Chapter 4
Soils in Historical Urban Parks

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Abstract Urban parks are one of the large infrastructures that enhance quality of life in a metropolis. It is therefore important to maintain a record of soil history, including the development and alteration of land in urban areas. Three historical urban parks were surveyed to obtain information of the land use history. The Institute for Nature Study, designated as a national monument and historical landmark in 1949, is a particularly important site for the study of pedogenesis in urban green spaces. As compared to a reference site, "the Meiji Shrine", past construction activities, production of artifacts, and land cutting and banking resulted in a disruption of natural soil horizons. Horizon sequences were relatively similar among sites on earthworks but not on terrace surfaces, reflecting the high frequency of change in land use on these areas. Accumulation of total organic carbon decreased with increasing soil depth probably due to forest regeneration. Non-crystalline components increased with increasing soil depth mainly as a result of leaching of non-crystalline components by complexation with soil organic matter under forest vegetation. $\delta^{13}C$ values of soil increased with increasing soil depth reflecting vegetation succession. The $\delta^{13}C$ values of soil were significantly negatively correlated with a color index of extracted organic matter, indicating that C4 plants have contributed to accumulated carbon, mainly after episodes of fire. Shinjuku-Gyoen site

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has experienced changes in its land use history during the past four centuries. There were several drastic differences in general soil properties with depth. These soil characteristics reveal signatures of anthropogenic impact such as banking and cutting in the soil profiles. Short and frequent complex anthropogenic alterations were observed in the historical park. High variability of soil properties in the Shinjuku Gyoen site indicates high frequency of land use changes within its history. In the Kitanomaru Garden connected to the East Gardens of the Imperial Palace, three large-scale constructions were performed from the Edo era (1603–1868) to the present. Soils in Kitanomaru Garden are classified as Urbic Technosols, and feature artifacts such as bricks, tiles, concrete, or potteries originating from buildings from the past 400 years. Soils in Kitanomaru Park had a higher soil pH, lower total carbon content and relatively high cation exchange capacity (CEC) compared with natural volcanic ash soils. Moreover, the vertical distribution of soil compactness was characterized by disorders of the compaction layers or having a consolidated layer within 1 m deep. The spatial distribution of the soils having non-intrusive and densely-compacted layers correspondences with the restoration position of a building and land-grading works.

Keywords Urban parks · Land use history · Land creation history · Urbic technosols

4.1 Introduction

Urban areas and green spaces created within cities are gradually expanding in Japan. The area of urban green space in Japan is 121,446 ha or 10.14 m^2/person as of March 2015 (Ministry of the Environment Government of Japan 2017a), which is about 0.4% of the Japanese land area.

Expansion of urban areas causes specific environmental problems in a metropolis, such as "urban heat islands" and "urban floods". In order to provide healthy ecosystem services, the soil in urban ecosystems must be conserved, as soil is an essential natural resource for maintaining life. Urban soils develop under circumstances associated with intensive stress of human activities, and their properties may further change by various processes of human activities. Nevertheless, soils in urban area may have miscellaneous functions that create sustainable urban environments such as mitigation of heated atmosphere, recovery of infiltration capacity, biodiversity, and storage of carbon.

Tokyo is recognized as a large city, but in fact, many green spaces within the city have existed quite some time. An urban park is one of the large infrastructures to support a comfortable life in a metropolis. In this chapter, three historical parks in the Tokyo Metropolis, including the Institute for Nature Study park, the Shinjuku-Gyoen park, and the Kitanomaru park, are introduced to understand basic characteristics of soil development of urban park soils in consideration with land use history, land creation methods, current land coverage, and management.

4.2 The Institute for Nature Study, Shiroganedai, Tokyo

4.2.1 History of Land Use at the Institute for Nature Study

The Institute for Nature Study, managed by the National Museum of Nature and Science of Japan, is located on the site of the former imperial estate Shirogane-Goryouchi, and covers an area of approximately 20 ha in Shiroganedai, Minato-ku, Tokyo (35°38′7.6–29.0′′ N, 139°43′1.7–21.3′′ E; Figs. 4.1 and 4.2). This area is on

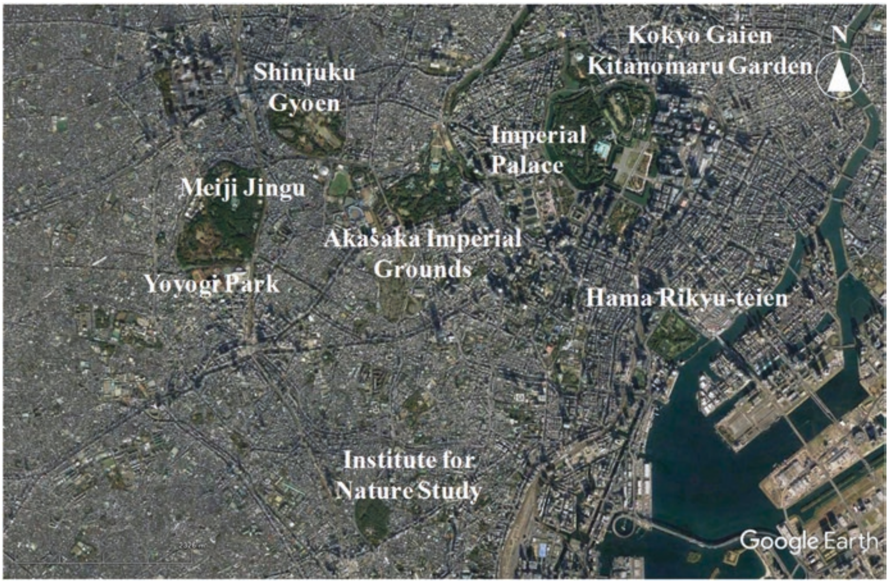

Fig. 4.1 Urban green spaces in Tokyo. Base photo map is taken from Google Earth

Fig. 4.2 Overview of the Institute for Nature Study in Tokyo. (**a**) Aerial panorama photograph, (**b**) promenade, and (**c**) earthwork site No. 5 (Fig. 4.4), (**d**) valleys and wetland

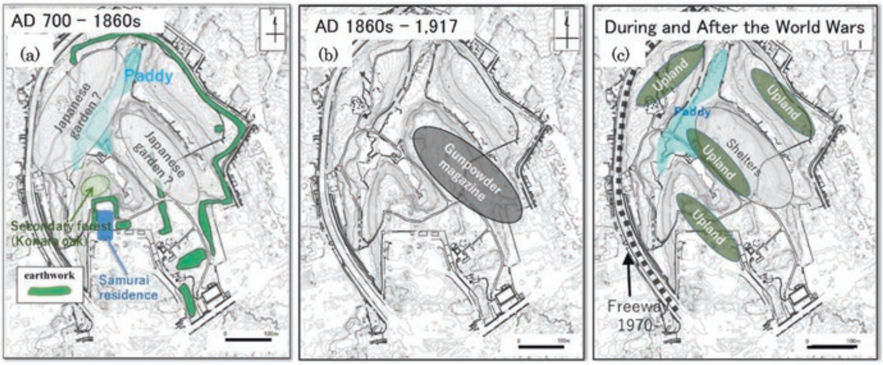

Fig. 4.3 Land use history of the Institute for Nature Study in Tokyo

the Yodobashi-dai of the Shimosueyoshi surface, and forms flat valley bottoms in the hills eroded by three effusive springs (Tokyo Metropolitan Government 1997). Extensive land disturbance has been prohibited since 1949 when the area was designated as a National Treasure and Historical Site. This is a particularly important site for the study of pedogenesis in urban green spaces, since there are many historical records on land use and vegetation cover available for this area.

