula,* notably at 8,000 years B.P.(Table 1).

However, the dominant trees at this stage were *Quercus* and *Pinus* (Diploxylon). Also, the non−arboreal pollen of Cyperaceae, Gramineae and spores was sharply decreased. The dominance of decidudous broadleaved trees, especially *Quercus,* along with *Alnus, Corylus, Juglans, Carya, Castanea* in Pohang, southeastern Korea(Jo,1987) shows similar vegetational distribution during the early Holocene period.

From 6,700 to 4,500 years B.P., the vegetation in central east coast remained dominated by *Quercus* and *Pinus* (Diploxylon), along with *Betula, Alnus, Tilia* and *Castanea.* Similar pollen assemblages are noticed from Pohang by Jo (1987). A gradual increase of *Artemisia,* Oleaceae, Gramineae, Chenopodiaceae, Typhaceae and spores over this period is also noticeable. The vegetation of southwestern Hwangdung(Jo,1987) from *c.*6, 260 to 4,950 years B.P. is characterised by the dominance of *Alnus,* along with *Quercus, Pinus* and Gramineae. At the same time, pollen evidence from elsewhere(Yasuda *et al,* 1980), which unfortunately has no dating for this period, suggests that thermophilous evergreen broadleaved trees, such as *Cyclobalanopsis* and *Castanopsis,* appeared in Bangojin, southeastern Korea, and in Kaheung, southwestern Korea. It should be noted that these two trees do not exist anymore in these areas today, though wheather this is due to deforestation or to a minor climatic fluctuation is not yet clear.

The postglacial hypsithermal period in Korea appears to have lasted from *c.*8, 000 to 5,000 years B.P., or possibly to *c.* 4,000 years B.P.(Chard, 1974;Pearson, 1977 ; Kim, 1983). The occurrence of large number of charcoal fragments *C.* 6, 700 years B.P.(Chang and Kim, 1982) may also indicate warm and dry climate which caused frequent natural fires. According to Sohn(1984), the mean annual temperature at *c.*5,000 years B.P., was 2° C warmer than that of today. The dominance of *Pinus*(Diploxylon) and *Quercus,* as well as a gradual increase of deciduous broadleaved trees in central Korea, and the appearance of thermophilous evergreen broadleaved trees in southern Korea, also suggest the postglacial hypsithermal from *c.*8,000 to 4,500 years B.P. Following this, increased cooling in the north, and a greater climatic differentiation between north and south in the peninsula marked the end of this phase.

After 4,500 years B.P. until 1,400 years B.P., *Pinus*(Diploxylon) and *Quercus* continued to dominate in central east coast, along with deciduous broadleaved trees, such as *Salix, Juglans, Carpinus, Corylus, Betula, Alnus, Ulmus, Tilia, Castanea* and *Celtis.* However, in contrast to the proceding period, cryophilous coniferous trees, such as *Abies* reappeared. At the same time, according to Yasuda *et al*(1980), thermophilous evergreen broadleaved trees (*e.g.Cyclobalanopsis*, *Castanopsis*, *Myrica* and *Camellia*) began to occur from Bangojin, and the first three of these were present in Kaheung as well. The reappearance of cold-tolerant species at Lake Younglang, coupled with the presence of warmth-loving evergreen broadleaved trees in the southeastern Bangojin and southwestern Kaheung, seem to imply that the latitudinal divisions of climate in the Korean peninsula were becoming more exaggerated than formerly. Addittionally, an expansion in the frequency of non-arboreal pollen and spores suggests an increased rate of deforestation for the region within the period. Some three degrees latitude to the south of Lake Younglang, early agriculture clearly was well under way at this time, for Kim(1980) has reported the presence of cultivated rice pollen(*Oryza*) from Naju(southwestern Korea) at *c*.3, 500 years B.P. and from Kimhae(southeastern Korea) at *c*.3,000 years B.P.

