Classification of Cultivated Soils in Japan

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Introduction

Some descriptions on the classification of arable soils are found in a textbook for agricultural practices written by S. Doi early in the 17th century in the Edo period. However, the work of M. Fesca et al., started in 1882, seems to have been the prolog to systematic soil-surveys in Japan. A century has elapsed since the first soil map[8,22] was published. The survey had covered about eighty percent of Japan by 1920. It laid much emphasis on nature of parent materials, from which survey methods proposed by Aso et al.[6] were partly inherited, whereas succeeding pedologists[9,14] were eager to reflect soil-forming factors and morphology to soil classification.

Later, assimilating progress in soil science, a soil survey for the Fertilization-Improvement Program from 1953,[4,5] and a soil survey for the Soil Conservation Project from 1959[3] were carried out by Ministry of Agriculture and Forestry, and prefectural authorities. The surveys had covered five-million hectares, or eighty-five percent of the cultivated land with the soil maps at a scale of one to fifty thousand until 1975. Some of the data were condenced in a soil map at a scale of one to two-million.[13] A large number of local soil series were being used through the surveys. Necessity for the correlation among these soil series has been increasing among soil-map users. The current classification system[17,18] has been prepared to answer to the request.

On the abovementioned background, the objects of the classification are neither soils outside the agriculture nor soils in foreign countries but cultivated soils in Japan.[11] Forest soils have another classification system.[10] Soil properties reflect combined effects of genetic factors. However, these factors or soil-forming processes themselves are not suitable for use as differentiae. For the differentiation between soils are used morphological features or properties which can be observed and measured in the field. This permits greater uniformity to the classification as applied by a number of soil scientists.

Environment around soils

Japan is an island country, situated off the east coast of Asia. The four main islands, viz., Honshu, Hokkaido, Kyushu and Shikoku, account for the thirty-six million hectares within thirty-seven million hectares of total area exclusive of water. The latitudinal range between 24°N and 46°N, and the location between Eurasia and the Pacific Ocean, between longitudes 123°E and 146°E, are the chief controlling factors of climate, vegetation and geology.

The climate ranges from subarctic to subtropical with mean annual temperatures between 5°C and 23°C, and frequent visits of typhoons and moisture-bearing monsoons ensure abundant precipitation between 800 mm and 4,000 mm annually. Accordingly Japan has neither Aridisols nor Oxisols. Soils of udic and perudic moisture regimes are able to support an appreciable amount of biomass, which helps humus accumulation on the soil surface.

Complicated geology gives wide variety to parent materials of soils. Igneous rocks and Tertiary sedimentary rocks dominate, and locally, Paleozoic or Mesozoic sedimentary

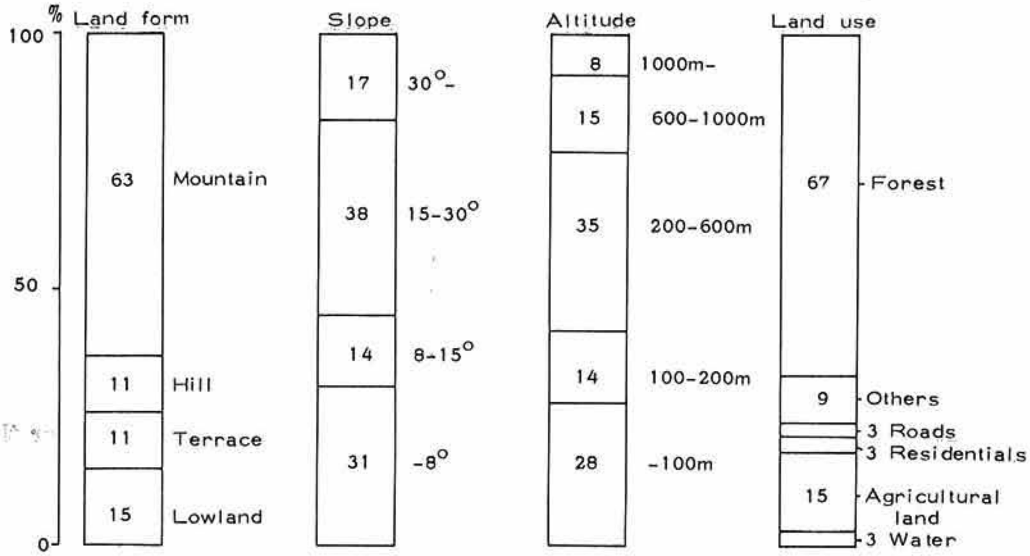

Fig. 1. The land surface (38 million ha) and land use (National Land Agency, 1976)

