Permeability Series of Lowland Paddy Soils in Japan

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It has become more generally realized that the pedogenic characters of paddy soils are typically developed in the soils with low ground water table. In such soils surface water (high in potential energy) and percolating water continue to exist for the greater part of the rice-growing season, which is followed by desiccation upon drainage. This unique water regime, combined with the intensive management practices, brings about qualitatively new pedogenic processes characteristics of paddy soils.

Kamoshita[2] classified the soils of lowland paddy fields into Peat Soils, Muck Soils, Meadow Soils (Gley Soils), Gray Lowland Soils and Brown Lowland Soils according to the hydrological situations (conveniently termed here 'catenary' series).

His system has been criticized, however, for the reason that the characters acquired through rice cultivation were disregarded, rice-growing being considered merely as a type of land utilization.

Several authors[3),5),7),9)] have since then proposed the classification systems of paddy field soils, each placing emphasis on the pedogenic characters of paddy soils.

In these systems, however, possibly with one exception[7], the soils of paddy fields are divided into several groups according to the intensity of ground water hydromorphism. Distinction between Ground-water Gley, Intermediate gley-like and Surface-water gley-like Rice Soils[3] is an example for this.

Therefore, these systems are also 'catenary' in character and may be regarded as attempts to classify the intergrades between 'paddy soils' and natural hydromorphic soils.

Recently Kyuma and Kawaguchi[4] proposed a great soil group 'Aquorizem' for those paddy soils which exhibit a horizon differentiation between the eluvial and illuvial horizons of iron and manganese. Thus they excluded from 'Aquorizem' such hydromorphic soils as Peat, Muck and Gley Soils that do not exhibit the horizon differentiation rice cultivation.

However, recent investigations have indicated that the pedogenic processes occurring in paddy soils cannot be confined to the eluviation-illuviation process alone as done by many authors cited above. Field observations have further suggested that different types of paddy soils can arise within paddy soils with low-water table according to the difference in the permeability of soils[6),7)].

Genesis and characteristics of paddy soils of permeability series

In lowland paddy fields where ground-water table is sufficiently low, three different types of paddy soils are distinguished. Different types arise principally from the difference in the degree of water saturation under flooded condition. The degree of saturation is chiefly governed by texture and pore-size distribution, which, in turn, determine the permeability of soils.

Generally speaking, in coarser-textured and/or loosely packed soils a saturation and resultant reduction occurs only in the upper horizons, whereas in finer-textured and/or densely packed soils a reducing condition spreads to a greater depth in the profile.

1) Brown Lowland Paddy Soils (Fig. 1)

Highly permeable paddy soils which normally develop on sandy and/or porous materials. Beneath the plough layer is invariably formed a densely packed plough pan, which enhances the separation between water-saturated upper horizons and aerobic subsoils.

