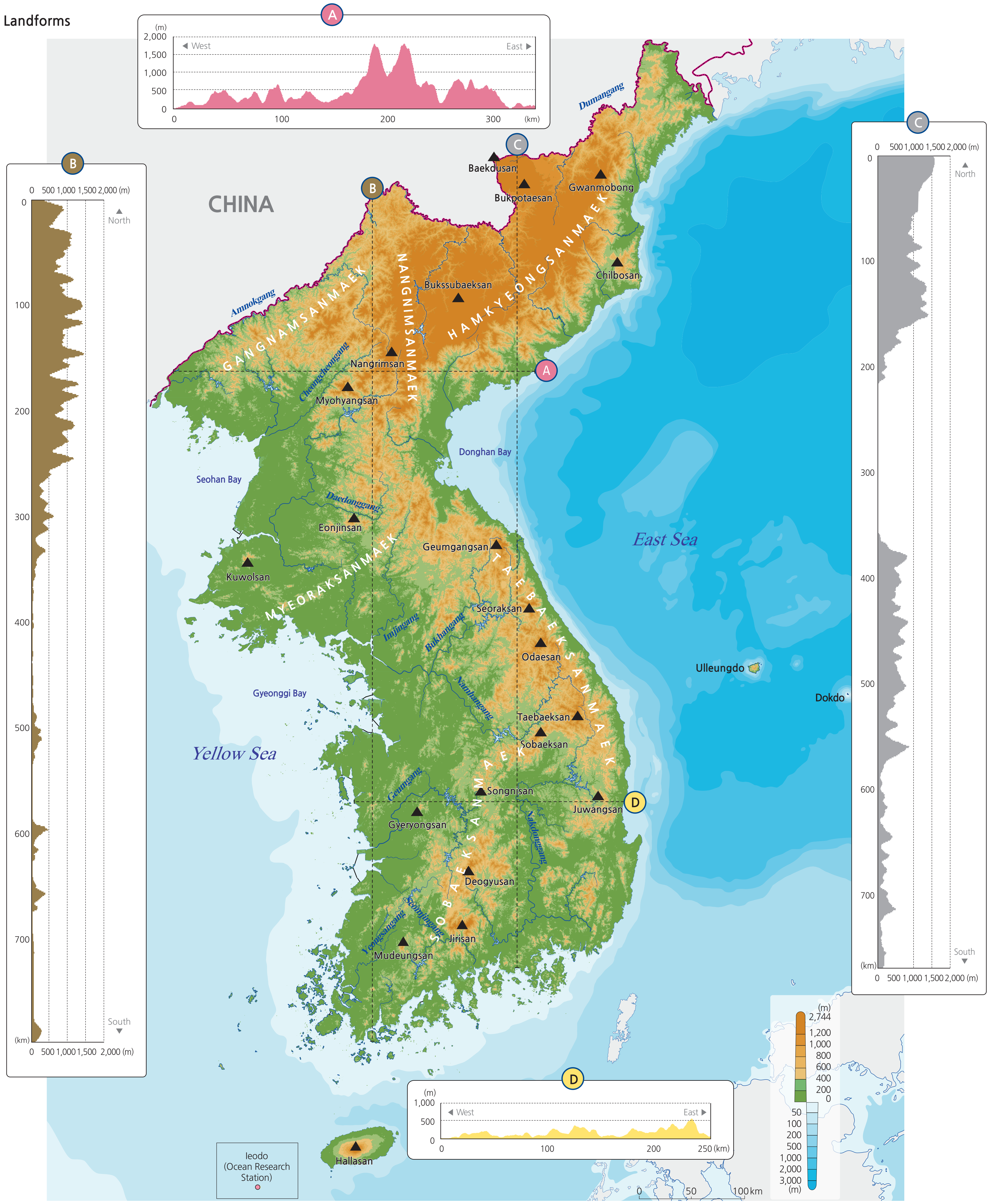
Physical Setting and Climate Change Patterns

Physical Setting of Korea

Landforms



National Geographic Information Institute (2015)

Introduction

The term "Physical Settings" encompasses everything that occurs in nature without human intervention. *The National Atlas of Korea* addresses such physical settings on the Korean Peninsula as the actions of the lithosphere, the biosphere, the atmosphere, and the hydrosphere. But because humans live on the land and have a great deal of interactions with these physical "spheres," scientists identify a special sphere called anthroposphere. The term "anthropo" refers to "pertaining to humans." The lithosphere includes the study of landforms, geology, rocks, minerals, and soils. The biosphere refers to the realm of all living things, including all classifications of plants and animals. The atmosphere encompasses all studies relating to the composition of the air around our planet, how it moves, and how weather and climates interact with the sun's energy and the locations of elements on the surface of the earth. The hydrosphere pertains to the water systems on our planet, including tthe seas and oceans, arctic and alpine snow and ice, as well as inland water systems in rivers, lakes, and underground aquifers.

This section introduces landforms in the lithosphere, the atmosphere, and the hydrosphere. More detailed discussions of the biosphere can be found in The National Atlas of Korea Vol. II. For the introduction of the anthroposphere, discussions shall center on the human-environment interactions on the Korean Peninsula as well as factors of climate change. Chapter 4 introduces the anthroposphere and human interaction with the natural spheres and the environment on the Korean Peninsula.

Landforms

The Korean Peninsula has long coastlines for its size. In contrast to its smooth eastern coastline, its southern and western coastlines are extremely complex with a great deal of indentations and offshore islands. According to a 2014 survey, the total coastline of the mainland is 7,753 km while the coastlines of Korea's associated islands constitute 7,210 km. Artificial coastlines resulting from land reclamations for coastal development and port construction have reached 5,086 km.

One of the most significant geographic characteristics of the Korean Peninsula is its prominent NNW-SSE oriented mountain ranges: Nangrimsanmaek (Nangrim Mountain Range) and Taebaeksanmaek (Taebaek Mountain Range). The term "sanmaek" translates literally as "mountain arterials" or figuratively as mountain chains. These mountain ranges resulted from the formation of a back-arc basin on the edge of the Asian continent, a process that also produced the Hamgyeongsanmaek (Hamgyeong Mountain Range) and the Sikhote Aline Mountain Range in Russia. The Ulleung Basin, located in the East Sea, was formed as a result of the Taebaeksanmaek uplift.

High mountains are asymmetrically located to the east and north of the Peninsula, following the ranges of Taebaeksanmaek, Nangrimsanmaek, and Hamgyeongsanmaek. The last two ranges contain the highest peaks that stand above 2,000 m: Dojeongsan, Kwanmobong, and Duryusan of Hamgyeongsanmaek and Heesaekbong, Maengbusan, and Nangrimsan of Nangrimsanmaek. On the other hand, Taebaeksanmaek – which runs 500 km from Youngheung Bay in North Korea along the east coast to Busan in South Korea – has much lower elevations. Major mountains in this range such as Geumgangsan, Seoraksan, and Odaesan are about 1,500 – 1,700 m high.

Toward the southern part of the Peninsula, granite is distributed in circular or girdle-shaped areas between metamorphic rocks. Well-developed erosional basins formed on the granite provide gentle slopes of 1 – 10° that are located between steep mountains and at plains to enable major transportation routes to pass, including a high speed railroad. In geographic analysis, this is a typical human-land interaction as physical geography dictates the landscape while humans adapt to its use.

