IMPROVEMENT AND MANAGEMENT OF PEAT SOILS IN JAPAN

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Peat and peat bogs

Peat is a deposit of plant remains incompletely decomposed due to adverse conditions for microbiological activity, such as water saturation. World peat deposits are estimated at 277,000 million ton and 121,433 million ha, and Japan's figures indicate 625 million ton and 200,000 ha. These figures, however, only cover peat land in Hokkaido where soil surveys have been conducted since 1912. Recent statistics have revealed that at least 60,000 ha of peat land is under cultivation in the prefectures of Japan except for Hokkaido. Furthermore, taking into consideration the fact that peat deposits of various sizes and shapes are scattered in mountain land all over the country while some of the lowland peat deposits have been hidden by buildings or structures in the valleys of Tokyo and elsewhere, it is reasonable to assume that the total area of peat land in Japan amounts to about 300,000 ha.

According to Uragami and Ichimura (1937), pioneer soil surveyor and peat soil scientist in Hokkaido respectively, "peat soil derived from the natural deposits consists of somewhat humified plant remains and contains more than 50% (weight) of organic matter." "Peat land refers to the land covered by more than 30 cm of peat soil or 20 cm of it after drainage." Recently the limit of organic matter content has been lowered from 50% to 20% to include into the category of peat soils peat deposits related to flooding or volcanic ash fall.

All the peat bogs in Japan are swamp or lowland bogs and no blanket or hill peat bogs commonly found along the Atlantic coast of Northern Europe have been recognized. They are distributed in back swamps of alluvial plains in the northern part of Japan and various wet depressions formed by recent volcanic activities scattered from Hokkaido to Yakushima Is., south to Kyushu.

In the lowlands of Japan, sphagnum peat deposits are distributed in Hokkaido and Shimokita Peninsula, in the northern part of Honshu, where the isotherm of 20°C, mean temperature of July, is crossing. Peat lands large enough for agricultural development projects are found only in Hokkaido where raised bogs of sphagnum peat are expanding because they are free from eutrophic conditions of flooding as they are located relatively higher than the river water level.

Typical or theoretical plane figure of peat land consists of three concentric circles (Fig. 1). The outer zone is the Niedermoor* (low moor) or eutrophic (soligenous) peat land, where reed *(Phragmites communis)* is the main component, bordering with natural levee of river or hillside; the middle zone is the Uebergangsmoor (transitional moor) or mesotrophic peat land, where *Moliniopsis spiculosa* and/or cotton grass *(Eriophorum vaginatum)* are dominant; the inner circle is the Hochmoor (high moor) or oligotrophic (ombrogenous) peat land, where sphagnum moss flourishes thickly with the sedge, *Carex middendorfii* (Fig. 2).

Total area of peat land in Hokkaido, which covers 200,642 ha, consists of 70.6%, 12.4% and 16.9% of low, transitional and high moor, respectively. In the basins and plains of the River Ishikari, peat lands cover 55,000 ha, of which 45.5%, 3.6% and 50.9% are low, transitional and high moor respectively. Relatively high percentage of high moor in Ishikari indicates less volcanic influence than in southeast Hokkaido for the past thousand years although a few cm of volcanic ash layer which was deposited more than 200 years ago has been found at a depth of about 30 cm in sphagnum peat.

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* Since Japanese technical terms in peat soil science were initially introduced from Germany, the term "moor" does not follow the English usage.

