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Recent Vegetation History and Environmental Changes in Wangdeungjae Moor of Mt. Jiri

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ABSTRACT: To reveal vegetation history and environmental changes in Mt. Jiri, sediment cores were collected from Wangdeungjae moor of Mt. Jiri. Overall dry matter accumulation rates and sedimentation rates by ^{14}C-dating were 0.027 kg · m^{-2} · yr^{-1} and 0.184 mm/yr since 1250 (760±40 yrs BP, 14 cm in depth). There are three pollen zones; the first zone is below 14 cm depth where *Quercus* dominated, the second zone is from 14 cm to 6 cm depth where Gramineae increased and *Quercus* and *Salix* dominated and the third zone is from 6 cm depth to the top where *Pinus* and *Quercus* dominated. Total pollen concentration gradually increased from bottom to the top of sediment core, which implies wet, anaerobic and cool condition during covered period by the core. Calcium and magnesium contents had increased since 14 cm depth, with peaks at 13 and 20 cm depths. This indicates that groundwater had recently become relatively more important than surface water as water source of Wangdeungjae moor. Exotic plant or Chenopodiacea pollen was less than 1%. There was little variation in total N and P contents along the length of the core. These results support that Wangdeungjae moor has been little affected by anthropogenic activities. Also, nutrients and heavy metal contents indicate the baseline condition of Wangdeungjae moor.

Key words: Anthropogenic impacts, Baseline condition, Environmental changes, Pollen analysis, Vegetation history, Wangdeungjae moor

INTRODUCTION

Human activities since the Industrial Revolution have increased and changed many ecosystems (Schlesinger 1997). Increased human activities since Kabo reformation have changed the structure and function of many ecosystems in Korea (National Institute of Korean History 1982). The Korean war in early 1950's changed extremely the landscape of Korea. The Korean government employed an industrial policy after 1950's. This industrialization movement designed for export-oriented companies has generated substantial levels of environmental pollution and landscape has been changed (Kim 1997). Human activities including increase of agricultural field and construction of road and housing have caused significant changes in the function and structure in many ecosystems.

Environmental pollution has affected many ecosystems including wetlands in Korea and Ministry of Environment has launched environmental monitoring program and Korea National Parks Authority has been monitoring about natural variability to reveal changing pattern.

To protect ecosystems from these threats, it is important to understand which anthropogenic activities are responsible for specific ecosystem changes. Also, we require to know paleoecological knowledges such as baseline condition and natural variability for effective ecosystem management (Smol 1992). An anthropogenic impact on wetlands has been the increase in transport of pollutant and nutrient particle from watersheds and the atmosphere, and these impacts have recorded in sediment. Paleoecological studies have been used to estimate and track the nature and anthropogenic disturbances of watershed (Craft and Richardson 1998, Brenner *et al.* 1996, Punning and Koff 1997, Kim 1999, Kim 2001). The sedimentation process in aquatic systems is affected by environmental changes and sediments record those as changes in pollen, nutrient and pollutant concentration (Kim 1999). However, there were little paleoecological studies to find historical variation of environmental factors in Korea (Choi 1998, Kim 2005).

In this study, the factors that caused the changes in sediment characteristics were investigated by analyzing sediment record of Wangdeungjae moor in Mt. Jiri. Pollen, organic and inorganic contents, heavy metal contents, sediment accumulation rates and heavy metal accumulation rates were studied as indicators of past environmental condition.

Specific objectives are 1) to determine the accumulation rates by ^{14}C dating method, 2) to reveal changes in plant communities for the recent few hundred years in Mt. Jiri through pollen analysis, 3) to determine physical and chemical characteristics of the sediments,

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and 4) to assess the effects of human activities on sediment characteristics. Thus, this study provides the recent past condition of Wangdeungjae moor.

METHODS

Study Area

Wangdeungjae moor (N 35° 23′40″, E 127° 47′30″) is a montane fen at the altitude of 960 meters on the eastern ridge of Mt. Jiri national park in Sancheong-gun, Kyeongsangnam-do (Fig. 1) and was reported to the academic world in 1996 at first (National Parks Authority 1998).