Because Taebaeksanmaek and Hamgyeonsanmaek are located in the eastern region of the Korean Peninsula, most large rivers flow southwest from the major watersheds defined by the mountain ranges. Meanwhile, streams that lead into the East Sea on the steeper eastern slopes of the ranges are shorter. This disparity is a central characteristic of rivers on the Korean Peninsula. Due to the Peninsula's relatively high average slope and significant seasonal difference in precipitation, Korean rivers are also characterized by a high coefficient of river regime, meaning that there is great variability in water flow during the year. Furthermore, most rivers display wide valleys and gentle gradients.

The traditional Korean geographical portrayal of mountain ridges is to use lines to express the intertwined relationship between major mountains. Mountain ridge maps help us visualize the geographical unity of the Korean Peninsula by emphasizing that mountain systems are interconnected just as rivers are continuous. These maps specifically demarcate high peaks and mountain ridges, recognizing their importance as connecting passageways between living spheres and ridges. Even without modern scientific explanations of geological structures, terrain formation, and landscape changes, traditional geography emphasized watershed systems to differentiate human settlement areas. The Baekdudaegan is a traditional delineation of a first-order ridgeline that joins Baekdusan, a volcanic crater in the North Korea-China border, to Jirisan in the southern part of South Korea – the highest peak in mainland South Korea. The Baekdudaegan map provides a sense of unity and order throughout the Peninsula and helps to secure the national symbolism of Baekdusan. The full uninterrupted illustration of the watershed further helps to identify rivers and mountain ridges more easily. In summary, Korean traditional geography is beneficial for the efficient development and usage of the mountainous terrain and understanding Korean geomorphological features through the lens of Pungsu (Korea word for fung shui or geomancy). Making up a large proportion of the Korean Peninsula, mountainous regions and their complex distributions are mapped in multiple ways. There are three main methods that are currently being used to represent mountain distribution: the mountain range map, the mountain ridge map, and the mountain chain map.

Mountain range maps classify mountains based on the premise that mountain ranges display characteristics of the nation's geological history and tectonic movements. On the other hand, the mountain ridge system of Baekdudaegan resembles the watershed dividing lines of the ten main river basins in Korea and reflects the connectivity of the mountains. Understanding mountains based on river basins is a unique way of geographically visualizing the indigenous nature of Korea.

Brief Interpretation of the Maps

The terrain pattern on the opposite page map is much more detailed than what was shown on the general map of Korea on pages 24-25. This detail creates a significantly different picture of the land than when it was combined with the cultural detail, especially given the information of the profile transects that run in NS and EW directions.

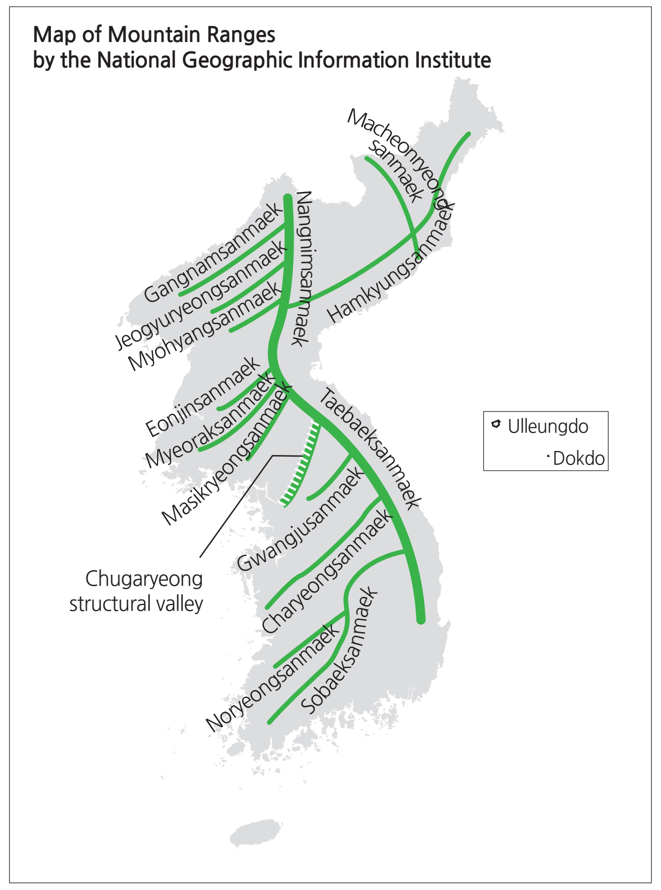
A very small element of the western coastline of the Korean Peninsula shows the landform changes created by the inhabitants of the cities. There are thin, dark blue lines that extend into the Yellow Sea. These are a series of seawalls that have been created to begin the process of reclaiming coastal sea areas into land for urban and agricultural development. The current lines in the ocean surround areas that are already significantly reclaimed in some areas. In the coastal areas of Incheon, the reclaimed land between the islands of Yeongjong and Yongyi is already in use as Incheon International Airport, one of the world's busiest airports that was ranked many times as the world's best. Over 180 km south of Seoul is the Saemangeum Seawall project, easily visible on the Landform map. This project in development for industrial and agricultural land is one of the world's largest reclamation projects and a controversial one for the loss of a large area of natural wetland habitat for sea birds and other species.

The three maps below are traditional Korean ways of visualizing mountains based on mountain ranges, mountain ridges, and mountain chains. These are people's perceptions of the land and the existence of the mountain systems. The maps are somewhat stylized as represented by lines. They help to provide images of the forms and directions of the mountains in an easily recognizable mental capacity. They also help to classify the order of the mountain ranges and chains.

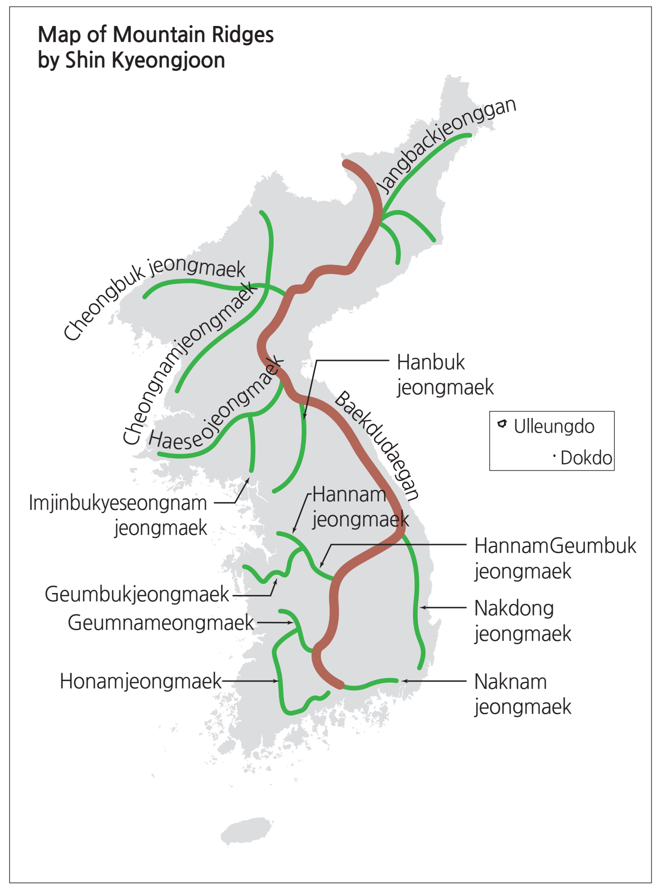
Look closely at the southwest and south coasts of Korea and project how much more land could be added to agricultural production in South Korea by similar reclamation projects. How would adding more projects of the size of the Saemangeum project affect the economy and environment of South Korea? How would these projects compare to the historical reclamation projects of the Netherlands, especially in the type of land now in the sea?