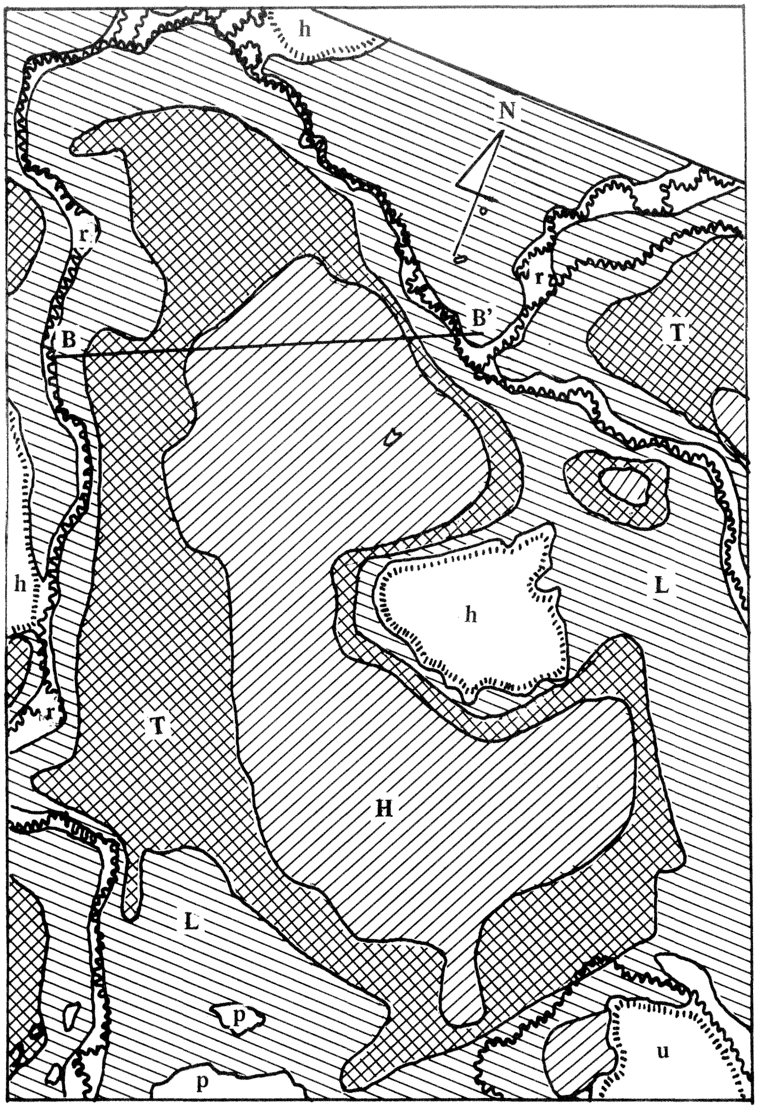

Fig. 1 Plane figure of the Upper Sarobetsu Peat Bogs. Transection of B – B' is shown in Fig. 2
H: High moor, T: Transitional moor, L: Low moor, h: hill, p: bog pool, u: upland,
r: Sarobetsu River and its tributaries.

