

Soils

Soil is an important natural medium for supporting plant growth and crop production. Recent changes in global climate and ecosystems are placing greater emphasis on the role of soil as a surface medium that connects water, atmosphere, and terrestrial ecosystems. In order to respond to increasing societal demands for detailed knowledge in this field, it is necessary to gain a better understanding of the spatial distribution, temporal changes, and nutrient status of soils.

Previously, Korea's soil classification methods emphasized the relationship between soil-forming factors and soil characteristics. Current classifications are generally made by utilizing the Soil Taxonomy established by the United States Department of Agriculture (USDA). Forest soil is separately classified according to soil morphological data such as soil color, moisture condition, and parent materials.

Korea has a fairly homogenous climate and vegetation pattern throughout its territory, but its soil distribution pattern is quite complex. This can be attributed to the country's long history of intensive land use, diversified geological features, and rough terrain. According to Soil Taxonomy (which categorizes 12 orders of soil recognized on a global scale), Korea has 7 orders, 17 sub-orders, and 27 great groups of soils. In addition, approximately 400 soil series (the lowest level of soil classification) have been identified to date.

64.8% (6.13 million ha) of Korean territory is

covered with Inceptisols, which can be defined as soils that do not have clear soil horizon development. The predominance of Inceptisols indicates that the land surface has undergone radical changes. For instance, rapid soil erosion constantly removes topsoil from slope surfaces, and active deposition in areas such as alluvial fans, valleys, and riverside flats hinders soil horizonation. The characteristics of Korean summers also serve as crucial factors of fast erosion; concentrated precipitation, high temperatures, and high humidity interrupt the accumulation of organic matter and weaken soil formation processes. Additionally, freezing during the winter also prevents active differentiation of soil horizons.

Entisols, occupying 1.07 million ha (11.3%), have a weakly developed A horizon. Even in flat areas, Entisols are commonly considered infertile as they have a low nutrient status and a decreased capacity for water storage. 58 soil series are currently classified as Entisols and 4 subgroups have been identified. Entisols are predominantly concentrated along major mountain areas – such as Taebaeksanmaek and Sobaeksanmaek – where active soil erosion occurs. Psammments (often found in sand deposits and shifting sand dunes) and Fluvents/Aquents/Orthents (mostly formed on riverbanks and tidal mudflats) are some identifiable suborders of Entisols.

Alfisols and Ultisols have a well-developed B horizon that characteristically appears in clay-en-

riched argillic horizons. These soils occupy 13.2% and 8.7% of the land, respectively. Alfisols are located in riverside flatlands or on hillsides composed of neutral or basic rocks. Ultisols are acidic, and can usually be found along hillsides or foothills consisting of acidic rocks.

Andisols are formed in volcanic rocks and are mainly distributed on volcanic islands that were formed during the Quaternary eruption (such as Jeju-do and Ulleungdo). They also appear in inland regions, where they show local distribution in the Tertiary volcanic rock zones along Taebaeksanmaek, Sobaeksanmaek, Gyeonggi-do, and the northern part of Gangwon-do. Andisols, however, only occupy 1.4% of the total area of South Korea.

Histosols are developed in organic-rich environments. They can be observed throughout the coastal area of the South Sea and Jeju-do. On the other hand, Mollisols – soils illuviated with organic matter and nutrients – are common in the valleys of northern Sobaeksanmaek and southern Gangwon-do.

Korea is well-known for its success in combating land degradation. By the end of the Joseon dynasty, many of its mountains were devastated due to long years of slash-and-burn farming and firewood logging. The Japanese Colonial Period and the Korean War that followed only further deteriorated the situation through severe forest degradation and consequent soil loss. Since the

1970s, however, many of the barren mountains have successfully been transformed into lush green forest areas and soil quality has steadily improved. Korea's case of overcoming land degradation serves as a valuable example of sustainable development, particularly for developing countries.

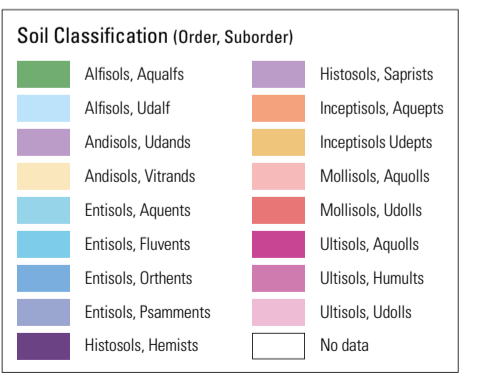
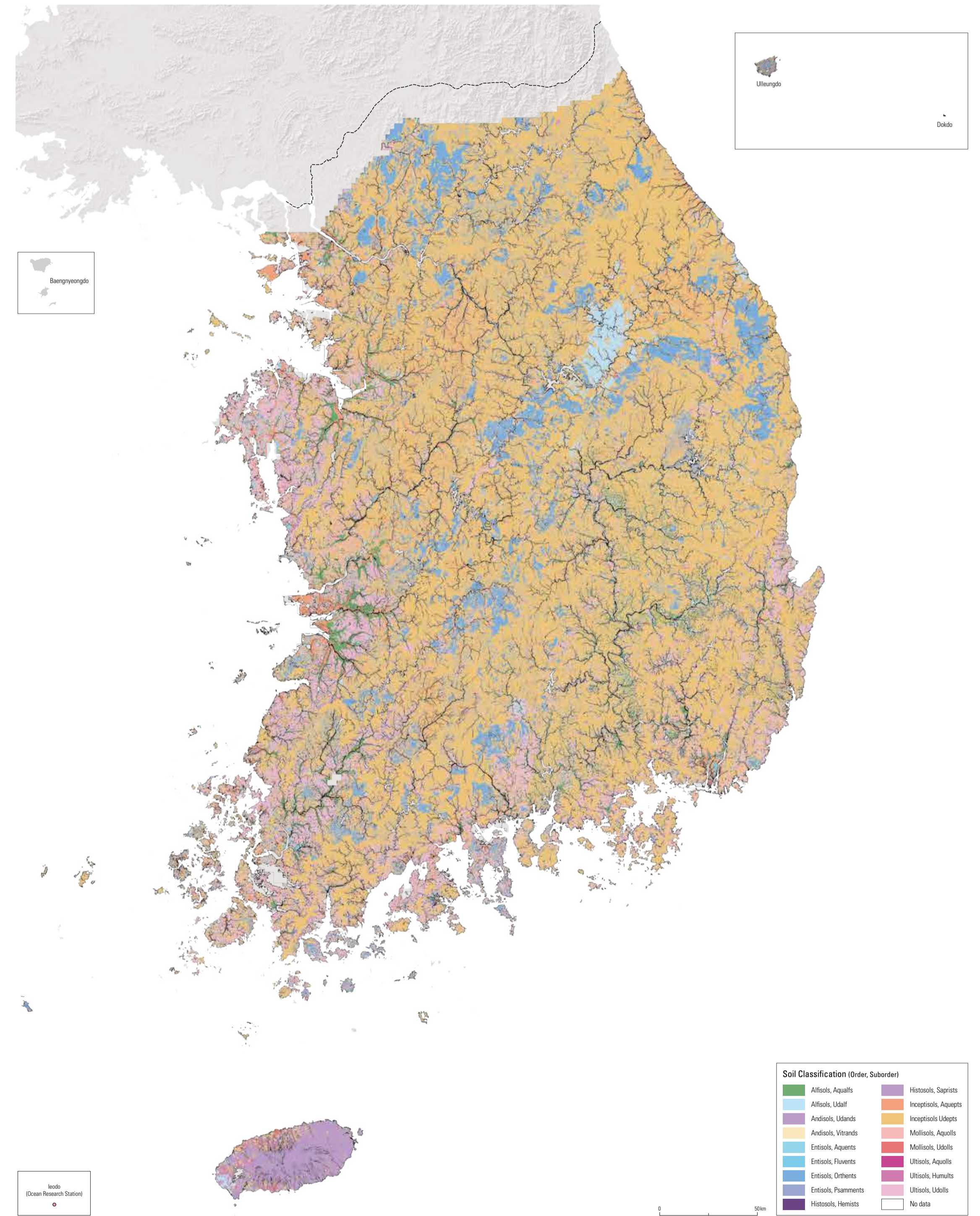
Soil Classification (Soil Taxonomy)

Order (7)	Suborder (17)	Soil Series (405)	Area (ha)
Inceptisols	Aquepts	54	529,809
	Udepts	97	5,602,668
Entisols	Aquents	11	28,001
	Fluvents	6	45,230
	Orthents	29	956,984
	Psammments	12	35,969
Ultisols	Aquults	5	36,316
	Humults	10	50,322
	Udults	50	1,159,747
Alfisols	Aqualfs	22	441,661
	Udalfs	47	378,585
Andisols	Udands	42	129,093
	Vitands	1	71
Mollisols	Aquolls	2	308
	Udolls	15	62,080
Histosols	Saprists	1	50
	Hemists	1	359

Rural Development Administration (2015)

Soil Status

Soil Map of Korea



Rural Development Administration (2014)

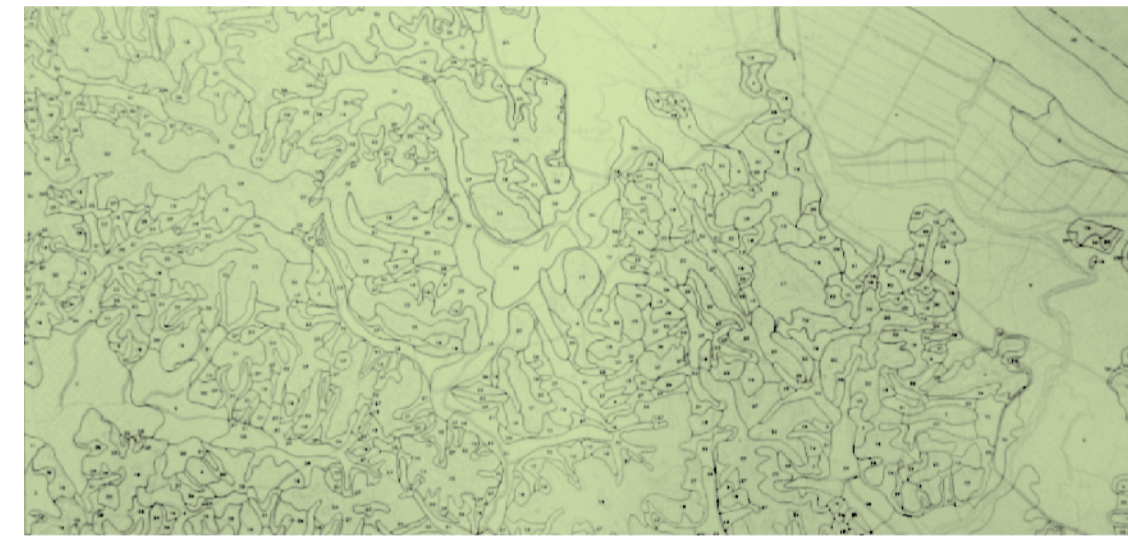
Soil Survey

Nongsa jikseol (農事直說, 1429)



Compiled during the King Sejong era (reigned, 1418 – 1450), *Nongsa jikseol* is Korea's first agricultural text that organized traditional agricultural practices and techniques. Before its publication, Korean farmers sought information from Chinese agricultural books, most notably *Nongsang jibyo* (農桑輯要). However, as *Nongsang jibyo* specifically referred to farming experience in China's northern region, it had limitations when applied to Korean climate and soil. In 1428, King Sejong ordered the governors of Gyeongsang-do, Chungcheong-do, and Jeolla-do to survey and record the agricultural technology of each region. Using this data, Jeong Cho (鄭招, ? – 1434) and Byeon Hyomun (卞孝文, 1396 – ?) constructed a viable agricultural system and published it as *Nongsa jikseol*. The book first contains general information on managing soil and seeds, and then elaborates on the cultivation methods of various crops.

Part of a 1:5,000 Soil Map (Bukbyeon-ri, Gimpo-si)



Rural Development Administration (1969)

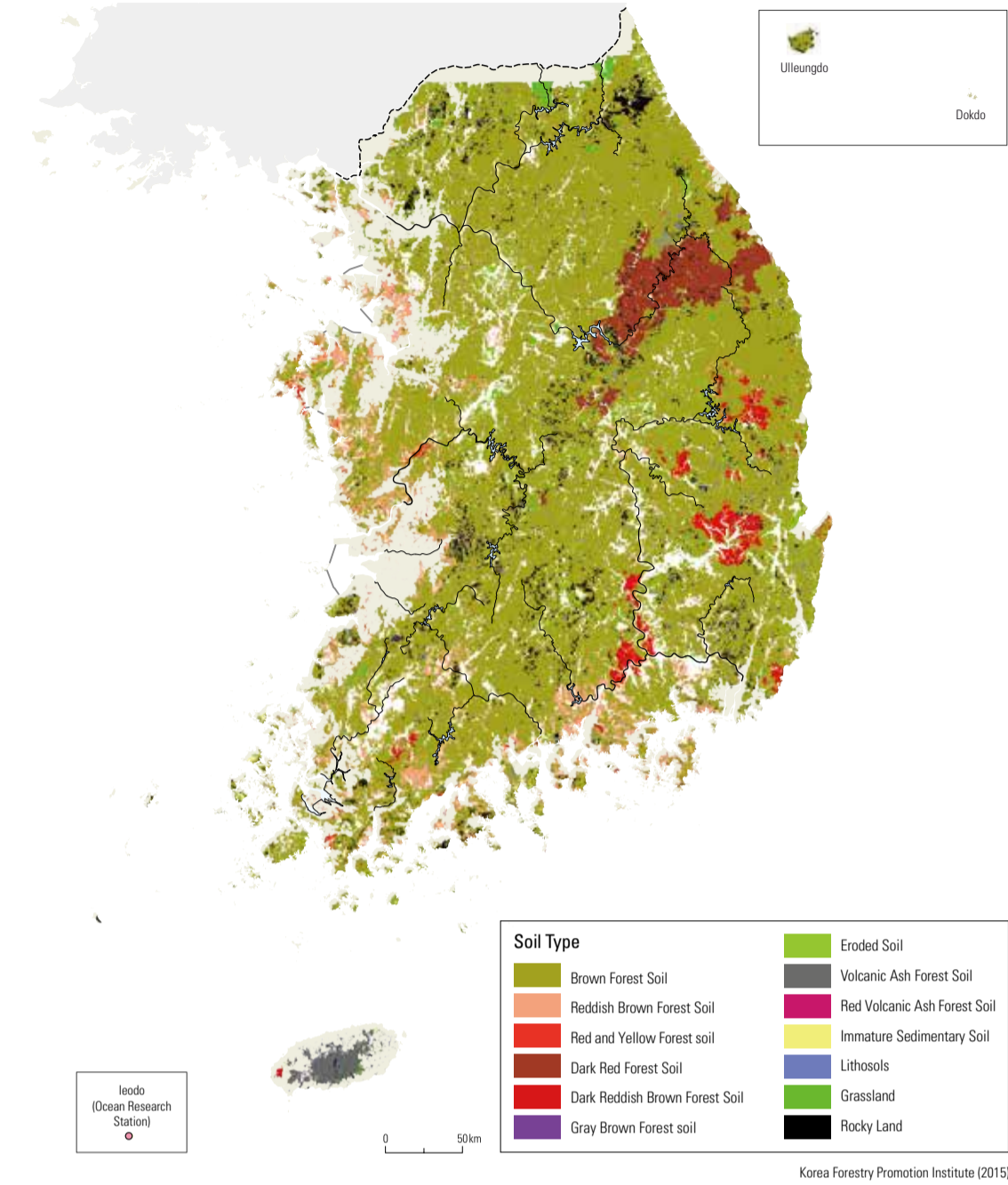
Soil Survey Methods

Class	Reconnaissance Soil Survey	Detailed Soil Survey	Super-detailed Soil Survey
Base Map Scale	1:40,000	1:10,000 – 18,750	1:1,200 – 5,000
Soil Map Scale	1:50,000	1:25,000	1:5,000
Minimum Mapping Unit Area in Soil Map	6.25 ha	1.56 ha	1 ha
Survey Precision and Soil Classification	Interpretation based on aerial images	Field-based survey	Survey of each land unit
	Higher categories (great soil groups, soil phases)	Lower categories (soil series, mapping units, soil types, soil phases)	Lower categories (soil series, mapping units, soil types, soil phases, on-site land use)
Distance Between Survey Points	500 – 1,000 m	Within 100 m	50 m
Results	Study of nationwide soil formation and distribution of great soil groups	Farming supervision plans for Gun or Myeon units	Detailed farming plan for each farm
	Comprehensive development plan for central and provincial governments	Development plans for each region	Data for soil management in each land unit
	Distribution file of potential agricultural development areas	Construction of chief producing areas for each agricultural belt	Selection of crops according to soil characteristics
		Improvement of fertilizer usage in each region	Study of proper sites for farms or groves
		Fundamental data for soil management	Selection of sites for soil introduction, deep cultivation, and drainage

Korea's mountainous topography and high population density have led the country to have the highest social demand for soil resources. In response to this, Korea carried out an extremely elaborate and sophisticated soil survey, the results of which have been made available to the public through a digitalized soil information system. According to *Nongsa jikseol* (the agricultural text written by Jeong Cho and Byeon Hyomun in 1429), the taste of the soil served as the standard for soil classification at the time. Records state that the fertility of soil differs according to its taste; sour-tasting soil indicates barrenness, while sweet-tasting soil refers to richness. Modern soil surveys were first conducted in 1905, when Japanese scholars were dispatched

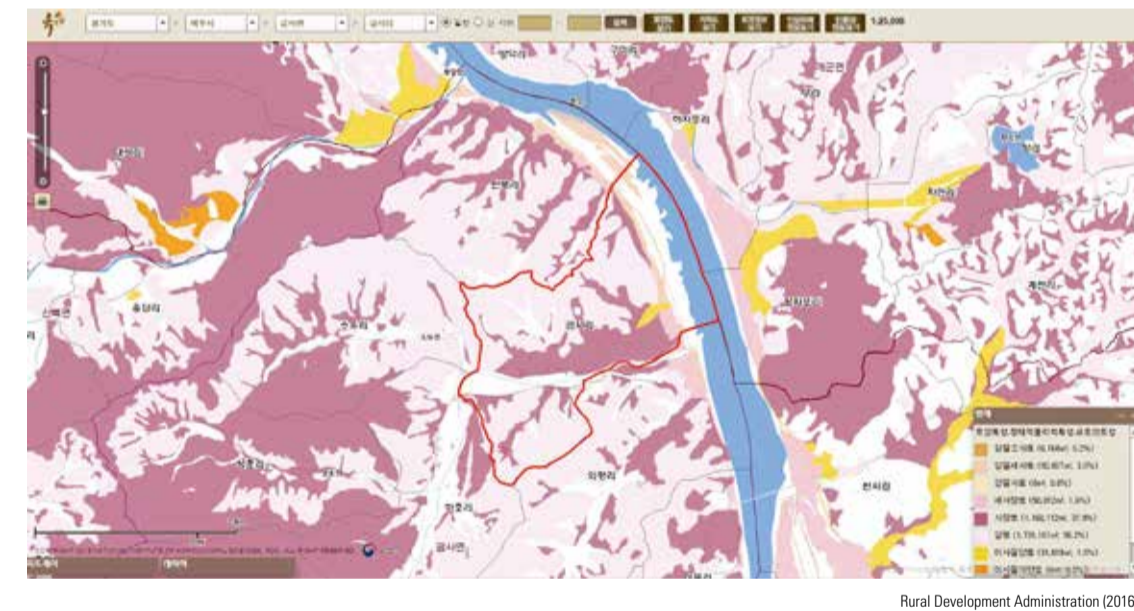
to study the climate, geology, and other natural characteristics of Korea. In 1930, an irrigation association conducted a survey in order to set a standard for fertilizer usage. The first planned soil survey project was launched in 1936 with a decade-long plan to study cultivated land. However, it was halted due to the outbreak of World War II and the Korean War. Advanced scientific soil survey methods were introduced in 1959, when the country received overseas aid to conduct a survey of Daedeok-gun, Daejeon-si under the USDA soil classification system. Between 1964 and 1999, extensive national soil survey projects were carried out as part of the United Nations Special Fund. There are three types of soil surveys: reconnais-

Forest Soil Map



Korea Forestry Promotion Institute (2015)

Korean Soil Information System



Rural Development Administration (2016)