Different traditional ways of portraying Korea's mountain ranges

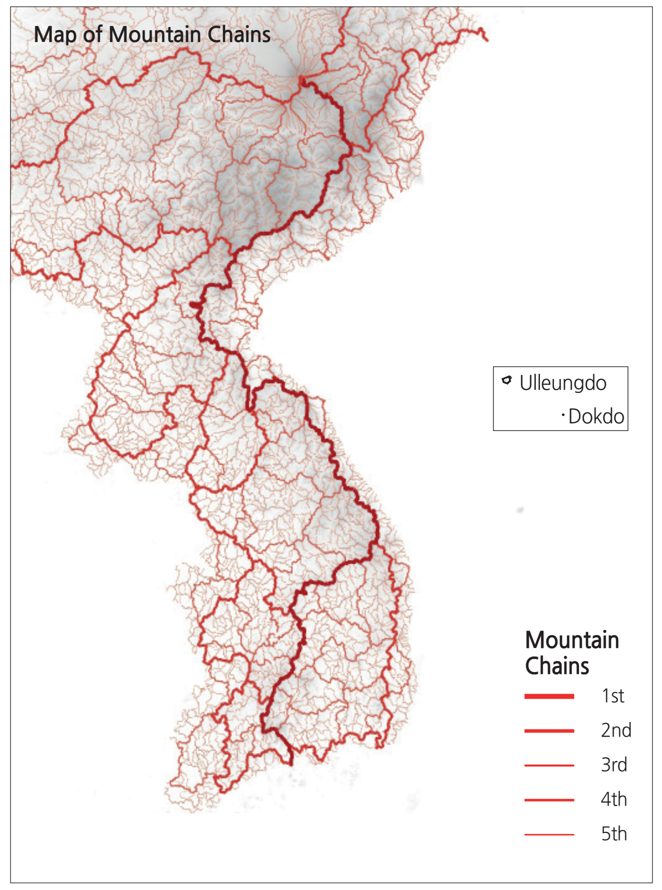
Map of Mountain Ranges by the National Geographic Information Institute



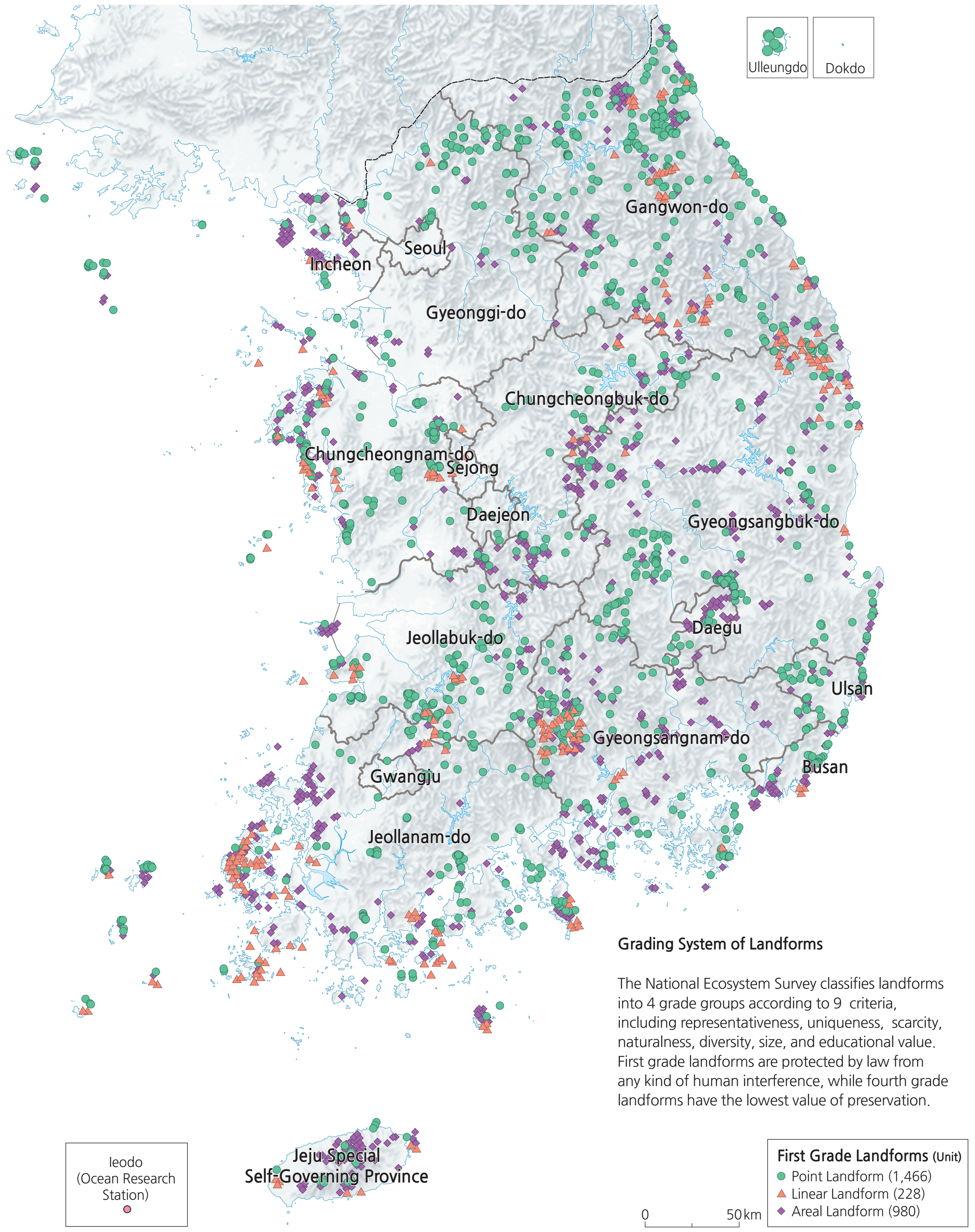
Map of Mountain Ridges by Shin Kyeongjoon