Although it is not known when the first humans settled this area, pottery and shell mounds from the mid-Jōmon period (about 2500 years ago) were found here, suggesting that the region was already settled at that time. From 700 to 1860, this area was under the control of powerful clans and samurais. Archeological evidence suggests that they constructed earthworks and residences, produced some artifacts, and may also have developed Japanese gardens, a secondary forest, and paddy fields for food production (Fig. 4.3a). During the Meiji period (1868–1912), the site was used as a gunpowder magazine, under the control of the Army Ministry. It was taken over by the Imperial Household Ministry in 1917 and renamed the Shirokane Imperial Estate (Fig. 4.3b). The area seems to have considerably degraded during the World Wars because of disorganized land use. However, after World War II, its management was taken over by the Ministry of Education, and designated as a special natural treasure in 1949. Since then, the area has been recovering, including regeneration of natural environments (Fig. 4.3c). Presently, most of the area is covered with forest and grass. The park has been opened to the public and has become an oasis. Whereas terrace surfaces have had several land uses, earthworks have not changed much for the past 500 years. Therefore, a comparative study of earthworks and terraces would be useful to understand how man-made alterations influence the pedogenesis of an urban area.

4.2.2 Soil Description and Soil Properties Including $\delta^{13}C$ Values

Soil surveys and sampling sites are shown in Fig. 4.4. Soils in this area are mostly covered with Silandic Andosols according to the world reference base for soil resources (WRB; IUSS Working Group WRB 2014). Here, the Andosols are derived from volcanic ejecta, and primary volcanic ash, pumice, and scoria from eruptions of Mt. Fuji.

Soil profiles are shown in Fig. 4.5. As a reference site, the soil profile of the Meiji Shrine soil is also shown (Kaneko et al. 1991). The Meiji Shrine is located on the same geomorphic surface (the Shimosueyoshi terrace) and is located ~4.5 km north-northwest from the Institute for Nature Study (Fig. 4.1). The horizon sequence of the Meiji Shrine soil has been essentially maintained as an undisturbed sequence, and is composed of four chronological black soil horizons, dated at ~300 to 10,000 years of age, and the Kanto-Loam that was formed in the Pleistocene following the eruption of tephra from Mt. Fuji. Black soil infers that horizons A1–4 are rich in humus. The color of the black soil horizon has the value ≤3, chroma ≤3, except 3/3. A dark brown horizon refers to horizon AB, which has the soil color "3/3" – "3/4."

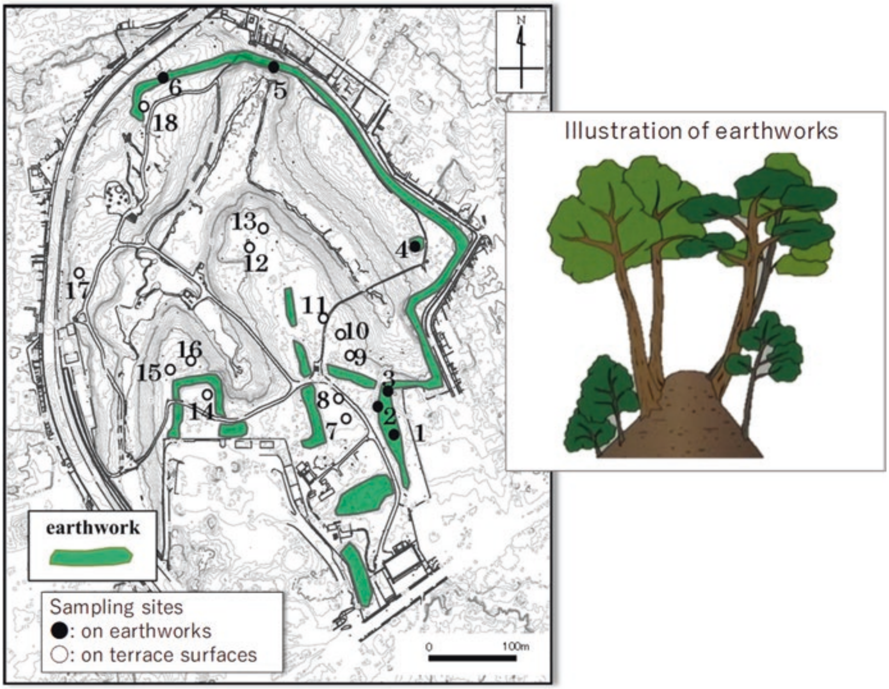

Fig. 4.4 Sampling sites shown on a topographic map at the Institute of Nature Study and with illustration of earthworks indicated by green shading