Wangdeungjae moor is a small rectangular wetland. The length is 150 meters and width is 50 meters. Wangdeungjae moor is surrounded by five small mountain peaks. Major water source of the wetland is groundwater from the surrounding mountains (National Parks Authority 1998). It is known that Wangdeungjae moor has been little affected by anthropogenic activities due to its location. Mt. Jiri is dominated by Oak trees (*Quercus mongolica* and *Q. serrata*). Wangdeungjae moor is dominated by Cyperaceae (*Carex biwensis*, *C. heterolepis*, *C. oxyandra*, *Eleocharis attenuata* var. *laeviseta*, *Scirpus hotarui*) (National Parks Authority 1998).

Average annual precipitation and annual mean temperature in Sancheong-gun are 1,518 mm and 12.7℃ (Fig. 2). The annual precipitation pattern in Yeosu is similar to that in Sancheong-gun and combined graph shows the changing pattern of annual precipitation since 1940. The average of annual temperature has been rising and the annual precipitation has fluctuated widely since 1980.

Sample Collection and Analyses

1. Sampling

Three sediment cores were taken from Wangdeungjae moor in November 2002 by driving plastic open-end samplers (5.6 cm diameter) to a depth of 50 cm. Cores were transported to the laboratory and then stored frozen until sectioned into 1 cm thick sediment. About 1 g of a wet sub-sample was taken from each section for pollen analysis and remaining sub-samples were air-dried.

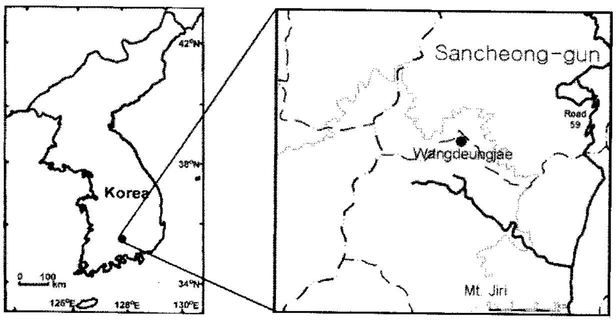

Fig. 1. Location of study site in Mt. Jiri and Wangdeungjae moor. ········ indicates boundary of Mt. Jiri National Park.

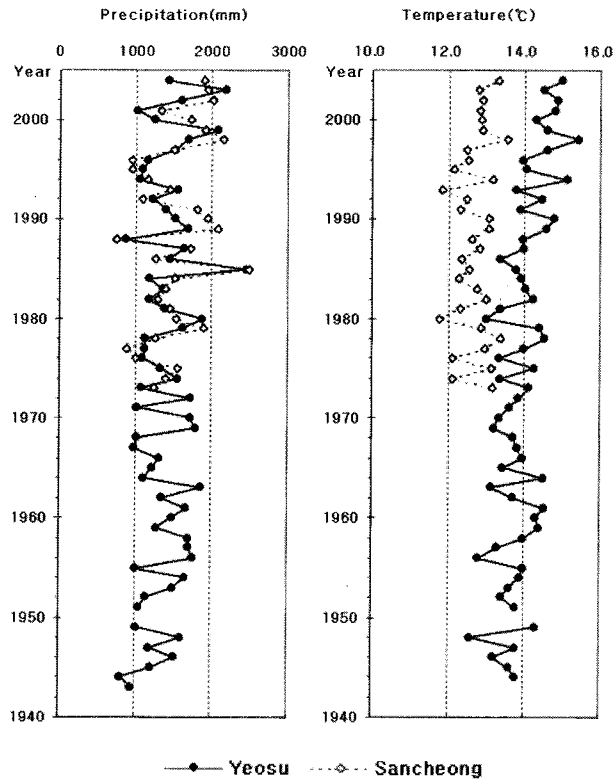

Fig. 2. Annual precipitation and temperature at Yeosu and Sancheong.

2. Dating

Sub-samples were taken from 5 cm, 10 cm and 14 cm depths of the core before application of any chemical treatment and dated with a radiocarbon dating method using the AMS (Accelerator Mass Spectrometry) at the National Center for Inter-University Research Facilities, Seoul National University. Most radiocarbon dates have been reported as radiocarbon years before present ("years BP"), where the present is defined as AD 1950 (Turetsky *et al.* 2004). The ^{14}C dates presented in this study are calendar-year age estimates based on the median values of the ^{14}C probability spectra derived from each uncalibrated age data.