From 1,400 years B.P., the pollen evidence at Lake Younglang suggests that there was a sharp decrease in the representation of *Pinus*(Diploxylon) and *Quercus* within the pollen spectra. Also, pollen from *Alnus*, *Corylus*, *Ulmus*, *Carpinus*, *Castanea*, *Juglans*, *Salix*, *Tilia* further was reduced. The presence of the cryophilous genera *Abies* and *Pinus* (Haploxylon) is noticeable. From *c*.1,000 years B.P., there was moreover a gradual increase of *Oryza* pollen in the central east coast of Korea, with a sudden and pronounced increase of *Oryza* at *c*.1,500 years B.P., in Kaheung and a similar sharp increase at *c*.1,000 years B.P., in Bangojin as well. Indications from the pollen data accordingly suggest that the climate was getting colder over this period; additionally, agricultural activity was becoming more intensive, and this was also the case in southern regions. The large number of cold and humid years in Korea between A.D. 1600 to 1800 is of interest, in that these appear to be related to the incidence of the Little Ice Age, a period which in Korea was marked by an increase in famine occurrences(Kim, 1984b, 1985). Pollen evidence from Lake Younglang suggests a sharp decline of the thermophilous coniferous and deciduous broadleaved trees, and a minor increase of the cryophilous coniferous trees, such as *Abies*, from 1,400 years B.P. However, the cool phase of the Little Ice Age in Korea is poorly reflected in the vegetation data.

2) Pollen Spectra of West and East Korea :

Recent reports (Yasuda et al, 1980; Jo, 1987; Choi, 1992; Youn, 1994) have enabled to reconstruct and compare vegetational distribution patterns and changes both in western and eastern Korea during the Holocene period. So far no fossil data with absolute data is available prior to 6, 250 years B.P. in western Korea. On the other hand, pollen spectra of Lake Younglang and Pohang in eastern Korea covers last 10,000 years(Table. 2).

In Ilsan, Koyang-gun(37°40′N, 126° 45′E) of western Korea, *Alnus* was predominant since 5,650 years B.P., along with *Quercus*, *Pinus* and herbs. Apart from *Alnus*, *Quercus* was more common than *Pinus* from 5,650 to 3,760 years B. P., but *Pinus* took over *Quercus* from 3,000years B.P. The sharp decrease of

Table 2. Holocene Vegetational Changes of Western and Eastern Korea.

Sites & Authors / Years B.P.	WEST					EAST			
	Ilsan, Koyang (37° 40′ N, 126° 45′ E)		Gunja, Siheung (37° 22′ N, 125° 45′ E)	Hwangdung, Iksan (36° 00′ N, 126° 57′ E)	Kaheung, Muan (34° 59′ N, 126° 38′ E)	Younglang, Sokcho (38° 13′ N, 128° 35′ E)	Jumunjin, Myongju (37° 53′ N, 128° 49′ E)	Pohang (36° 00′ N, 129° 22′ E)	Bangojin, Ulsan (35° 29′ N, 129° 25′ E)
	Yoon(1994)	Choi(1992)	Yasuda(1980)	Jo(1980)	Yasuda(1980)	Yasuda(1980)	Jo(1987)	Jo(1987)	Jo(1987)
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000	Alnus(40) ↓ Pinus(20)→ Quercus(15) ↑ 2270±50 Alnus(80) ↓ Pinus(10) ↑ 2770±60 Alnus(80)→ Pinus(10)→ Quercus(5)→ 3760±60 Alnus(80)→ Quercus(10)→ Pinus(5)→ 4720±50	Alnus(75) ↓ Pinus(15) ↑ Quercus(5) ↑ 3050±80 Alnus(85)→ Pinus(5) ↑ Quercus(5) ↑ 5240±70 Alnus(80)→ Quercus(10)→ 5650±60	Quercus(30)→ Pinus(15)→ 2670±80 Pinus(35) ↓ Quercus(30)→	Alnus(60)→ Quercus(15)→ Pinus(5)→ 4950±160 Alnus(60)→ Quercus(15) ↑ Pinus(5)→ 6260±180	Pinus(80) ↑ Quercus(5) ↓ Alnus(5) ↑ 1500±90 Pinus(75) ↑ Quercus(10) ↓ Cyclobalanopsis(5) ↓	Pinus(35) ↓ Quercus(20) ↓ Carpinus(5) ↓ 1410±80 Quercus(40)→ Pinus(40)→ Carpinus(5)→ - - - Quercus(35) ↑ Pinus(35) ↑ Carpinus(5) ↑ 6750±115 Quercus(20)→ Pinus(5)→ - - -	Pinus(60) ↑ Quercus(30)→ Corylus(5)→ 1990±100 Quercus(50)→ Pinus(20)→ Corylus(5)→	Pinus(70) ↑ Quercus(15) ↓ Salix(5) ↓ 1980±90 Pinus(70) ↑ Quercus(20) ↓ - - - Quercus(40)→ Pinus(10) ↑ Corylus(5)→ 7810±160 Quercus(40)→ Pinus(10)→ Castanea(5)→ 9820±195	770±90 Pinus(40)→ Quercus(30)→ Castanea(10)→ 2350±100 Quercus(55)→ Alnus(15)→ Pinus(15)→ 4060±100 Quercus(30)→ Alnus(20)→ Carpinus(10)→