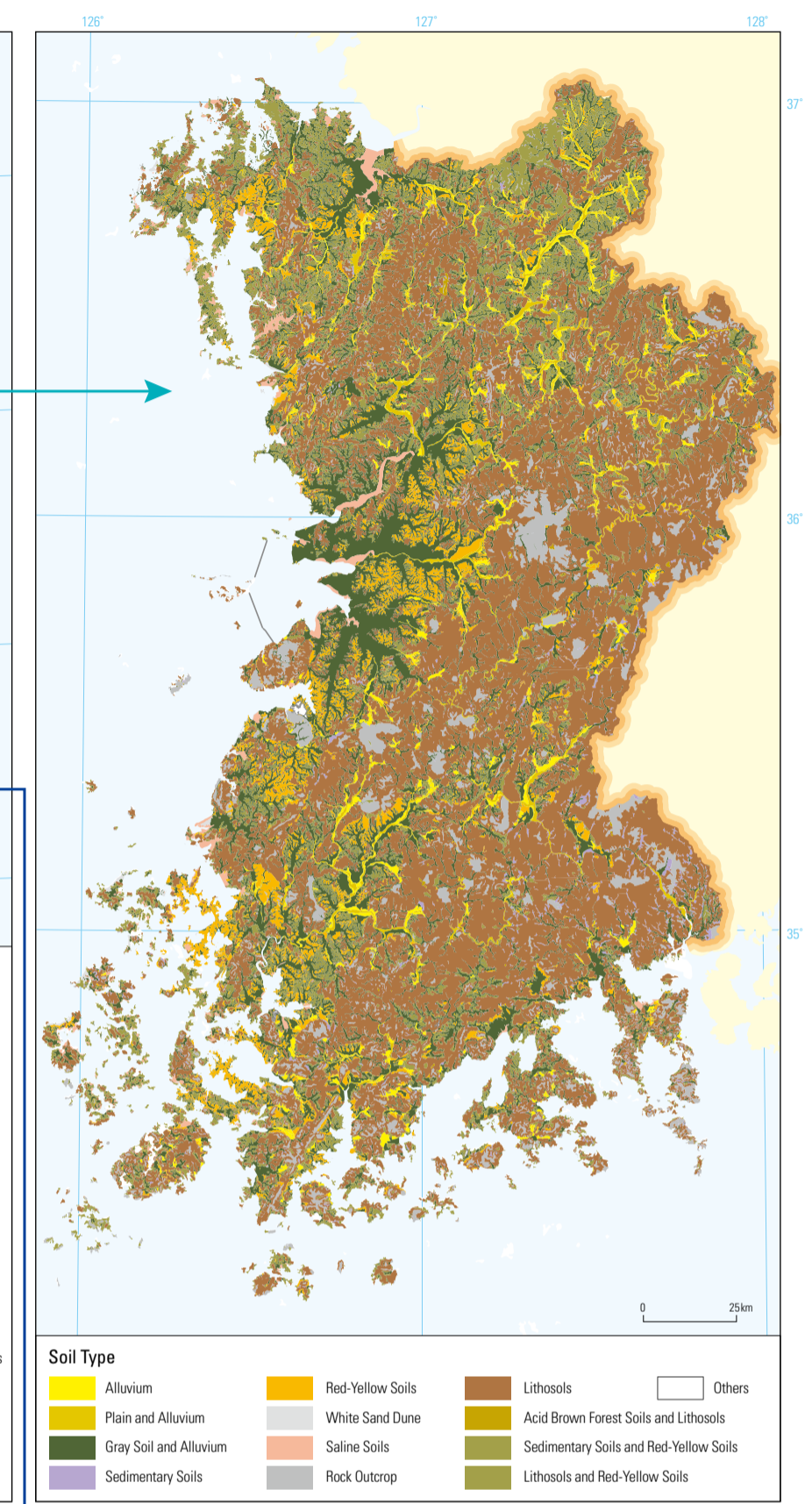
sance, detailed, and super-detailed. The categorization depends on the survey's objectives, base map scales, and precision. Reconnaissance soil surveys were carried out from 1965 to 1967 over relatively wide areas. The printed soil map resulting from these surveys was provided at a 1:50,000 scale with 6.25 ha as the minimum mapping unit. It is being used for various policies such as comprehensive land development plans. Detailed surveys began in November 1964 with the support of the UN Special Fund. Professional surveyors were recruited and trained to examine potential areas for future cultivation. Backed by the UN and the Korean government, the projects surveyed a total of 9,586,407 ha, or 96.6% of Korea's total area. As of now, only the areas

surrounding the Military Demarcation Line and newly reclaimed lands have yet to be surveyed. A government-led survey of forest soil was first launched by the Forest Service in 1968 in order to find suitable afforestation areas in the river basins of Anseongcheon, Dongjingang, and Sangjucheon. Beginning in 1995, annual soil surveys have been conducted to achieve systematic development and management of forest resources. A 1:25,000 scale national forest soil map was completed in 2003, and current projects are aimed towards enhancing this map to be on a scale of 1:5,000 to invigorate sustainable forest and ecosystem management, particularly for private forests.

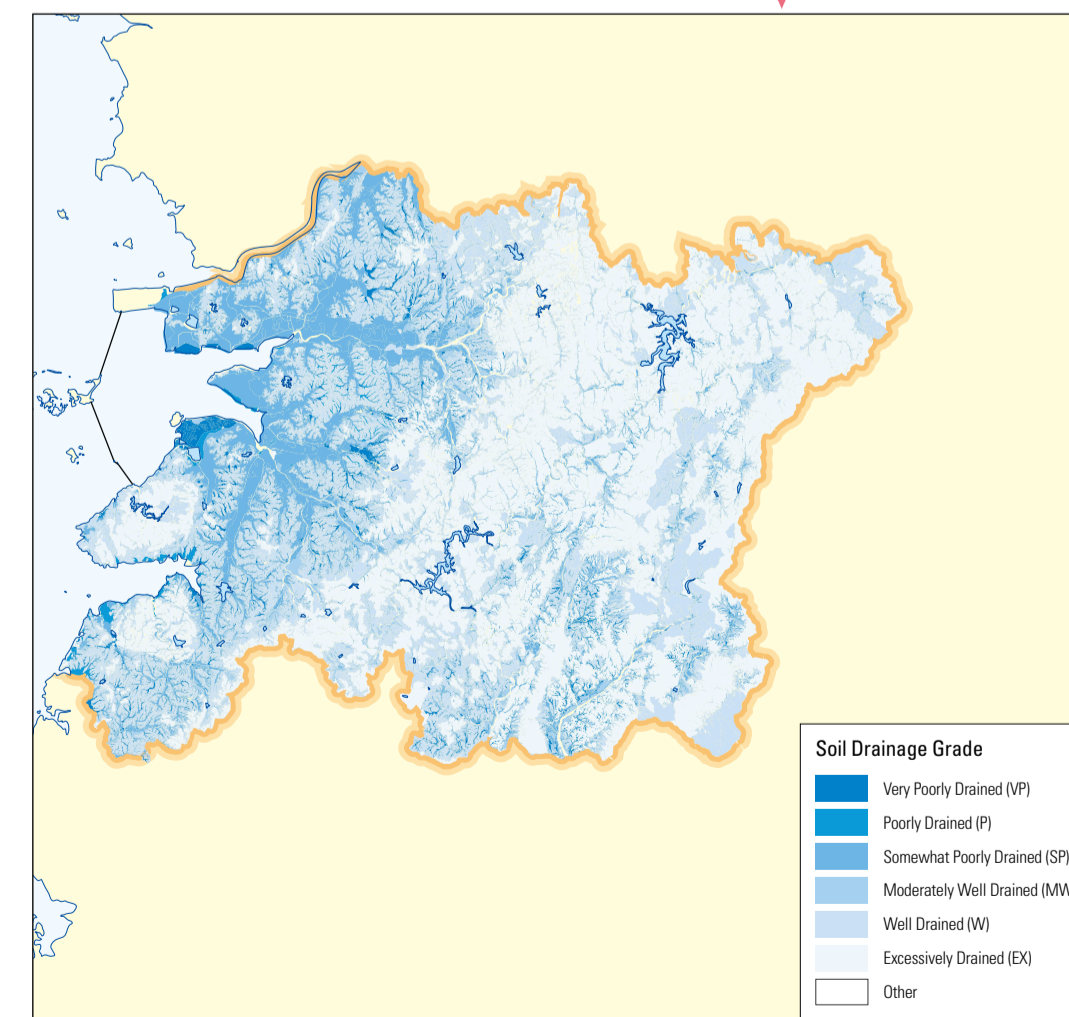
Reconnaissance Survey Soil Map at a Scale of 1:250,000



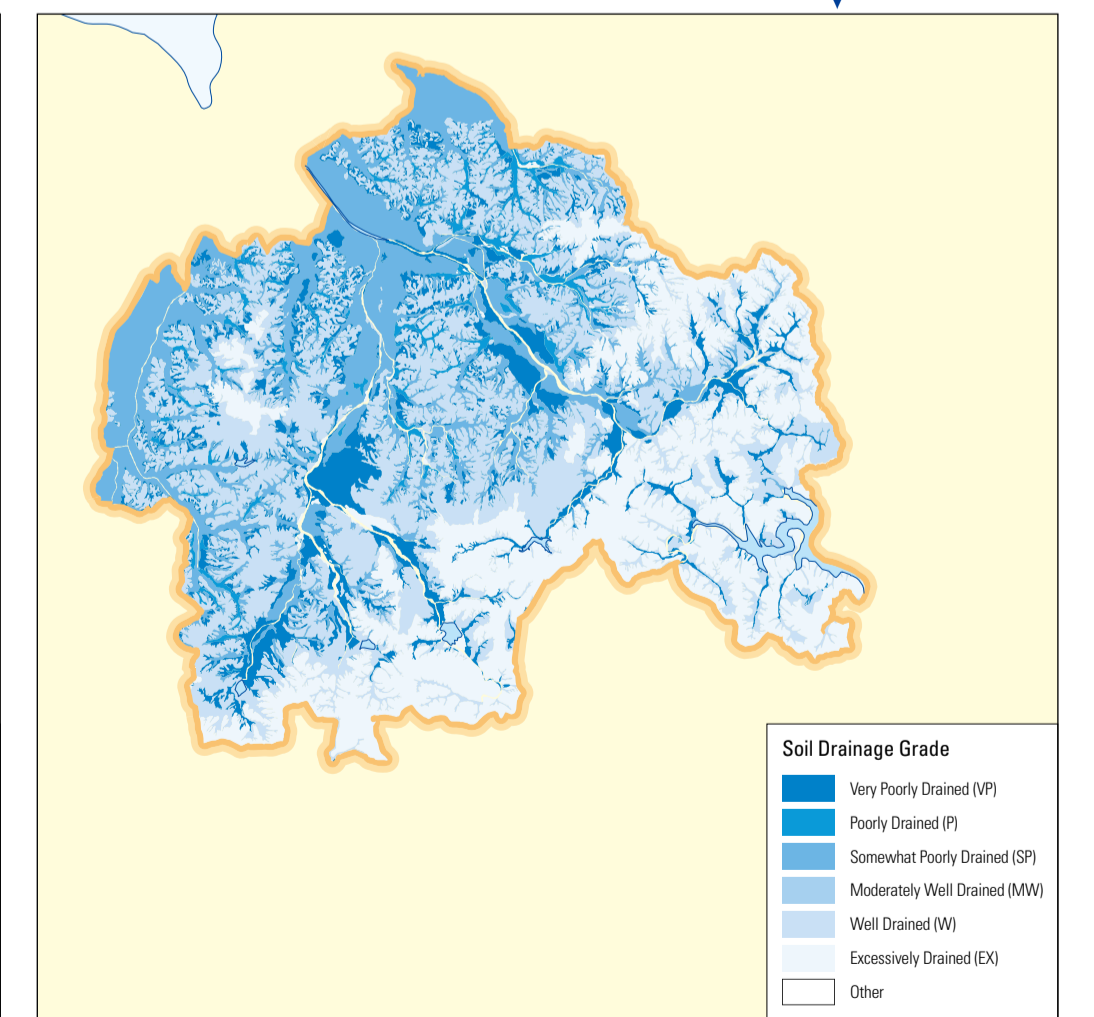
Example of Reconnaissance Soil Survey Map at a Scale of 1:50,000



Example of Detailed Soil Survey Map at a Scale of 1:25,000



Example of Super-detailed Soil Survey Map at a Scale of 1:5,000



Rural Development Administration (2016)

Representative Soils of Korea

Representative Paddy Soils

Ordinary Paddy Soil

Ordinary paddy soils are distributed in highly productive paddies with no specific limiting factor in rice cropping. These soils comprise approximately 32.6% of the total area of paddy fields in Korea. Adequate soil management followed by balanced use of fertilizer would sustain high productivity of the soils.

Poorly-drained Paddy Soil

As poorly-drained paddy soils are located in paddies that are only about 50 cm above ground water level, they are at high risk of damage from cold or dampness. Due to the intense reduction process in the soils, hydrogen sulfide and acidic organic matter can easily accumulate. These paddy soils require drainage installations to increase nutrient absorption by crops.

Immature Paddy Soil

Immature paddy soils can be found in new paddies with low levels of organic matter. The soils require intense care due to their low capacity for storing water and nutrients, compact texture, and low water permeability. These soils comprise 23.4% of the total area of paddy fields in Korea.

Saline Paddy Soil

Saline paddy soils form in reclaimed lands and have high salinity. The majority of these soils are located in fluvo-marine plains that comprise 2.5% of the total area of paddy fields in Korea. When including areas that are undergoing reclamation processes, the actual total size of saline paddy soil areas is considerably larger.

Sandy Textured Paddy Soil

Sandy textured paddy soils are incompletely formed soils that lack sufficient horizon development because of a shorter history of cultivation. Due to their high sand content, they exhibit severe leaching, which leads to low nutrition capacity. These soils comprise 32.3% of the total area of paddy fields in Korea.

Acid Sulfate Paddy Soil

Acid sulfate paddy soils are formed in the sulfate illuvial horizon located 50 cm beneath the surface, and can be found in the Gimhae plain. Due to its low pH value and high acidity, soil yield is very low. Drainage facilities must be installed to remove sulfate from the soils and maintain a neutral pH value.

Representative Farm Field Soils

Ordinary Upland Soil

Ordinary upland soils comprise up to 41.8% of the total area of farm fields in Korea and are mainly distributed in alluvial fans or valleys. While there is no limiting factor for ordinary farm field soils in rice cropping, the productivity of this type of soil is quite promising even without additional care for soils or crops. Adding lime powder may improve crop yield.

Immature Upland Soil

Immature upland soils are common in alluvial fans, mountain foothills, and hills. They form in farm fields that have a relatively short history of cultivation. These soils heavily depend on the amount of fertilizer, organic material, lime, and phosphate used for remediation, and comprise 19.0% of the total area of farm fields in Korea.

Sandy Textured Upland Soil

Sandy textured upland soils have a high sand content and are mostly found in plains, alluvial fans, and valleys. They comprise 22.7% of the total area of farm fields in Korea. Suitable irrigation methods and fertilization are required due to their insufficient water/nutrient storage capacity.

Plateau Upland Soil

Plateau upland soils are clayey soils or loams that contain high levels of clay. They comprise only 0.3% of the total area of farm fields in Korea and are found in the high reaches of Gangwon-do. As fertile soils, they are well-developed in areas where mean temperature is low during the summer, thus ideal for growing seasonal greens. However, they need preservation plans against rapid erosion.

Heavy Clayey Upland Soil

Heavy clayey upland soils, which can be found in low hills, valleys, and foothills, are distributed in slopes of less than 7%. While they have high water/nutrient storage capacity, permeability remains relatively low, thus potentially damaging crops through excessive moisture. Certain soil management practices like subsoil breaking are needed. This kind of soil comprises 14.3% of the total area of farm fields in Korea.

Volcanic Ash Upland Soil

Volcanic ash upland soils are black, organic-rich soils that comprise 2.4% of the total area of farm fields in Korea and are most common in Jeju-do. They contain clay minerals (mainly allophane), have high organic material content, and feature high cation exchange capacity, yet their high phosphorus fixation capacity leaves them with less available phosphate.

Representative Forest Soils

Brown Forest Soil

Ulleungdo Dado

Brown forest soils are loamy soils originating from granite or granite gneiss. They are estimated to be the most abundant forest soils in Korea, covering 80% of its forested area. The soil profile explains some of the characteristics of brown forest soils, including the dark black color from humus decomposed and accumulated in topsoil and the gradual increase of hue and particle size through soil depth, which is 50 – 60 cm on average.

Soils (Ocean Research Station)

Red and Yellow Forest Soil

Ulleungdo Dado

Red and yellow forest soils are mostly distributed in flat to gentle hillsides in the coastal regions of the Yellow Sea and South Sea. Their inclusion of hematite or limonite leads them to be classified into two different soil types, red forest soils and yellow forest soils, respectively. It is common for the subsoil layer of these soils to have less permeability due to their high silt and clay content. Thus, forest areas covered with red and yellow forest soils are considered to have lower yield than other areas.

Soils (Ocean Research Station)

Dark Red Forest Soil

Ulleungdo Dado

Dark red forest soils are differentiated according to their parent materials; the dark red forest subgroup develops from limestone and the dark red brown forest subgroup develops from tuff or red sandstone. These soils usually have high clay and gravel content and contain high levels of calcium and magnesium. Consequently, they may not be suitable for plant growth because of their thick texture, shallow depth, and low air permeability.

Soils (Ocean Research Station)

Gray Brown Forest Soil

Ulleungdo Dado

Gray brown forest soils are formed from parent materials such as mudstone, shale, and ash gray sandstone. Compared to other soils, these soils have less permeability due to high silt content. As they dry out easily and have little vegetation, erosion occurs easily, particularly on slopes. Productivity of these soils is low due to poor drainage, little water, and limited nutrient content.

Soils (Ocean Research Station)

Volcanic Ash Forest Soil

Ulleungdo Dado

Volcanic ash forest soils are distributed over small areas in Jeju-do, Ulleungdo, and Yeoncheon-gun of Gyeonggi-do. The average depth of these soils (about 80 cm) is deeper than the average of all forest soils (50 cm). Because they are formed from basalt, a porous material, volcanic ash forest soils have a low bulk density. Thus, they have a high capacity for organic matter and essential nutrients and can also hold a great amount of water.

Soils (Ocean Research Station)

Eroded Forest Soil

Ulleungdo Dado

Eroded forest soils are soils with partly or entirely removed topsoil because of erosion by rain and wind. They also refer to soils with stabilized top soils after carrying out restoration measures. These soils have the lowest productivity due to shallow soil depth (under 20 cm). Eroded forest soils are classified into three types according to the degree of erosion or soil restoration: slightly eroded soils, heavily eroded soils, and erosion controlled soil. These soils cover 0.11 million ha across Korea.

Soils (Ocean Research Station)

Korea Forestry Promotion Institute (2016)

Soil Association

Soils Developed from Granite

	Mountainous Area	Foot Slope	Upper Valley	Lower Valley	Valley	Valley	Flood Plain
Soil Series	Samgag Series, Typic Dystrudepts	Sangu Series, Dystric Fluventic Eutrudepts	Noegog Series, Fluvaquentic Dystrudepts	Eungog Series, Fluvaquentic Eutrudepts	Sachon Series, Aeric Endoaquepts	Yecheon Series, Fluvaquentic Endoaquepts	
Soil Profile							
Drainage Class	Excessively Drained (EX)	Well Drained (W)	Moderately Well Drained (MW)	Moderately Well Drained (MW)	Somewhat Poorly Drained (SP)	Poorly Drained (P)	
Land Use	Forest Land	Farm and Grove	Farm and Grove	Paddy Field	Paddy Field	Paddy Field	

Rural Development Administration (2015)

Soils Developed in River Alluvium

	River or Stream	Riverside	Riverside	Inland Mid Side	Inland Mid Side	Inland Upper Side	Inland Lower Side	Valley
Soil Series	Hwangryong Series, Typic Udipsamments	Namgye Series, Aquic Udipsamments	Deogcheon Series, Typic Udifluvents	Jungdong Series, Typic Udifluvents	Seogcheon Series, Fluvaquentic Endoaquepts	Hamchang Series, Typic Endoaquepts		
Soils Profile								
Drainage Class	Excessively Drained (EX)	Moderately Well Drained (MW)	Well Drained (W)	Well Drained (W)	Somewhat Poorly Drained (SP)	Poorly Drained (P)		
Land Use	Farm	Paddy Field	Farm and Grove	Farm and Grove	Paddy Field	Paddy Field		

Rural Development Administration (2015)

Soils Developed in Fluvio-Marine Sediments

	Levee	Shore	Shore	Mid-Shore	Mid-Shore	Upper Shore	Adjacent Land to Alluvial Plain	Alluvial Plain
Soil Series	Munpo Series, Typic Fluvaquents	Gwanghwal Series, Typic Endoaquepts	Mangyeong Series, Fluvaquentic Endoaquepts	Jeonbug Series, Fluvaquentic Endoaquepts	Buyong Series, Typic Endoaquepts	Gimje Series, Fluvaquentic Endoaquepts		
Soil Profile								
Groundwater Level	< 20 cm	< 20 cm	80 cm	90 cm	100 cm	100 cm		
Land Use	Paddy Field	Paddy Field	Paddy Field	Paddy Field	Paddy Field	Paddy Field		

Rural Development Administration (2015)

Soil forming factors that determine the morphological, physical, and chemical characteristics of soils consecutively appear on the land's surface in a predictable pattern. For example, a decrease in temperature or an increase in precipitation by elevation results in changes in vegetation, which are in turn reflected in the characteristics of the

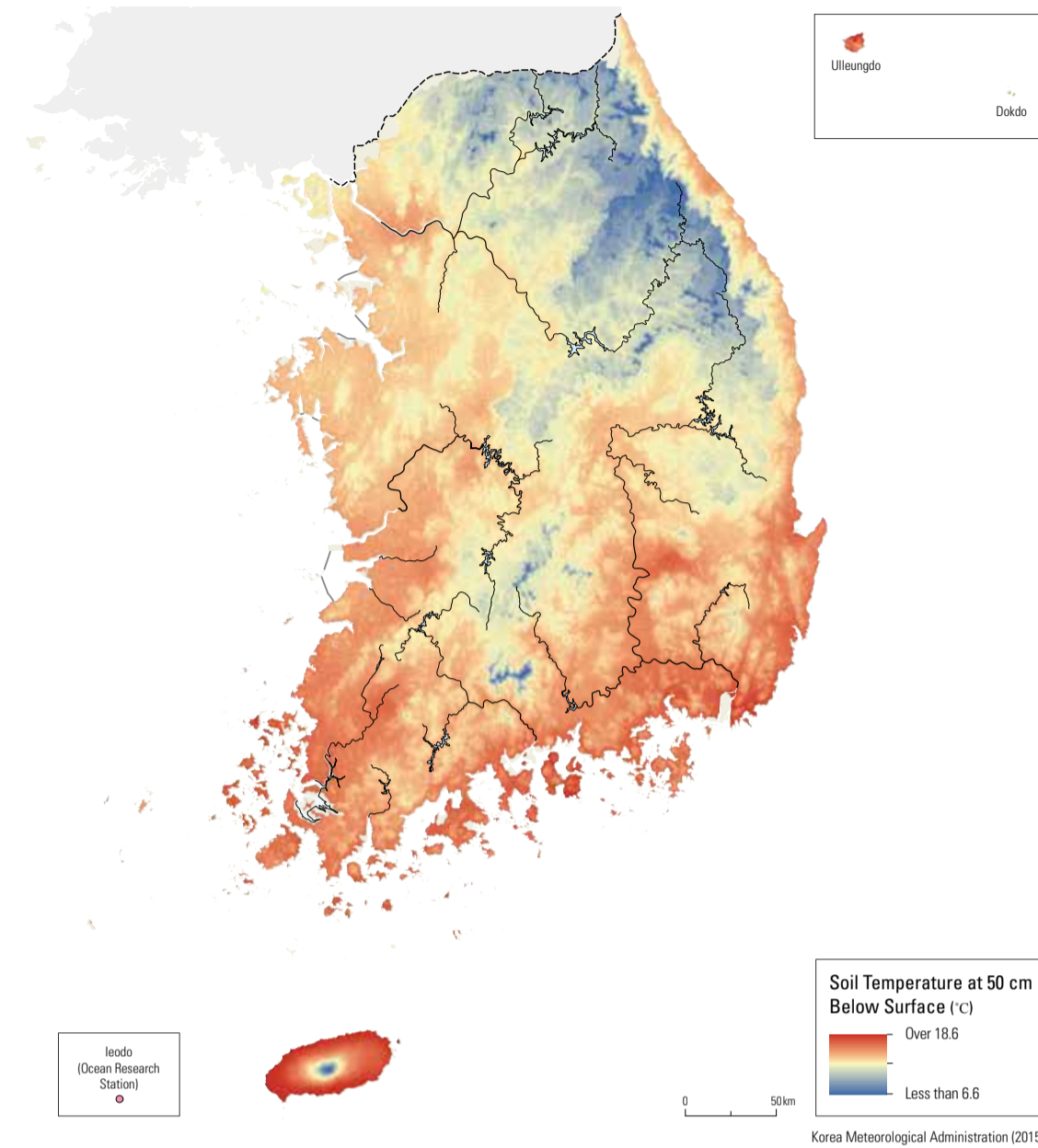
soil. A group of soils associated with one area that occur in a predictable pattern is called a Soil Association. Typical Korean topography shows floodplains on both sides of a river that are adjacent to the piedmonts, or foothills, of nearby gentle sloping mountains. These foothills are in turn connected

to the rear, steep-sloped mountains. The flow of water from mountain to river erodes soil particles, leaches soil nutrients, and then deposits them on the lower part of a mountain. Rainfall infiltrating and percolating into the soil increases its water content. Floodplains experience flooding during periods of high discharge and display high ground

water levels. As such, these soil-forming factors appear in a continuous manner, which leads nearby soil series to develop accordingly. This process is often called Soil Catena.