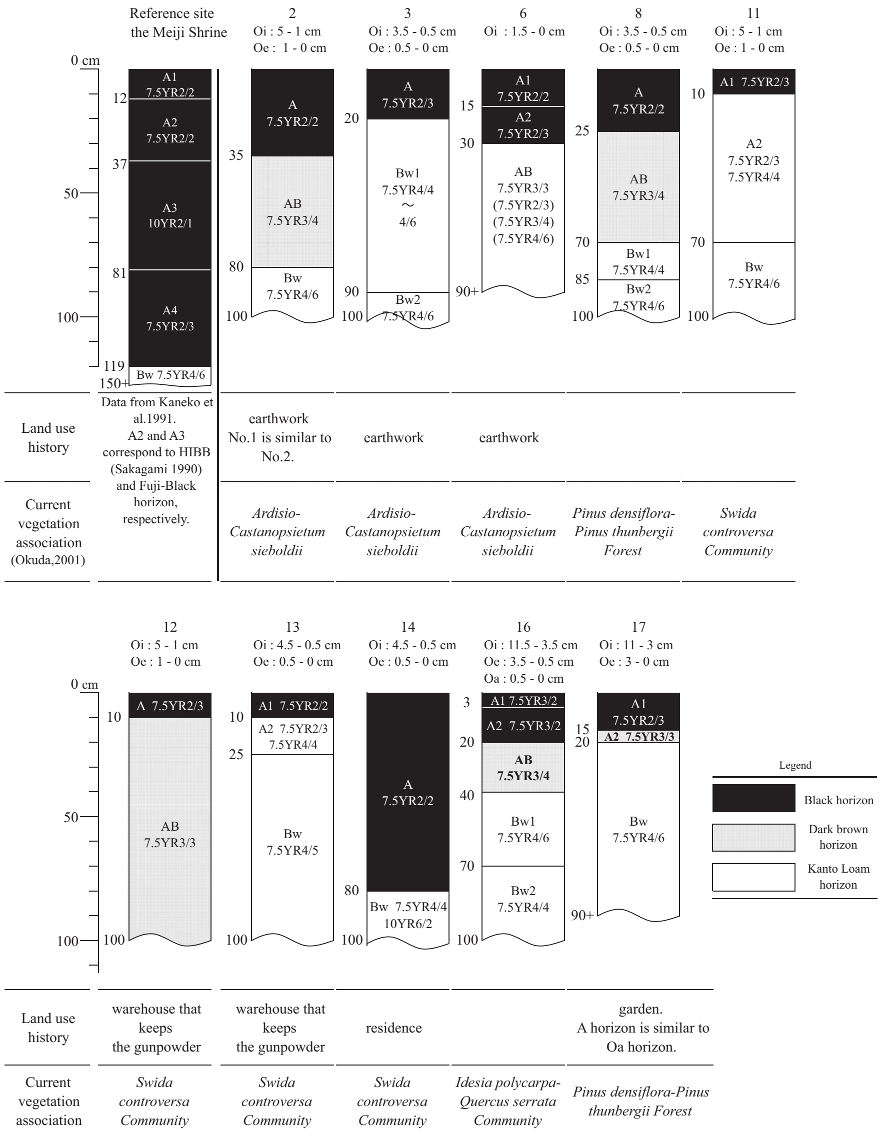

Fig. 4.5 Descriptions of soil profiles at the Institute for Nature Study. Site numbers over profiles indicate the profile location on the topographic map of Fig. 4.4

Results show that past construction activities, production of artifacts, and land cutting and banking resulted in a disruption of natural soil horizons at the Institute for Nature Study. In fact, undisturbed horizon sequences were not found in any of the sampled sites, meaning all sites were, at some point, more or less affected by man-made alterations. Still, the relative thickness of individual horizon sequences was relatively similar among sites on earthworks, but not on terrace surfaces, reflecting the high frequency of change in land use on these areas.

4.2.2.1 Soil Properties

Soil chemical properties at the sites on the grounds of the Institute for Nature Study are shown in Table 4.1. Accumulation of total organic carbon decreased with increasing soil depth. This might be due to forest regeneration, which allowed a high quantity of fresh organic matter to be returned to the soil surface by the existing vegetation.

The amounts of oxalate-extractable Al and Fe, such as non-crystalline components, met the requirements for Andosols in all sites and in all horizons. In both earthworks and terraces these amounts increased with increasing soil depth. This trend, particularly in the earthworks, might have resulted from the leaching of

Table 4.1 Soil chemical properties at the sites on the grounds of the Institute for Nature Study

Site no.	Horizon	Depth (cm)	pH (H_2O)	T-C (g kg^{-1})	Alo + 1/2FeO (%)	$\delta^{13}C$ (‰)	Melanic index
Earthwork							
2	A	0–35	5.1	186	5.4	−26.1	1.88
	AB	35–80	4.8	39	9.8	−20.9	1.64
	Bw	80–100+	5.6	20	11.8	−22.2	2.23
5	A	0–15	4.7	83	8.9	−24.7	1.99
	AB	15–25	4.7	68	9.3	−24.7	1.94
	Bw1	25–60	5.1	41	10.5	−24.0	1.92
	Bw2	60–100+	5.4	35	12.0	−23.1	1.78
Terrace surface							
8	A	0–25	4.6	200	6.5	−26.3	1.81
	AB	25–70	5.2	24	12.5	−22.6	1.67
	Bw1	70–85	5.7	20	12.2	−23.3	1.84
	Bw2	85–100+	5.8	19	7.1	−24.2	–
9	A	0–25	5.2	236	5.6	−27.7	1.97
	Bw1	25–70	5.2	17	13.5	−21.9	1.95
	Bw2	70–100+	5.8	16	12.6	−22.1	1.92
16	A1	0–3	4.5	282	3.9	−28.0	2.20
	A2	3–20	4.3	110	7.3	−26.5	2.01
	AB	20–40	4.6	67	8.5	−25.0	1.79
	Bw1	40–70	5.2	19	12.1	−23.7	2.11
	Bw2	70–100+	5.6	15	12.9	−22.5	–
18	A1	0–15	5.3	167	7.8	−26.9	2.08
	A2	15–35	4.8	54	9.5	−23.7	1.77
	AB	35–55	–	–	–	–	–
	Bw	55–90+	6.2	23	13.0	−22.6	1.95

non-crystalline components by complexation with soil organic matter, which is present in large amounts in the soil profiles.

$\delta^{13}C$ values of soil increased with increasing soil depth at most sites in this study. It is likely that grass vegetation of C4 plants (approximately −27‰ on average) such as *M. sinensis* had widely occupied this area and that soil organic matter (SOM) that was derived from present-day C3 plants (approximately −13‰ on average) (O'Leary 1995; Yoneyama et al. 2001) is now mixed into SOM derived from C4 plants that had grown at these sites in the past. Furthermore, the $\delta^{13}C$ values of soil had a significant negative correlation with the Melanic Index (the abundance of highly humified organic matter). Therefore, highly humified SOM as expressed by the Melanic Index was assumed to derive from C4 plants that had continuously been burned off. This study was detailed in Kawai et al. (2015).

4.3 Shinjuku Gyoen Park

4.3.1 History of Land Use at Shinjuku Gyoen Park

Shinjuku Gyoen Park (35°40′52.7′′–41′19.0′′ N, 139°42′15.1–56.0′′ E), is located on the Yodobashi upland of the Shimosueyoshi surface that formed 125 thousand years ago (Figs. 4.1 and 4.6). Within the park there is a water channel, running from the northwestern end toward the southeast, that is an abandoned channel of the Shibuya River, and also three ponds (Upper, Middle, and Lower ponds) that have been created by damming. Small plateaus exist on the northern and southern ends across the water channel. Other micro-topographical features have been altered to create a rolling landscape. Related history is provided on the website of Ministry of the Environment, Government of Japan, as follows (Ministry of the Environment Goverment of Japan 2017b). Shinjuku Gyoen Park was constructed on the site of a private mansion belonging to Lord Naito (Early 17 c.), a 'daimyo' or feudal lord of the Edo era, and has been one of the most important gardens since the Meiji era (1868–1912). The Naito Shinjuku Research Institute was founded in this park in

Fig. 4.6 Aerial photographs of (**a**) Shinjuku Gyoen Park, (**b**) landscapes of the French Formal Garden, and (**c**) the English Landscape Garden

1872, as a result of public aspiration to promote modern agriculture. In 1906, the Gyoen was completed as an imperial garden. During the Second World War, the Gyoen was used as a field. In 1945, the Great Tokyo Air Raids resulted in burning of buildings in Shinjuku Gyoen. After the Second World War, Shinjuku Gyoen was re-designated as a National Garden and opened to the public in 1949. Currently, three formal gardens, the French Formal Garden (Fig. 4.6b), the English Landscape Garden (Fig. 4.6c), and the Japanese Traditional Garden, are arranged within the 58.3 ha area.