(Compiled from records by the author)

Note : 1) Only the pollen diagrams with an absolute dating are employed to produce the diagram
2) Numbers in the parenthesis indicate an approximate percentage of pollen at each period
3) Dashed lines mean an approximate division without absolute dating
4) ↑ increase of pollen composition
↓ decrease of pollen composition
→ minor change of pollen composition

Alnus pollen as well as the increase of *Pinus* and *Quercus* pollens from 2,270 years B.P. may imply a gradual climatic amelioration and sea level change in western Korea. *Pinus* and *Quercus* remained dominated in another mid−western site, Kunja, Siheung−city(37°22′N, 126°45′E) about 2,670 years B.P.

In southwestern area, Yulchon, Iksan −gun(36°00′N, 126°57′E), *Alnus* continued to dominated, along with *Quercus* and *Pinus* from 6,260 to 4,950 years B.P., and also thereafter. In southwestern site, Kaheung, Muan−gun(34°59′N, 126°38′ E), *Pinus* took over other temperate trees from 1,500 years B.P.

In general, *Alnus*−dominated vegetation continued from 6,250 to 1,500 years B.P., but *Pinus* took over *Alnus* from 1, 500 years B.P. in western Korea.

In mid−eastern area, Lake Younglang, Sokcho − city(38°13′N, 128°35′E), *Quercus* and *Pinus* dominated from 10, 000 to 6,750 years B.P. *Pinus* gradually increased, along with *Quercus* and *Carpinus* from 6,750 to 4,500 years B.P. Similar vegetational type continued thereafter. In another mid−eastern site, Jumunjin, Myongju−gun(37°53′N, 128° 49′E), *Quercus* was dominant tree, along with *Pinus* and *Corylus* until 2,000 years B.P., but *Pinus* became more common since then.

In southeastern Korea, Pohang(36°00′ N, 129°22′E), dominant vegetation consisted of *Quercus* as well as *Pinus*, *Carya*, *Corylus*, *Castanea* so on from 9,800 to 5, 000 years B.P., but *Pinus* overwhelmed other trees since then.

In general, *Quercus* and *Pinus* predominated from 10,000 to 2,000 years B.P., but *Pinus* became dominant from 2,000 years B.P. in eastern Korea.

Overall, on a time−spatial basis, different vegetational distribution pattern can be recognised between western and eastern Korea. The dominance of *Alnus* in western Korea but that of *Quercus* and *Pinus* in eastern Korea continued until 2, 000 or 1,500 years B.P. It may imply the presence of environmental differences, such as climate, sea level, local environment and so on between western and eastern Korea.

3) Written Records ;

Over the last 650 years, seven historical works are useful in the reconstruction of these vegetation patterns and changes, even though many of these deal with cultivated plants. These are the Kyungsangdo Chiriji(Regional Geography of Kyungsang Province) of 1425 ; the Saejong Sillok Chiriji(Annals of King Saejong) of 1454 ; the Shinzung Dongguk Yeoji Seungram(Augmented Survey of Korean Regional Geography) of 1531 ; the Takriji(Selection of Suitable Habitat) of 1751 ; the Kongsashinseo(New Bibliography of Administration) of 1771, and the Chosun Mulsan(Products of Korea) of 1928. The records within these works provide information relating to the distribution of 32 trees, four textile plants, four medical herbs, nine cereal plants, etc. and of these, the records of 23 are especially complete and accordingly are presented herein(Table 3).

But before this table was compiled in final forms, some interpretation of available data was necessary, in that the old descriptions of trees, herbs, cultivated plants and other products needed to be reassessed for the purpose of species classification. This painstaking work involves comparisons between present and past floras. Always, one has further to remem-