rocks and metamorphic rocks distribute on the Pacific side of the so-called Medium-Tectonic line. Geologically these rocks compose seventy-nine percent of Japan. However, the island arc of Japan, located in the western part of the circum-Pacific ring of fire, has numerous violent volcanoes. Volcanic ejecta are wide-spread, which alter and form Andosols. Unconsolidated materials of Holocene or Pleistocene deposits cover twenty-one percent of land surface, where agriculture is concentrated. Intensive paddy-rice cultivation is found on the Holocene fluviatile deposits (Fig. 1).

Mountains dominate Japanese landscape. Mountains and steep slope limit land use of Japan. About two-thirds of the land are covered with forests, viz., subtropical temperature, evergreen-broadleaved, cool-temperate deciduous, and subarctic coniferous forests. Only fifteen percent of the land is flat lowland, which has permitted paddy-rice cultivation for thousands of years and supported the dense population.

Outline of the soil classification system

Cultivated soils in Japan are classified into soil groups, soil series-groups and soil series, as the higher, medium and lower classification units, respectively.

Cultivated soils are classified into eighteen soil groups according to their morphology and parent materials, as shown in Table 1.

The most extensive soil groups are derived from pyroclastic materials, which are Andosols, Wet Andosols and Gleyed Andosols. Gray Lowland soils and Gley soils follow them. These five major soil groups cover about sixty percent of the cultivated land (Fig. 2).

The soil groups are divided into fifty-six soil series-groups on the basis of such morphological variations as thickness of humus layers, mottling and texture.

The soil series is the basic unit of the classification. A soil series is a group of soils from almost similar parent materials and with similar morphology, resulting from similar process of soil formation. Three-hundred

Table 1. Soil groups in Japanese system, and the correlations with great groups in US Soil Taxonomy[16] and soil units in FAO/Unesco Soil Map of the World[7]

Japanese system	US Soil Taxonomy	FAO/Unesco Soil Map of the World
Soil groups	Great groups (Subgroups)	Soil units
Lithosols	Lithic Udorthents	Lithosls Rankers
Sand-dune Regosols	Udipsamments	Dystric Regosols
Andosols	Hydrandepts (Vitrandepts)	Humic Andosols (Vitric Andosols)
Wet Andosols	Aquic Hydrandepts, Andaquepts	Andosols (Gleyic)
Gleyed Andosols	Andaquepts	Andosols (Gleyic)
Brown Forest soils	Dystrochrepts	Dystric Cambisols
Gray Upland soils	Haplaquults (Eutrochrepts)	Gleyic Acrisols (Eutric Cambisols)
Gley Upland soils	Haplaquepts	Dystric Gleysols
Red soils	Hapludults	Orthic Acrisols
Yellow soils	Hapludults Aquic Hapludults	Orthic Acrisols Gleyic Acrisols
Dark Red soils	Rhodudults Rhodudarfs	Acrisols (Rhodic) Luvisols (Rhodic)
Brown Lowland soils	Udifluvents Fluvaquentic Dystrochrepts	Eutric Fluvisols Dystric Fluvisols
Gray Lowland soils	Haplaquepts	Eutric Gleysols
Gley soils	Haplaquents Haplaquepts	Eutric Gleysols
Muck soils	Saprists	Dystric Histosols
Peat soils	Fibrists Hemists	Dystric Histosols
Man-made Upland soils	Arents	
Man-made Lowland soils	Arents	