Map of Mountain Chains



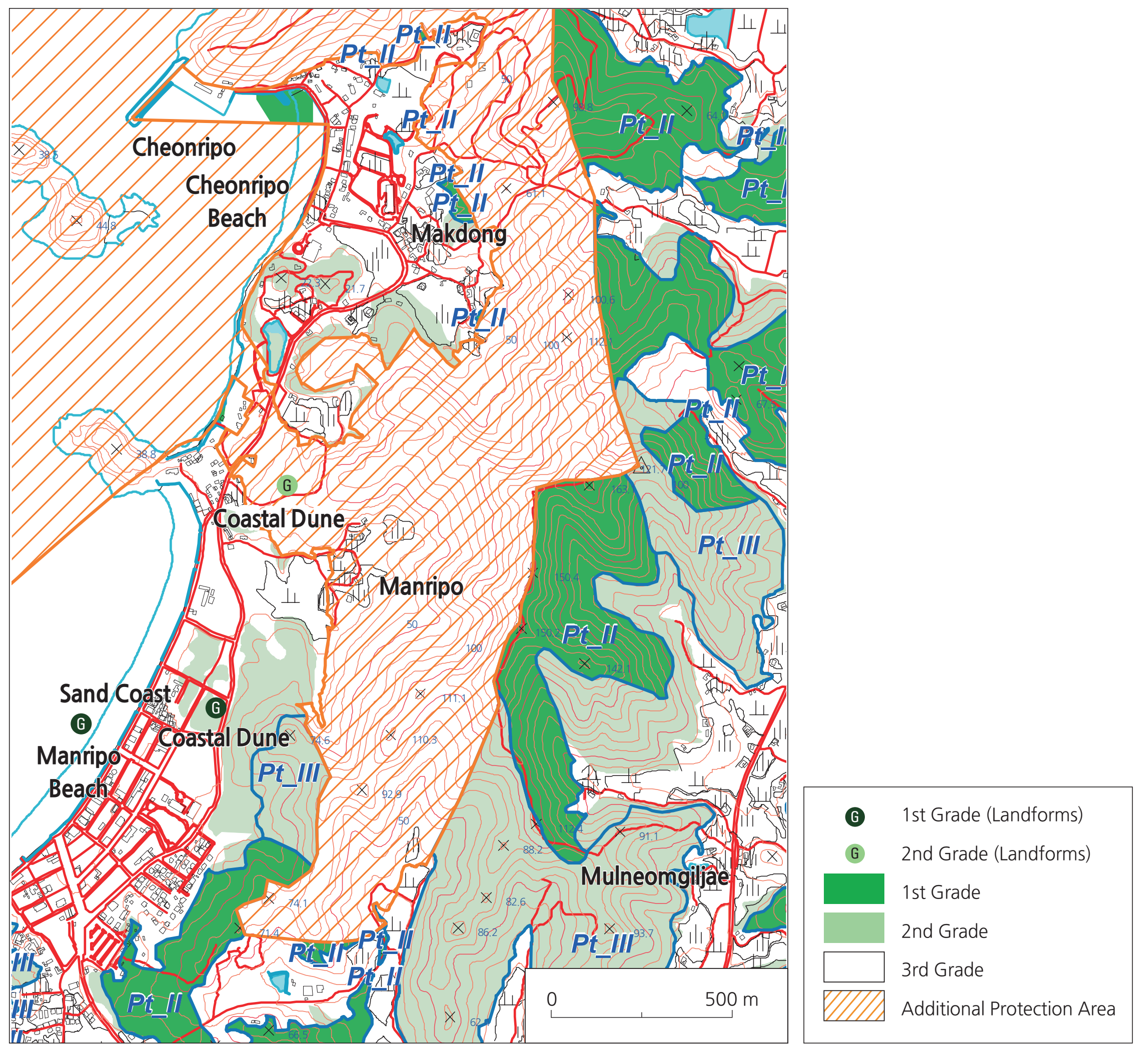
First Grade Landforms by National Ecosystem Survey



Grading System of Landforms

The National Ecosystem Survey classifies landforms into 4 grade groups according to 9 criteria, including representativeness, uniqueness, scarcity, naturalness, diversity, size, and educational value. First grade landforms are protected by law from any kind of human interference, while fourth grade landforms have the lowest value of preservation.

Example of Ecosystem Survey Map (Landforms)



Ministry of Environment (2014)

Korea conducts a national ecosystem survey that inspects the comprehensive status of the natural environment. It covers abiotic components (topography, geology, land, and soil) as well as biotic components (plants and animals). This survey enhances the understanding of topological features, the distribution of plant and animal species, the level of environmental destruction, conservational value, and so on, by analyzing the characteristics of each individual element.

The National Ecosystem Survey has three components: first, a comprehensive national environment survey as a basic investigation for the natural environment; second, a targeted survey of key ecological landscapes that include inland wetlands, uninhabited islands, coastal sand dunes, estuaries, and other landscapes of outstanding ecological importance; and lastly, a species survey on legally protected, rare, and endangered wild flora and fauna. This survey is the largest scale of its kind conducted annually in Korea, involving around 500 researchers in various fields including landforms and taxonomic groups of plant and animal species. The nation's very first survey (1986 to 1990) covered terrestrial, freshwater, and coastal ecosystems and was based on the basic plan for the national ecosystem survey (1986. Feb. 24). The landform survey was included in the second-phase survey (1997 to 2003) and has been continuously updated ever since the third survey (2006 to 2012).

Evaluation of all environmental features is based on a general grading system. By law, Grade 1 features have the highest preservation value and are to be protected at all times. Lower level grades decrease accordingly in preservation value.

Geomorphology is the study of landforms, particularly their formations, changing forms through erosion and deposition. Geomorphic and landscape features are some of the most fundamental components of the natural ecosystem. Topographic features directly influence surface geology, soil distribution, ground water status, and growth and reproduction of plant and animal species. The national landform survey is composed of two different surveys: one is a general survey of features such as mountains, river landforms, and coastal landforms; the other is a special survey of volcanic and karst landforms. The results of the topographic survey are categorized into points, lines, and polygons based on their attributes. The third phase survey has reported that valuable topographic features of the first grade comprise 1,446 points, 228 lines, and 980 polygons in Korea.

The data collected through the national ecosystem survey enhance our understanding of the landscape and are foundational to understanding the natural resource potential and the distribution of biodiversity. By incorporating this information into ecological maps, experts such as environmental managers, development planners, and government officials may utilize the comprehensive overview of the survey to understand the distribution of biological diversity, establish development plans, carry out environmental impact evaluations, and conduct natural environment assessments. The National Ecosystem Survey classifies landforms into 4 grade groups according to 9 criteria, including representativeness, uniqueness, scarcity, naturalness, diversity, size, and educational value. First grade landforms are protected by law from any kind of human interference, while fourth grade landforms have the lowest value of preservation.