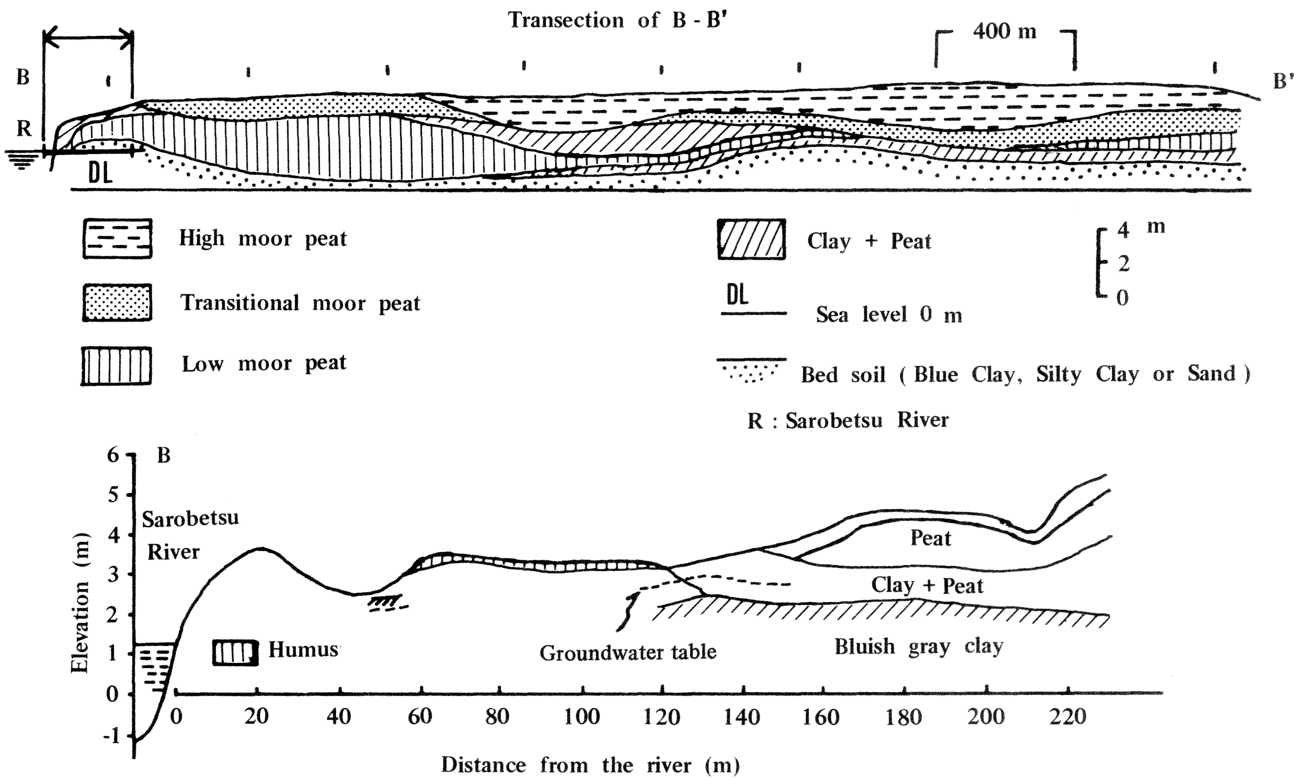

Fig. 2 Transection of the Upper Sarobetsu Peat Bog (B–B'). Peat accumulation started at the shallow back swamp of Sarobetsu River about 3–4000 years ago with the formation of low moor peat.
This was followed by the formation of transitional and high moor peat successively.
The diagram below is an enlargement of the zone indicated by arrows. The surface of peat is several meters higher than the river water level.

Agricultural development in peat lands of Ishikari Plain

As an example, the development processes in the Bibai Peat Bogs on the lower Ishikari River will be introduced in this section.

Colonization of the Bibai area started with the settlement of farmer soldiers belonging to the colonial troops in the 1890s. Up to the 1920s when the main drainage canals were constructed in Bibai Peat Bogs, agricultural activities were confined to the paddy and upland fields of alluvial, mineral soils. Then, cultivated land penetrated into the marginal strips of peat bogs, although the primary vegetation of the high moor part of the bogs had been preserved until the late 1950s when large scale peat land reclamation projects started to meet the nationwide food crisis prevailing after World War II.

In the 1970s, most of the areas were developed as paddy fields. Recently, to alleviate the overproduction of rice, upland crops such as vegetables, various forage crops, soybean, wheat, sunflower, etc. have been introduced into paddy fields and wheat is the most common crop in these areas.

Soil management in upland field

1 Drainage

Although the level of the peat dome is higher than the river levee by several meters, marked subsidence is likely to take place after reclamation. Thus flood control projects such as short cuts, embankment construction, etc. should precede reclamation.

At first the main drainage canal is constructed, then accessory canals are dug up in a herringbone pattern and connected with drainage ditches so as to reach the end of drain pipes buried under the ground (Fig. 3). If sphagnum peat is fully saturated with water or in the initial stage of drainage, drains dug up will be closed again by the expansion and pressure of swollen peat moss. For underground drainage, clay tile and various types of plastic pipes 50 – 100 m long are buried at a depth of 60 – 80 cm, 18 m apart.

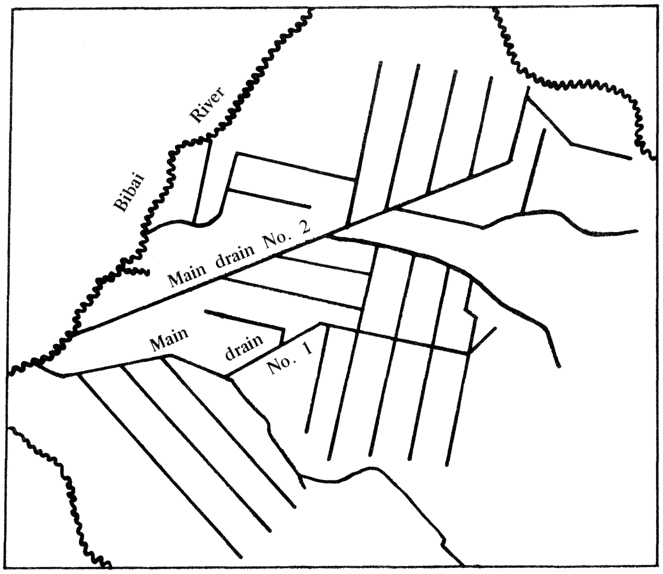

Fig. 3 Development of main drainage systems in the Bibai Peat Bogs.

2 Liming

It is essential to apply lime to get good yield of upland crops, although crops highly tolerant of soil acidity, such as oats, potato and lupin can be grown in peat soils without liming. Buckwheat, maize, soybean and kidney bean show ordinary acidity tolerance, while wheat, barley, naked barley, sugar beet, rape, flax, pea and red clover show low tolerance. One ton of lime (calcium carbonate) per ha is the average dose for upland crops in peat soils.

In the early days of peat land reclamation, burning of cut and dried woods, grasses and sedges was practiced to prepare the fields for cropping, as it is commonly practiced now in Malaysia. After harrowing, the field is planted with crops. The introduction of power tiller in the 1950s enabled the farmers to cultivate a certain depth of fibric peat layer in the first year of cropping.