Table 3. Historical Changes of Selected Korean Plant Ranges

Plant	Period			
	1425–1531	1751–1787	1864–1907	1910–1928
Mulberrry	NW SW	NW SE S	NW S	–
Paper Mulberry	S NW	S NW M	S NW M	S M NW
Lacquer	ME SE SW NW	ME SE SW	SE SW NE NW	SE NE
Pomegranate	S	S	S	–
Tea Plant	SW SE	SW SE	SW SE	SW
Box Tree	ME N	ME N	NE ME	–
Machilus	Cheju	Cheju	Cheju	–
Citrus	Cheju	Cheju	Cheju	–
Pear	SE SW	M S	NE NW SW M	SW MW SE
Chestnut	SE SW	SE SW MW	S NW M	NW M S
Jujube	M SE SW	M S	M S N	M
Korean Pine	N M S	N M S	N M S	–
Persimmon	S M	S M	S M	S M
Nutmeg	SW SE Cheju	SW SE Cheju	SW SE Cheju	–
Mandarin	Cheju	Cheju	S Cheju	–
Large Bamboo	S MW	S MW	S MW ME	S
Small Bamboo	S ME MW NE	S ME MW NE	S ME MW	ME S
Cotton	N M	N M	N M S	M S N
Hemp	N M S	N M S	N M S	N M S
Ramie	ME S	ME S	ME S	MW SW
Ginseng	N ME S	N ME S	NE ME	NW M SW
Tobacco	–	–	M N S	M S N
Soy Bean	–	–	N M S	M S N

The data indicate major areas of distribution for each species, and have been compiled from various records, *viz.* the Kyungsangdo Chiriji (1425), the Saejong Sillok Chiriji (1454), the Shinzung Dongguk Yeoji Seungram (1531), the Takriji (1751), the Kongsa Shinseo (1771), and the Chosun Mulsan (1928), and analyzed by the authors.

Legend: E: East W: West S: South N: North M: Midland

ber the risk that some artificial manipulation of these data, *e.g.* for tax purposes, might have been made by the original recorders, and that this must be discounted as far as possible.

Bearing all this in mind, it is clear that several recurring patterns of distribution of these mainly cultivated species, and of other distributional changes associated with them, occurred in Korea over the years 1425 to 1928.

First, some species grow over the

whole of the peninsula, *e.g.* lacquer(*Rhus verniciflua*), Korean pine (*Pinus koraiensis*), and ginseng(*Panax schinseng*) ; secondly, other species occur predominantly in northern Korea, such as mulberry(*Morus alba*), cotton(*Gossypium nanking*), and hemp(*Cannabis sativa*) ; thirdly, some species are found mainly in northern and central Korea, *e.g.* paper mulberry(*Broussonetia kazinoki*) and soy bean(*Glycine max*) ; fourthly, others are located mainly in central Korea, *e.g.* the box tree(*Buxus koreana*) and the jujube (*Zizyphus jujuba*) ; fifthly, species such as the small bamboo(*Pseudosasa japonica*), the persimmon(*Diospyros kaki*) and the ramie(*Boehmeria frutescens*), occur in both central and southern Korea ; sixthly, other species occur almost solely in southern Korea, *e.g.* the pomegranate(*Punica granatum*), tea plant(*Thea sinensis* var. *bohea*), nutmeg(*Torreya nucifera*) and large bamboo(*Sinoarundinaria reticulata*) ; seventhly, certain species are found mainly in southern Korea and Cheju Island, *e.g.* citrus(*Citrus junos*) ; and finally, some are restricted to the subtropical Cheju Island itself, *e.g.* machilus(*Machilus thunbergii*) and mandarin(*Citrus* spp.).

On a temporal basis, five patterns of distributional change can be recognised from Table 3.

First, species which have no noticeable change in their range over the last 500 years include paper mulberry, lacquer, pomegranate, box tree, machilus, nutmeg, mandarin and *Citrus junos.* The stability of distribution implied by these records is perhaps surprising. Secondly, a general decline in range can be seen in the case of the tea plant, large bamboo, small bamboo, ramie and ginseng. This might be the result of a response to climatic deterioration in the case of thermophilous plants, such as tea plant and bamboo, but it also may relate to a relative decline in range associated with the expansion of other crops. Thirdly, an expansion of range can be noted in the case of some fruit trees, *e.g.* pear, chestnut, persimmon and jujube. This expansion is probably due to a steady and increasing demand from markets. Fourthly, a southward expansion of species can be seen in the case of the mulberry, cotton, hemp, tobacco and soy bean. The sudden expansion of tobacco(*Nicotiana tobacum*) and soy bean(*Glycine max*) in central and southern Korea since 1864 again suggests the active cultivation of cash crops in demand for commercial purposes, since no clear evidence for climatic change over this small period of time is forthcoming. Finally, the sudden appearance and expansion of certain grain crops, such as buckwheat(*Fagophyrum esculentum*), oats(*Avena sativa*), wheat(*Triticum aestivum*), barley(*Hordeum sativum*), maize(*Zea mays*), barnyard grass(*Echinochloa frusanentacea*), millet(*Panicum miliaceum*) and foxtail millet(*Setaria italica*) in northern Korea since 1864 may be the result of the sometimes frequent failure of the rice crop in this region. The occurrences of cold episodes by the use of tree—ring analysis in the mountains of central Korea(Choi *et al,* 1992) at the period of 1838 to 1847 may explain a sudden expansion of above mentioned substitute crops.