4.3.2 Soil Compactness and Physico-chemical Properties

Soil surveys were conducted at three sites within the lawn areas of the park (Fig. 4.7) (Uoi 2014; Uoi et al. 2013). OP-A was a site in the French Formal Garden developed ca. 1908. The area where OP-B and -C are located was developed in a former forest or Japanese garden ca. 1908. OP-C was close to OP-B and subject to redevelopment by raising of the ground level for construction of a central rest house in 1998.

Vertical profiles of soil compactness were obtained by measuring softness (cm drop^{-1}) using a cone penetrometer at a maximum depth of 1 m (Fig. 4.8; H-100; Daitou Techno Green Inc. Tokyo, Japan). The measurement was conducted by dropping a 2 kg weight from a height of 50 cm to penetrate a ϕ 20 mm cone with an angle of 60°. Softness was defined as the depth penetrated in (cm) per drop,

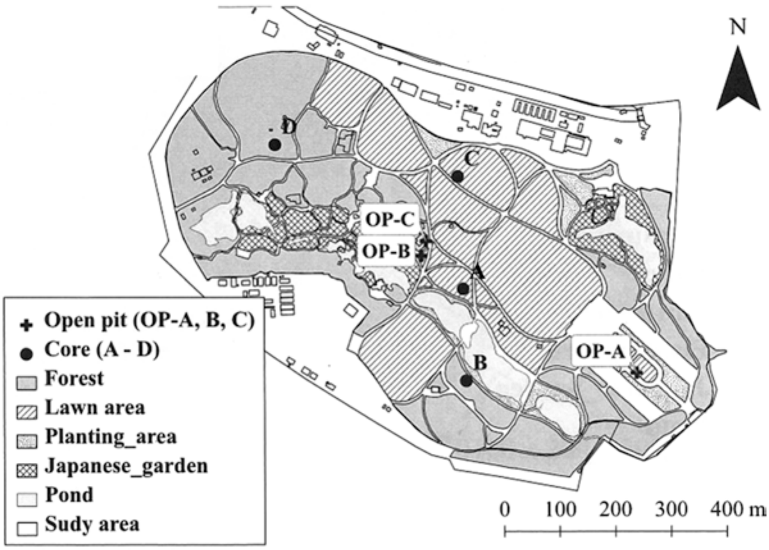

Fig. 4.7 Location map of the study area and survey sites in the Shinjuku Gyoen park

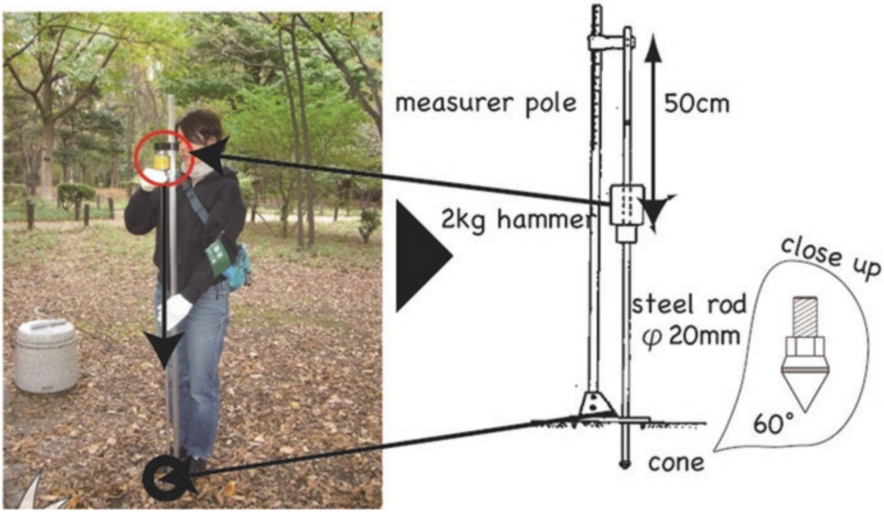

Fig. 4.8 Methodology of measuring soil compactness (soil softness) using the Hasegawa-type corn penetrometer

which has practical applications in planting techniques to evaluate the physical condition and properties of the soil. The critical values for tree and root growth, as suggested by the Research Committee of Japanese Institute of Landscape Architecture (2000), are:

Softness ≤1.0: interference for tree root extension
Softness ≥4.0: strength deficiency and water shortage for trees

4.3.2.1 Soil Properties

There were several drastic differences in soil properties across a horizon (layer) boundary at a depth of 20 cm in the soil profile of OP-A (Fig. 4.9 and Table 4.2). Soil color changed drastically, from 10YR2/3 to 10YR4/6. Field soil texture became more clayey with increasing soil depth (CL → LiC). In addition, the compactness, measured by the Yamanaka method using a pushing corn, was 8–9 mm at 0–20 cm depth compared with 23 mm at 20–80 cm depth. A dramatic increase in the soil liquid phase ratio and a decrease in gas phase ratio were observed with increasing soil depth. In contrast with the soil compactness, soil softness decreased with increasing soil depth and a drastic shift was observed around the horizon boundary. These soil characteristics indicate signatures of anthropogenic impact such as banking and cutting in soil profiles.

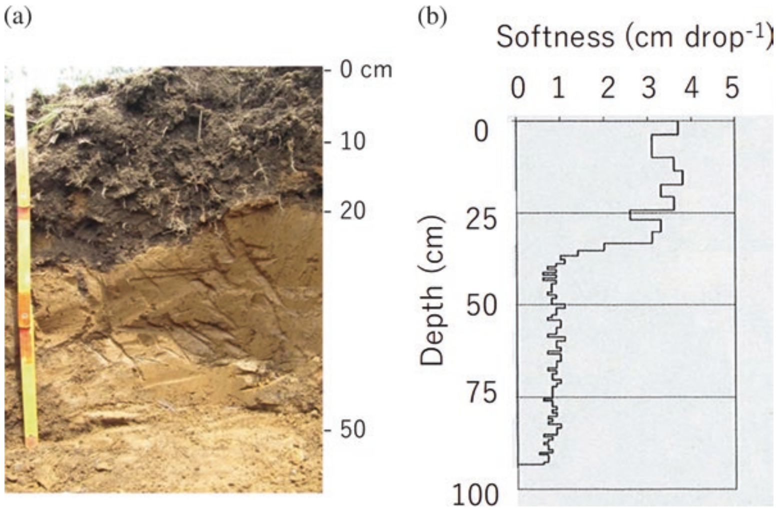

Fig. 4.9 (**a**) Soil profile and (**b**) vertical distribution of soil softness (cm/drop) of profile OP-A