3 Fertilizer

Among the nutrient elements, nitrogen is relatively abundant in peat soils. Phosphorus is deficient in new fields and yield response to phosphate will decrease by early application. Crop in a new field shows a little response to potassium fertilizer, but after several years crop without potassium produces nearly any yield. Magnesium deficiency appears some years after potassium deficiency. Heavy application of potassium enhances magnesium deficiency. Boron, copper and manganese deficiencies are possible in peat soils. For example, sugar beets planted in well mature or deeply decomposed peat soil fields have been fertilized with 100 kg of N, 150 kg of P_2O_5, 100 kg of K_2O, 50 kg of MgO and 10 kg of borax / ha.

Although peat soil is rich in organic matter, beneficial effect of farmyard manure or compost can be expected in fields of peat soil, because they promote microbiological activity in the soil.

4 Soil dressing

Soil dressing is not as essential for upland fields as it is for paddy fields. However, dressing of mineral soils in peat soils offers the following advantages: mineral soils (1) supply nutrient elements deficient in organic soils, (2) increase soil bearing capacity, (3) increase heat conductivity, (4) increase nutrient retaining capacity and intensity.

Soil management in paddy field

Soil dressing

At least six cm of mineral soil dressing is essential for lowland rice cultivation in peat soil areas. Advantages of and need for soil dressing are based on the following considerations: (1) Trafficability of horses or agricultural machines is increased. (2) Transplanted rice seedlings can stand firmly. (3) Vertical and horizontal permeability of soil is controlled and water management is conducted much more easily. (4) Too high and too rapid mineralization of soil organic nitrogen, which may delay heading and increase the frequency of sterile and immature grains, is controlled. (5) Mineral soil supplies nutrients and increases retaining capacity and intensity of fertilizer elements. (6) Floating up of surface soil, which is likely to occur in a newly opened field is prevented.

Formerly, soil dressing was done by the farmer's own means. In winter, mineral soil obtained at nearby river levee was transported to a farmer's field by a horse sleigh, sliding on hard snow. In a large project, a fleet of steel box sleighs fully loaded with soil was carried by crawling tractor over the snow. As soils for dressing became hardly available near the river banks, in the public peat land reclamation project at Bibai, a diluvial hill was allocated to supply soil materials. The soil moved from the hill to the soil deposit in the lowland by a rope way with hanging buckets. In the areas where road systems were not well established, soil was brought from the deposit to a field by hand-propelled trucks on light rails, which could be shifted from field to field.

Appropriate quantity and quality of soil dressing were determined in several experiments carried out in the Peat Soil Experiment Station in Bibai, and some of the results are presented in Tables 1 and 2. As soils from diluvial hill are poor in nutrients, rice yields in the plots of those

Table 1 Amount of mineral soil subjected to dressing and rice yield

(Average for 6 crops)

Depth of mineral soil (cm)	0	3	4.5	6	9	12
Yield, brown rice (ton/ha)	3.44	4.02	4.16	4.30	4.26	4.30
Index	100	117	121	125	124	125

Table 2 Texture of mineral soil subjected to dressing and rice yield

(Six cm of mineral soil was placed on high moor peat)

Mineral soil	Yield, brown rice (ton/ha)					
	1961	1962	1963	1964	Mean	Index
Without mineral soil	4.64	5.11	4.28	2.99	4.26	100
Sandy soil from diluvial hill	4.13	4.01	4.35	3.74	4.06	95
Clayey soil from diluvial hill	4.41	4.18	4.43	3.43	4.11	96
Clay from river bottom	7.31	5.10	4.12	3.88	5.10	120
Riverine sandy loam	5.91	5.29	4.73	3.84	4.94	116
Riverine clay	6.18	4.83	4.12	3.45	4.65	109

soils were lower than those of the control plot. But, the yields became higher with cropping time, because chemical properties of the mineral soil could be improved by fertilization and mineralization of peat layer.

Rice culture

1 Variety

As rice plants grown in peat soil have a low Si content and a comparatively high N content, they are susceptible to pests and diseases. Among those, rice blast used to be the most harmful disease, until highly resistant varieties were released from the Experiment Stations.

2 Fertilization

Mineral soil is one of the best sources of available silica, but an additional dressing of mineral soil on the peaty field is not an economic way to supply silica to rice plants. One or two ton per ha of furnace slag from the iron and steel industries consisting of calcium silicate has been used as silicate fertilizer in fields with low silica availability.