Soil Forming Factors

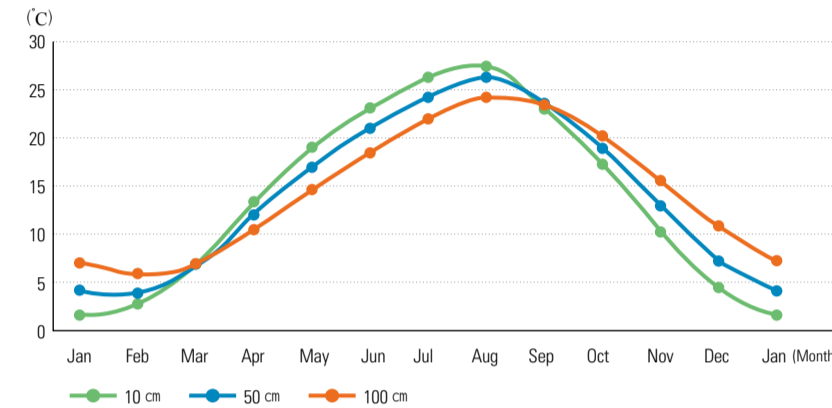
Soil Temperature



Climate – especially precipitation and temperature – has the biggest influence on the formation of soil. The Korean Peninsula has a temperate monsoonal climate with four distinct seasons of spring, summer, autumn, and winter. Heavy rainfall occurs during July and August, which causes slopes to have shallow soil due to soil loss. Summer has an average temperature of approximately 20 – 25°C with August being the hottest, while winter has an average temperature of -5 – 5°C with January being the coldest.

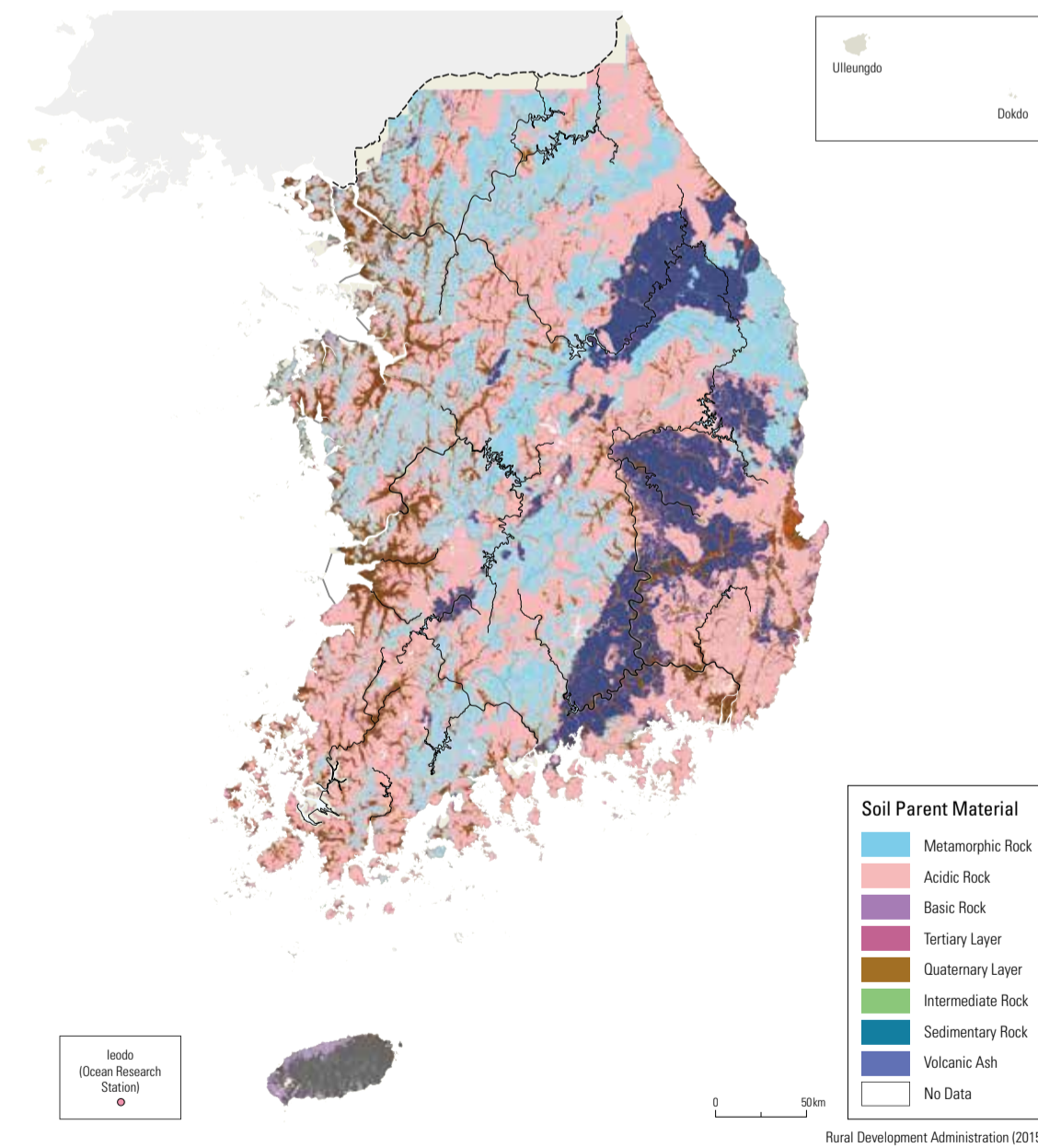
Mean annual soil temperature in Korea is 14.5°C, ranging from 7.1°C in Daegwallyeong to

Change of Mean Soil Temperature by Depth

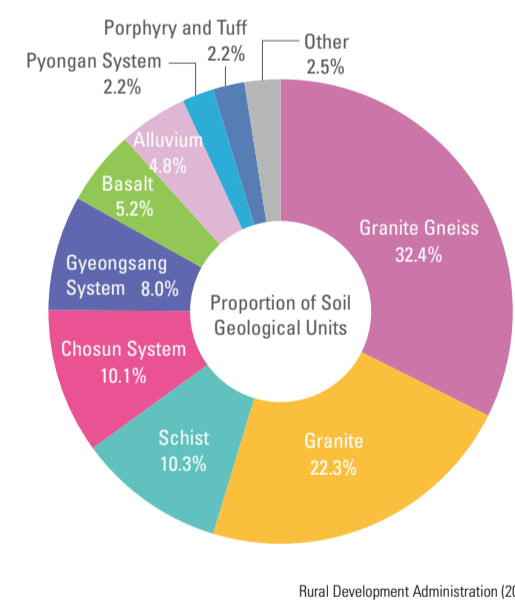


18.1°C in Seogwipo-si. According to the soil temperature regimes, Korean soils mostly belong to the mesic (8°C to 15°C) or thermic (15°C to 22°C) regime. The Korean mean annual soil temperature at 10 cm of soil depth (which is highly relevant to underground plant growth) is reported to be 1.6°C lower than the atmospheric mean temperature. This difference varies in the summer (1.9°C in August) and winter (1.8°C in January), and also ranges from 0.9°C in March to 2.2°C in September. The difference is more significant during summer and autumn than it is during spring.

Soil Geological Map



Proportion of Soil Geological Units



northern Chungcheongbuk-do. Soils from limestone have shallow soil depth, and are usually fine-textured and slightly acid or neutral.

The Gyeongsang Supergroup is a representative sedimentary rock layer that is distributed in Gyeongsang-do. Within this supergroup, there are two subordinates, the Nakdong group and Silla group. The rocks in the Nakdong group are mostly shale, sandstone, or conglomerate, while rocks in the Silla group are andesite, basalt, rhyolite, and tuff. Soils from sandstone or conglomerate are coarse and bright. On the other hand, soils from shale are fine and

Soil Changes Through Time



When time is considered as a soil-forming factor, the key concern is the relative time of soil formation rather than the absolute duration of time passed. The duration of time required for the soil profile to exhibit fine differentiation between horizons depends on the intensity of other formation factors such as climate, vegetation, parent materials, and topographical conditions. Soils with a shorter soil formation time would retain more of the characteristics of the parent material, whereas soils with a longer soil formation time would feature

reddish and often have a deep, well-developed soil profile. Rocks from the Tertiary period of the late Cenozoic era consist of unconsolidated sandstone, shale, and conglomerate, and are common in Gyeongsang-do. Soils from unconsolidated sandstone are coarse and bright, while those from shale are thin and medium-textured.

Basalt is most commonly located in Jeju-do, and soils developed from basalt are dark brown, fine-textured soils with average depth. Soils from volcanic ash are very dark brown or black due to their high organic material content.

As the climatic pattern of Korea shows little difference between regions, topographic factors play critical roles in soil forming processes. Consequently, the soil survey system classifies different landforms into ten soil geomorphological units, according to slope gradient and cause of formation.

Among the ten units, mountainous areas constitute the highest proportion with 43.2% of total land area. These areas are generally used as forest land as they have shallow soil layers resulting from erosion. Hills take up approximately 19.9% of land area, and are mostly located in western coastal areas or granite erosion basins. Although hills have better-developed soil than mountainous areas, they are also used for forests due to the high slope gradient. Valleys (10.9%) refer to the low area between

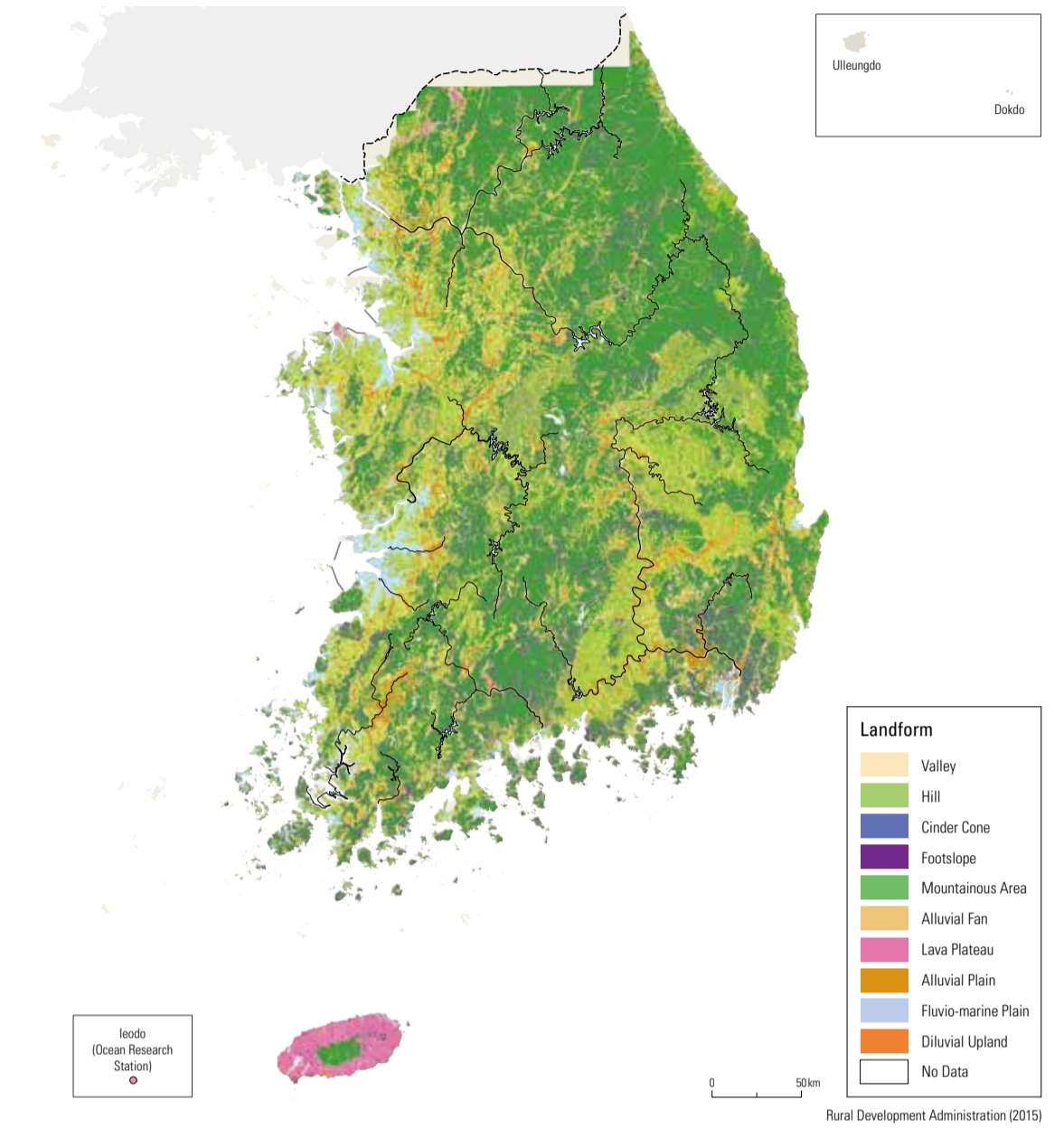
mountains that have steep slopes, commonly filled with mountain sediments and thus possessing a deeper soil layer. As they usually have convenient access to water sources, valleys are often utilized for small-scale paddies. Footslopes (8.0%) can be defined as the gentle slopes that connect mountains and plains. They are more suitable for farmlands rather than paddies as they lack a water source. Alluvial plains (4.9%) and fluvio-marine plains (3.5%) are each formed by river deposits and joint action of the sea and river, respectively. They are adequate for agriculture usage as they have deep soil layers with high productivity. Other landforms – alluvial fans, lava plateaus, diluvial uplands – each constitute less than 3% of total land area.

Proportion of Soil Geomorphological Units

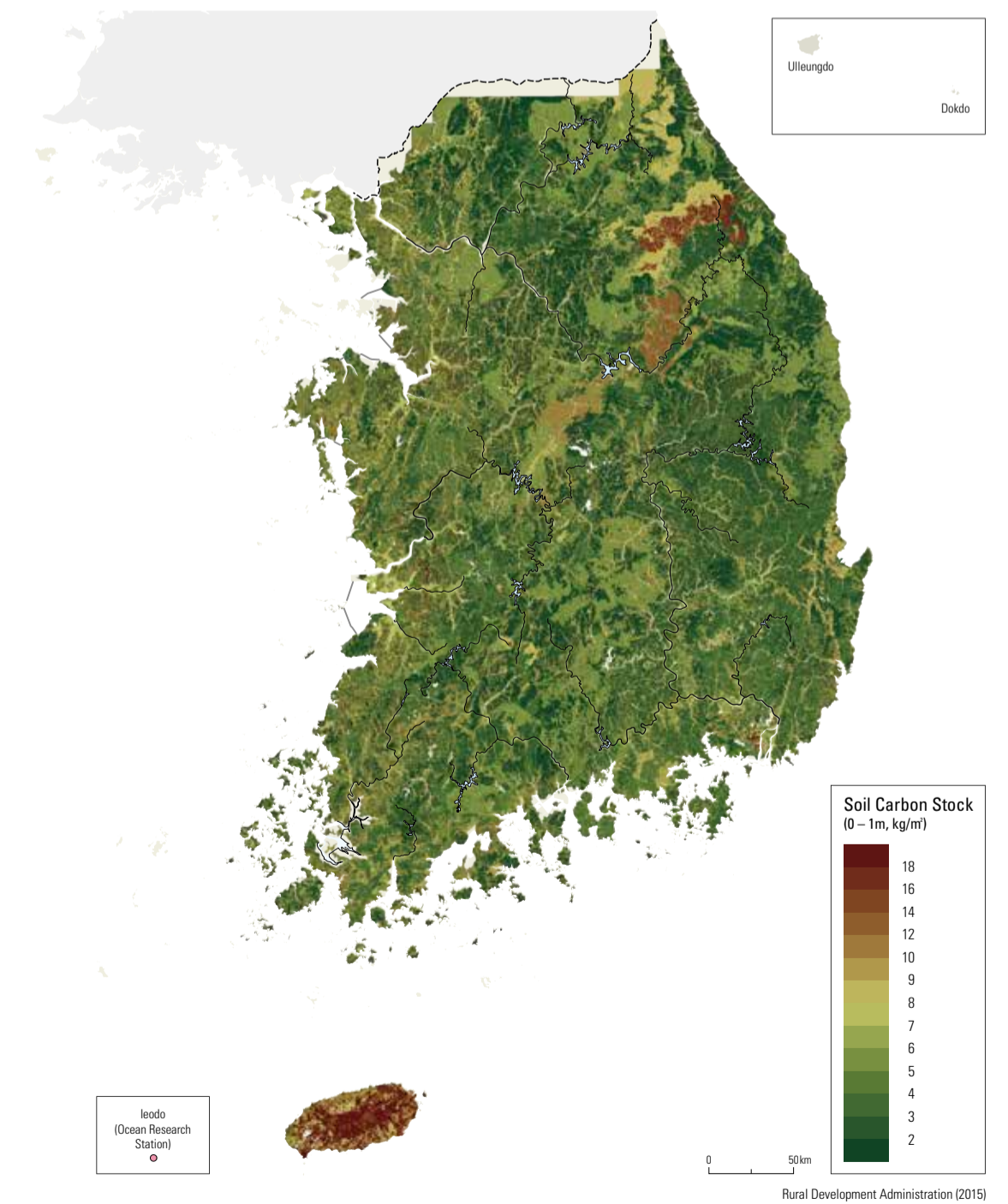
Soil Geomorphological Unit	Area (ha)	Percentage (%)
Mountainous Area	4,180,428	43.2
Hill	1,922,008	19.9
Valley	1,052,741	10.9
Footslope	776,633	8.0
Alluvial Plain	470,124	4.9
Fluvio-marine Plain	341,000	3.5
Alluvial Fan	279,542	2.9
Lava Plateau	155,481	1.6
Diluvial Upland	94,077	1.0
Other	402,711	4.1
Total	9,674,745	100.0

Rural Development Administration (2015)

Soil Geomorphological Map



Soil Carbon Stock



Animals and plants produce organic matter that plays a role in supplying and circulating nutrients to the soil. Soil that has a high content of organic matter is dark in color and has higher levels of water content and cation exchange capacity.

The characteristics and volume of organic matter that is supplied to the soil depends on the type of vegetation, which is another important factor in soil formation. The types of mineral content that are contained in natural vegetation also influence the formation of soil. As needle-leaf trees have low levels of cations (calcium, magnesium, potassium, and so forth), soil that is produced in coniferous forests is acidic compared to that produced in deciduous forests. Natural vegetation in South Korea is generally composed of mixed forests of needle-leaf and broad-leaf trees or natural grasslands. Forests are more common in higher elevations where soil moisture is sufficient due to higher rainfall and lower evapotranspiration rates. On low-level plains, grasslands and farmlands are predominant.