Table 4.2 Soil properties at OP-A

Depth (cm)	Horizon	Soil color (moist)	Texture	Compactness (mm)	Three phases of soil (%)			pH (H_2O)	TC	TN
					Solid	Liquid	Gas		(g kg^{-1})	
0–10	A1	10YR2/3	CL	8 ± 2	19.7	41.1	39.2	5.5	77.8	6.3
10–20	A2	10YR2/3	CL	9 ± 1	32.0	54.7	13.3	5.3	57.2	4.7
20–80+	Bw	10YR4/6	LiC	23 ± 2	20.8	68.5	10.7	5.6	13.6	1.1

In contrast to OP-A, there was little vertical variation in soil softness at OP-B, where the values ranged from ~1–2.5 cm drop^{-1} (Fig. 4.10). Compaction was accomplished in a complicated manner, and the vertical profile showed signs of discontinuity, which could be a result of short and frequent anthropogenic alteration (Table 4.3).

Although OP-C was located very close to OP-B, the soil profile characteristics were definitely different. This profile contained a greater amount of anthropogenic debris such as asphalt in every layer (Fig. 4.11, Table 4.4). Therefore, various soil properties changed at the depth of every 3–10 cm. Anthropogenic compaction might reduce gas phase ratios in the whole soil profile and the values at OP-C were much lower than those at OP-A and OP-B. Furthermore, anthropogenic inputs such as debris of asphalt and concrete might induce an increase in soil pH values. Horizon names in these soil profiles are still provisional.

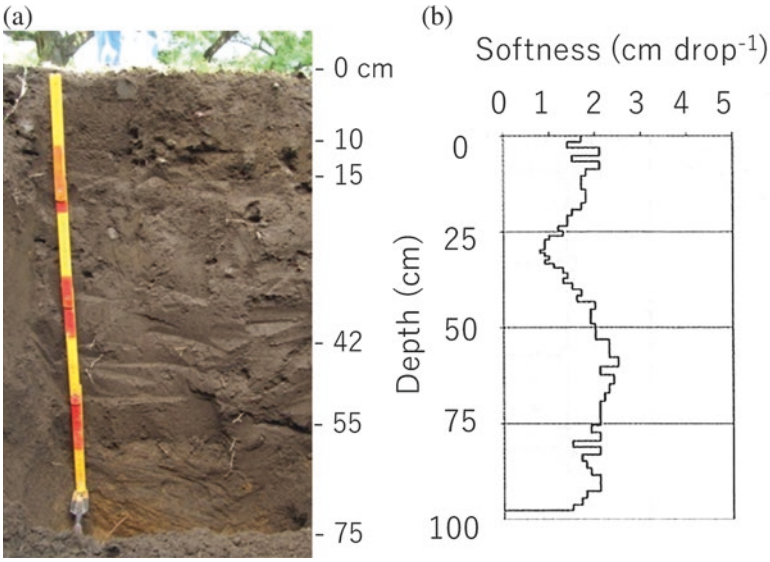

Fig. 4.10 (**a**) Soil profile and (**b**) vertical distribution of soil softness (cm/drop) of profile OP-B

Table 4.3 Soil properties at OP-B

Depth (cm)	Horizon	Soil color (moist)	Texture	Compactness (mm)	Three phases of soil (%)			pH (H_2O)	TC	TN
					Solid	Liquid	Gas		($g\ kg^{-1}$)	
0–15	A1	10YR3/2	SiCL	19 ± 1	28.9	49.9	21.2	5.3	42.2	3.2
15–42	A2	10YR3/3	CL	25 ± 4	25.3	46.5	28.2	6.2	40.8	3.1
42–55	A3	10YR3/3	CL	15 ± 1	18.8	54.4	26.8	6.3	40.2	3.0
55–75	A/B	10YR3/3	CL	16 ± 2	37.2	50.0	12.8	6.3	39.7	2.9
75–110+	Bw	10YR4/4	LiC	–	21.4	47.0	31.5	6.1	14.4	1.3

4.4 Kitanomaru Garden

4.4.1 History of Land Use at Kitanomaru Garden

Kitanomaru Garden, with an area of approximately 19.3 ha, is connected to the East Gardens of the Imperial Palace (Fig. 4.12). The park was opened to the public as a National Garden in 1949. Prior to this date, this area was a part of the Imperial Palace grounds and the Kitanomaru district was occupied by the Konoe Military Regiment (Special Imperial Guard) or Government Buildings from 1874 until early 1945. Prior to this time period, this vast area was densely populated by relatives of the Tokugawa Shogun (Fig. 4.13).

When the Shogun Tokugawa Ieyasu entered Edo (currently Tokyo), several private houses, a forest, and a shrine were situated in the area. In 1607 (Edo era), a castle tower base, mound, and moat were created. Since this area was constructed as

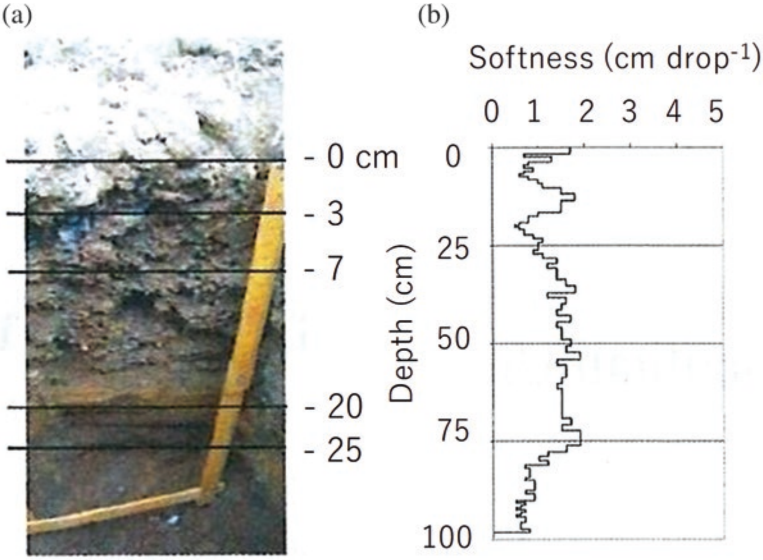

Fig. 4.11 (**a**) Soil profile and (**b**) vertical distribution of soil softness (cm/drop) of profile OP-C

Table 4.4 Soil properties at OP-C

Depth (cm)	Horizon	Soil color (moist)	Texture	Compactness (mm)	Three phases of soil (%)			pH (H_2O)	TC	TN
					Solid	Liquid	Gas		(g kg^{-1})	
0–3	A(C)	10YR3/2	LiC	15	38.1	43.9	18.0	7.2	12.0	0.7
3–7	AB(C)	10YR3/1	SL	20	–	–	–	7.0	31.9	2.3
7–20	AC2	10YR3/2	LiC	17	35.2	58.3	6.5	7.0	32.2	2.3
20–25	Bw	10YR4/6	CL	18	25.9	72.3	1.8	6.9	17.5	1.4
25–40	2A	10YR2/3	LiC	19	30.0	61.9	8.1	6.4	48.5	3.8
40–90+	2Bw	10YR4/6	–	–	–	–	–	6.2	25.4	2.1

a part of the Shogun castle, the mansions of Tokugawa Shogunate hereditary daimyo, and the Tayasu and Shimizu families occupied the land until the Household Division was created in 1874.