The upper horizons including the plough pan have gray colored matrix with some

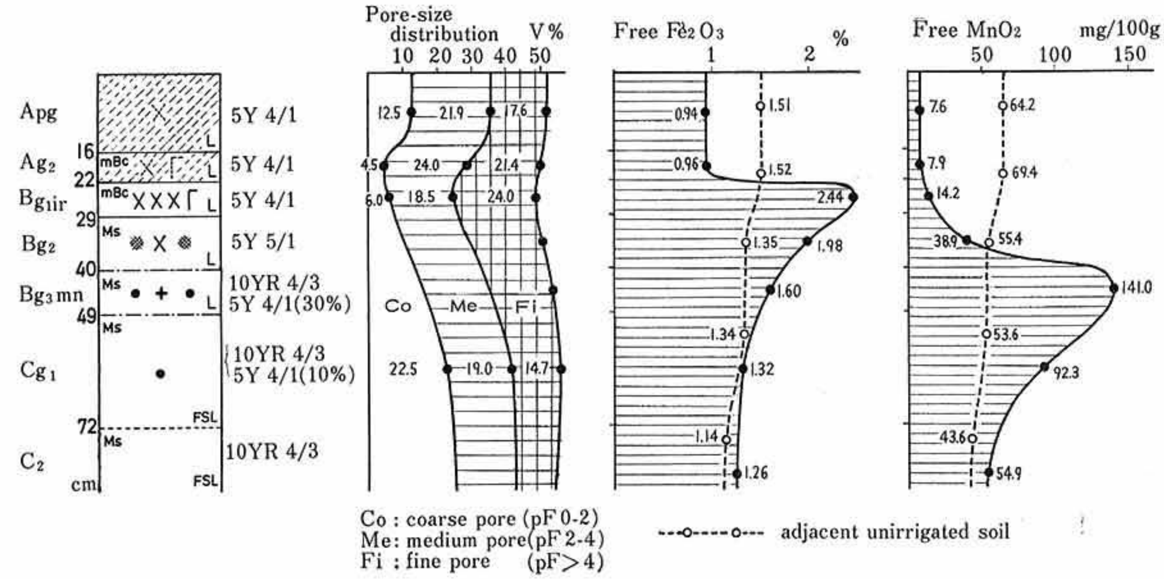

Fig. 1. An example of Brown Lowland Paddy Soils (Sekijo, Ibaraki Prefecture)

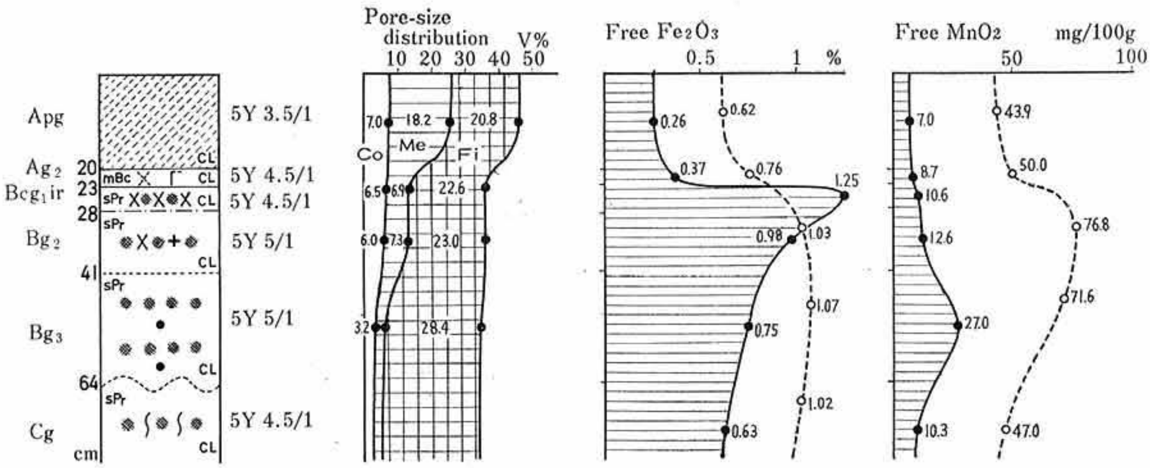

Fig. 2. An example of Gray Lowland Paddy Soils (Tadotsu, Kagawa Prefecture)

rusty mottles caused by seasonal reduction and oxidation, while the subsoils retain the original brown color indicating continuously oxidizing condition. Eluviation-illuviation process of iron and manganese is marked in these soils. Fe^{II} and Mn^{II} leached from upper horizons are oxidized and precipitated nearly quantitatively when they reach the porous and aerobic subsoil, resulting in the marked development of illuvial horizons in the uppermost part of the brown colored subsoils. The subsoils abound in coarse pores and