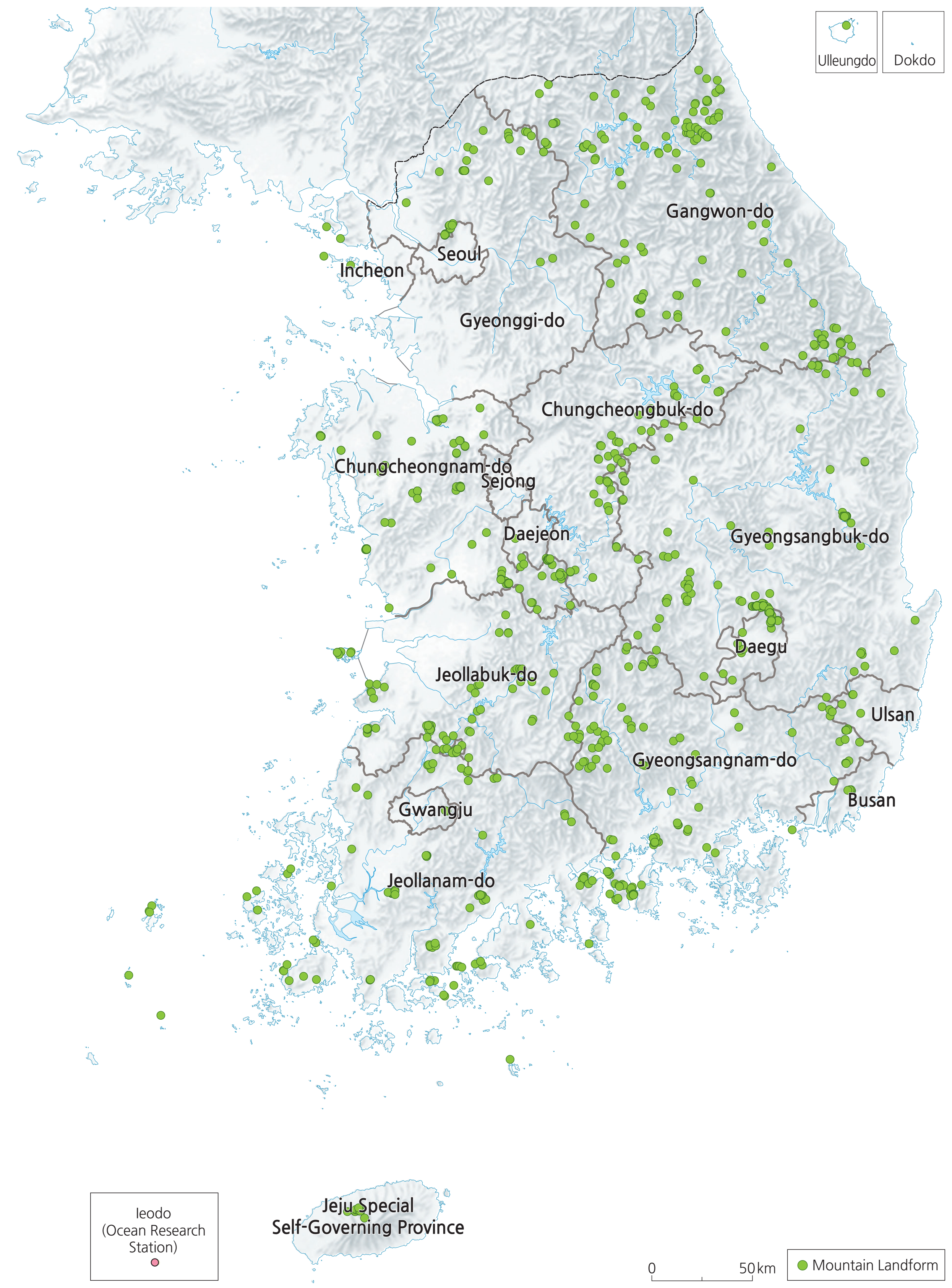
Brief Interpretation of the Map

The map lists all Grade 1 landforms that are determined to be worthy of preservation and limitations on human activity. The general geographic pattern clearly covers the non-urban and non-agricultural areas of Korea. Symbols of different colors and shapes were used to depict point landforms (such as a peak), linear landforms such as a clean river, and areal landforms such as a piece of wetland. In Korea, there is a great diversity of different kinds of landforms. The map suggests that there are many places of pristine condition in the country that still contribute to a clean living environment away from the congestion and pollution generally associated with urban areas. The Ecosystem Survey Map is a testament to the emphasis that the government places on important mapping activities to help enhance the standard of living and the quality of life for Korean citizens.

How far do urbanites have to travel in order to enjoy natural settings and pristine landforms? What are their responsibilities when they reach these places? Should they assume the role of environmental stewards for future generations?

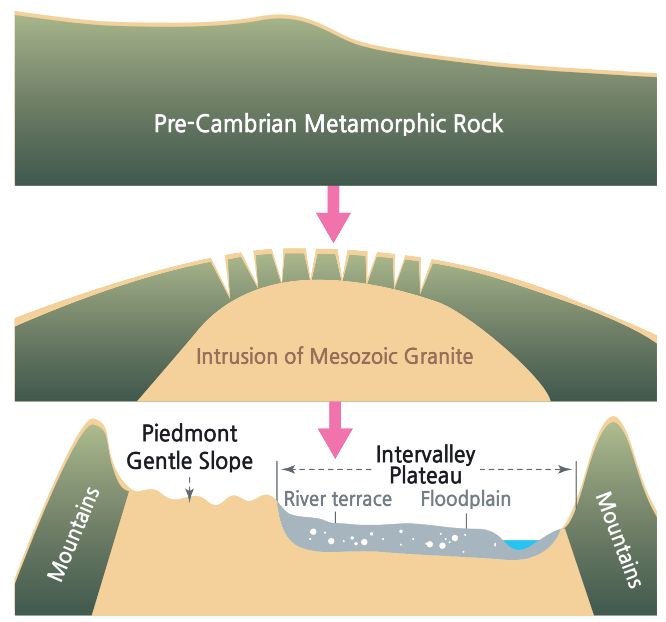
Geomorphological Landscapes

First Grade Mountain Landforms

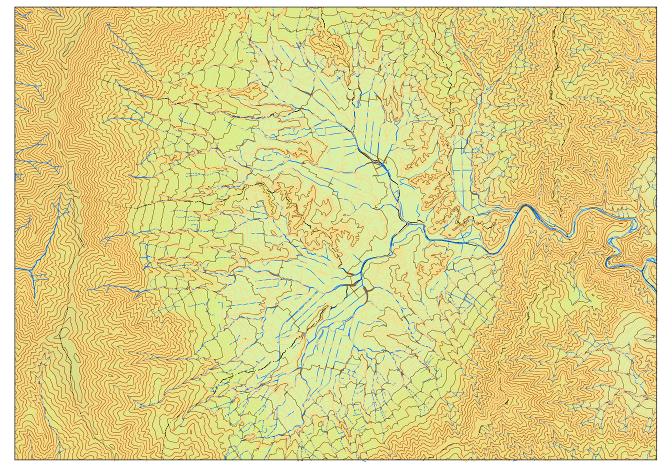


Ministry of Environment (2015)

Formation of Erosional Basins



Example of Erosional Basin (Haean Basin)



National Geographic Information Institute (2015)

Erosional Basin (Haean Basin in Yanggu, Gangwon-do)

Tafoni (Maisan, Jinan, Jeollabuk-do)

Dome (Bukhansan, Seoul)

Block Field (Seoraksan, Inje, Gangwon-do)