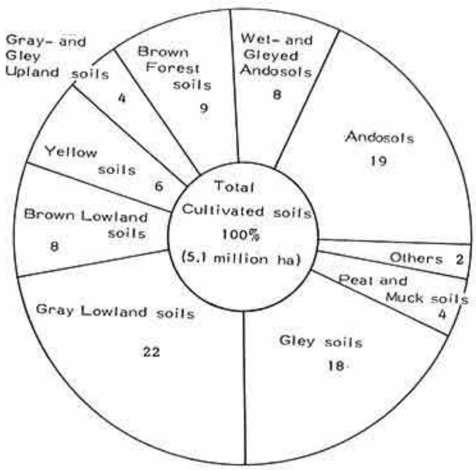

Fig. 2. The extent of soil groups in cultivated land

and twenty soil series have been recognized until 1983.

1) *Criteria for the differentiation of soils*[19,20,21]

A. Humus layer

Soils are divided into 5 classes on the basis of humus content and thickness of humus layers.

(1) Thick high-humic horizon
(2) Thick humic horizon
(3) High-humic horizon
(4) Humic horizon
(5) Low-humic horizon

B. Color of subsurface horizon

C. Lithic contact

D. Pan

Pan is a layer with compactness index higher than 29 by a cone penetrometer of Yamanaka type.

E. Mottling

F. Texture

G. Soil structure

Plate 1

Plate 2

Plate 3

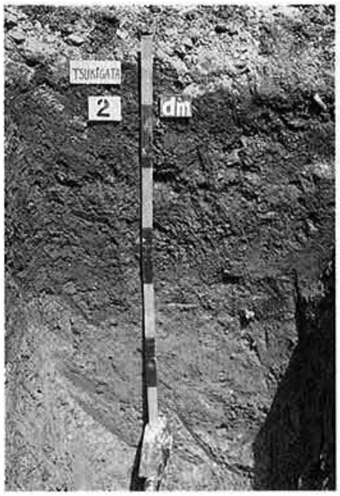

Plate 4

Plate 5

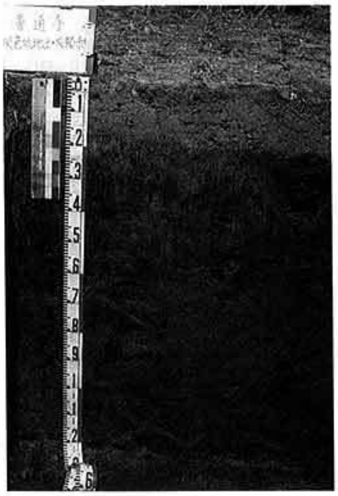

Plate 6

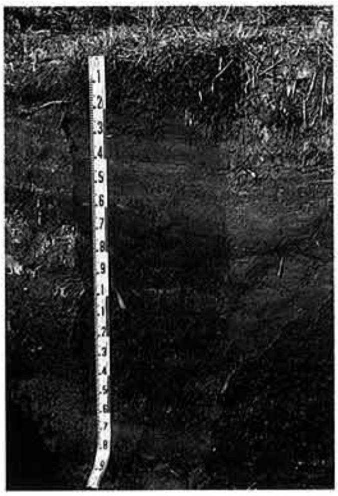

Plate 7

Plate

1. A surface expression of Andosols. Fuji, Honshu.
2. Road cut showing horizons of an Andosol with buried tephra layers (scale: 1 m). Miyazaki, south Kyushu.
3. A Thick High-humic Andosol scale in 20 cm). Tokachi, Hokkaido.
4. A Brown Forest soil (scale in 10 cm). Hokkaido.
5. A Gray Upland soil (scale in 10 cm). Hokkaido.
6. A Gray Lowland soil, gray-brown type (scale in 10 cm). Zentsuji, Shikoku.
7. A High-moor Peat soil (scale in 10 cm). A Sphagnum-peat layer with a lower boundary at 60 cm overlies a low-moor peat layer. Bibai, Hokkaido.

H. Peat and muck layers

I. Gley horizon

Gley horizon shows bluish gray or gray color and positive reaction to 2,2′-dipyridyl test.

J. Parent materials and the mode of formation

(1) Pyroclastic materials; volcanic ash, pyroclastic-flow deposits etc.