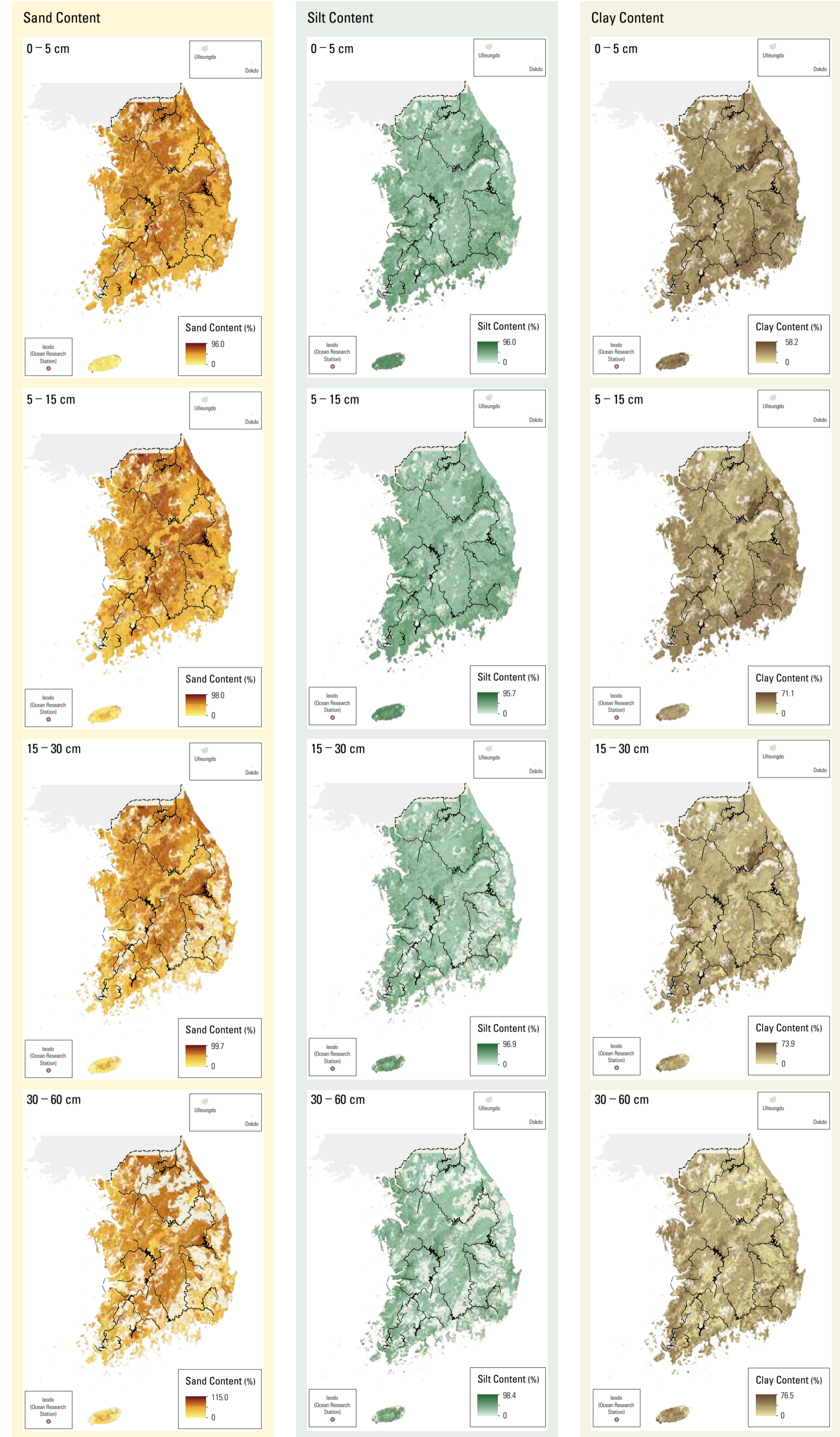
The soil organic carbon stock can be calculated by extracting the organic content per soil horizon and the volumetric density data from detailed soil maps. Under this method, the national soil carbon density for up to 1 m in depth is estimated to be around 5 kg/m² and the total carbon stock comes out to 449 Gg. According to the type of land use, forests have the highest total carbon stock at 249 Gg, followed by agricultural land at 174 Gg, and grassland at 16 Gg.

Carbon Stock in Soil

Class	Forest	Farmland	Grassland	Wetland	Bare Land
Land Use Area (km ²)	61,394	25,648	1,858	1,780	1,439
Carbon Storage Per Unit (kg/km ²)	4.05	6.77	8.82	1.10	4.24
Total Carbon Storage (kg/km ²)	249	174	16	2	6

Rural Development Administration (2015)

Soil Properties

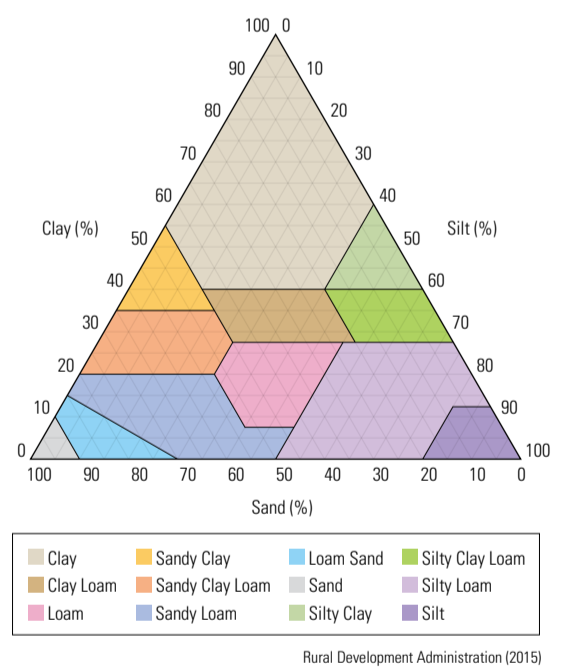


Soil texture is determined by the relative proportion of three kinds of soil mineral particles; sand (0.05 – 2 mm), silt (0.002 – 0.05 mm), and clay (particles smaller than 0.002 mm). Soil texture is often considered as one of most important attributes that controls the physical and chemical characteristics of soil.

On average, the soil in the paddy/farm areas of Korea is composed of 41.7% sand, 41.5% silt, and 16.8% clay. Major soil textures are moderate coarse sandy loam (44.5%) and fine-textured clayey loam (34.1%), and these soils cover up to 7.8% of the total land area. Gravelly soils are also observed in 5.9% of the total area. Because Korean soils have high porosity and show good water drainage, the possible leaching of nutrients and organic matter may result in less productivity.

Paddies have the lowest percentage of sand in soil, followed by farms and forests. Silt and clay content decrease in the same order. While paddy soils have particularly higher silt content, farm and forest soils are sandier. Soils with higher sand content are distributed throughout the mountainous regions from southern Gyeonggi-do to Chungcheongnam-do and Chungcheongbuk-do. On the other hand, the amount of silt in soil is high in coastal regions, the limestone areas of the Okcheon System from southern Gangwon-do to Jeollanam-do and Jeollabuk-do, and the sedimentary rock areas of the Gyeongsang System in Gyeongsangnam-do and Gyeongsangbuk-do.

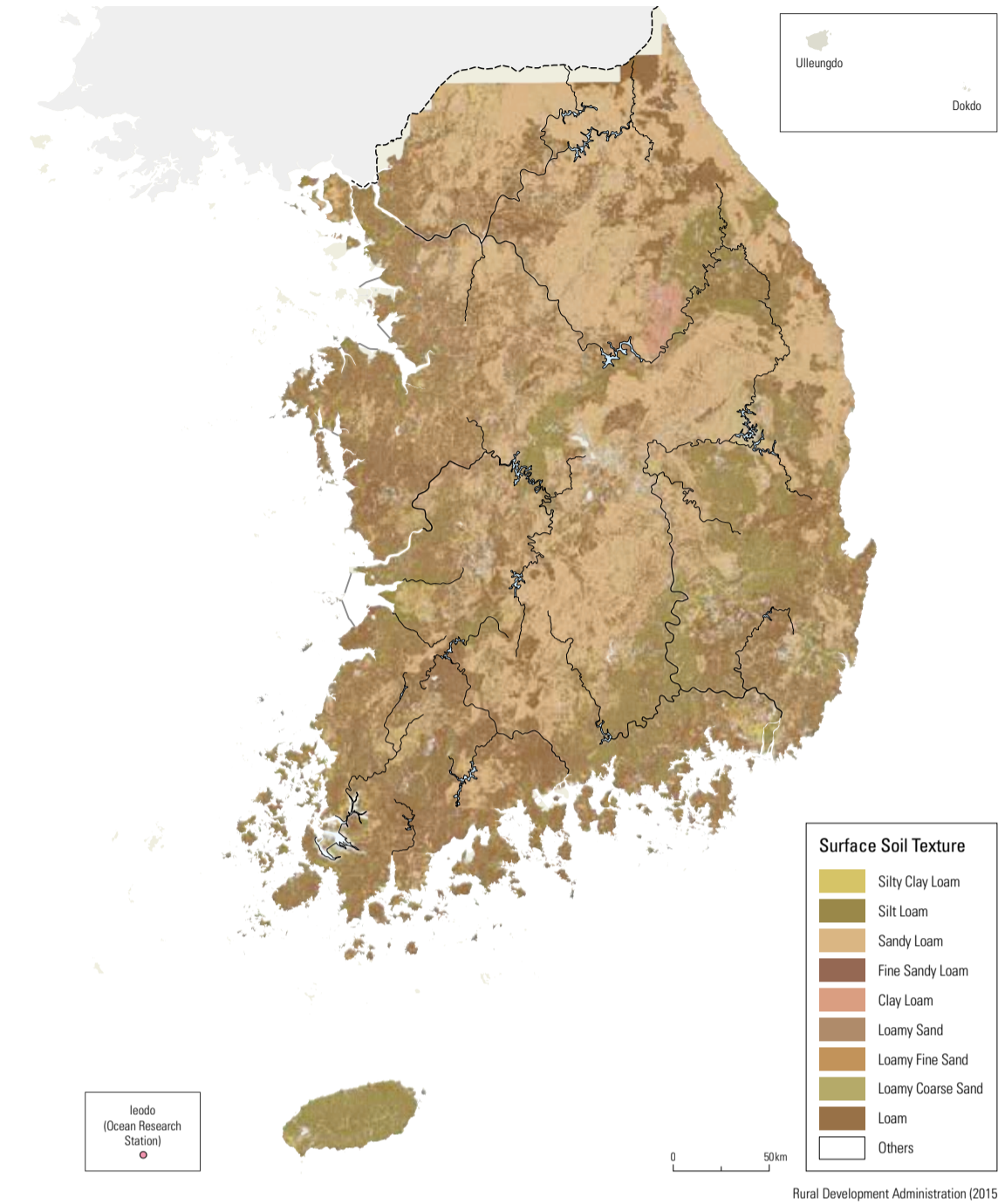
Soil Texture Groups



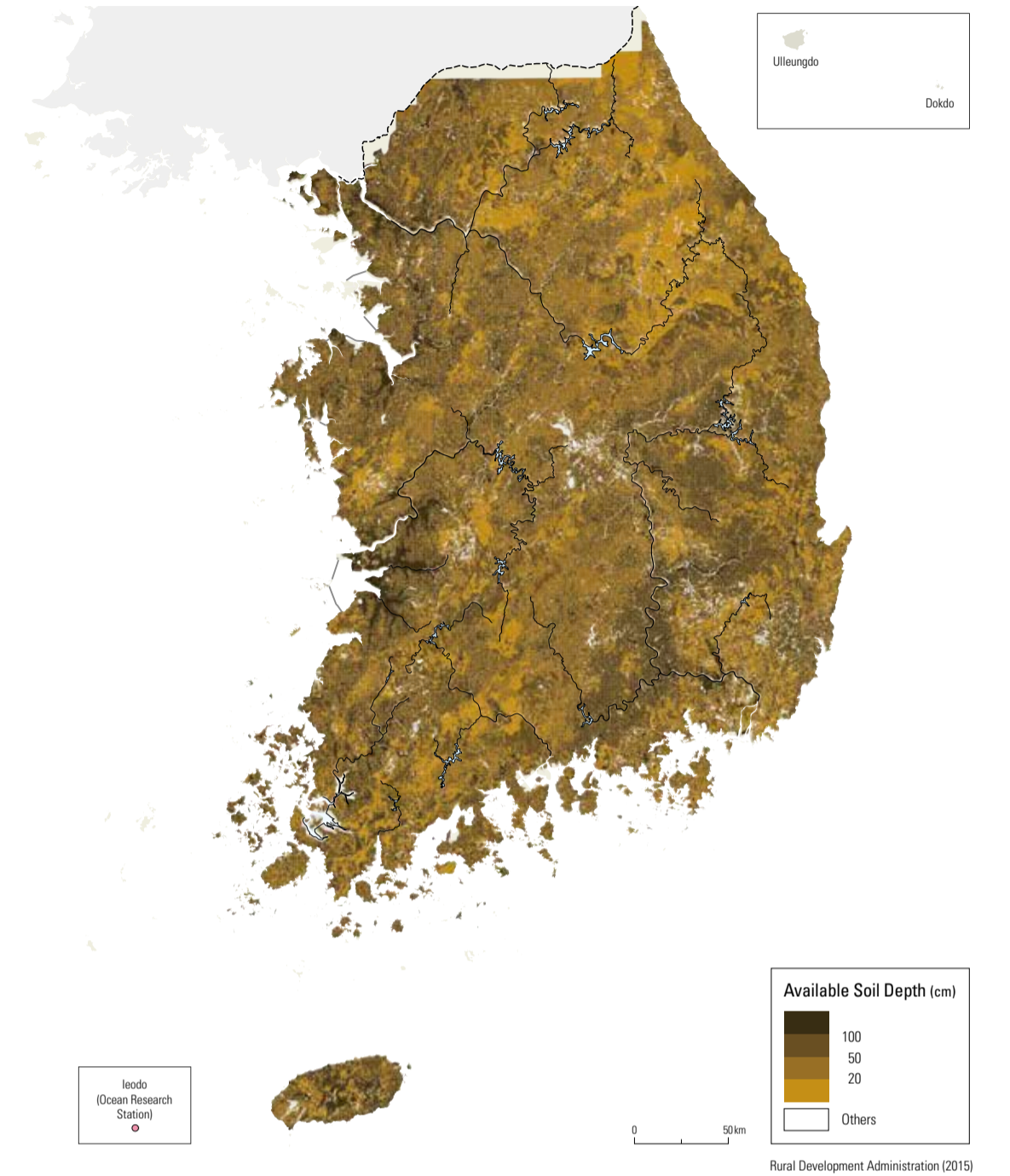
Proportion of Soil Texture Group

Texture	Area (ha)	Proportion (%)
Coarse Loamy	4,287,812	44.5
Fine Loamy	3,284,051	34.1
Gravelly	568,358	5.9
Fine Silty	462,448	4.8
Clay	398,397	4.1
Gravelly Sandy	373,075	3.9
Coarse Silty	213,243	2.2
Sand	51,814	0.5
Total	9,639,198	100.0

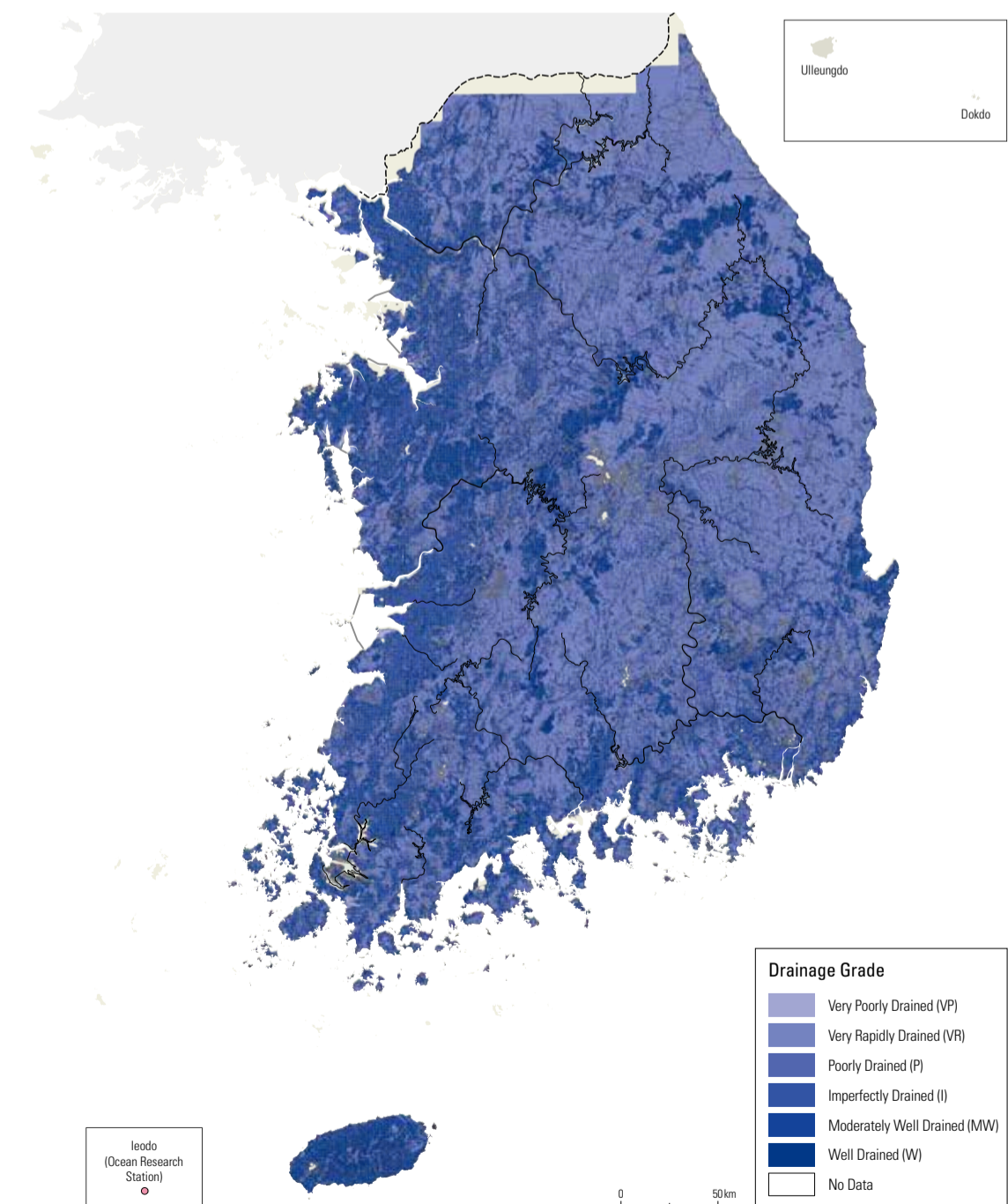
Surface Soil Texture



Available Soil Depth



Soil Drainage



Proportion of Available Soil Depth

Effective Soil Depth	Area (ha)	Ratio (%)
Very Shallow (20 cm or Below)	1,833,112	19.0
Shallow (20 – 50 cm)	2,067,736	21.5
Moderately Deep (50 – 100 cm)	4,003,722	41.5
Deep (> 100 cm)	1,734,624	18.0
Total	9,639,194	100.0

Proportion of Soil Drainage Grade

Drainage Grade	Area (ha)	Ratio (%)
Excessively Drained (EX)	4,409,384	44.7
Well Drained (W)	3,137,992	31.9
Moderately Well Drained (MW)	744,276	7.6
Somewhat Poorly Drained (SP)	802,046	8.2
Poorly Drained (P)	86,326	0.9
Very Poorly Drained (VP)	174,134	1.8
Other	485,886	4.9
Total	9,840,044	100.0

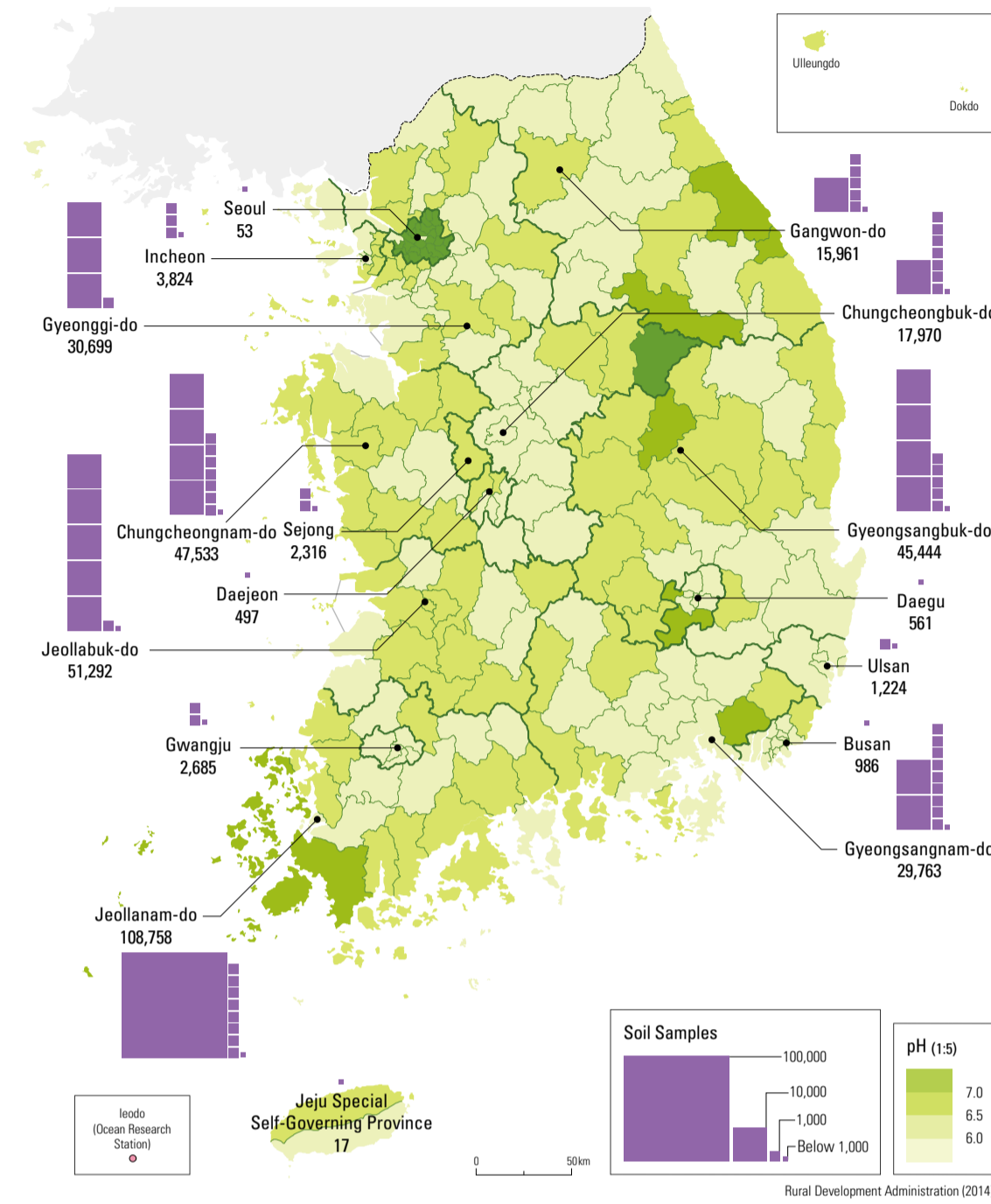
Available soil depth represents the depth of soil horizons. Areas with deep soil are often found in areas with well-weathered bedrock or areas where sediments are deposited, while areas with shallow soil represent poor soil formation or soil removal by erosion. Soil scientists classify soil by available soil depth into very shallow (< 20 cm), shallow (20 – 50 cm), moderately deep (50 – 100 cm) and deep (> 100 cm). It is recommended that available soil depth should be at least 50 cm to be used as rice paddies or farmlands. In the case of South Korea, moderately deep soil depth (50 – 100 cm) constitutes the largest area at 41.5%. Shallow (20 – 50 cm) makes up 21.5%, very shallow (< 20 cm) constitutes 19.0%, and deep (> 100 cm) constitutes 18.0%.