3. Pollen Analysis

Pollen analysis was performed with a modification of the standard method (Faegri and Iversen 1989). This procedure included KOH treatment, sieving, $ZnCl_2$ flotation and acetolysis. In oder to calculate the concentration of pollen grains in the sediment, 2 tablets of *Lycopodium* spore (SEK 250/500 tablets. Batch No. 938934, Department of Quaternary Geology, Lund University) containing about 10,679 grains were added to each sample as a tracer. Pollen concentration was calculated based on dry weight of sediment because water content of sediment was different along the core.

More than 300 grains of pollen or 100 grains of *Lycopodium* spore were counted under a light microscope (×400). Identified pollen taxa were divided into three groups: arboreal, herbs, aquatic/wetland taxa. A sum of all counted pollen for the aquatic/wetland taxa and a sum of arboreal and herbs for these types were used for calculation of pollen percentages (Faegri and Iverson 1989).

4. Biogeochemical Analysis

Air-dried samples were ground in a mortar with a pestle and sieved with a standard #60 sieve (mesh size 250 μm). Dry weight was determined after drying at 105℃ for 24 h. Bulk density was calculated as dry weight per wet volume and LOI (loss on ignition) content was determined by combustion in a muffle furnace at 550℃ for 4 h (Dean 1974, Boyle 2004). Total amounts of carbon (C) and nitrogen (N) were determined on an element analyzer (CE instrument, Model EA1110) at the National Center for Inter-University Research Facilities, Seoul National University. After nitric acid digestion of sediments, total amount of phosphorus (P), sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) were determined by ICP-AES (Perkin-Elmer, Model OPTIMA 4300DV) and total amount of lead (Pb), copper (Cu), nickel (Ni) and cadmium (Cd) were determined by ICP-MS (Perkin-Elmer, Model ELAN 6100) at the National Center for Inter-University Research Facilities, Seoul National University.

RESULTS AND DISCUSSION

1. Vegetation History

The eastern ridge of Mt. Jiri is dominated by Oak (the Ministry of Home Affairs 1993) and percentage of *Quercus* pollen reflects this well (Fig. 3). *Quercus*, *Salix* and *Pinus* pollen composed about 33.1%, 21.4% and 17.9% of the terrestrial pollen. Cyperaceae pollen composed about 8.9% of the total pollen. The average concentration of pollen in sediment is 187,876 grains per 1g dried sediment.

The pollen record of Wangdeungjae moor can be divided into three zones based on the percentages of dominant pollen types. The first zone is below 14 cm depth (AD 1250) where *Quercus* dominated. Percentages of *Quercus*, *Salix*, *Pinus* and Gramineae pollen were about 35.2%, 29.1%, 13.1% and 11.0%, respectively. Cyperaceae pollen composed about 6.0% of the total pollen. The average concentration of pollen in this zone is 138,791 grains/gram dry weight. The second zone is from 14cm (AD 1250) to 6cm (AD 1956) depth where Gramineae pollen increased and *Quercus* and *Salix* dominated. The percentages of *Quercus*, *Salix*, Gramineae and *Pinus* pollen were about 31.6%, 23.3%, 21.9% and 6.9%, respectively. Cyperaceae pollen composed about 10.8% of the total pollen. The average concentration of pollen in this zone is 140,983 grains/gram dry weight. The third zone, top from 6cm depth is dominated by *Pinus* and *Quercus* pollen. *Pinus*, *Quercus*, Gramineae and *Salix* pollen were about 39.9%, 32.2%, 10.0% and 7.2%, respectively. The