4) Deforestation :

It is fairly clear that Neolithic man appeared in Korea at some time between *c.* 7,500 and 6,000 years B.P. During this time, his active presence was noticed throughout the peninsula. The first dwelling sites of Neolithic man are mainly associated with the banks of rivers, streams and seas. With time, these people then seem to have occupied inland areas as well. This inland expansion may have given rise to early deforestation. Prior to the Holocene period, the occurrence of *Pinus* charcoal in human occupied caves probably suggests an early−stage anthropogenic disturbance of natural vegetation during the Middle Pleistocene(*c.*700,00 to 11,000 years B.P.) of Korea(Kong, 1992). The sharp increase of charcoal fragments since 10,000 years B.P. in Lake Younglang(Yasuda *et al*, 1980) may suggest the active anthropogenic deforestation in this area. The coexistences of carbon fragment and *Oryza* pollen since 2, 350 years B.P. in Bangojin, southeastern Korea(Jo, 1987) are also indicative of man−made clearance of natural vegetation for agriculture.

From *c.*4,500 to 1,400 years B.P., intensive agricultural activity took place in the Late Neolithic, Bronze and Early Iron Ages(Table 1). This was marked most noticeably by the cultivation of rice. According to Grigg(1984), the introduction of rice to Korea took place at *c.*5,000 years B.P. ; in turn, Nelson(1982) proposed that rice cultivation had been well established by *c.*3,500 years B.P. In Kaheung, Muan, southwestern Korea, the cultivated rice pollen *Oryza* dated back to *c.*3,500 years B.P., and to *c.*3,000 years B.P. in Bangojin, Ulsan, southeastern Korea(Yasuda *et al*, 1980 : Scarre, 1988). In central Korea, rice cultivation began between *c.*2,850 and 2,350 years B.P.(Yi, 1984). Clearly, by this time, a sophisticated agricultural technology centred on rice had emerged in the Korean peninsula and had accelerated the deforestation of natural vegetation.

From the Bronze Age, the Korean population began to dwell on higher ground more widely, as its density increased. This was a classic age for metal making skills, especially in the preparation of tools and ornaments. In the process of expansion, forest must have been cleared quickly to provide agricultural and residential space, as well as for a source of charcoal in the smelting of ores for metallurgical purposes. Further deforestation might have been caused by the development of the classic Korean heating system "Ondol'(Korean−style under−floor flues for heating, which commened in this period), which in itself, in its operation, requires a large amount of fuel, the building of wooden houses, and the use of wood in pottery kilns. It is known that deforestation for rice cultivation in central Korea dates back to *c.*2,500 and 2, 300 years B.P.(Kim, 1980, Kang, 1987) elsewhere the dates are not yet clarified. The increased presence of *Oryza* indicates an extension of rice cultivation activities and this eventually caused conspicuous deforestation.

There are several factors which are responsible for the rapid deforestation generally found in Korea since 2,000 years B.P. During the cold and/or humid stages, mainly between A.D. 101 to 200, 801 to 1400 and 1601 to 1800 (Kim, 1983, 1984a,b), are uneven seasonal distribution of rainfall often occurred as well. This often had the effect of accentuating drought during the sowing season of rice, and frequently also produced unusually severe floods during the main growth season of the crop, so that both of these features accentuated the potential for famine ; and at the same time, people then were forced to disturb forest land at a rate which was well above average in their search for substitute foods. The most common method of cultivation in mountain areas until very recently has always been a form of slash-and burn, and millets, potatoes and oats have been grown on this burned-over forest land since the Neolithic. Even though this method of land clearance was banned by law at several times in the past, as in 1469, 1592 and 1736. It was maintained widely even so, and was still noted in 1963 on the upper parts of the Han River in central Korea(McCune, 1956 ; Korean Commission for Nature and Natural Resources, 1971 ; Sample, 1974 ; Kang and Iizumi, 1981). Although the extension of rice cultivation in recent years has generally been confined to the intensification of lowland production, some movement upslope on mountain land did take place, and this involved further deforestation.