Standard doses of macronutrients in peaty paddy fields are 40 kg of N, 60 kg of P_2O_5 and 40 kg of K_2O/ha. Under submerged conditions, a large amount of ammonium nitrogen is mineralized and released from the peat, thus fertilizer may only serve as a starter in the initial stage of growth. As a result, the total nitrogen uptake of plants becomes always higher than the amount of application.

Phosphate application is essential, as phosphorus is lacking in the soil, while the utilization coefficient of phosphatic fertilizer is rather high, since the phosphate sorbing force is very weak in organic soil, in spite of a higher capacity.

In a few crops after reclamation, Helminthosporium leaf spot, which is thought to indicate potassium deficiency, can be observed, but the effect of potassium application is not so conspicuous presently, possibly due to adequate supply from irrigation water as long as rice roots keep a healthy condition.

Even after mineral soil dressing, the effect of farmyard manure or compost on the rice yield is strongly felt in peaty paddy fields, although the soil is very rich in organic matter.

3 Control of the water level

The control of the water level in the drainage canals bordering paddy fields, in particular the vertical movement of surface water is the most important agronomic practice for rice cultivation in peaty soil areas.

In the early growth stages, in early summer, water gates are closed to raise the water level for preventing the percolation of irrigation water through the soil layer, because excessive leaching out results in a loss of nutrients and a lowering of soil temperature. In midsummer, the rise in temperature exerts adverse effects on rice growth in the peaty layer of paddy soil. It is then necessary to reopen the water gates to increase the amount of percolating water, for washing out the toxic substances from the soil. After several days, the water gates are closed again to keep the water level of the field stable until the ripening stage of rice.

4 Sterility in new field

In peat soil areas, sometimes abnormal growth and high sterility of rice plants are being encountered in the newly opened paddy fields or in the paddy fields converted from grassland. Water level control mentioned above is a means to control those phenomena. Recent studies on abnormal panicles or sterility observed in the paddy fields of acid mineral soils to which wheat or barley straw had been applied in Saitama Prefecture suggest that these disorders are caused by the harmful substances produced by delayed and incomplete decomposition of organic materials. The disorders can be grouped into 3 types as follows:

Type A (Dwarf stem and panicle, long, sterile spikelets and interrupted heading)
Type B (Normal stem but abnormal panicles, less fertility and long spikelets)
Type C (Normal growth with high sterility, 30 – 90%)

It can be assumed that the release of harmful substances depending on the stages of growth of rice results in different types of abnormalities. In a pot experiment, the adverse effect could be alleviated by drainage.

References

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Discussion

Somasiri, S. (Sri Lanka): 1) What would be the cost of soil dressing per hectare? 2) When you drain the peat soils with soil dressing, is the subsidence different from the case when peat is drained without soil dressing?

Answer: 1) The cost would amount to 700,000 yen (3,200$) per hectare. 2) Subsidence of peat land is caused by both compression and decomposition. Subsidence is more serious in case of soil dressing and compression is enhanced although decomposition is delayed. Without soil dressing, there is less subsidence particularly if heavy machinery is not used.

Watanabe, I. (IRRI): I believe that in the tropics heavy soil dressing as it is practiced in Japan would be difficult. Is there an alternative way of improving peat soil productivity without soil dressing, as presently in the tropics many peat areas are under reclamation?

Answer: Experiments on crop cultivation on peat soil both in paddy and upland fields were successfully carried out at the Peat Soil Research Station in Bibai in 1948–1954 by the application of lime, nitrogen, phosphorus and potassium fertilizers and farmyard manure or compost without mineral soil dressing. Such a method can only be applied on a small scale. Physical properties of peat soils such as excessive percolation of water, workability of machines can hardly be improved without soil dressing.

Tanaka, A. (Japan) **Comment**: In Hokkaido, grassland agriculture is commonly practiced on peat soils without soil dressing.

Hew, C.K. (Malaysia): Can you use peat for composting, aquaculture or horticulture?

Answer: As peat lands in Japan are of the swamp type, after digging of peat, only ponds or lakes would be left. Thus peat digging is authorized only in restricted areas. For horticultural purposes, sphagnum peat is being imported from northern Europe and the United States.

Sakuma, T. (Japan): In the northeastern districts of Hokkaido peat lands are being developed as upland fields for the cultivation of forage crops. In such cases, subsurface drainage systems and canals are essential, but mineral soil dressing is not always recommended. When the mineral matter content of the top soil is lower than 60%, mineral soil dressing is advisable. The amount of mineral soil for dressing is in the range of 25 m^3/ha and 75 m^3/ha.