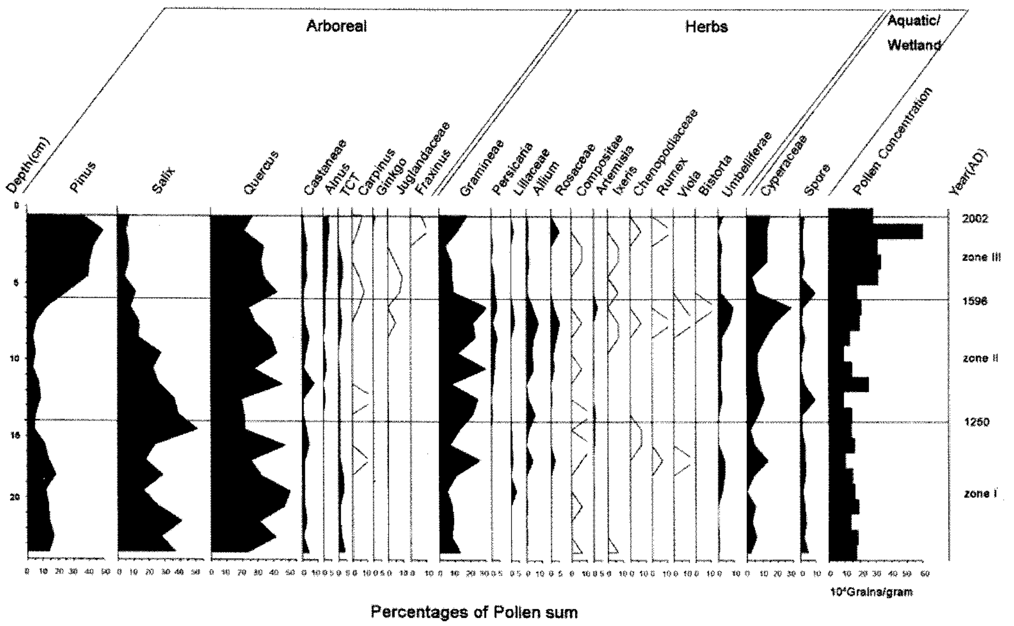

Fig. 3. Diagram of pollen percentage for Wangdeungjae moor. Unshaded curves are ten-fold exaggerations. Horizontal lines indicate ^{14}C-derived sediment dates. TCT (Taxodiaceae, Cupressaceae, Taxaceae).

average concentration of pollen in this zone is 324,028 grains/gram dry weight.

The concentration of *Quercus* pollen was relatively constant along the core as about 33%. However, *Pinus* pollen increased steadily in the top 6 cm. The increase of *Pinus* pollen above 6cm corresponded to the decrease of *Salix* pollen. *Salix* pollen profile reflects water condition; decrease of *Salix* since 1596 (14 cm depth) from 29.1% to 7.2% might be caused by dry condition. Decrease of *Pinus* pollen in uppermost zone was also observed in other researches (Chang *et al.* 1987, Choi 1998, Park and Chang 1998). This pattern can be caused by human impact, extended dry climate, deforestation and infertile soil, etc. Precipitation has been constant but temperature has been increasing recently (Fig. 2). This means that evapotranspiration might increased recently and soil must be drier than before. Therefore, the changing pattern in this study were probably related to extended dry climate. Also, this result coincides with other researches. In Mt. Daeam, *Pinus* pollen has increased since 300 yrs BP (Chang *et al.* 1987). *Pinus* pollen increased in M3b zone (top from 20 cm depth) in Mujechi-neup and dry climate was appointed as major cause of this change (Choi 2001). Also, Park and Chang (1998) concluded the cause of *Pinus* pollen increase in Mujechi-neup might be dry condition.

Gramineae pollen concentration was higher in zone Ⅱ than in other zones. The average Gramineae pollen percentage in zone Ⅰ, Ⅱ and Ⅲ were 11.0%, 21.9% and 10.0%, respectively. The increase of Gramineae pollen reflects increase of open space or agricultural area. In this study, the increase of Gramineae pollen is related to the expansion of grassland because wetland/aquatic taxa (mainly Cyperaceae) were a little bit increasing in zone Ⅱ. Even though wetland/aquatic taxa are very susceptible to water level change (Mitsch and Gosselink 2000) and disturbance, pollen concentrations of aquatic/wetlands plants are constant in this study. This indicates that there was little disturbance and water level change in this wetland.