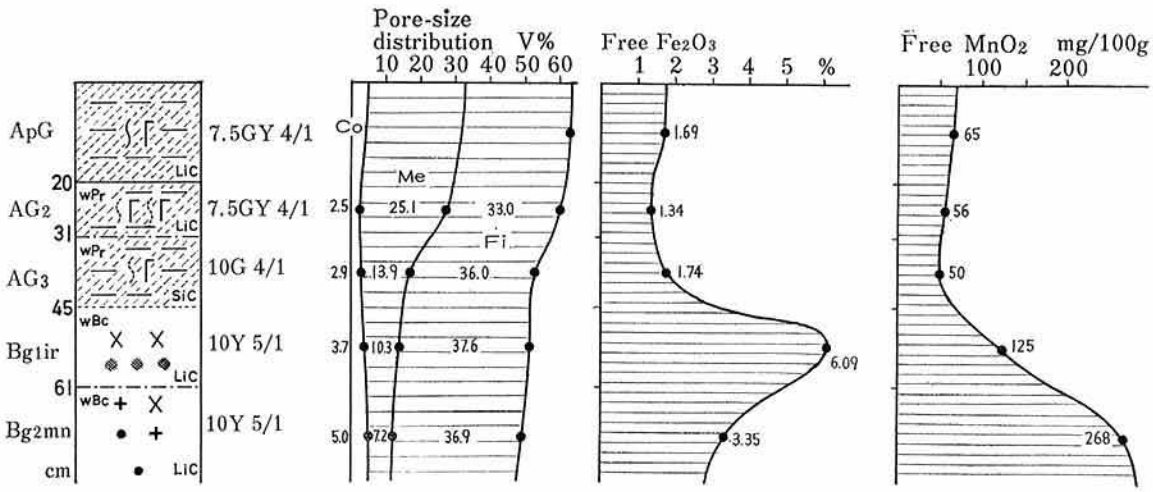

Fig. 3. An example of Hanging-water Gley Lowland Paddy Soils (Azai, Shiga Prefecture)

Rusty mottles
shape......... X thread-like, ferruginous
ʃ tube-like, ferruginous
cloud-like, ferruginous
\+ thread-like, manganiferous
• spot-like, manganiferous
abundance..... X few XXX plenty
XX common XXXX abundant
contrast...... X, ʃ strongly contrasted
X, ʃ weakly contrasted
Structures
shape......... Bc; blocky
Pr; prismatic or columnar
Ms; massive
development... w; weak, m; medium, s; strong
Strong gleyzation........ — — —
Horizon boundary... —— sharp, —·—·— clear, -------- gradual
Organic matter... □ <2%, ▨ 2–5%

Illustrations of the symbols in the columnar sections of soils in Figs. 1 to 3 are unsaturated with water even under flooded condition.

Typical horizon sequence is gray eluviated horizons (Apg, Ag_2..)/Fe·Mn-illuvial horizons (Bgir, Bgmn)/brown residual horizons ((B)).

2) Gray Lowland Paddy Soils (Fig. 2)

These soils develop on the materials more clarey and/or more densely packed than those of Brown Lowland Paddy Soils. This physical nature of materials causes a saturation of water throughout the profile under flooded condition, and consequently a reducing condition spreads to a greater depth in the profile. Long-term alternation of flooding and drainage leads to the development of thick gray colored profiles.

Iron and manganese are severely leached from the upper horizons that become strongly reduced under flooded condition. The behavior of the iron and manganese after leaving the upper horizons is rather different from that in Brown Lowland Paddy Soils. As subsurface soil is rather strongly reduced, Fe^{II} and Mn^{II} leached from the upper horizons cannot be oxidized there, but are adsorbed in considerable part by clay minerals[8].

Upon drainage they leave the exchange sites and precipitate forming thread-, spot- or film-like rusty mottles. But some part of Fe^{II} and the greater part of Mn^{II} are removed from the profile being carried by percolating water.

It should be stressed that eluviation of iron and manganese considerably occurs also from subsurface soils that become rather strongly reduced under flooded condition. The enrichment of iron and manganese in subsurface illuvial horizons is, therefore, the net effect of the two opposite processes, illuviation of Fe^{II} and Mn^{II} leached from the upper horizons and eluviation of those generated in-suit. Consequently the development of the illuvial horizons is less pronounced than in Brown Lowland Paddy Soils.

Weakly reducing condition also spreads to the lower horizons, it being particularly distinct in the vicinity of pores (inter-ped pores and conducting channels). Eluviation of iron and manganese occurs considerably from the matrix facing these pores, which gives rise to the characteristic mottled patterns with the gray colored part spreading along the pores and cloud- or spot-like rusty mottles in the matrix (a process closely resembling pseudogleyzation).

Distinct loss of iron and manganese from the profile is the characteristic feature of these paddy soils. Alternate expansion and contraction encourage the formation in subsoil of blocky or columnar structures of which the surfaces often have grayish luster (cutanic feature).

These soils have normally the horizon sequence of gray eluviated horizons (Apg, Ag_2..)/gray Fe·Mn-illuvial horizons (Bgir, Bgmn)/pseudogley-like horizons (Bg).