(2) Residual materials

a) Igneous rocks; agglomerate, rhyolite, andesite etc.

b) Consolidated sedimentary rocks; conglomerate, sandstone etc.

c) Metamorphic rocks

(3) Pleistocene deposits (old alluvium)

(4) Holocene deposits (recent alluvium)

(5) Colluvial deposits

(6) Dune sands

(7) Organic materials; high-moor peats, low-moor peats etc.

(8) Man-modified materials

K. Soil pH

Brief explanations of soil groups

1) Lithosols

Lithosols have lithic or paralithic contact within 30 cm of the surface. They are low-productive due to shallow soil, erosion and acidity. Lithosols are found on steep slope of hills and mountains, and partly used for tree crops.

2) Sand-dune Regosols

Japan is an island country, surrounded by a long (27,000 km) and largely irregular coastline. Sand dunes are common features. Sand-dune Regosols are coarse-textured soils derived from eolian sand in coastal plains. Their characteristics are low water-holding capacity, low CEC and low content of nutrients. They are mostly used for vegetables and ornamental crops.

3) Andosols

Numerous volcanoes traverse the Japan island arc, paralleling the backbone-mountain ranges. Volcanoes have frequently provided a vast amount of ejecta since the Pleistocene epoch. The ejecta have extended to the eastern side of the island arc under the influence of the strong westerly jet-stream which has been blowing in the stratosphere. The tephra, therefore, cover the land independently of landform except steep slope or recent flood plain.

Andosols are developed from air-borne, mainly andesitic and dacitic, volcanic ejecta. They have dark epipedons rich in organic matter accumulated under the well-drained conditions. They show specific physical and chemical properties due to high content of active aluminum, such as high content of humus, high C/N ratio, high phosphate fixation, low base-saturation, low content of available phosphorus etc.

One-half of upland crops and one-fifth of tree crops are raised on Andosols. The agricultural production on Andosols has markedly increased by the heavy application of phosphate since 1960.

Andosols are divided into five soil series-groups by the difference in humus content and the thickness of humus layers.

4) Wet Andosols

Wet Andosols are developed from volcanic ejecta under somewhat poorly-drained conditions and have mottlings due to ground water or sometimes due to irrigation water. Wet Andosols also have dark epipedons rich in organic matter.

They are spread in depressions adjacent to Andosol area and partly in alluvial bottom land. Chemical properties of these soils are almost the same as Andosols, but the drainage is a problem for Wet Andosols. Tile-drain is usually employed for them.

About eighty percent of the soils are used for paddy-rice cultivation, and the remainder in north Japan are used for upland crops. Wet Andosols are divided into five soil series-groups by the difference in the thickness of humus layers and humus content.

5) Gleyed Andosols

Gleyed Andosols are developed mainly from secondary deposits of volcanic ejecta under water-saturated conditions and have gley horizons which show positive reaction to 2,2'-dipyridyl test. They also have dark epipedon rich in organic matter and frequently have peaty subsoils.

Gleyed Andosols occur on the Holocene lowlands and sometimes in depressons on the Pleistocene terraces. Most of them are used for paddy-rice cultivation. Drainage, phosphate application and top-dressing of clay are practiced for the soil amelioration. Gleyed Andosols are divided into three soil series-groups by the difference in humus content.

6) *Brown Forest soils*

Brown Forest soils are well-drained soils with yellow-brown subsurface horizons. They are developed from various parent materials, viz., igneous rocks such as andesite or rhyolite, metamorphic rocks, consolidated sedimentary rocks, and pleistocene deposits on terraces. Erosion, shallow solum, and low fertility are main problems for them.

They are wide-spread in mountainous area throughout Japan, but small part of them are cultivated and used for upland crops, tree crops and pasture.

Brown Forest soils are divided into three soil series-groups by the difference in texture.

7) *Gray Upland soils*

Gray Upland soils are characterized by gray color of the subsurface horizons and commonly have mottlings due to stagnant water. They are developed mostly from Pleistocene fine materials and sometimes from marl in the Southwest islands. They usually have thin, low-humic epipedons and very compact subsoils. Their base saturations are usually very low, whereas their CEC are high. They are used mainly as paddy-rice field and partly as upland field and grassland.