Pollen concentration gradually increased to the top sediment; the average pollen concentration of whole core was 187,876 grains/gram dry sediment and pollen concentration between 0~5 cm was 324,028 grains/gram dry sediment. Pollen can be preserved for a long time in anaerobic, wet and cool condition (Faegri and Iversen 1989) and pollen concentration is low in the changing condition of water level (Bradbury and Van Metre 1997). Therefore Wangdeungjae moor might be the wet, anaerobic and cool condition since 23 cm (AD 856) because pollen concentration was constant or a little bit increased. The increase of Chenopodiaceae-*Amaranthus* pollen type reflects the increase of human activities or the drawdown of water level (Kim 2001). In this study, exotic plant or Chenopodiacea pollen was less than 1%. *Humulus*, an indicator of nutrification (Mun 1997), wasn't observed all over the sediment. This supports that Wangdeungjae moor has been little effected by anthropogenic activities including anthropogenic input of nutrients.

2. Accumulation Rates of Nutrients, Heavy Metals and Dry Mass

Radiocarbon dating is the most reliable method presently used for the dating of Holocene deposits. Although much development in radiocarbon focuses on the more distant past, Turetsky *et al.* (2004) highlights the potential for high-resolution dating of recent peat since last 300 yrs. Sediments at 5 cm, 10 cm and 14 cm depths were dated as modern, 530±40 yrs BP (AD 1420) and 760±40 yrs BP (AD 1250), respectively. Plant roots were distributed in 5cm depth of the core and dating result appeared as modern.

Table 1 shows accumulation rates of nutrients, heavy metals and dry mass. Overall dry matter accumulation rates were 0.027 kg · m^{-2} · yr^{-1} since 1250 and 0.014 kg · m^{-2} · yr^{-1} since 1420. Overall sedimentation rates in Wangdeungjae moor were 0.184 mm/yr since 1250. It was very low compared to that in Mujechi-neup and

Table 1. Accumulation rates of nutrients, heavy metals, dry mass and sedimentation rates in Wangdeungjae moor

Depth (cm)	Period (AD)	Total C	Total N	Total P	Total Na	Total Ca	Total Mg	Total K
		g m^{-2} yr^{-1}	g m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}
1~10	1420~2002	0.90	0.05	25.57	25.67	139.44	37.09	60.07
11~14	1250~1420	1.09	0.05	27.07	39.87	136.76	48.92	88.58
1~14	1250~2002	0.95	0.05	26.02	29.97	138.63	40.67	68.70
Depth (cm)	Period (AD)	Total Pb	Total Ni	Total Cu	Total As	Total Cd	Dry Mass	Sedimentation rate
		mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	mg m^{-2} yr^{-1}	kg m^{-2} yr^{-1}	mm yr^{-1}
1~10	1420~2002	0.51	0.18	0.21	0.11	9.90×10^{-4}	0.014	0.189
11~14	1250~1420	0.30	0.26	0.29	0.17	9.95×10^{-4}	0.025	0.174
1~14	1250~2002	0.45	0.20	0.23	0.13	9.92×10^{-4}	0.027	0.184

Sanggae-reservoir (0.94 mm/yr and 1.43 mm/yr), which were calculated by ^{210}Pb dating (Kim 2005). Also, sedimentation rate and nutrient (C, N, P) and heavy metal (Pb) accumulation rates were much lower than other researches (Kim and Rejmankova 2001, Kim *et al.* 2001, Wang *et al.* 2004, Kim 2005).

3. Biogeochemical Responses

The result of biogeochemical analyses in sediment is useful for tracing changes in environmental condition. The sedimentation process in aquatic system is affected by environmental changes and sediments record those changes in nutrients (Kim 2003). The averages of bulk density, water contents, LOI, total C content and total N content of sediment in Wangdeungjae moor were 0.063 g/cm^3, 89.2 %, 78.0%, 39.3% and 2.0%, respectively (Fig. 4). The sediment of Wangdeungjae moor was organic peat. LOI decreased from the 10 cm depth to the top. The changing pattern of total C and C/N ratio was similar to that of LOI. LOI, C, N contents and C/N ratio were determined by balance of the production and decomposition of the organic matter. High C/N ratio indicates that the high content of less decomposed plant fragments (Kim 2001). Even though wetlands are in anaerobic and wet condition, organic matters are still decomposed slowly. Therefore, this decreasing pattern from 10 cm depth to the top might come from rapid nutrient cycling through decomposition or high input of N-rich inorganic material.