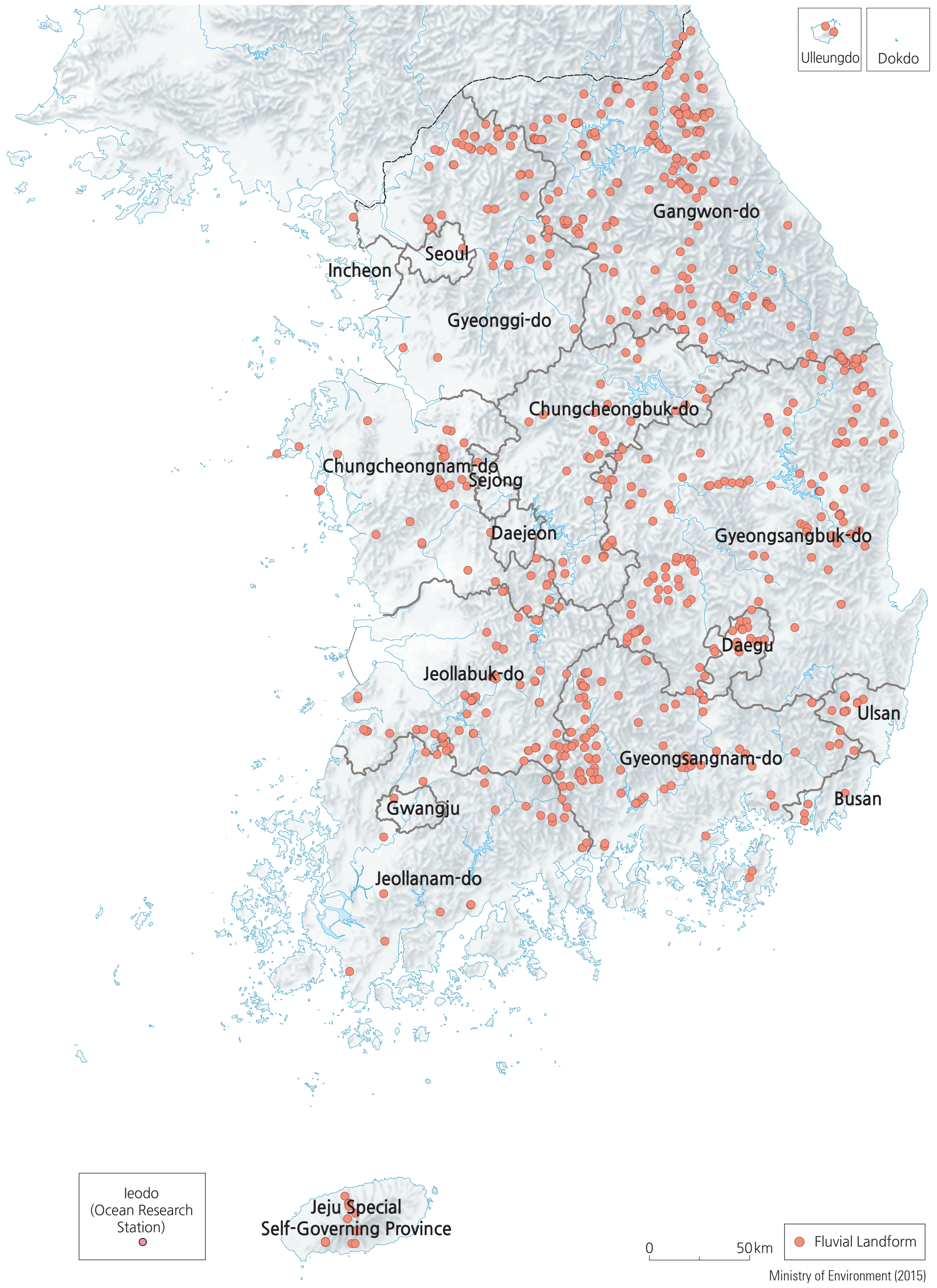
Although approximately 70% of Korea's territory consists of mountainous areas, there are not many mountains with high elevations. The highest peak in South Korea (excluding Hallasan in Jejudo) is Jirisan, located about 50 km north of the south-central coastline. It stands at less than 2,000 m. The higher mountains are distributed toward the eastern side, a phenomenon that was caused by the uneven warping of the Korean Peninsula. Bedrock that is resistant to weathering and erosion constitutes the high rugged mountains, while less resistant rocks characterize the lowlands, basins, and valleys. South Korea displays a complex topographic regime due to various bedrock compositions formed over different geological periods. For example, metamorphic rocks originate from the Pre-Cambrian period (over 540 million years ago), granite and volcanic rocks were formed during the Mesozoic period (between 66 and 250 million years ago), and sediments remain from the Tertiary and Quaternary periods (less than 3 million years ago). Typical eroded and weathered landforms include erosional basins, sinuous or meandering rivers, rock cliffs, rock domes, tors (large rock outcrops), tafoni (singular: tafone; small coastal caves in sandstone or granite formations), and caves. Depositional landforms include block streams, talus deposits, and upland wetlands. According to the Natural Ecosystem Survey, first grade landforms are generally located along the high mountains of Taebaeksanmaek and Sobaeksanmaek, and are also widely distributed in island areas.

Brief Interpretation of the Map

The map depicts the locations of Grade 1 mountain landforms of various kinds as illustrated by the photographs. Not surprisingly, their distribution pattern correlates with the mountain chains map on page 43. Different mountain landforms provide different utility values to human activities. While tafoni continue to erode, they, along with block fields, may cause hazards. On the other hand, erosional basins with alluvial depositions provide valuable farmlands. Locations of these landforms affect human activities.

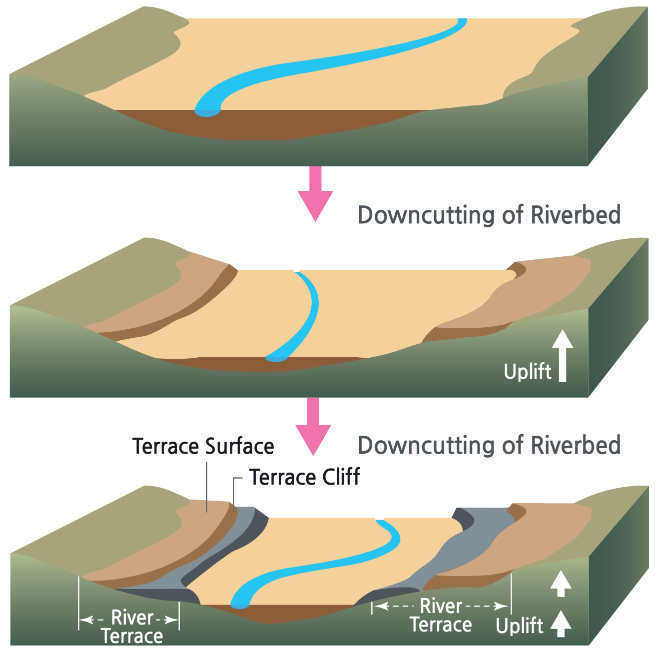
Considering slope or gradient, hardness or softness of bedrock material, degree of ease for further erosion, effects on the neighboring environment, what are some of the criteria relating to landforms that you may need to consider in the construction of a highway?