Soil drainage grades indicate the type of drainage found within a soil profile and are determined by factors such as amount of runoff, permeability, and groundwater level. Drainage classes are defined as follows: excessively drained (EX), well

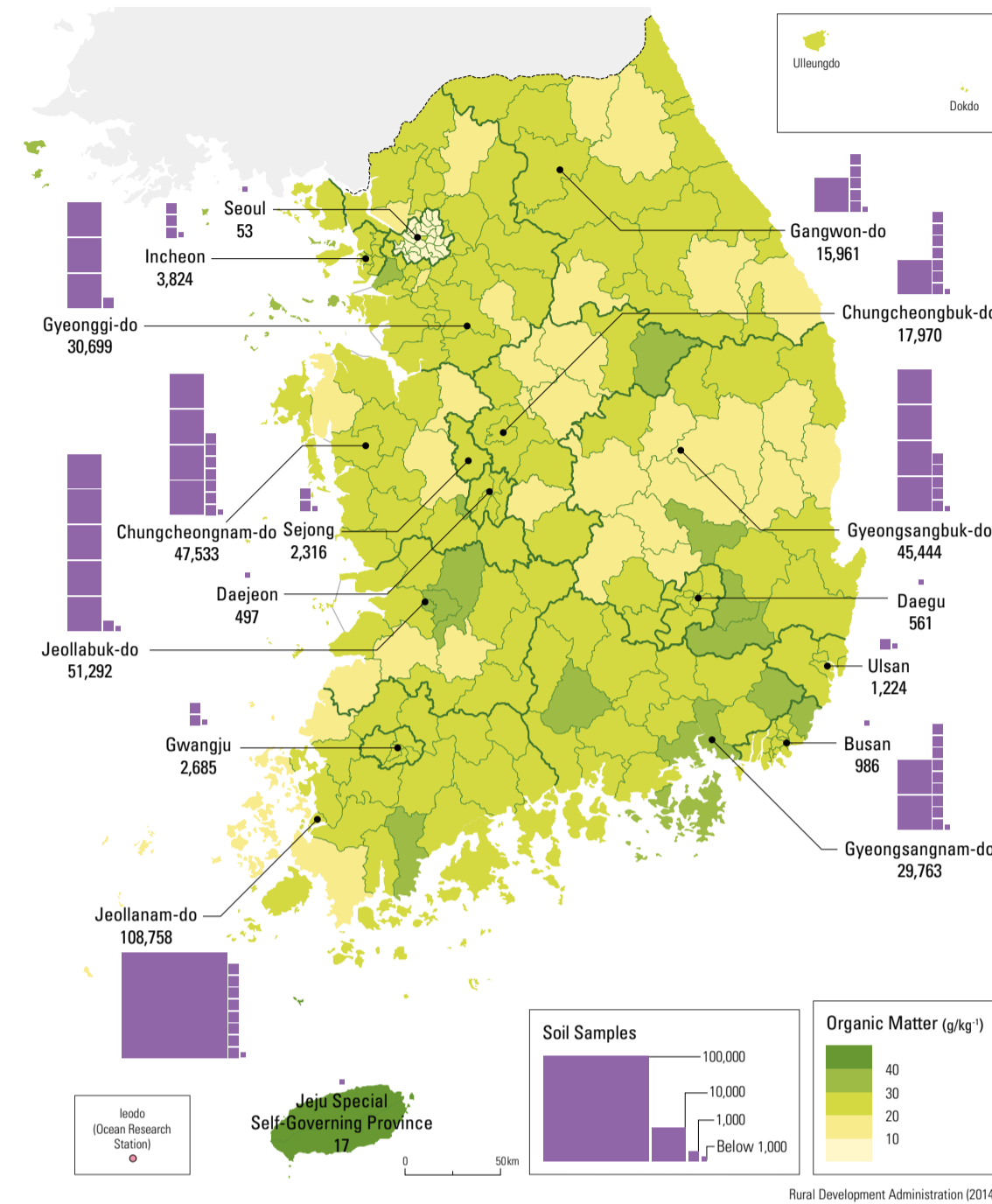
drained (W), moderately well drained (MW), somewhat poorly drained (SP), poorly drained (P), and very poorly drained (VP). Most farm field soils are classified as W, while soils in two-crop farming paddies, semi ill-drained paddy fields, and poorly drained paddies are classified as MW, I, P, and VP, respectively. Lithosols of steep slopes and sandy-gravelly soils of riverbanks are known to be EX.

EX occupies 44.7% (4,409,384 ha) of the total area and W makes up 31.9% (3,137,992 ha). The combined area of these two classes constitutes 76.7% of the total area. The percentages of the total area that other drainage classes hold are as follows: MW, which could be used for both paddy and farm field soils (7.6%); SP, mostly paddy soils (8.2%); P (0.9%); and VP (1.8%). These last three classes cover 10.9% of total soils.

pH Value of Paddy Soil



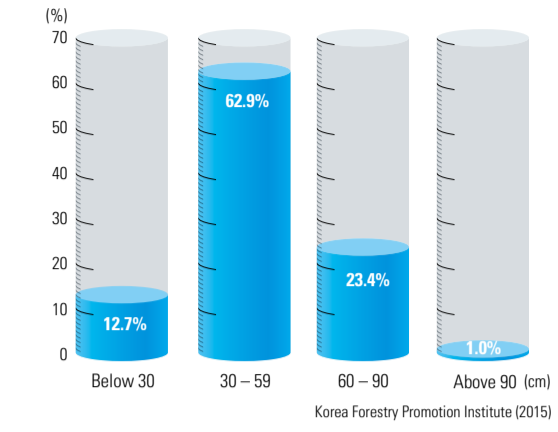
Organic Matter Content in Paddy Soil



Forest Soil Depth



Proportion of Forest Soil Depth

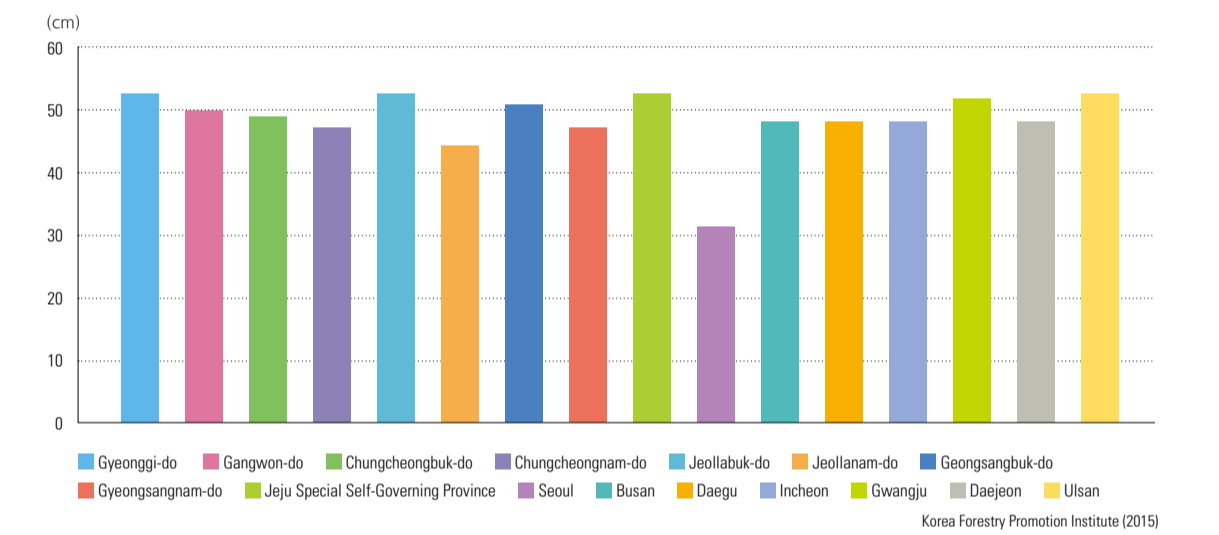


for most forest soil depth characteristics. Along with the fact that 51% of Korea has mountain areas steeper than 20°, the exploitation of forest resources during the Japanese Colonial Period and the Korean War caused severe topsoil loss. Throughout the 1970s and 1980s, a series of nationwide afforestation projects stabilized most of the devastated forest areas. However, soil development processes have yet to achieve full maturity.

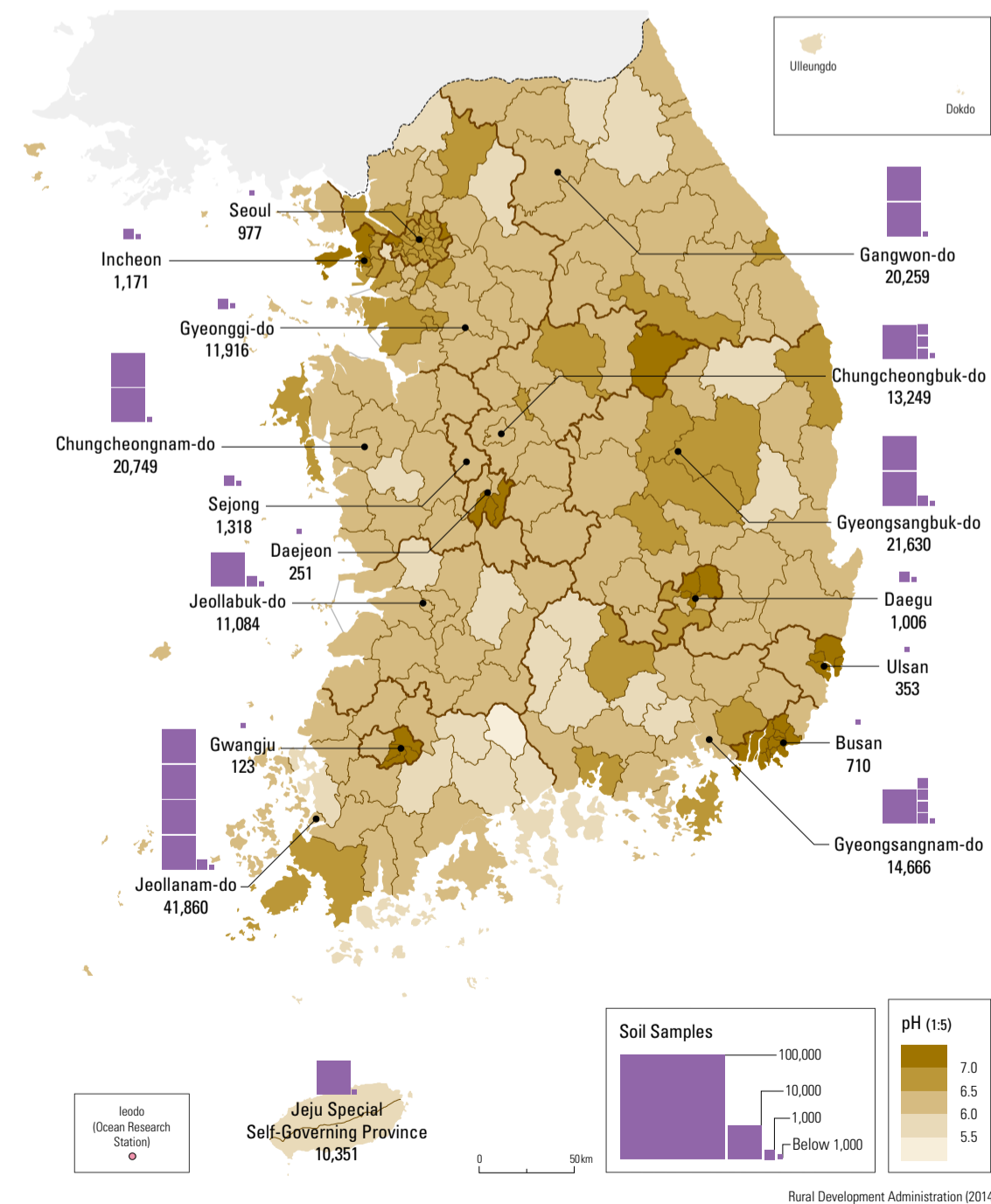
The average soil depth of Korean forests is 51 cm, which is considered to be quite shallow. Furthermore, 76% of forest soils have a depth of less than 60 cm, indicating that productivity is low. Recently, forest soil management has become more important as social demands for sustainable forest resources (timber, raw material, etc.) continue to grow.

The depth of forest soil is affected by various soil-forming factors including climate, topography, organisms, parent material, and anthropogenic disturbance. In the case of forest soil in Korea, topographic and anthropogenic factors account

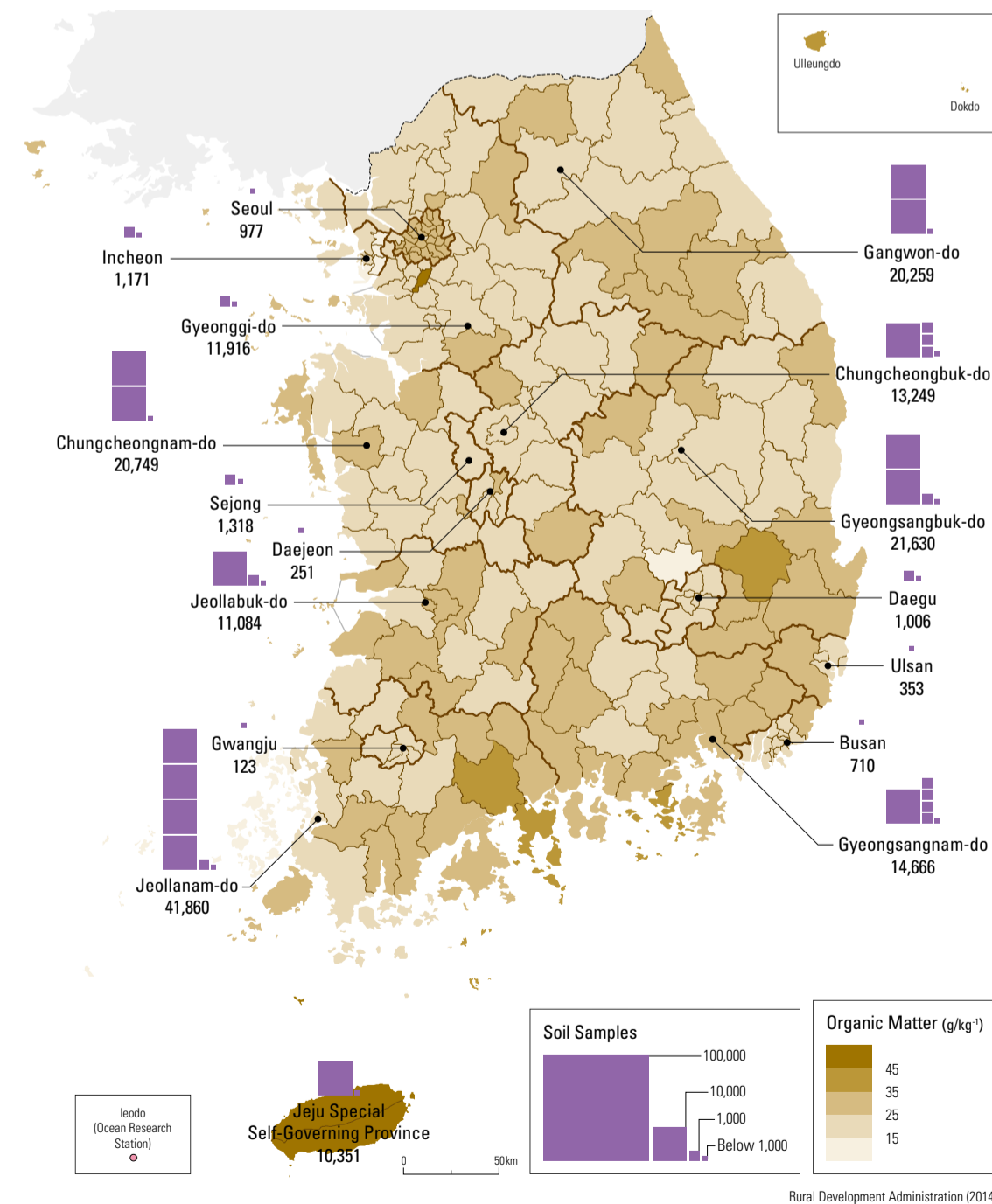
Forest Soil Depth by Province



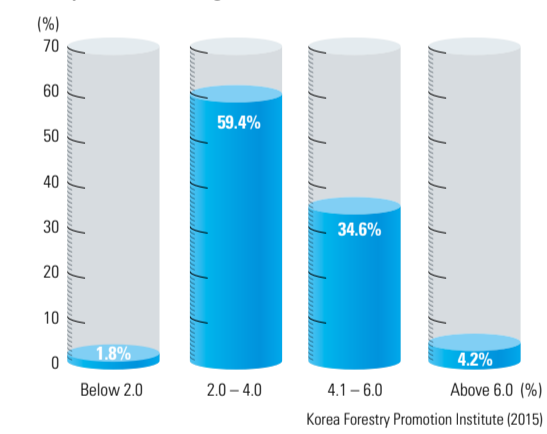
pH Value of Upland Soil



Organic Matter Content in Upland Soil



Proportion of Organic Matter Content in Forest Soil

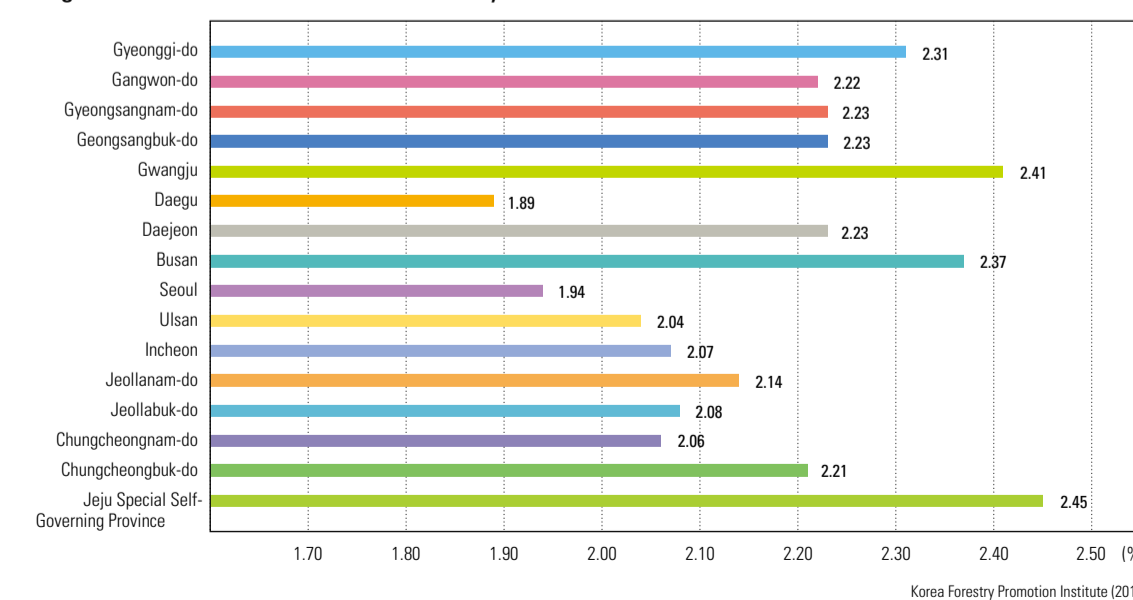


face and enrich the soil as humus. The resulting mixture of organic material within the soil increases the capacity for water and nutrient storage and also alters the degree of potential yield.