After World War II, the remains of the Household Division became a national asset, and a student dormitory and government agency buildings were constructed. These two to three story (24,133 m^2) buildings were composed of brick architecture, reinforced concrete (18,426 m^2), wooden mortar (10,620 m^2), and wood (19,046 m^2). There was vacant land for training and a hippodrome in the center of the garden when the Household Division was based there. The park construction project was approved in 1946, and launched in 1961. Construction was completed in 1969, and the park was opened to the public.

About 400 years from the Edo era to the present, three large-scale landscaping projects were performed in the Garden, as documented in existing records. The last

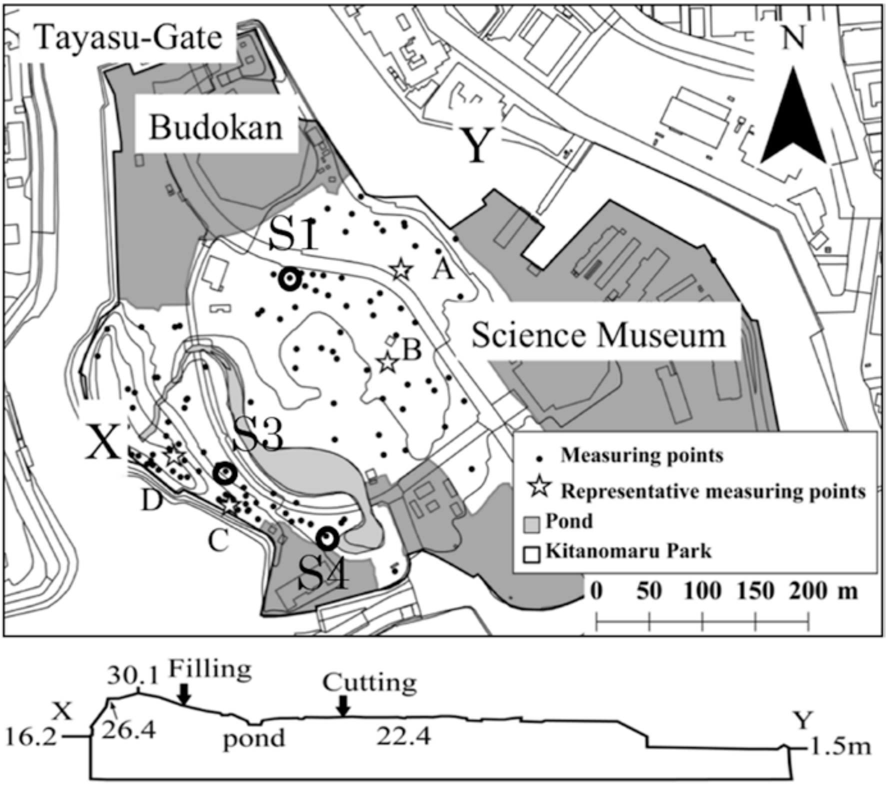

Fig. 4.12 Location map of the measuring points and topographical cross section X–Y in the Kitanomaru Garden

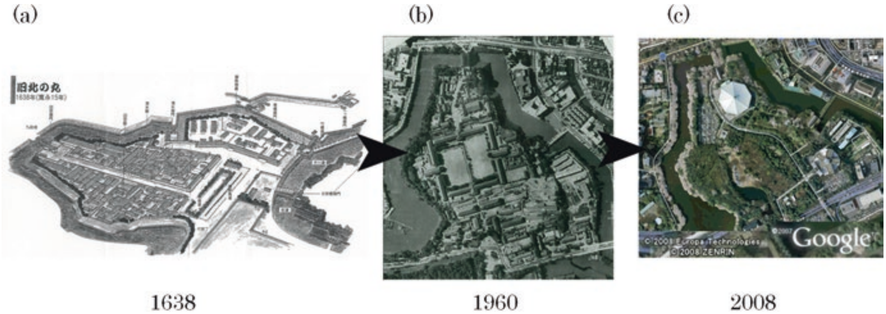

Fig. 4.13 Land use history of Kitanomaru Garden. (**a**) Edo era (1603) through the Meiji period (1868), showing the mansion area for the Tokugawa Shogunate hereditary daimyo, (**b**) Early Meiji period through mid-Showa period (1961), used for housing during World War II, and later became government buildings, private facilities, and houses after the war, (**c**) Mid-Showa period (1969) to Present, opened to public as a National Garden

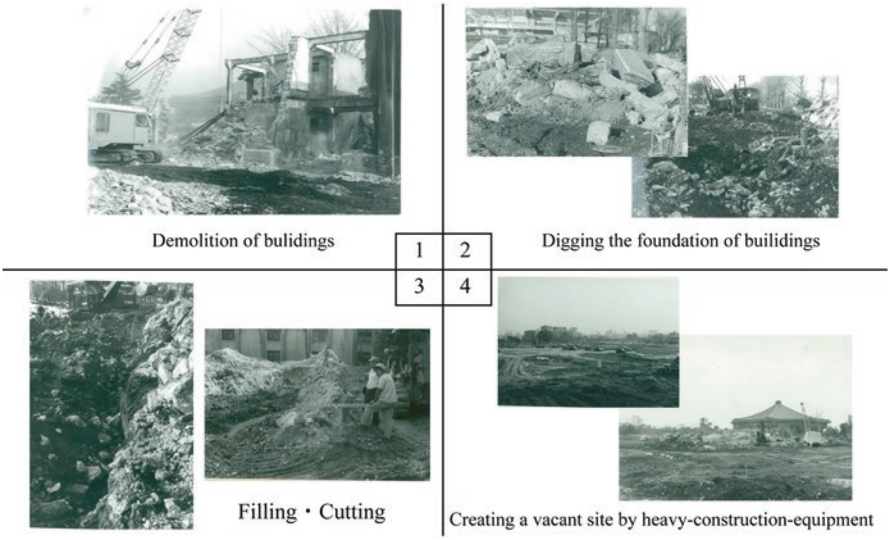

Fig. 4.14 Procedure of land modification, 1961–1969. Land modifications were performed using the following procedure (*1*) demolition of buildings, (*2*) building foundation excavation, (*3*) filling and cutting, (*4*) ground smoothing by heavy construction equipment