First Grade Fluvial Landforms

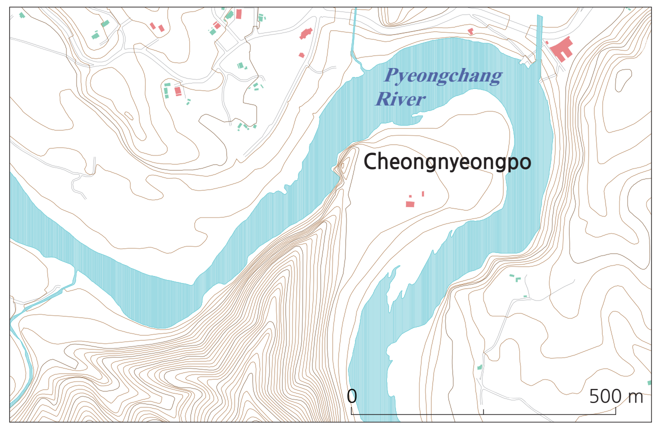


Ministry of Environment (2015)

Formation of River Terrace



Example of Fluvial Landforms (Entrenched Meander, River Terrace)



National Geographic Information Institute (2015)

Entrenched Meander (Yeongwol, Gangwon-do)

Riverine Wetland (Yeongwol, Gangwon-do)

Waterfall (Seoraksan, Inje, Gangwon-do)

Riverside Cliff (Yeongyang, Gyeongsangbuk-do)

Rivers in Korea can be classified into straight, meandering, and braided. Straight rivers are bounded by exposed bedrock between narrow valleys and mounds; meandering rivers develop on wide floodplains; braided streams occur in almost flat, alluvial deposits where stream flows are slower and branch off into several unorganized parallel channels. Typical erosional landforms include waterfalls, potholes, riverine cliffs, and riverine caves, while typical depositional landforms are deltas, alluvial fans, riverbanks, point bars, and riverine wetlands. The floodplains formed by Hangang, Nakdonggang, and Geumgang (gang is the Korean word for river) constitute major agricultural plains in South Korea. The natural levees and backswamps of these floodplains developed from the last glacial period. Eroded valleys were filled with sediments due to rising sea levels. Deltas, which are an extension of floodplains, are shaped by sediment discharge from rivers, ocean tides, and waves. They are generally located where the mouth of a river on the floodplain meets the sea. The Nakdonggang Delta is a representative example. Alluvial fans are formed from small rivers and are mainly used for agriculture. Most eroded stream topography is observed in upstream areas of large rivers or around small rivers. In Korea, many of these regions have become tourist destinations as the exposure of bedrock creates a unique landscape. As a result, the most notable examples of river topography within the nation are generally located in upstream regions, rather than near the mouth of a river.

Brief Interpretation of the Map

The geographic pattern for first grade fluvial landforms is generally associated with inland reaches of the upper and middle courses of rivers in relatively higher grounds. By the time they reach the lower course, their environmental quality changes. Since river patterns follow closely to watersheds as defined by ridgelines, this fluvial landform map corresponds to the northeast to southeast trend of the mountain landforms of the previous page. In Korea, there is great diversity of fluvial landforms, from meandering rivers to riverside cliffs to hanging waterfalls. They provide different economic value to humans; scenic fluvial landforms attract tourists while lowland meandering landforms provide water for agriculture. Wetlands serve dual purposes: to provide sanctuary to biotic species and maintain a rejuvenated environment.

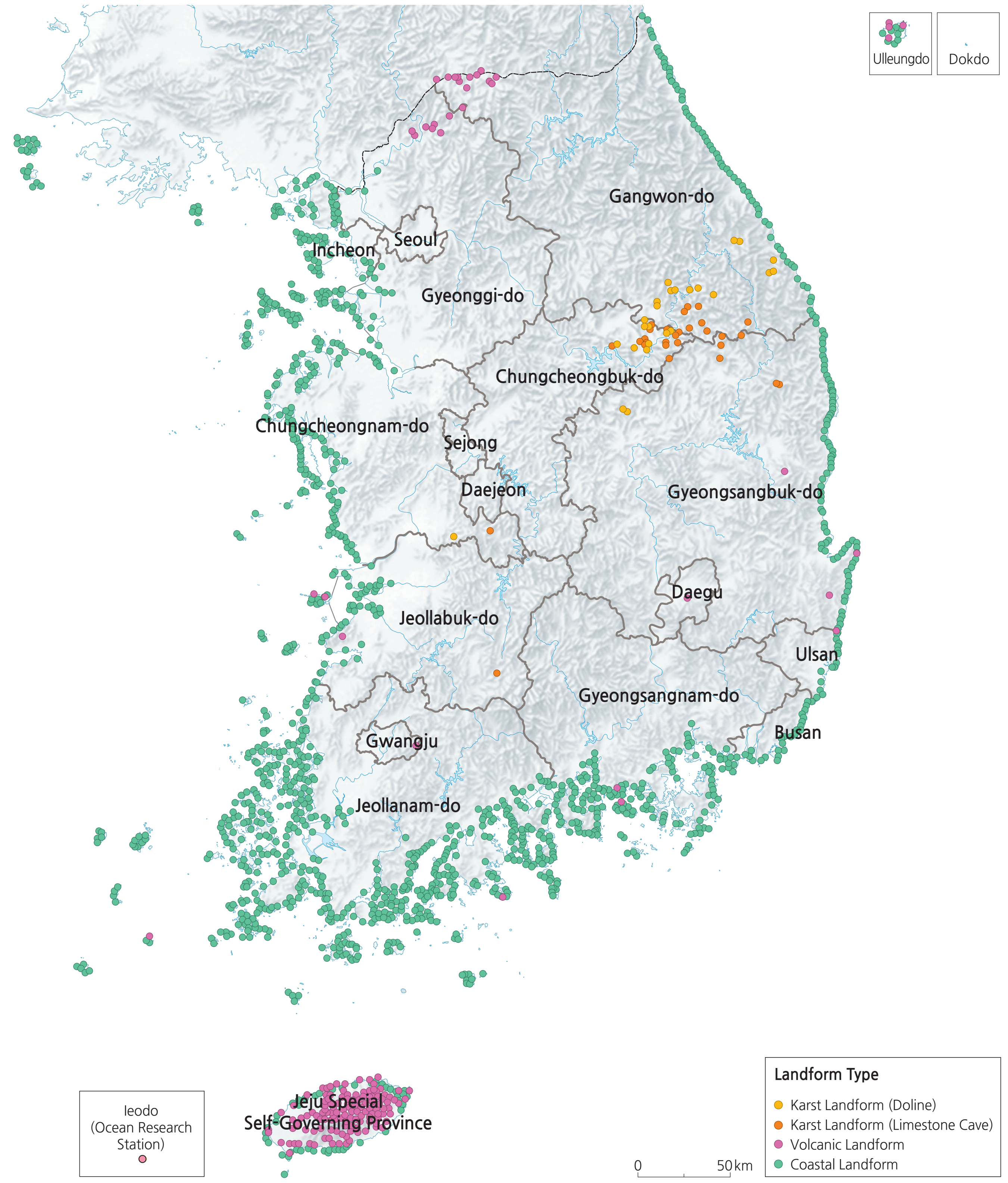
Given that water sustains life, including human lives that requires potable (suitable for drinking) water and clean hydroelectricity, what might be the best strategy in locating and building dams that sustain human life but at the same time, create adverse environmental conditions? Discuss some of these adverse environmental conditions. There are many dams in South Korea; most are purposely built away from the north and some are built close to industrial centers and urban centers: discuss the pros and cons of their locations (refer to The Major Land Development Projects Map on Page 69).