Gray Upland soils are divided into three soil series-groups by the difference in texture.

8) *Gley Upland soils*

Gley Upland soils are developed under poorly-drained conditions on Pleistocene terraces. They are characterized by gley horizons. Most of the soils are used for paddy-rice cultivation. Gley Upland soils are divided into three soil series-groups by the difference in texture.

9) *Red soils*

Red soils are developed from various parent materials such as igneous or sedimentary rocks as well as Pleistocene unconsolidated sediments under humid, warm to temperate climate in west Japan. Red soils are characterized by thin, low-humic A horizons and red-colored B horizons. They are strongly acid and have extremely low base-saturations.

Red soils occur sparsely on terraces and hills of low altitude near seacoasts. They are used for upland crops, tree crops and grasses. They are divided into three soil series-groups by the difference in texture.

10) *Yellow soils*

Yellow soils are developed under humid-warm and humid-temperate climates. Their morphology and distribution are apparently similar to those of Red soils except yellow color of subsurface horizons. Some of them are somewhat poorly drained. They are divided into six soil series-groups by the difference in texture and mottlings.

11) *Dark Red soils*

Dark Red soils are developed under the similar climate to those of Red and Yellow soils. The characteristic color of subsurface horizons can be attributed to the basic parent materials such as basalt, serpentine etc. They are thinly scattered on hilly regions, and used for upland crops and tree crops.

Dark Red soils are divided into two soil series-groups by the presence of lithic contact.

12) *Brown Lowland soils*

Brown Lowland soils are developed from Holocene alluvial sediments under well-drained conditions. They are characterized by yellow-brown subsurface horizons. They are found in alluvial plains such as natural levees, alluvial fans etc. They are used mainly for paddy-rice, and partly for upland crops or tree crops.

Brown Lowland soils are divided into six soil series-groups by the difference in texture.

13) Gray Lowland soils

Gray Lowland soils are developed on Holocene alluvial plains or polders under well- to imperfectly-drained conditions. They are characterized by gray to gray-brown subsurface horizons. They are mainly used for paddy-rice cultivation, and are the most productive and widely spread soils among cultivated soils in Japan.

Gray Lowland soils are divided into nine soil series-groups by the difference in texture, mottlings and andic or peaty layers in subsoils.

14) Gley soils

Gley soils are developed on poorly-drained alluvial plains with high ground-water tables. Gley soils are characterized by bluish gray subsurface horizons which show positive reaction to 2,2′-dipyridyl test. Gley soils are used for paddy-rice cultivation.

Gley soils are divided into seven soil series-groups by the difference in texture, depth of gley horizons and the presence of peaty or andic layers.

15) Muck soils

Muck soils are developed in back marshes, margins of peat moor etc. They have layers of well-decomposed plant remains with twenty percent or more of organic matter, and show relatively low phosphate-retention comparing with Andosols. Most of them are used as paddy-field.

16) Peat soils

Peat soils are found in back marshes of bottom lands and sometimes in depressions on terraces. They are characterized by peat layers with thirty percent or more of organic matter. Most of them are used for paddy-rice cultivation.

17) Man-made soils

Japan has three-hundred and fifty inhabitants per square kilometer on the average, whereas the flat alluvial plains are only fifteen percent of the total area. Population density for the flat lands may exceed two-thousand-three-hundred inhabitants per square kilometer. Moreover, recent urbanization and industrialization have resulted in changes of land use. During the decade from 1965 to 1975, four-hundred and thirty thousand hectare of agricultural land were converted to the land for housing, highways, industries etc. On the other hand, a lot of forest and farm land have been modified and reshaped by man. An appreciable amount of hilly land has been reclaiming to compensate the disappearance of agricultural land. Man-made soil groups have been proposed for these morphological changes of soils.