Today, the total forest area in Korea is about 67 per cent of the nation's territory. However, some mountains have been denuded of timbers, mainly due to reckless deforestation during the last half century, and also as a result of damage induced by the Korean War(1950-1953). During the early 1960s, a national reforestation scheme was launched, and laws concerning the preservation of forests then were instituted. Under the afforestation policy, huge numbers of trees were planted. At present, the 5,742,000 hactares of forest in South Korea consists of 3,317,000 hactares of coniferous forest, 1,217, 000 hectares of deciduous forest, 1,201,000 hectares of mixed forest and only 7 hactares of bamboo stands (FAO, 1976 ; Korean Overseas Information Sevice, 1978). For the exact number of species present in the Korean peninsula, Lee(1982) reported 4,164 species.

The growing number of intentional and/or accidental introductions of alien plants also have changed the vegetation of Korea, particularly since 1900, since some have become naturalised. Numerous alien plants have been introduced from China, Europe, America, Asia, Africa and Australia for the purpose of horticulture, industry, food, plantations or other uses (Lee and Kim, 1961 ; Lee, 1970). Yim and Jeon(1980) have noted that, from these and arriving weeds, 110 have become naturalised. These are predominatly herbaceous plants, including representatives from the Compositae(13 spp.), Polygonaceae(13 spp.), Gramineae(11 spp.), Leguminosae(8 spp.), Solanaceae(6 spp.), Cruciferae(6 spp.), Convolvulaceae (6 spp.) and Malvaceae(4 spp.). The origin of these species is diverse, being attributed to Europe(33.6%), North America(26.2%), Asia(20.6%), Middle and South America(17.8%) and Africa and Oceania (0.9%). Recently Kong(1989, 1990, 1991) has delineated eight biogeographic division, and its component plant groups, its species composition, its physiognomy and the three dimensional distribution patterns of species found therein has provided invaluable information as to the nature and history of the biogeography of Korea.

3. CONCLUSION

The vegetational and environmental history of Korea during the Holocene period has reconstructed by the use of floral, palaeoclimatological, archaeological data and written records.

From *c.*10,000 to 6,700 years B.P. in central east coast, deciduous broadleaved trees gradually increased in numbers, contemporaneously with the disappearance of cryophilous trees, notably at *c.*8, 000 years B.P. From *c.*6,700 to 4,500 years B.P., the vegetation remained dominated by *Pinus* (Diploxylon) and *Quercus*, along with other temperate trees. The dominance of *Pinus*(Diploxylon) and *Quercus*, as well as the appearence of thermophilous broadleaved trees in southern Korea suggests the postglacial hypsithermal from *c.*8,000 to 4,500 years B.P.

After 4,500 until 1,400 years B.P., the reappearence of cold−tolerant species in the central east coast, coupled with the presence of warmth−loving evergreen broadleaved trees in the southeastern Korea seems to imply that the latitudinal divisions of climate were becoming more exaggerated than formerly. Additionally, an expansion in the frequency of non−arboreal pollen and spores, as well as the presence of cultivated rice pollen(*Oryza*) suggests an increased rate of deforestation within the period.

From 1,400 years B.P., there was a sharp decrease in the representation of temperate trees, but the presence of the cryophilous genera *Abies* and *Pinus* (Haploxylon) is noticeable and might be related to the occurence of the Little Ice Age.

On a time−spatial basis, vegetational difference can be noticed between western and eastern Korea. In western Korea, *Alnus*−dominated vegetation continued from 6,250 to 1,500 years B.P., but *Pinus* took over *Alnus* from 1,500 years B.P. In eastern Korea, however, *Quercus* and *Pinus* dominated from 10,000 to 2,000 years B.P., but *Pinus* became predominant from 2,000 years B.P.

Agricultural activity which inevitably caused the acceleration of deforestation was becoming more intensive in the peninsula. The use of seven historical records also reconstructed the distributional pattern and temporal change of vegetation from 1425 to 1928.

Though the early−stage anthropogenic disturbance of natural vegetation during the Middle Pleistocene have given rise to early deforestation, intensive agricultural activity took place from the Late Neolithic *c.*4,500 B.P. The rich vegetation and diverse flora in Korea is in danger if current global warming trend continues. Therefore, a plea for more urgent research on present flora and vegetation is required for the better understanding of biogeography of Korea.

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