Nitrogen and P profiles reflect human activities and N and P contents increase with human activities (Kim 2003). Especially human activities such as agricultural drainage have enhanced the transport of P from terrestrial to aquatic environments. There was little variation in total N and P contents along the core (the average P and N contents were 2.0% and 1003 ppm). Phosphorus has a little

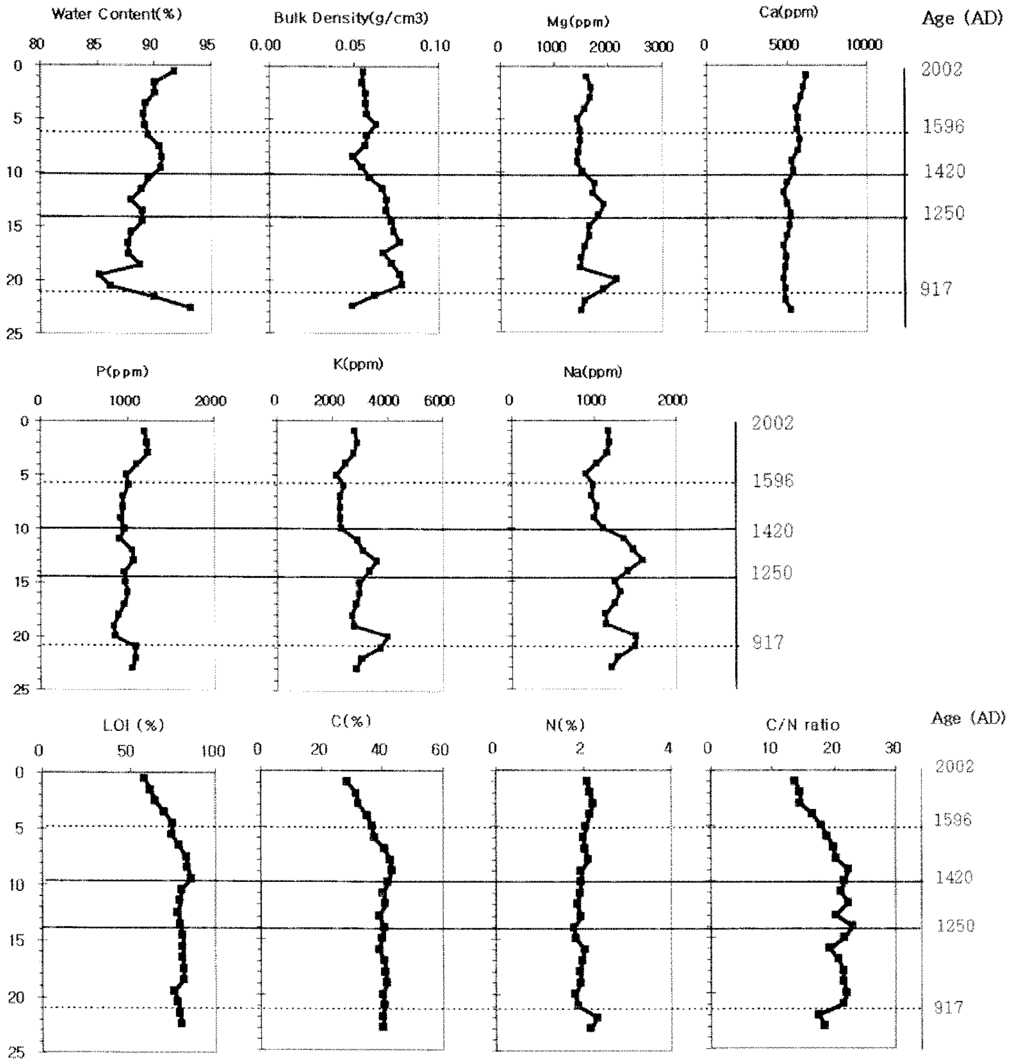

Fig. 4. Depth distribution of nutrient variables in the sediment core collected from Wangdeungjae moor. Horizontal lines indicate ^{14}C-derived sediment dates.