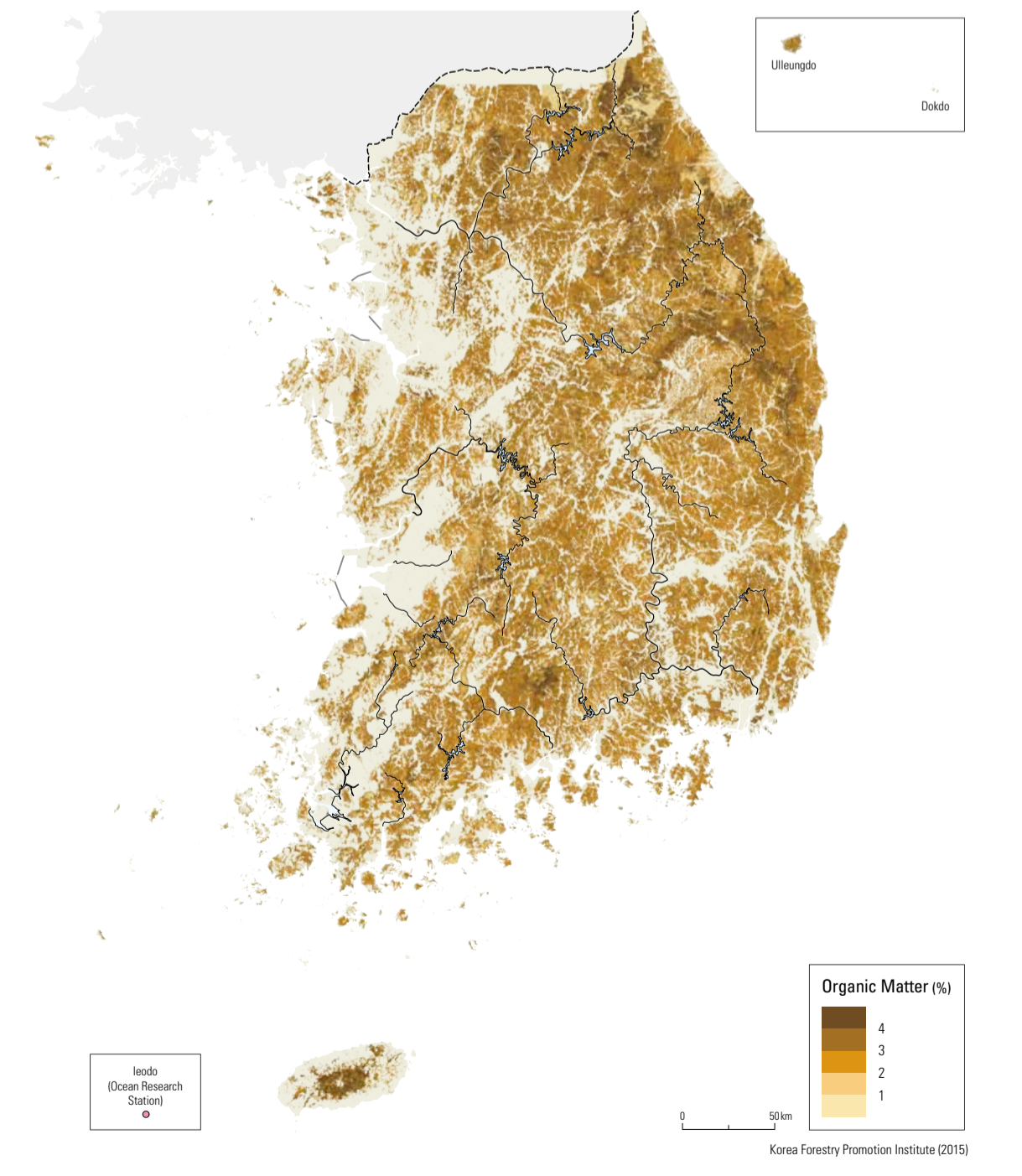
In Korean mountain forests, soils with 2.0 - 4.0% and 4.1 - 6.0% organic matter content at a soil depth of 50 cm comprise up to 59% and 35% of the forest soil, respectively. When compared with tree species, organic matter content is 3.6% in coniferous forests where pines are the main trees, and 6.1% in broadleaf forests with mainly oak trees. This difference is due to the litter-fall decomposition rates between tree species, which determine the amount of organic matter in forest soil.

Forest soils generally contain an organic matter content that is more than twice of what is found in ordinary farm field soils. The leaves and branches that fall from trees decompose on the ground sur-

Organic Matter Content in Forest Soil by Province

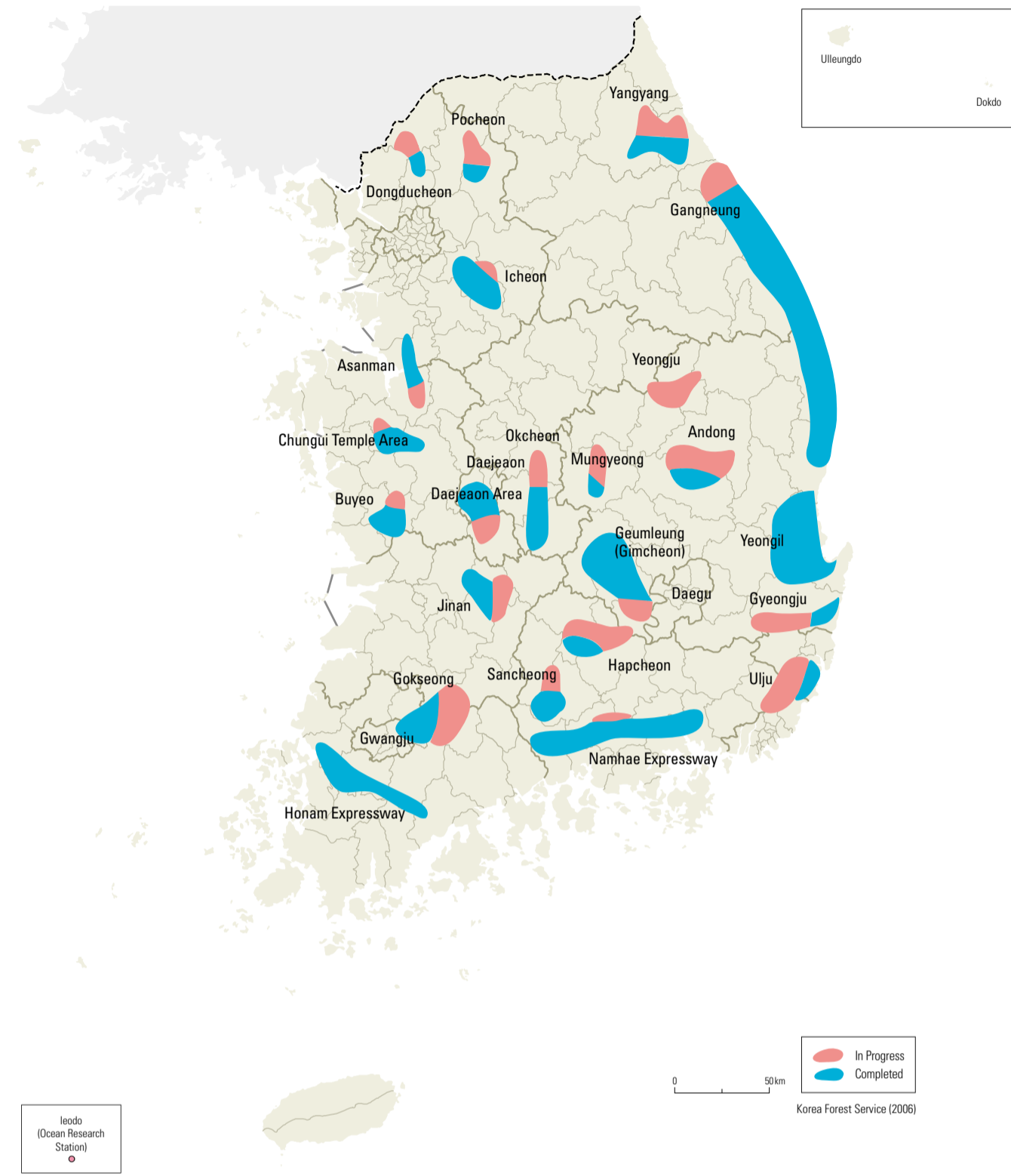


Organic Matter Content in Forest Soil

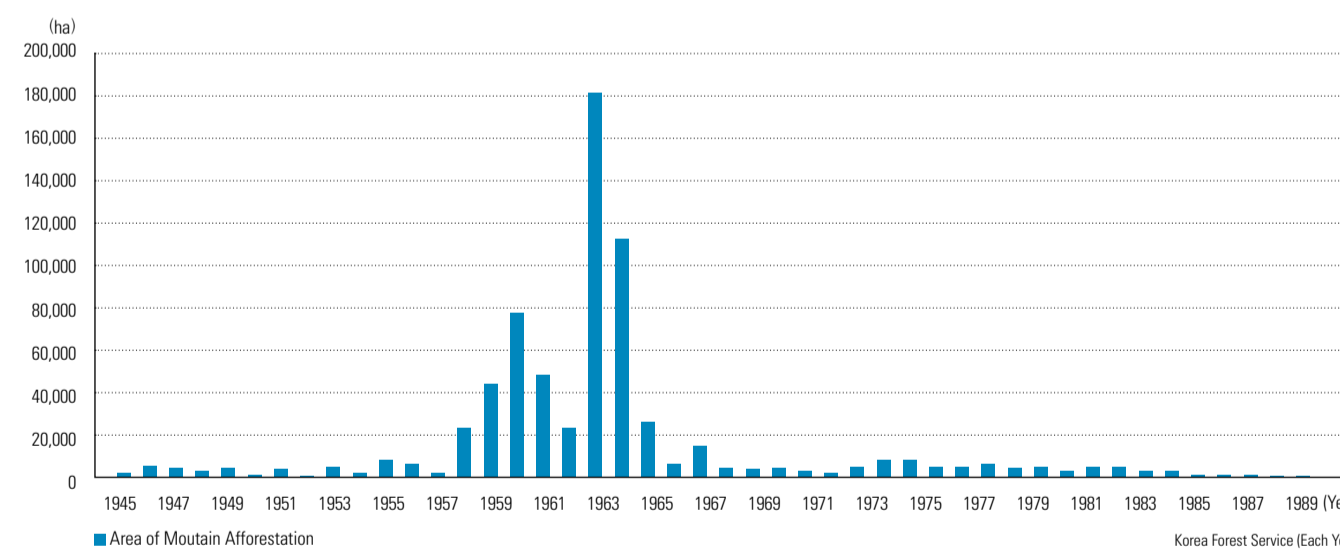


Overcoming Forest Soil Degradation

Major Afforestation Areas



Mountain Afforestation Results by Year



Korea is known for its success in combating land devastation. Long years of slash-and-burn farming and firewood logging left many parts of its territory devastated at the end of the Joseon Dynasty. To mitigate this situation, a forestation project was planned and completed for deteriorated forests around Changuimun Gate in 1907, which is now considered the first modern erosion control project in Korea. Some major cases of land erosion control projects conducted during the Japanese Colonial Period include reforestation for watershed conservation, poverty relief, and aid for flood victims. These projects were generally carried out in response to frequent natural disasters

as well as relief for the poor. However, during the last few years of the Japanese Colonial Period and the Korean War, forest exploitation and deforestation for war material accelerated throughout the country. Devastation reached its peak in 1956, with around 0.68 million ha, or 10% of South Korean forests, destroyed and in need of restoration. Forest restoration and erosion control projects from the late 1950s to early 1980s prioritized the recovery of devastated land. However, before the establishment of the Korea Forest Service in 1967, many restoration areas failed to meet their objectives as they were not able to build a fundamental vegetation base. Soon after the declaration

of the Erosion Control Law (1962), a large area (0.18 million ha) was restored within a single year in 1963. Numerous projects for erosion control followed suit, including the decade plan for reforestation, coastal dune fixation plan, disaster restoration plan, Youngil District Special Restoration (1973 – 1977), First National Decade Plan for Forestation (1973 – 1978), and the Second National Decade Plan for Forestation (1979 – 1987). Restorations for such large-scale devastations were completed around 1983. There are four reasons for Korea's success with afforestation. First, it was the late President Park Chung-Hee's leadership and persistence regarding

Example of Afforestation on Devastated Forest Land



Normalized Difference Vegetation Index (NDVI) on the Korean Peninsula (2010)



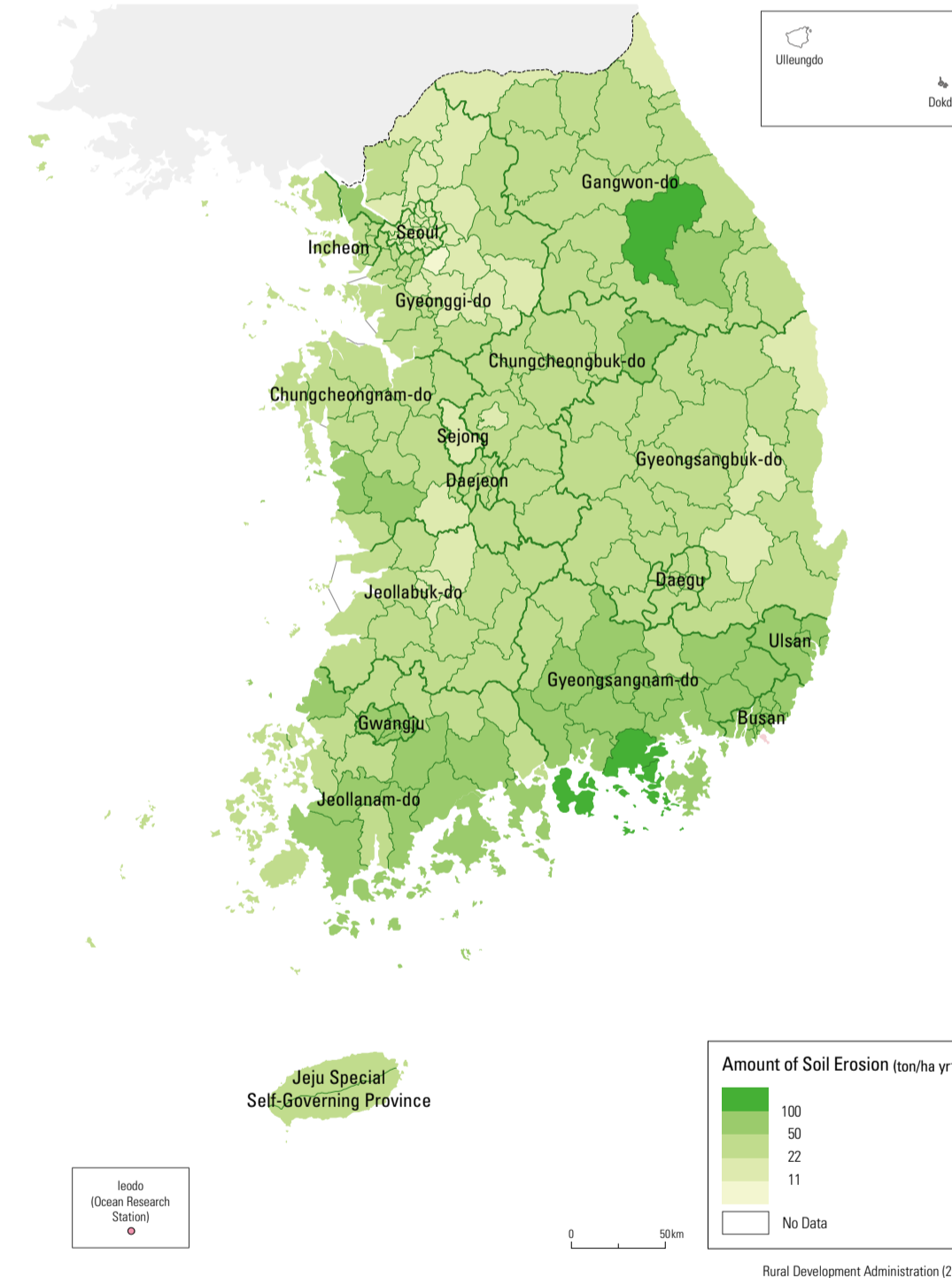
Forest Devastation in North Korea
In contrast to South Korea's great success in the afforestation and restoration of its forest areas, most of North Korea's mountain areas still remain devastated. Satellite images clearly show the immense difference of vegetation that cover the two Koreas.

Soil Erosion

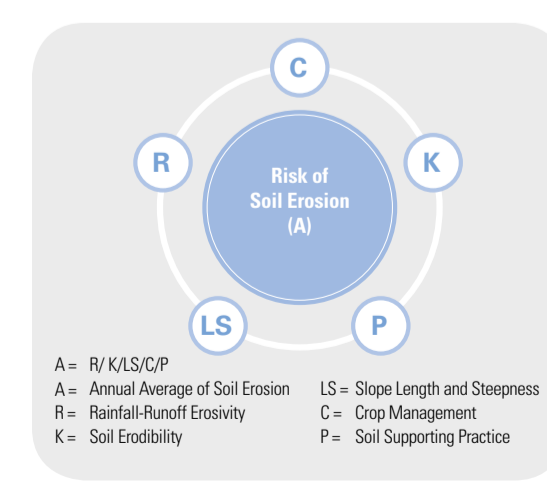
Sandy soils make up the majority of soils in Korea due to the large distribution of granite and granite gneiss. Most Korean soils are coarse, clastic soils that result from topographic and climate factors such as the large proportion of mountainous area, seasonal temperature changes, concentrated precipitation in summer, and freezing in winter. These factors cause soils to have low pH values, low organic content, rapid nutrient leaching, and thus, low possible yield. One of Korea's main soil management issues is erosion. Currently, annual net loss of soil is estimated to be more than 50 million tons, with the most damage occurring on cultivated lands. Total loss of soil from farm fields is estimated to be 37.7 tons/ha on average, while it is 3.5 tons/ha in forests and under 0.3 ton/ha in paddy fields. Ultimately, as much as 27 million tons of soil are lost over a mere 10% of cultivated land. The loss

is severe, particularly in the mountainous areas of Gangwon-do, Yeongnam and Honam regions, and regions of high precipitation such as Namhae-gun, Geoje-si, and Goseong-gun. Recent expansion of highland farming serves as yet another reason for rapid soil loss. Eroded soil from these farms eventually flows into nearby rivers, causing a destructive effect on the river and riparian ecosystem. To prevent further worsening of the situation, Korea has been establishing agricultural technology centers in every province to assist active soil management. Some major functions performed by these centers are as follows: developing and disseminating new crop breeds, education of proper crop selection and cultivation, and evaluations and treatment for certain soils to enhance productivity.

Risk of Soil Erosion (Farm Soils)



Risk Factors for Soil Erosion



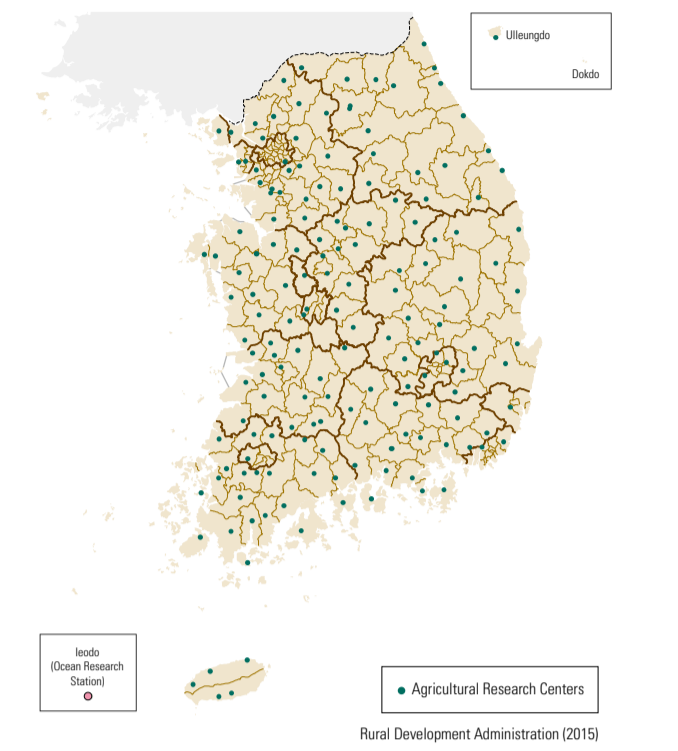
The majority of soil erosion in Korea can be identified as surface runoff erosion, while wind erosion occurs locally in coastal areas, islands, and high mountains. Soil erosion is produced by surface runoff generated by rainfall, and its rate depends on the following five variables: rainfall-runoff erosivity (R), soil erodibility (K), slope length and steepness (LS), crop-management (C), and soil supporting practice (P).