3) Hanging-water Gley Lowland Paddy Soils (Fig. 3)

Very clayey and impermeable paddy soils that have gley surface and subsurface horizons* of considerable thickness are underlain by gray illuvial horizons*. It is hanging-water held by soil against gravity that permanently saturates the upper horizons and causes gleyzation (Hanging-water gley horizon). Some other factors than heavy texture and impermeability appear to be necessary for the formation of this horizon, e.g. dominance of expanding clay minerals, ample supply of fresh organic matter and sufficient amount of free iron oxides, etc.

Eluviation of iron and manganese, although weak due to impermeability of soils, occurs from hanging-water gley horizons, and weakly developed illuvial horizons usually form in the lower part of the profile.

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* In many other countries our Gley Soils and Gray Lowland Soils are collectively termed Gley or Meadow Soils. In Japan Gley Soils are restricted to those strongly reduced soils which contain sufficient amount of active Fe^{II} ion capable of reacting readily with α-α' dipyridyl solution to impart a red color to soils. The same applies for the distinction between gley and gray horizon.

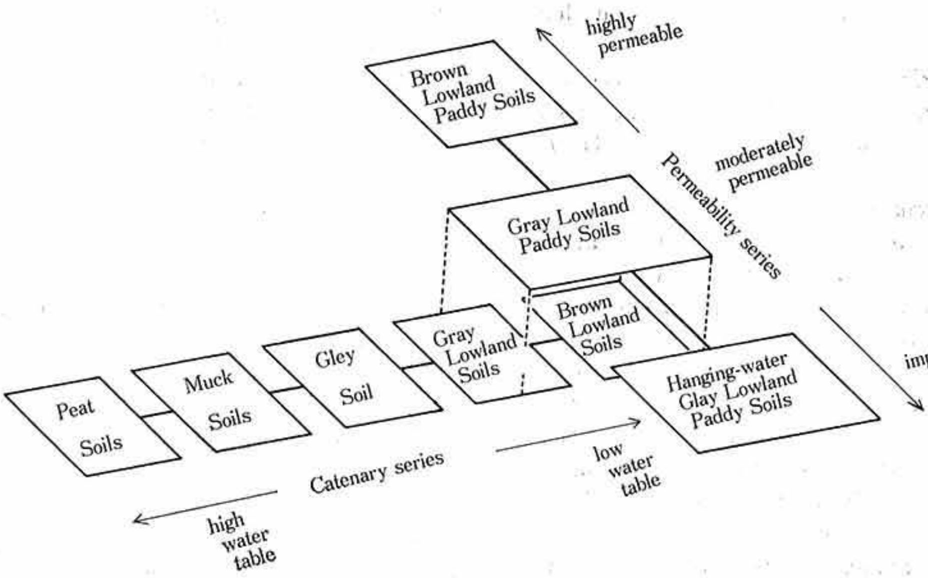

Fig 4. Relation between permeability series and catenary series

Paddy soils of this type normally have the horizon sequence of hanging-water gley horizons (AGp, AG_2..)/gray Fe·Mn-illuvial horizons (Bgir, Bgmn)/pseudogley-like horizons (Bg) or gley horizons (G).

Relation between 'permeability' series and traditional 'catenary' series

As mentioned before, the soils of lowland paddy fields have long been classified into Peat Soils, Muck Soils, Gley Soils*, Gray Lowland Soils* and Brown Lowland Soils[2] (catenary series). In the case of the former three and a part of Gray Lowland Soils, rice cultivation does not change, or modifies only slightly the original soil characters because it brings about no significant changes in the water regime.

In the case of Brown Lowland Soils and a part of Gray Lowland Soils, long use for rice cultivation can change the soil characters strongly, and three different types described above result depending on the difference in the permeability of soils.

The changes caused by rice cultivation are generally by far stronger in Japan than was realized in tropical Asia[1]. This could be attributed both to higher organic matter status and to higher activity and hence reducibility of iron and manganese, which may be closely associated with the temperate and prehumid climate with no distinct dry season in Japan.

Soils in lowland paddy fields should, in the writer's opinion, be classified based on the combination of two soil series, permeability series discussed here and traditional catenary series, as presented in Fig. 4.

Paddy soils of permeability series have as a whole a unique combination of characters that deserve to distinguish them from original soil types as well as from any natural hydromorphic soils so far known. The difference between the three types also appears to be that in kind rather than that in degree. These facts should be taken into consideration in classifying these soils.

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