Man-made soils occur in materials emplaced at least to a depth of 35 cm from the surface. Man-made soils that can be identified their taxa in line with the criteria are named as man-made phase of the taxa. Soils, which are so deeply disturbed or reshaped by man that their original taxa can hardly be designated are defined according to their topographical positions as follows:

Man-made Upland soils
Man-made Lowland soils

Land evaluation based on the soil classification: soil-capability classification for crop production

One of the most important purposes of soil surveys is the interpretation of soils to keep and strengthen agricultural productivity. Knowledge of soil environment favorable or unfavorable for plant growth is inevitable to push up agricultural production. Soil-capability classification and mapping for the above-mentioned purpose have been carried out simultaneously with the basic soil classification.[15] Laboratory tests[12] of soil chemical and physical properties have succeeded the field soil-surveys. Soil maps, soil-capability maps and their explanatory texts based on those data have been prepared.

Limiting factors for crop production picked up to make soil-capability classification are as follows:

- t Thickness of plowed layers
- d Effective depth for root development
- g Gravels in top soil
- p Easiness of tillage operation
- w Drainage
- l Water-permeability
- r Redox potential
- f Inherent fertility (CEC, phosphate sorption & base saturation)
- n Available nutrients
- i Harmful substances and physical hazards
- s Slope
- e Erodibility
- a Frequency of flooding and risk of land creep

Soils are evaluated and grouped into the following four grades according to the above-mentioned factors:

Grade I: Soils have neither limitation nor hazard, and have high potential for crop production without any improvement.

Grade II: Soils have some limitations or hazards for crop production. They require some improvement to achieve good production.

Grade III: Soils have many limitations or hazards for crop production. They require fairly intensive improvement.

Grade IV: Soils have so great limitations or hazards that they can hardly be used for agriculture, otherwise they require very intensive improvement.

The grade of a soil is assessed at the lowest value among the enumerated factors. The

Table 2. Quality of cultivated soils in Japan[2)]

Grade	Paddy-rice		Upland crops		Tree crops	
	Area	Extent	Area	Extent	Area	Extet
	1000 ha	%	1000 ha	%	1000 ha	%
I	4	<1	2	<1	2	<1
II	1,748	61	562	31	142	36
III	1,124	39	1,162	63	212	53
IV	12	<1	107	6	47	11

Table 3. Area and major limiting factors of each soil group[2)]

Soil Group	Paddy-rice			Upland crops			Tre crops		
	Area*	Extent**	LM***	Area	Extent	LM	Area	Extent	LM
Lithosols	0	0		7	<1	dgi	8	3	(w)sd
Sand-dune Regosols	0	0		22	2	(w)fn	2	1	(w)f
Andosols	14	1	fl	597	47	fn	44	17	fn
Wet Andosols	106	9	f	63	5	fwn	0	0	
Gleyed Andosols	29	3	rf	19	<1	fwn	0	0	
Brown Forest soils	4	<1	p	180	14	sd	103	40	tl
Gray Upland soils	37	3	p	67	5	wp	4	1	
Gley Upland soils	28	2	pl	4	<1		0	0	
Red soils	0	0		24	2	pn	15	6	npl
Yellow soils	43	4		73	6	pnw	60	23	npl
Dark Red soils	0	0		28	2	(w)dp	6	2	
Brown Lowland soils	42	4		105	8		14	5	
Gray Lowland soils	281	25	ln	53	4	w	3	1	wd
Gley soils	462	41	r	10	1	wn	1	<1	
Muck soils	32	3	r	2	<1	wna	0	0	
Peat soils	58	5	r	32	3	wna	0	0	
Total	1,136	100		1,268	100		259	100	

* 1,000 ha, ** %, *** Abbreviations of limiting factors shown in the above portion of this page.

capability classification of cultivated soils in Japan by the above-mentioned procedure is shown in Table 2. The chief limitations are shown in Table 3. For example, the main problems of Andosols for upland-crop raising are the low inherent-fertility and the low nutrient-availability.

Soil surveys of Japan have been rapidly promoted. Soil amelioration and fertilization improvements based on the survey have been carried out by the efforts of farmers with assistance of government. Agricultural productivity or yield per unit area has markedly increased by the soil improvement as well as by the progress in plant breeding and plant protection.

Creation of a coming soil classification system and its application to advanced management[1] and conservation of soil environment should be a very important problem in the near future.

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