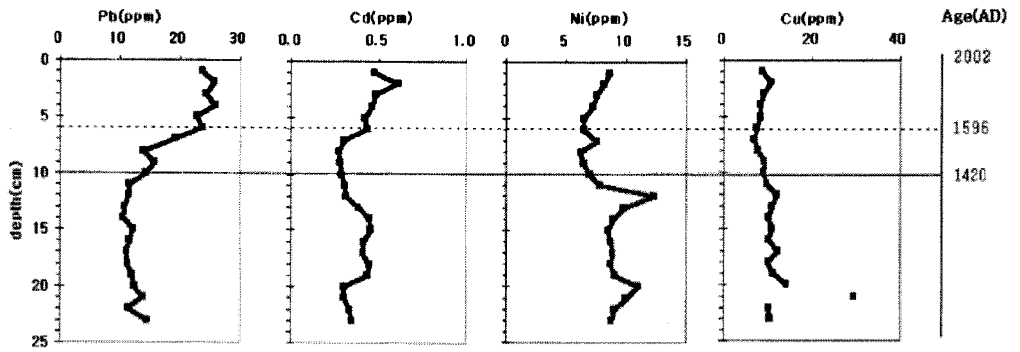

Fig. 5. Depth distribution of heavy metals in the sediment core collected from Wangdeungjae moor. Horizontal lines indicate ^{14}C-derived sediment dates.

bit increased since 1596 (6 cm depth) and this might be related to the input of phosphorus bonded soil. This result indicates that there was no serious input of nutrient from human activities.

Concentrations of cation such as Ca, Mg, K and Na were related to the water source of wetlands and environmental changes. Potassium and Na contents reflect the change of surface water from watershed and Mg and Ca contents are related to groundwater (Schlesinger 1997). Also, other environmental factors such as climate, geographic, ecosystem change and human activities can change the composition of cation. In this study, the averages of total P, Na, Mg and Ca were 2,868 ppm, 1,222 ppm, 1,625 ppm and 5,311 ppm, respectively. Calcium and Mg contents have increased since 14 cm depth (AD 1450) with the peaks at 13 and 20 cm depths. This indicates that the inflow of groundwater plays more important role recently in this wetland. Previous study showed that water is continually provided to this wetland from the groundwater (Ministry of Environment 1998) and our result indicates that this has been occurred since 1450.

4. Heavy Metals

Average contents of Pb, Ni, Cd and Cu were 15.8, 8.4, 0.4 and 10.7 ppm, respectively (Fig. 5). Lead content has increased since 1450 (10 cm depth) and decreased around 5 cm depth and Cd content increased since 7 cm depth. There was no written historical record indicating human activities and the increase might come from hydrological change in Wangdeungjae moor as increase of Ca and Mg contents in this period. Background Pb content in Wangdeungjae moor was much lower than in Mujaechi-neup and Sanggae reservoir, Ulsan (about 30 and 40 ppm, Kim 2005).

SUMMARY AND CONCLUSIONS

For effective ecosystem management, we need to know paleoecological knowledges such as baseline condition and natural variability (Smol 1992). In this study, natural variabilities in sediment characteristics were investigated by analyzing sediment record of Wangdeungjae moor in Mt. Jiri. Pollen, organic and inorganic contents, sediment accumulation rate and heavy metal contents were studied as indicators of past environmental condition. Overall dry matter accumulation rates and sedimentation rates by ^{14}C-dating were 0.027 kg · m^{-2} · yr^{-1} and 0.184 mm/yr since 1250 (760±40 BP, 14 cm in depth).

Pollen concentration was almost constant in the whole core and this implies that Wangdeungjae moor has been kept in the wet, anaerobic and cool condition. Biogeochemical data such as LOI, C, N contents and C/N ratio support this conclusion. Exotic plant or Chenopodiacea pollen was less than 1% and there was little variation in N content along the core. These support that Wangdeungjae moor has been little effected by anthropogenic activities. Calcium and Mg contents have increased since 1450 (14 cm depth) and this implies that the inflow of groundwater plays more important role recently to maintain water level in Wangdeungjae moor. There was no indication of anthropogenic impacts and biogeochemical characteristics and sediment accumulation rates in this study can be considered a baseline in this area.

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