Land use in Korea can be divided into four main categories: forest, paddy field, farmland, and de-

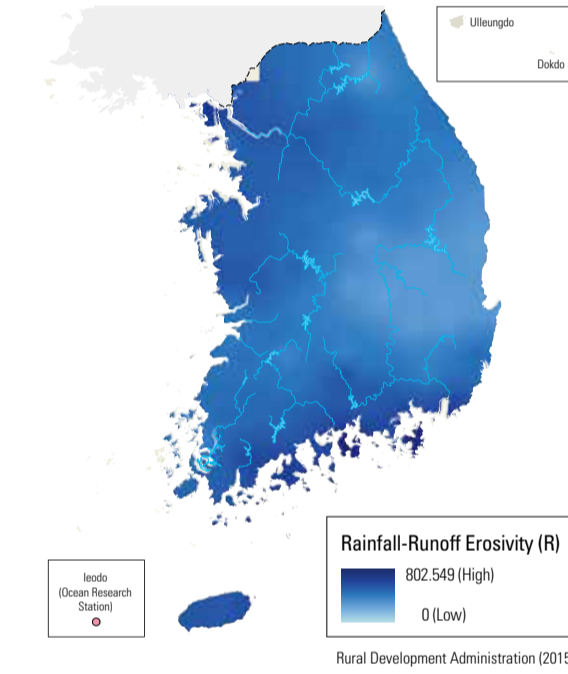
Highland Farming and Risk of Soil Erosion



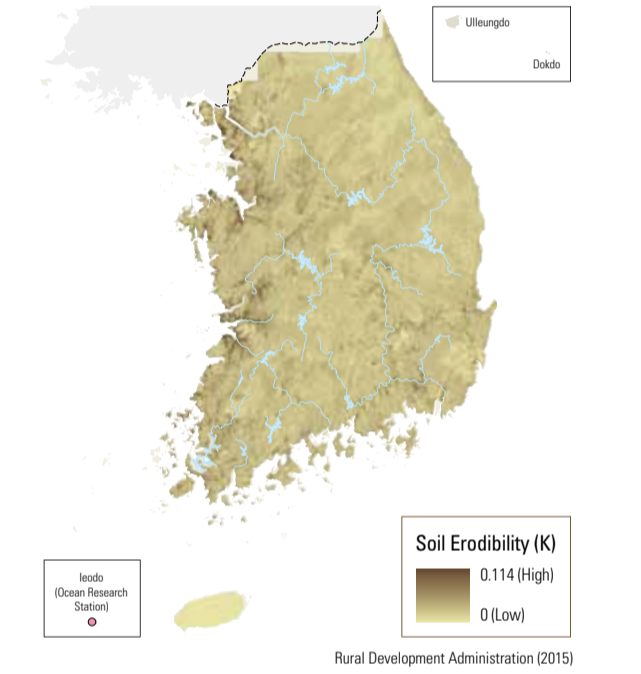
Distribution of Agricultural Research and Extension Service Centers



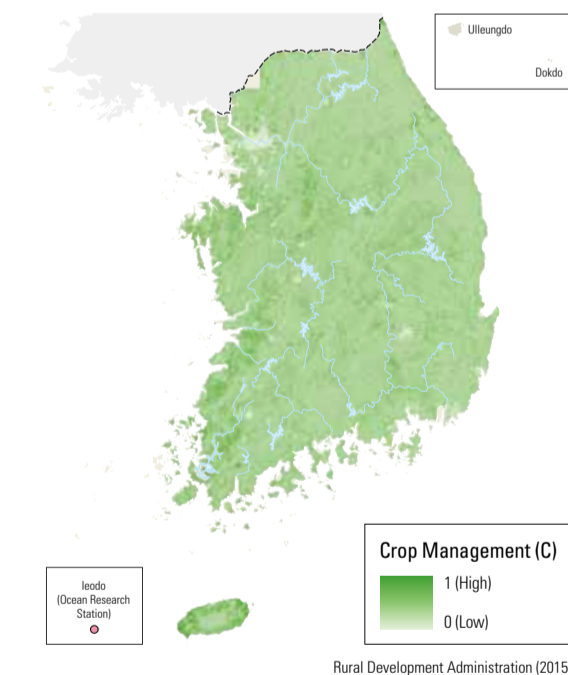
Rainfall-Runoff Erosivity (R)



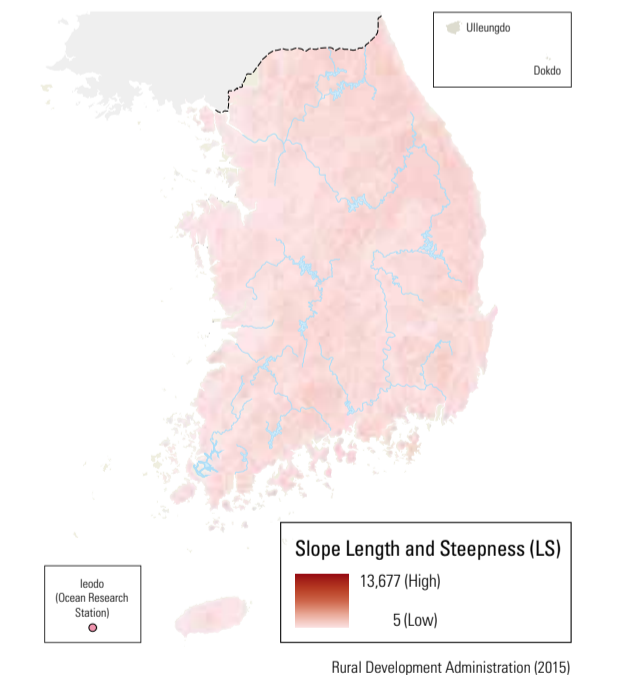
Soil Erodibility (K)



Crop Management (C)



Slope Length and Steepness (LS)

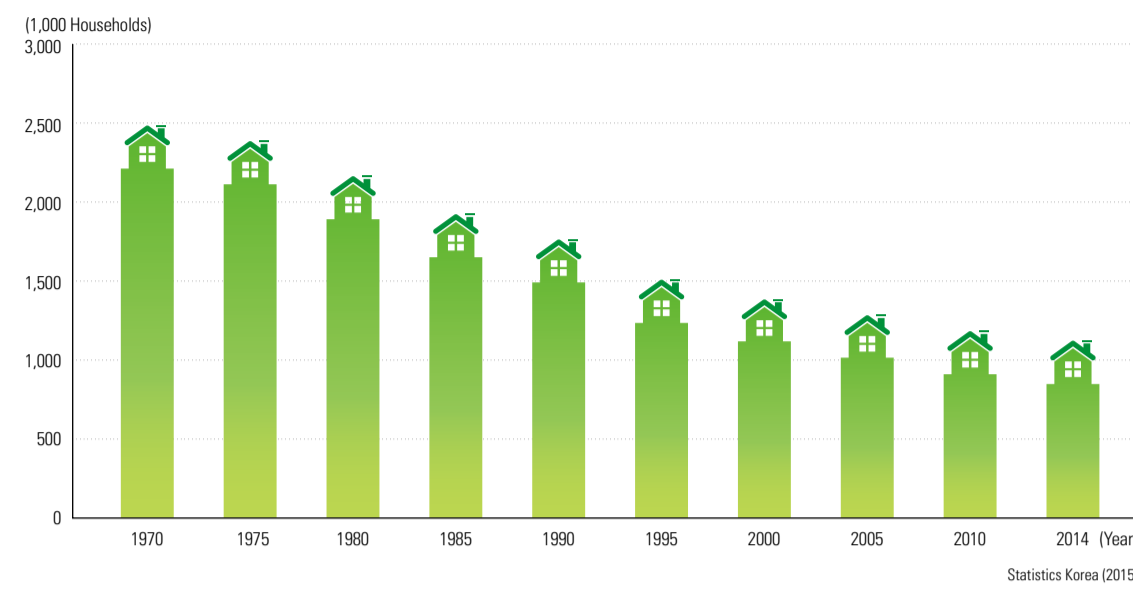


veloped land. Soil loss in paddy fields is expected to be less compared to other types of land use since the area is covered with water during the heavy rainy season in the summer, and its ridges act as barriers preventing runoff. Even on slopes, a staircase-formed paddy terrace has little chance of erosion. Forests and grasslands also have low erosion rates due to the vegetation on the surface. On the other hand, there is a risk of intensive soil erosion in farmlands, as these areas are mainly located on slopes and are exposed or bare during the fallow

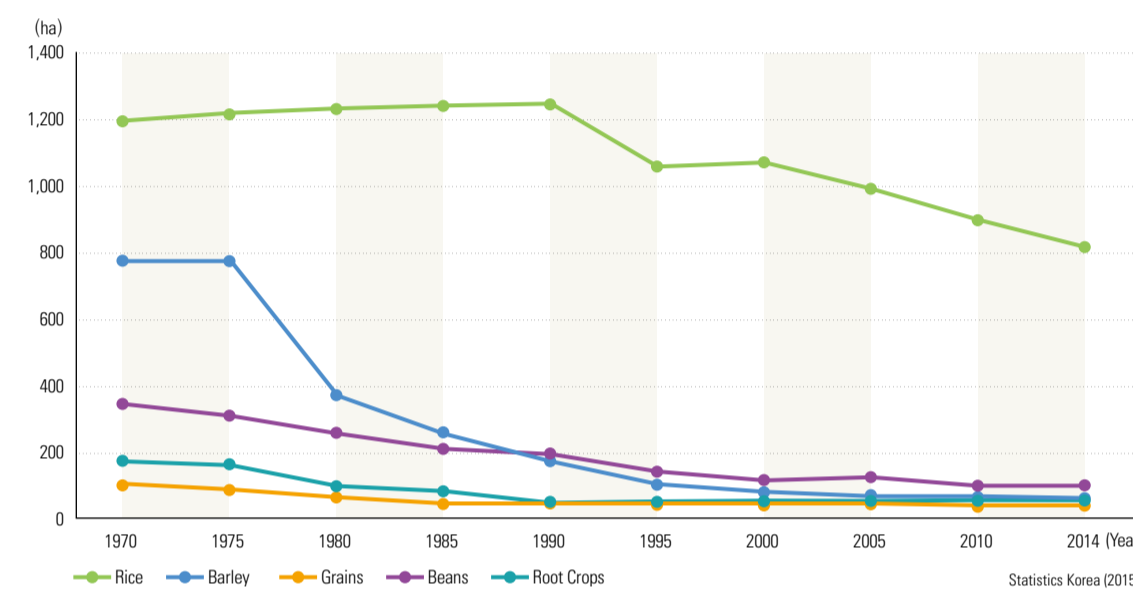
season. The risk of erosion due to rain runoff is high in certain places like the mountain areas of Gangwon-do and the South Sea coastal areas like Goseong-gun, since R factor is high in the south-west coastal areas and LS factor is high in mountainous areas. Unlike other variables, K is high in the southwest plains rather than in mountain areas in the eastern part of the country, because light soil particles are carried by rainwater flow.

Environmentally Friendly Land Use

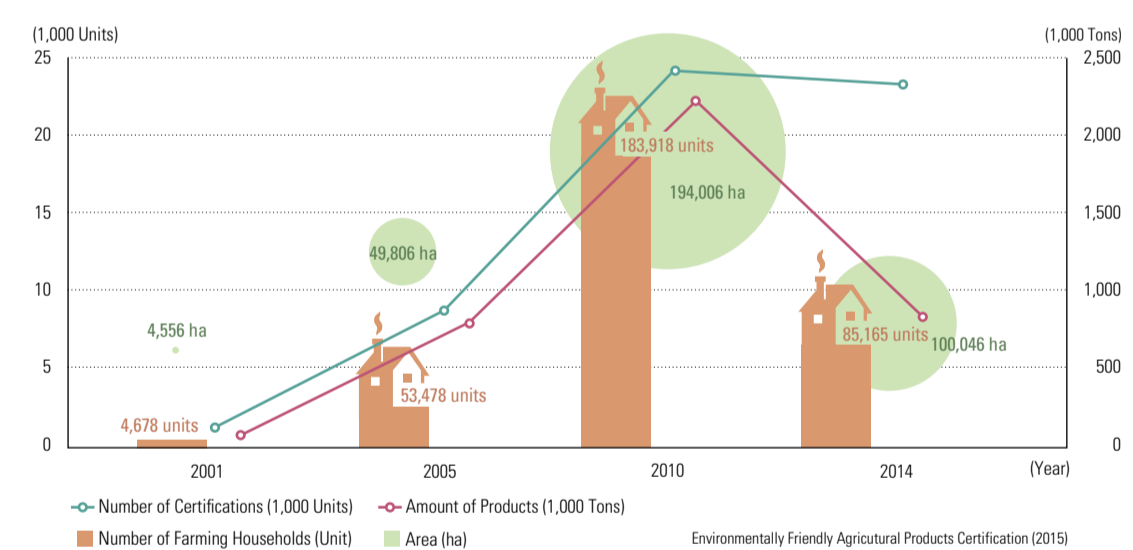
Number of Farming Households by Year



Crop Cultivation Area by Year



Environmentally Friendly Organic Agricultural Products Certification



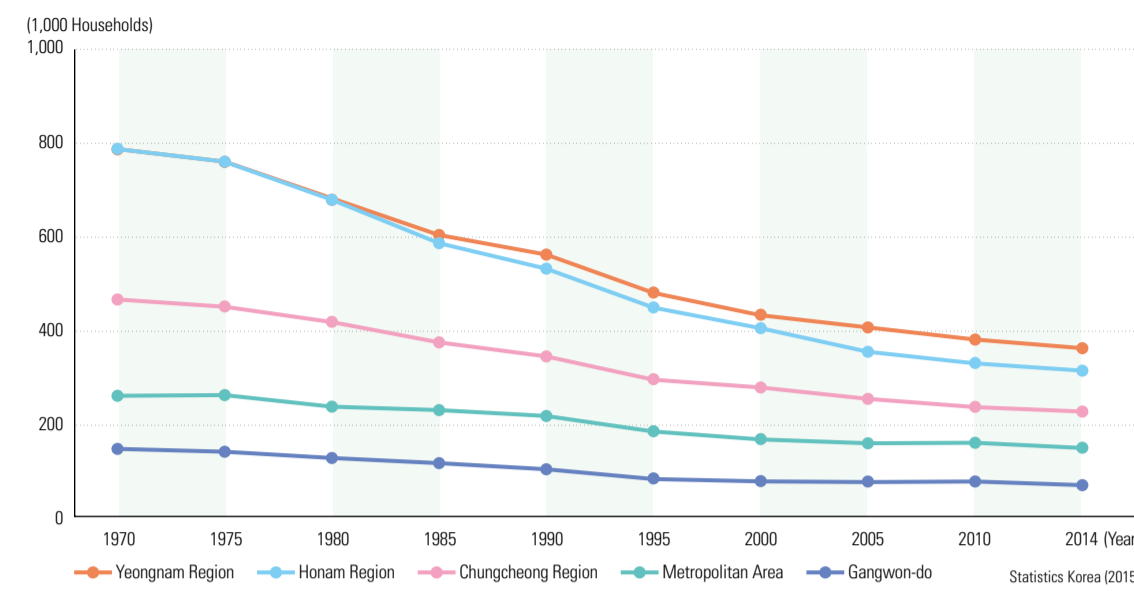
As of 2013, the total land area of South Korea is 10,027,000 ha. Arable areas are estimated to be 1,712,000 ha, constituting 17.1% of the total land area. These areas consist of paddy fields and farm fields, which each comprise areas of 964,000 ha and 748,000 ha, respectively. 6,369,000 ha (63.5%) of South Korea's terrain is mountainous with forests.

Since the 1970s, Korea has been experiencing rapid change in its economic structure. It shifted from an agrarian society to a post-industrial society, consequently bringing about a diminished social reliance on soil. In 2014, the total number of farming households was estimated to be 1.12 million, a 54.8% decrease from 2.48 million in 1970. The agricultural population also dramatically decreased by 81% from 14.42 million in 1970 to 2.75 million in 2009.

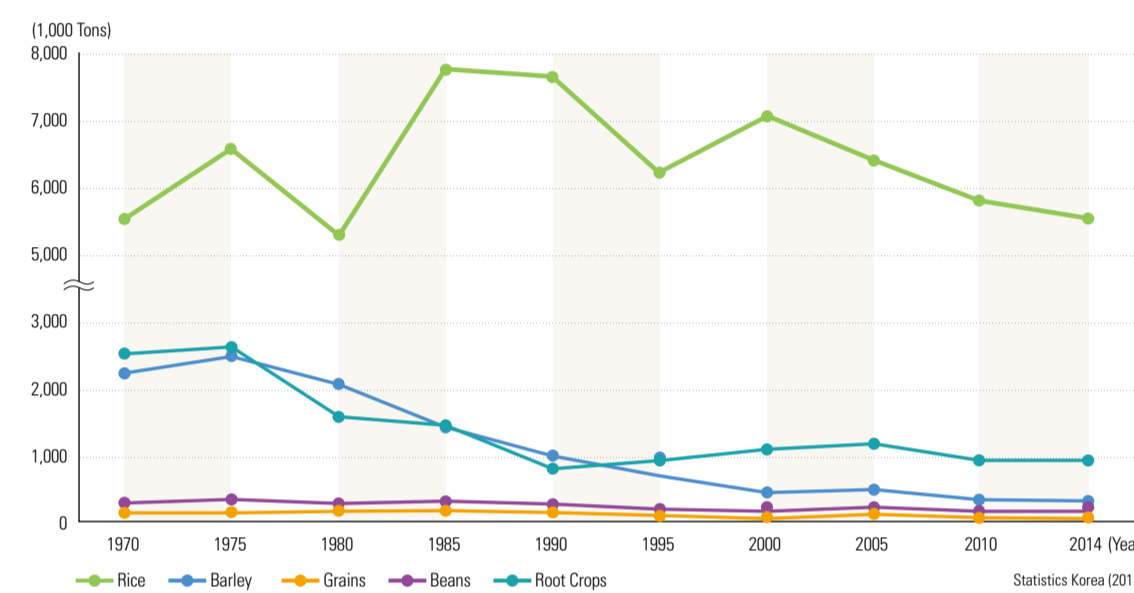
Arable land area in Korea increased until the mid-1970s due to active land reclamation in

coastal regions. However, industrialization and urbanization has prompted a constant decline in arable lands ever since. In 1975, Korea had a total of 2.24 million ha of cultivated land; by 2014, that sum was reduced to 1.70 million, reflecting a 24% decrease over a span of 40 years. The total area of paddies in 2014 is 0.93 million ha, making up 55% of all cultivated land. While paddies have been on a constant decrease since 1988, the area of farm fields only experienced a slight decline over the same time period, remaining at 0.7 million ha since the 1980s. Starting in 2008, farm fields actually began to spread as economic growth encouraged farmers to grow more fruit trees and other cash crops. Due to the drop in rural agricultural population, cultivated land per household is steadily increasing, experiencing a growth from 0.94 ha in 1975 and 1.11 ha in 1985 to 1.51 ha in 2014. Yield per unit area is also increasing steadily.

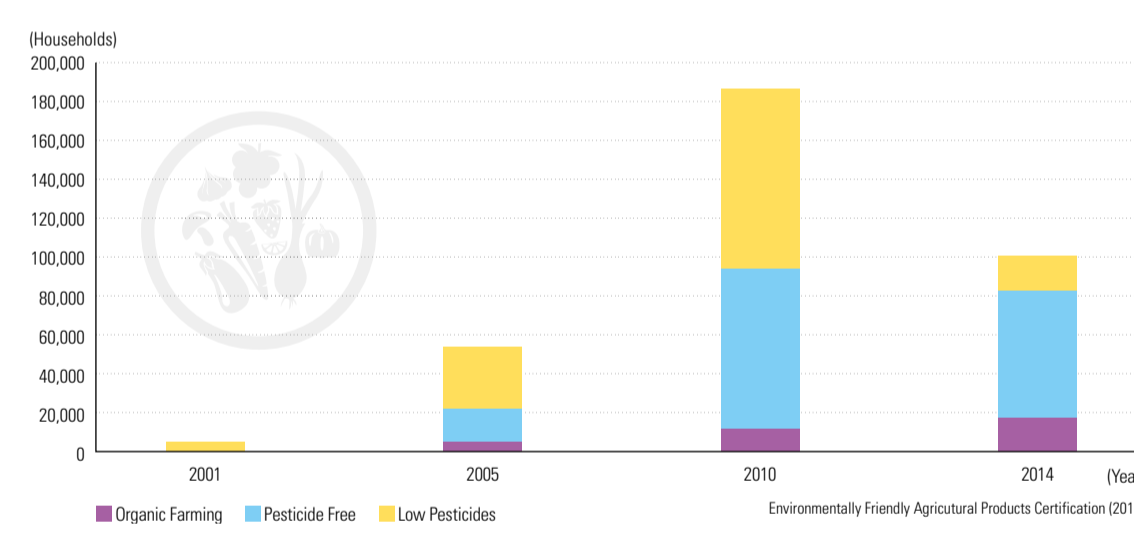
Change in the Number of Farming Households by Region



Crop Yield by Year



Number of Environmentally Friendly Farming Households by Year



Rice production in 1975 was 5.5 tons/ha, but jumped to 6.9 tons/ha in 2014. Despite showing a massive decrease in area, paddy yields experienced a 2.3% increase from 5.55 million tons in 1971 to 5.68 million tons in 2014. This long-term enhancement in crop production benefited largely from the genetic improvement of rice varieties, mechanization of agriculture, fertilizer, and advancement of farming techniques.

Barley has undergone the largest drop in both yield and area. In the early 1970s, barley production was close to 2.50 million tons; in 2014, however, the recorded yield was 0.26 million tons. Other crops such as beans, potatoes, sweet potatoes, and grains are also declining, but are relatively more stable than rice and barley.