landscape project was performed in parts for several years as it took a great deal of time to be executed. Landscaping from 1961 to 1969 was conducted on a large scale using heavy machinery (Fig. 4.14). First, all buildings were removed. Second, cutting and filling were carried out in the newly vacant area. These places were ground leveled, and homogenized. After this step, the roads, garden paths, ponds, and planting zones were constructed. Bricks of the former building and reinforced concrete with deep foundation were dug up to 30 cm and removed. The ground was smoothed to mimic a natural gradient. Concrete debris, pieces of rock, and rebar exposed at the surface were removed. Before filling, the surface was plowed more than 10 cm depth and consolidated. After such works, soil was filled up to 30 cm depth. Fifteen-ton tire rollers and ten-ton bulldozers were used to compact the fill (Ministry of the Environment Government of Japan 2017c; Uoi et al. 2014).

4.4.2 Soil Classification and General Properties

The features of three representative soil profiles (S1, S3, S4) are shown in Fig. 4.15 (Uoi 2014). The constructed soils in Kitanomaru Garden were classified as Urbic Technosols, according to the WRB (IUSS Working Group WRB 2014), that is soils having 20% or more (by volume, by weighted average) artifacts in the upper 100 cm

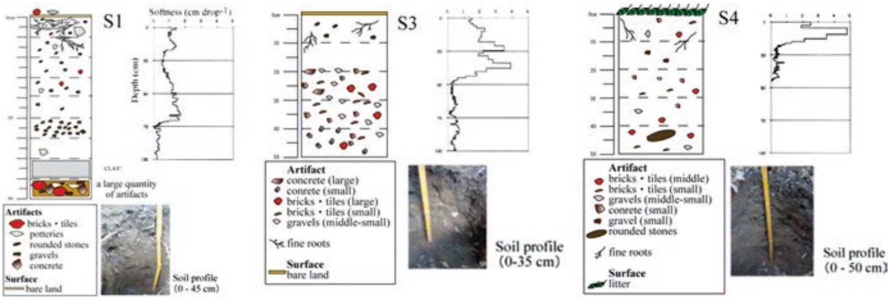

Fig. 4.15 Soil profile descriptions and vertical chart of soil compactness (Softness cm/drop) of survey sites S1, S3, and S4 at Kitanomaru Garden

from the soil surface or to a continuous rock, cemented, or indurated layer, whichever is shallower, and having a layer >20 cm thick within 100 cm of the soil surface, with >20% artifacts containing >35% (by volume) rubble and refuse of human settlements. The studied soils in Kitanomaru Garden had artifacts >20 wt% in the profile within a depth of 50 cm, including bricks, tiles, concrete, or potteries originating from pre-existing buildings during the past 400 years. Moreover, the vertical distribution of soil compactness was characterized by disorders of compaction layers or having a consolidated layer beneath 10 cm depth.

4.4.2.1 Soil Chemical Properties

Samples of S1, S3, and S4 were obtained at 10 cm intervals, up to depths of 30–90 cm depth, depending on the site. Chemical analyses from Uoi et al. (2014) and Uoi (2014) are shown in Table 4.5. Soil pH (H_2O), total carbon content (TC) and cation exchange capacity (CEC) ranged from 6.0–7.8, 9.6–56.9 g kg^{-1}, and 22.8–40.5 $cmol_c$ kg^{-1}, respectively. Overall, the constructed soils in Kitanomaru Park were characterized by higher soil pH, lower TC content, and relatively high CEC compared with natural volcanic ash soils. S1 is located in a forest area where the soil surface was bare because of regular removal of litter. However, the pH (H_2O) value was alkaline in the deeper layers. TC content was highest for layers at 0–10 cm and 60–70 cm. CEC decreased in the 10–20 cm and 40–50 cm layers. S3, also in the forest area, had a bare soil surface because of regular removal of litter. The pH (H_2O) values (6.9–7.3) ranged from weakly acidic to weakly alkaline. TC content decreased towards the lower layers, but showed an inversion at the depth of 40–50 cm.

Table 4.5 Soil properties at Sites S1, S3, and S4. S1 and S3 correspond to Point A and B, respectively, in Fig. 4.12

Site (point)	Depth (cm)	Soil color (moist)	Texture	pH (H_2O)	TC ($g\ kg^{-1}$)	TN	CEC ($cmol_c kg^{-1}$)
S1	0–10	7.5YR3/2	SL	6.0	36.0	2.7	26.2
(A)	10–20	7.5YR3/2	SL	6.5	19.3	1.6	24.3
	20–30	7.5YR3/4	SL	7.0	19.0	1.5	25.5
	30–40	7.5YR4/6	SiL	7.1	19.9	1.4	26.8
	40–50	7.5YR5/6	SiL	7.0	18.2	1.3	22.8
	50–60	7.5YR4/4	SL	7.0	20.1	1.5	26.8
	60–70	7.5YR3/1	L	7.8	24.9	1.7	24.6
	70–80	7.5YR4/2	SiL	7.8	11.2	0.7	25.3
	80–90	7.5YR5/6	CL	7.6	9.6	0.7	24.4
S3	0–10	10YR2/2	SL	6.9	48.4	3.5	39.4
(B)	10–20	7.5YR2/3	SL	6.8	41.0	2.8	33.0
	20–30	7.5YR3/3	SiL	7.1	20.6	1.4	26.2
	30–40	7.5YR3/2	SiL	7.5	18.0	1.1	28.3
	40–50	7.5YR2/2	SiL	7.3	35.2	1.7	27.7
S4	0–10	7.5YR3/2	SL	6.2	56.9	4.2	40.5
	10–20	7.5YR3/3	L	6.7	25.5	1.9	26.2
	20–30	7.5YR4/4	L	7.3	14.9	1.1	25.9
	30–40	7.5YR3/4	L	7.5	13.2	1.0	28.2
	40–50	7.5YR4/6	SL	7.7	14.2	1.0	29.3

4.4.2.2 Soil Physical Properties

Vertical soil hardness was measured at 134 points in the Kitanomaru Garden using a cone penetrometer. Then, spatial analysis was carried out using GIS software to analyze the correspondence of the soil physical characteristics with anthropogenic land use, such as history of previous buildings, reclamation methods, and current park management. A non-intrusive layer, defined as one with a penetration depth of less than 50 cm, was counted up to 34 times (25%) among the entire 134 points. The dense-compacted layer was observed at 115 (85.8%) points out of 134. It is not clear whether there is a relationship between compactness by building and the non-intrusive layer or the dense-compacted layer. The total thickness of the dense-compacted layer was thicker at 25–50 cm. At the points of cutting and lawn areas, the total thickness of the dense-compacted layer was particularly thicker, more than 50 cm. In the study area, the dense-compacted layer formed from 0–25 cm depth, and appeared 1–2 times in a soil profile. In addition, the total thickness of the dense-compacted layer became 25–50 cm, and occupied more than half entire soil profile. Furthermore, the frequency of appearance of dense-compacted layers was less than two at points in the vacant land surrounded by buildings in the past. The formation of non-intrusive layer versus dense-compacted layer of soils revealed a spatial correlation with land use history and land grading (Fig. 4.16).