In recent years, improved income levels and interest in health have introduced a newfound demand for environmentally friendly produce. Since 2000, the government-run Environmental-

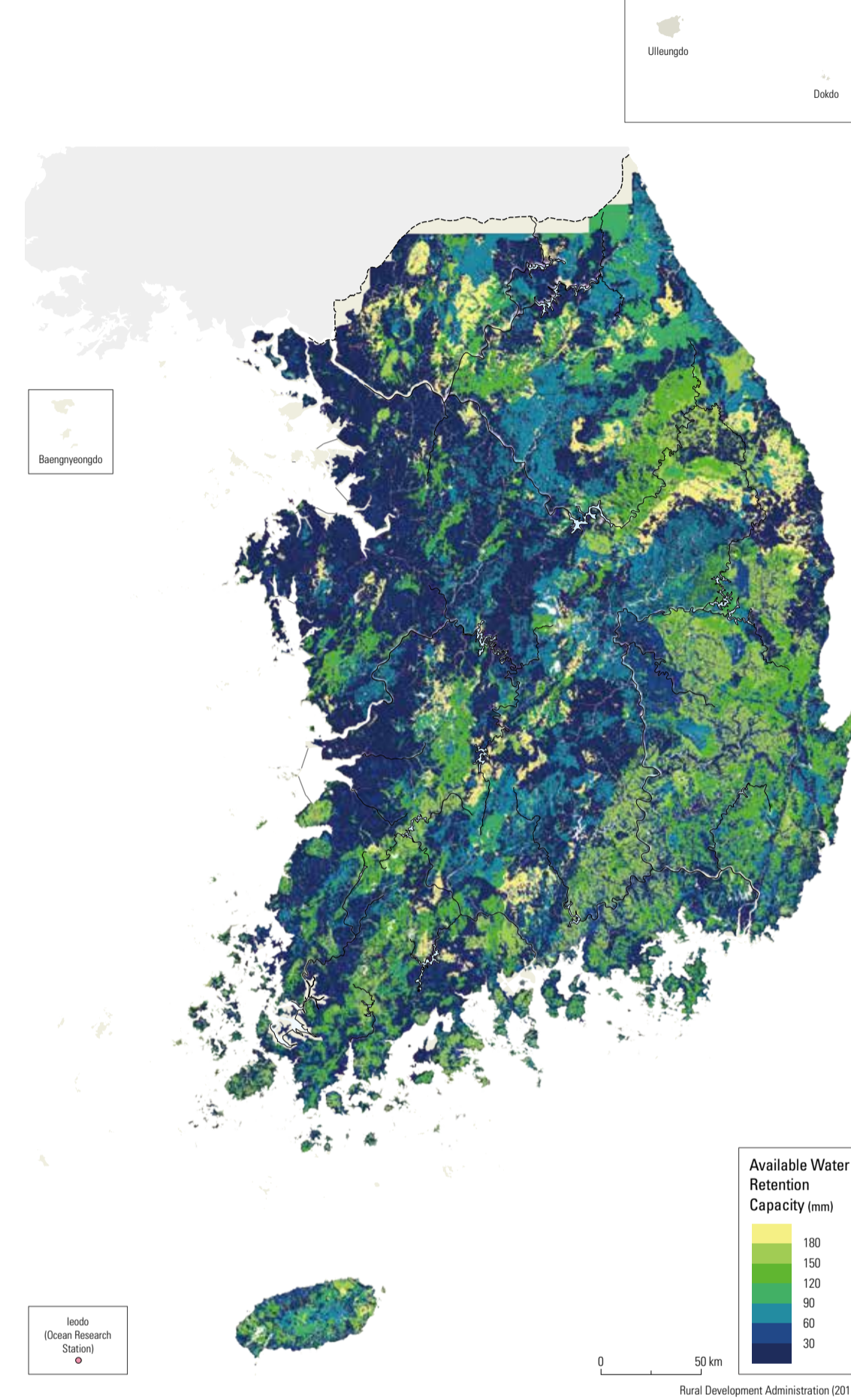
Friendly Agricultural Products Certification has rapidly gained popularity with its positive effects on environmental conservation and produce safety. Recently, the government implemented measures to abolish the certification of low pesticide products, which occupied the highest ratio among organic, non-pesticide, and low pesticide products. This has caused a drastic decrease in certified producers of low pesticide crops. Nonetheless, organic product certification – which is the most difficult to achieve in terms of technique – is constantly increasing.

National Land Usage (2013)

Land Area	Lowlands (1,000 ha)			
	Paddy	Crop Field	Forest Area	Other
10,027.0	964.0	748.0	6,369.0	1,947.0
Ratio (%)	9.6	7.5	63.5	19.4

Climate Change and Future Land Use

Available Water Retention Capacity



Modern industrialized agriculture utilizes large amounts of water, thus heightening water shortage problems and pollution. Recent climate change in Korea is predicted to only further aggravate these issues. Consequently, it is essential to cut back on the intensive usage of water in agricultural practices. Ecological organic farming may reduce the need for rigorous irrigation, increase the water holding capacity of soil, and enhance water quality.

Available Water Retention Capacity (AWRC) of soil is one of the most important soil attributes

that affects a wide range of factors, including plant growth, carbon storage, nutrient cycling, and the photosynthetic rate of plants. Determined by soil bulk density, which considers particle size and organic content as main variables, AWRC serves as a key indicator for evaluating the current physical status and characteristics of soil. It also has an influence on climate as it affects evapotranspiration rates and hydrologic processes such as runoff and leaching.

Differences in Water Retention Capacity

Area (ka)	Water Retention Capacity (mm)		
	Mean	Standard Deviation	
Alfisol	3,474	205	27
Andisol	1,394	138	54
Entisol	14,291	149	73
Inceptisol	70,868	192	55
Ultisol	4,736	206	55

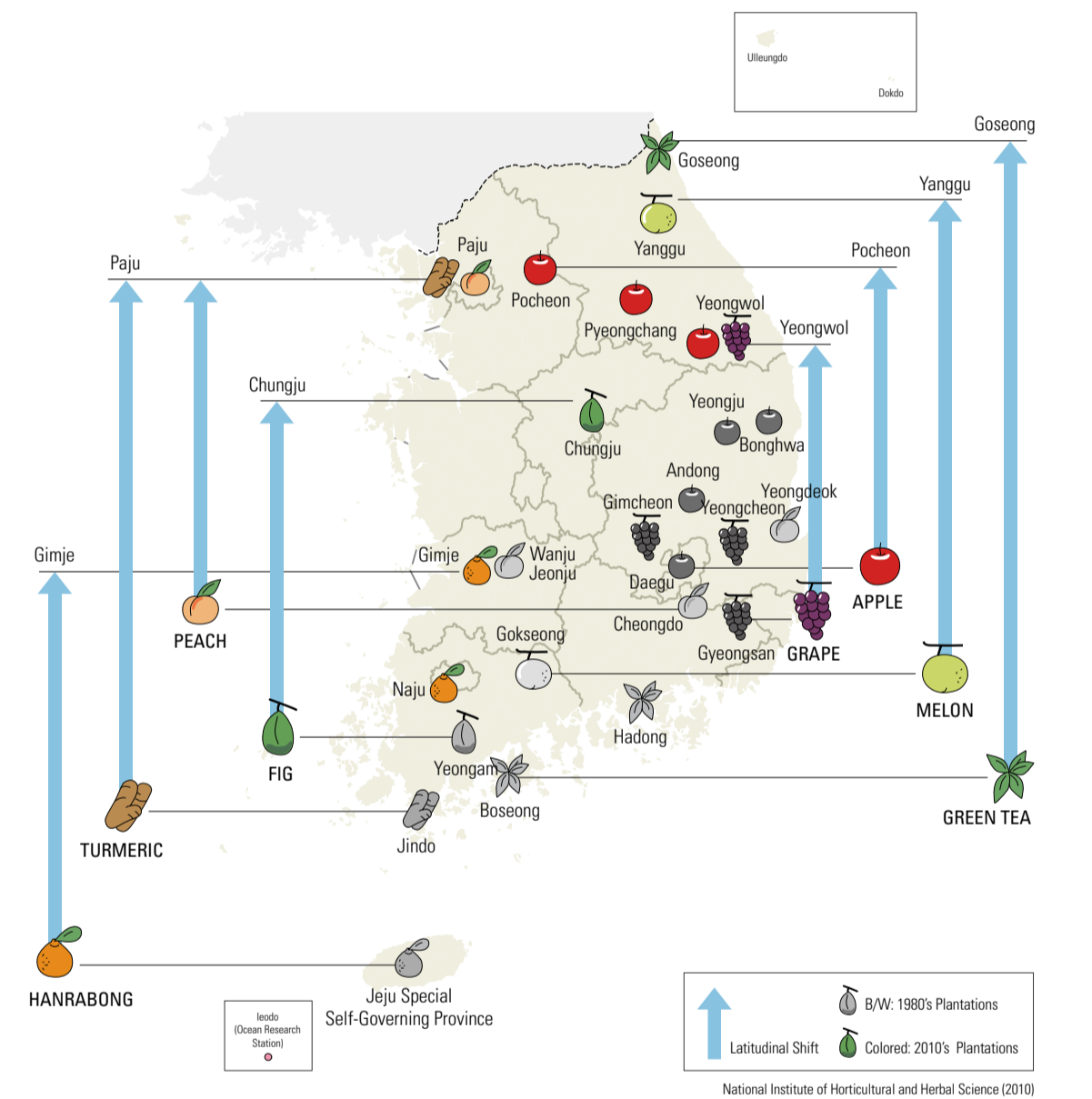
Average global temperature has increased by about 0.7°C over the last century, and Korea has experienced double that rate of increase (1.5°C) during the same period. If this trend continues, the country is expected to have a 6.0°C increase in annual mean temperature and 20.4% more annual precipitation by 2099.

An appropriate indicator of Korea's temperature shift is the northward movement of major crops. Subtropical fruits such as tangerines and Hanrabong (local specialties of Jeju-do) were usually only produced on the island. However, they can now be grown in areas such as Gimje-si, Goheung-gun, and Cheongju-si, while Jeju-do now produces tropical crops like mango, dragon fruit, papaya, and sugar apple. Similarly, apple plantations have moved north from Daegu to Pocheon-gun, grapes to Yeongwol-gun, figs to Cheongju-si, and peaches to Paju-si. Climate change is not

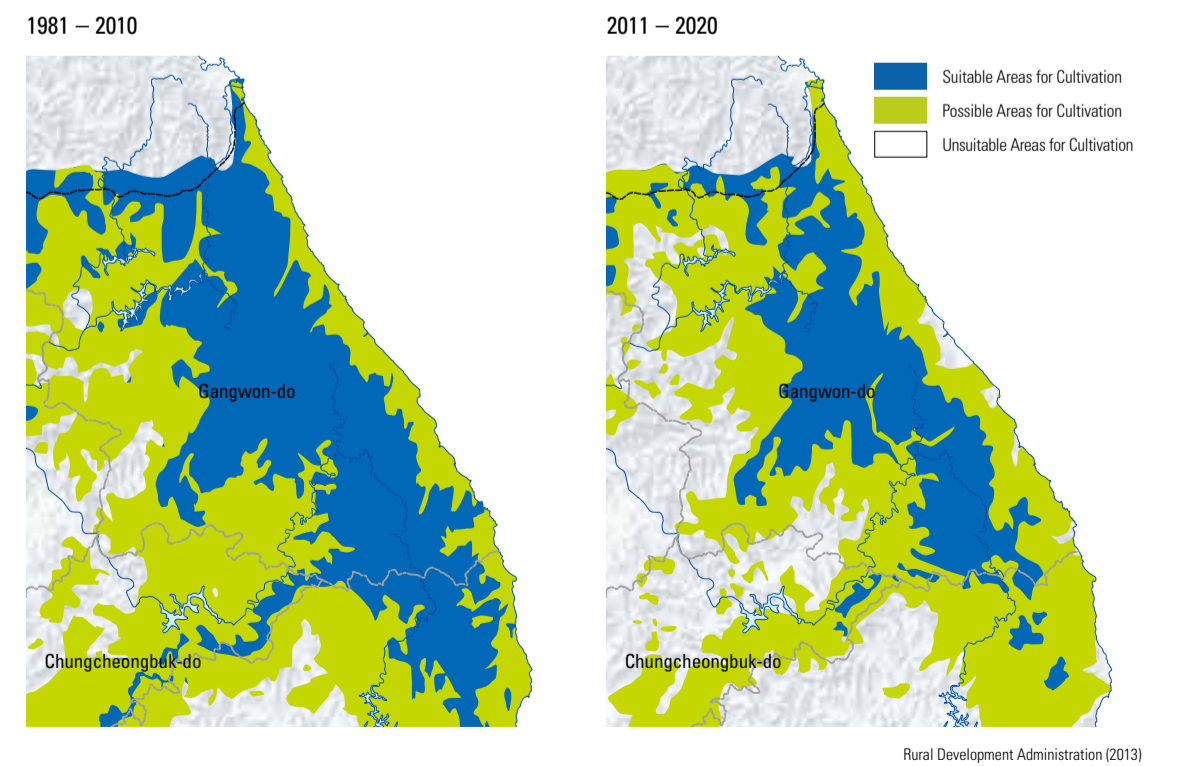
only changing the plantation pattern of Korea, but is also posing potential threats to food security such as plant diseases and insects. Even the active highland farming areas in Gangwon-do are predicted to decrease as well.

In order to mitigate the impacts on agricultural sectors caused by possible climate changes, the Korean government is developing various policies for establishing adaptive plans such as long-term regional agricultural and farming plans. New crops have been introduced, and various resource crops in subtropical/tropical regions have been collected through scientific collaboration with overseas countries. Scientific diagnosis and evaluation of the impacts of climate change on the agricultural sector are important in establishing future visions of the agricultural industry and the direction of its policies.

Geographic Shifts of Major Fruit Farmlands Affected by Climate Change



Change in Alpine Chinese Cabbage Cultivation Area



International Cooperation

The recent global expansion of desertification and land degradation has raised international concern regarding issues of food security, poverty eradication, and climate change. In response to this, the United Nations declared the UN Decade for Deserts and the Fight against Desertification

to be carried out from 2010 to 2020 in order to establish strategic measures to counter the problems.

As a leading country that has overcome heavy land degradation and successfully achieved reforestation, Korea serves as a pioneering example in

the global movement against desertification.

After hosting the 2011 UNCCD COP 10, Korea continues to actively contribute to afforestation efforts both in Asia and across the globe. In the case of developing countries, desertification and land degradation has caused a serious setback to

poverty eradication. By implementing various cooperative projects, Korea aims to build a foundation that will enable these countries to independently pursue sustainable development.

Supporting Afforestation in Desert Areas of China

Each spring, Korea suffers a great deal of damage caused by yellow dust from the drylands of northern China. Various afforestation projects are being carried out in inland China in order to counteract the source of the issue. In particular, the Kubuqi desert in Inner Mongolia, China has an ongoing project that is held alongside cultural festivals to solidify environmentally cooperative relations between the two countries and foster

friendships among youth.

Since 2007, these projects, supported by the Korea Forest Service, have carried out afforestation over 1,199 ha of desert area. The Korea Green Promotion Agency, Future Forest, Inc., Communist Youth League of China, and Dalate Qi Administration of Inner Mongolia are just some of the participants of these operations.



Aerial Photography of Kubuqi Desert 2007 (Before Afforestation)



Aerial Photography of Kubuqi Desert 2011 (After Afforestation)

Hosting UNCCD COP10

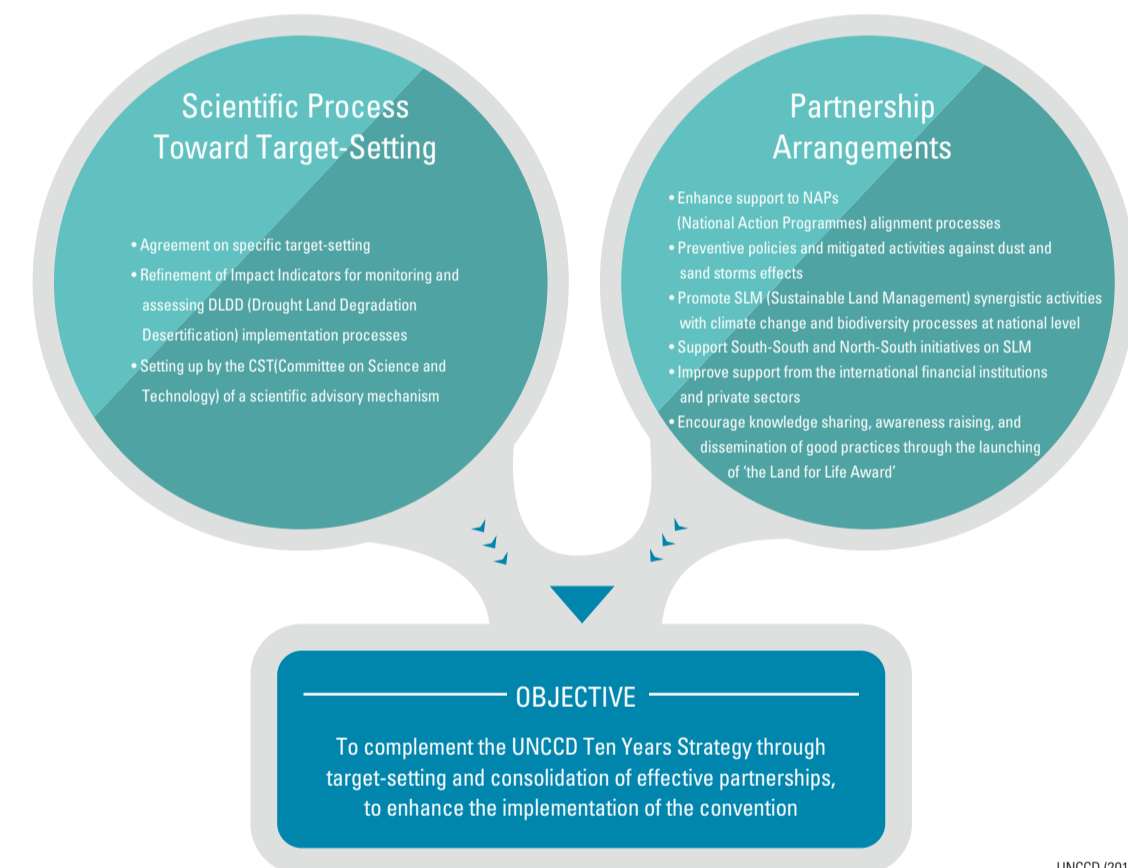
Joined by 137 country representatives and personnel from international organizations and NGOs, the Tenth Session of the Conference of the Parties to the United Nations Convention to Combat Desertification (UNCCD COP 10) was held in the Changwon Convention Center in October 2011. Hosted in Asia for the first time, COP 10 was the largest meeting of its kind with 3,000 participants in attendance.

On October 18th, the *Changwon Initiative* was adopted during high-level talks. The initiative appealed greatly to participants with its main

points: 1. Agreement on long term perspectives of the UNCCD and establishment of a scientific foundation; 2. Building partnerships to mitigate desertification and land devastation effectively; 3. Increased mobilization of resources that includes the private sector; 4. The establishment of the Land for Life Award to encourage sustainable land management.

UNCCD COP 10 served as a valuable opportunity for raising awareness on desertification in the northeast Asian region as the issue was mainly focused on Africa up till then.

Main Components of the *Changwon Initiative*



UNCCD (2011)



Greening Drylands Partnership

As part of the *Changwon Initiative*, the Greening Drylands Partnership promotes a series of sustainable land management projects to counter environmental issues in arid regions, such as desertification and drought, by utilizing networks to transfer knowledge and know-how from international organizations to developing countries. In particular, this partnership recognizes that Korea's experience in successful afforestation projects may contribute to the economic prosperity of developing countries and decrease devastated land areas in African regions. The partnership's first project (2012 - 2013) was carried out in Ghana, Morocco, and Tunisia. Its second project (2013 - 2014) was performed in Peru, Ecuador, Benin, and Ethiopia, and its third project (2015 - 2016) is currently ongoing in Kazakhstan, Kyrgyzstan, and Tajikistan.

Mongolian Greenbelt Afforestation Project

Acknowledging an agreement from the Korea-Mongolia summit in 2006, the Korea Forest Service launched a large-scale afforestation project to establish 3,000 ha of afforestation area in Lun soum and Dalanzadgad soum of Mongolia. As of 2015, around 2,446 ha has been established. The project also hosts annual training courses for government officials and carries out joint research regarding species selection and pest control. Furthermore, it deploys forestation technique support and education for local residents in order to raise awareness on the significance of preventing desertification.

Green Projects in Arid Regions of Central Myanmar

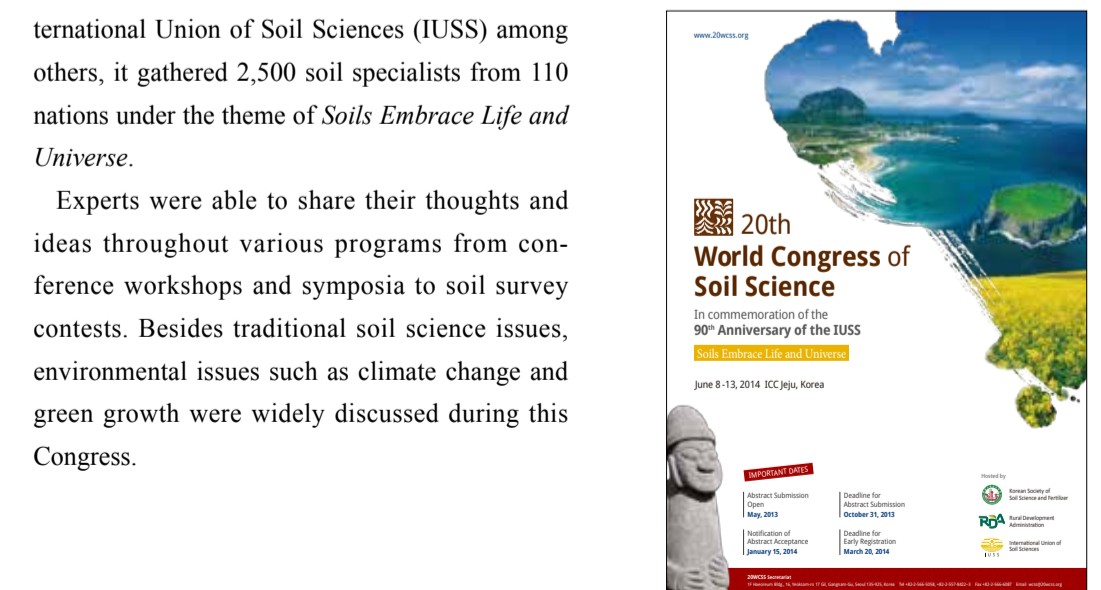
From 1998 to 2016, the Korean Forest Service and Korea International Cooperation Agency (KOICA) conducted a series of four reforestation projects in Bagan, an ancient city located in the Mandalay Region of Myanmar, famous for its world-heritage Buddhist remains. The area was suffering from desertification and climate change.

As a result, 840 ha of forest around the remains have been recovered, and a total of approximately 900,000 trees have been planted. Both organizations also passed on seedling production systems,

strengthened forest management capacity, and improved local living conditions. Agricultural yield has gone up and job opportunities have increased in related fields. The projects have since strengthened the reforestation capacity of both the Myanmar government and local residents.

20th World Congress of Soil Science

On June 8 - 13, 2014, the 20th World Congress of Soil Science was held at the Jeju International Convention Center. Co-hosted by the Rural Development Administration (RDA), the Korean Society of Soil Science and Fertilizer (KSSSF), and the In-



International Cooperation on Agriculture