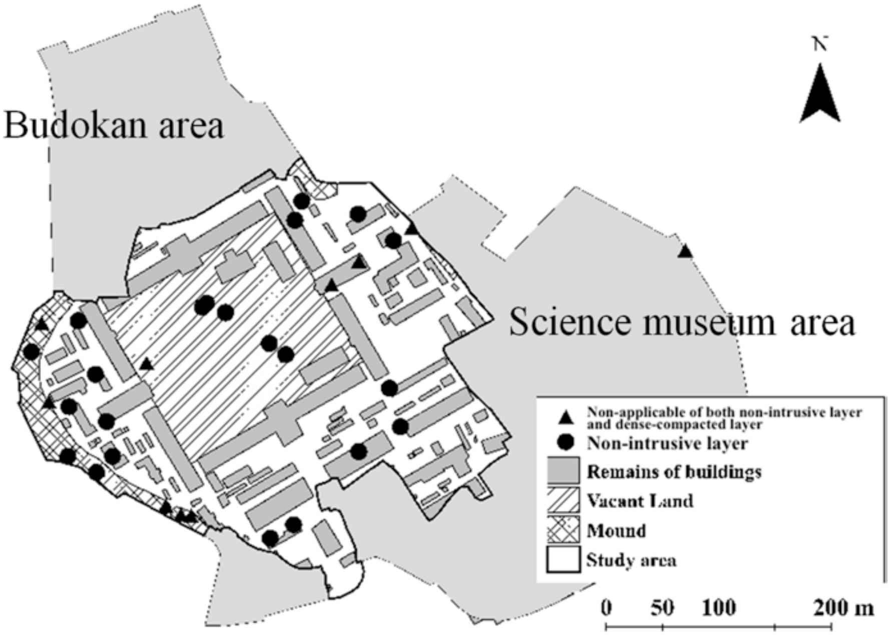

Fig. 4.16 Spatial correspondence of the physical properties of the Kitanomaru Garden soils with past land use before 1961, including locations of building remains, vacant land, and a mound. Solid circle (●) and solid triangle(▲)represent the location of the non-intrusive layer counted up to 34 times (25%) among the entire 134 points surveyed, and the location of the absence of non-intrusive layer or dense-compacted layer, respectively. (Revised from Uoi et al. 2014)

4.5 Conclusion

Soil properties obtained by soil surveys and chemical and physical analyses provide records of vegetation succession and land use history in urban parks. Vertical distribution of organic carbon stable isotope ratios document a vegetation change from C4 to C3 plants by forest regeneration. Amorphous Al and Fe also reflect vertical leaching with dissolved organic matter from the forest floor. These processes have been occurring since the construction of earthworks five centuries ago. Discoloration of black soil was also confirmed to accompany forest regeneration. The process of construction of urban parks can be identified by frequent changes in physical properties such as soil softness and distribution of artifacts. Anthropogenic impacts are recognized in drastic changes between soil layers as a sign of artificial cut and banking, and irregular distribution of organic carbon and related soil properties. Relatively high pH is considered to be an effect of artifacts buried in subsoils. A precise survey of spatial distribution of soil compaction, known as one of the representative characteristics of anthropogenic soils in an urban area, revealed a significant correspondence of the appearances of non-intrusive and dense-compacted layers with land use history and land grading.

References

IUSS Working Group WRB (2014) World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps, World soil resources reports no. 106. FAO, Rome

Kaneko S, Tanaka N, Takahashi M (1991) The natural soils of the Meiji shrine forest in Tokyo. Jpn J For Environ 33:92–98 (in Japanese with English summary)

Kawai N, Murata T, Watanabe M, Tanaka H (2015) Influence of historical manmade alterations on soil-forming processes in a former imperial estate (Shirogane-goryouchi), the institute for nature study: development of a soil evaluation technique and importance of inventory construction for urban green areas. Soil Sci Plant Nutr 61:55–69

Ministry of the Environment Government of Japan (2017a) Annual report on environmental statistics. http://www.env.go.jp/en/statistics/index.html

Ministry of the Environment Government of Japan (2017b) Shinjuku Gyoen National Garden, Ministry of the Environment. http://www.env.go.jp/garden/shinjukugyoen/english/index.html

Ministry of the Environment Government of Japan (2017c) Kokyo Gaien National Garden, Ministry of the Environment. https://www.env.go.jp/garden/kokyogaien/english/index.html

O'Leary MH (1995) Environmental effects on carbon isotope fractionation in terrestrial plants. In: Wada E, Yoneyama T, Minagawa M, Ando T, Fry BD (eds) Stable isotopes in the biosphere. Kyoto University Press, Tokyo, pp 78–91

Okuda S (2001) Vegetation map of the institute for nature study. Rept Inst Nat Stud 33:71–79 (in Japanese)

Research Committee of the Japanese Institute of Landscape Architecture (2000) Ground maintenance manual in landscape planting. J Jpn Inst Landscape Architec 63:224–241 (in Japanese)

Sakagami K (1990) Kurobokudo. In: Asami S (ed) Soil geography. Kokon-shoin, Tokyo, pp 186–194 (in Japanese)

Tokyo Metropolitan Government (1997) Fundamental land classification survey "West-South part of Tokyo" scale 1:50,000 map. Tokyo Metropolis, Tokyo (in Japanese)

Uoi N (2014) A study on soil classification and evaluation based on vertical soil compaction for urban green spaces. Doctoral dissertation of Tokyo Metropolitan University

Uoi N, Kawahigashi M, Ono M, Murata T, Watanabe M (2013) Estimation of soil carbon storage in Shinjyuku Gyoen national garden based on land use history and soil compactness profiles. Geogr Rep Tokyo Metrop Univ 48:13–24

Uoi N, Watanabe M, Murata T (2014) Relation between vertical soil compaction and land use history in urban green space. – a case study in Kitanomaru Garden, Kokyo Gaien national garden. J Jpn Soc Reveget Tech 39:412–421 (in Japanese with English abstract)

Yoneyama T, Nakanishi Y, Morita A, Liyanage BC (2001) δ13C values of organic carbon in cropland and forest soils in Japan. Soil Sci Plant Nutr 47:17–26. https://doi.org/10.1080/00380768.2001.10408364