Tideland (Gomsoman, Gochang, Jeollabuk-do)

Sea Stack (Yokjido, Tongyeong, Gyeongsangnam-do)

Coastal Sand Dune (Sinduri, Taean, Chungcheongnam-do)

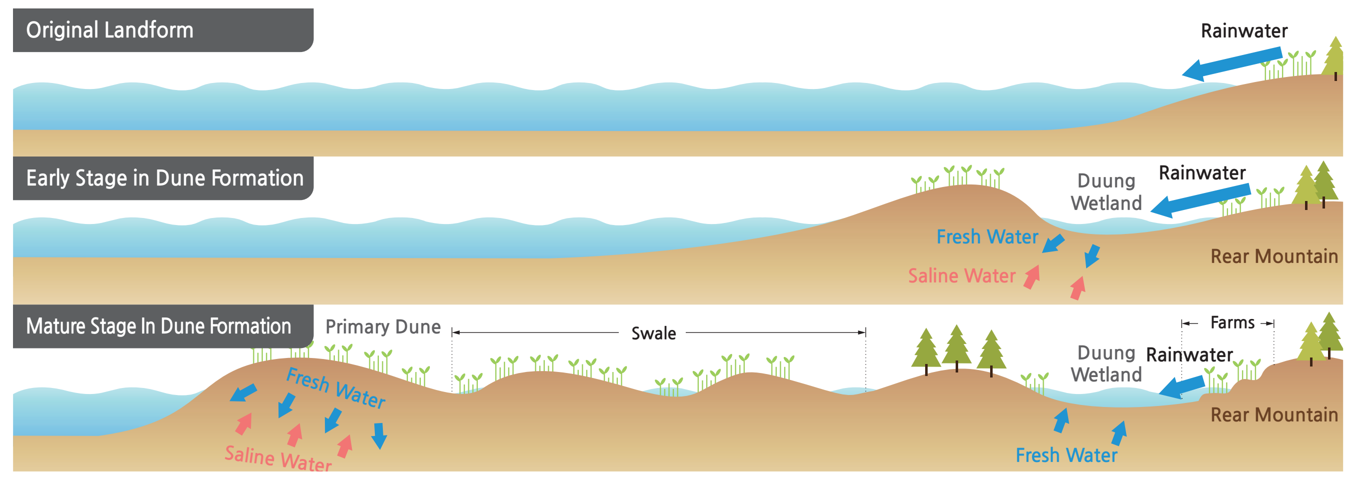
First Grade Coastal Landforms, Volcanic Landforms, and Karsts



Ministry of Environment (2015)

Example of Coastal Landforms (Sinduri Coastal Sand Dune)

Formation of Coastal Dunes (Taean, Chungcheongnam-do)



First grade coastal landforms are evenly distributed along the coastline, mainly around relatively less-developed islands. Korean coastal landforms can be classified as rocky, sandy, or muddy. Sandy coasts are observed in bays where active sedimentation by waves occurs. Coastal depositional landforms include beaches, sand dunes, sand spits, sand bars, lagoons, and tombolo (a sandbar that joins two islands or from one island to the mainland). Sandy coasts prevail in the eastern and western coastal areas, especially along regions exposed to the open sea such as the Taean Peninsula. Rocky coasts are indicative of erosional topography and develop along the headlands of mountainous and mound regions near the sea or where wave activity is strong. They are often found near major mountain ranges along the eastern and southern coasts. Sea cliffs, wave-cut platforms, and coastal terraces are also visible along the eastern coast of Korea. Muddy coasts are found along the western and southern coasts where flood and ebb tides are farther apart, wave activity is weak, and silt-sized particles are deposited. The largest tidal flats occur in Gyeonggiman (Gyeonggi Bay), where tidal range is as large as 8 – 10 m. Intermingled with first grade coastal landforms are reclaimed lands, which normally have straight coastlines and dykes. Although reclaimed lands cannot be considered natural or classified as first grade, they do affect the surrounding water quality, wave actions, and deposition patterns around their environments.

Brief Interpretation of the Map

From this map, it is obvious that all first grade coastal landforms are along the coast and have great physical interaction with ocean waters through their waves, tides, and suspended sediments. Although the first grade level classification is artificially given to them, they do require constant protection from humans and the government because of their tremendous economic value. Harbors are built for protection of vessels during rough weather and frequent typhoons. Seaside recreation facilities provide leisure activities to citizens. The fishing industry depends on access to the seas and an appropriate environment for the maintenance of vessels. Scenic outlooks attract tourists and promote tourism. Since the 2010s, many wind farms have been built on coastal landforms and even into shallow bays to harness renewable energy. There are even hydrothermal power plants that are built in shallow offshore locations. Aquaculture (farming for seafood) has become an important industry in Korea, providing such food as oysters, seed weed (a constant in the Korean diet) and various species of fish. The many benefits of coastal landforms interact in a very complex manner with human activities.

Can you think of ways to protect coastal landforms without curbing human use? Discuss some of the strategies for maintaining important human activities while preserving first grade coastal landforms.

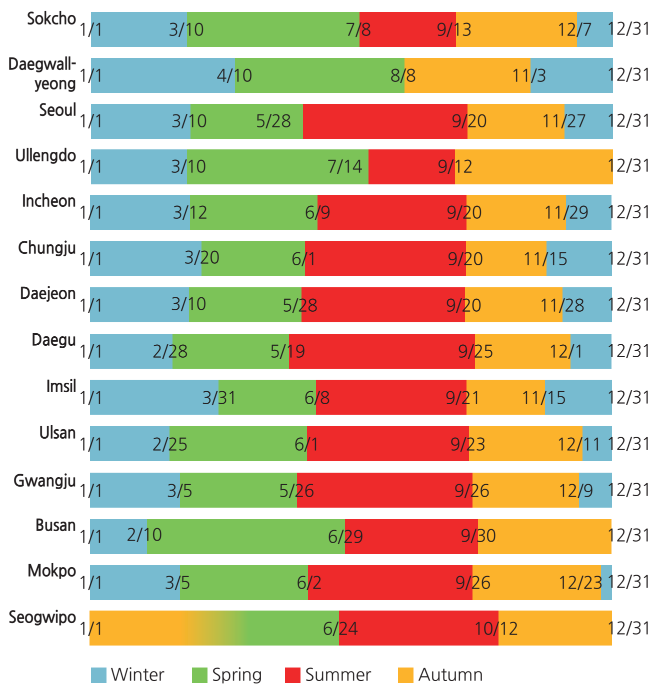
Weather and Climate

Criteria for Classification of Natural Seasons

Season	Daily Mean Temperature	Daily Maximum Temperature	Daily Minimum Temperature
Spring	≧ 5℃		≧ 0℃
Summer	≧ 20℃	≧ 25℃	
Autumn	≦ 20℃	≦ 25℃	
Winter	≦ 5℃		≦ 0℃

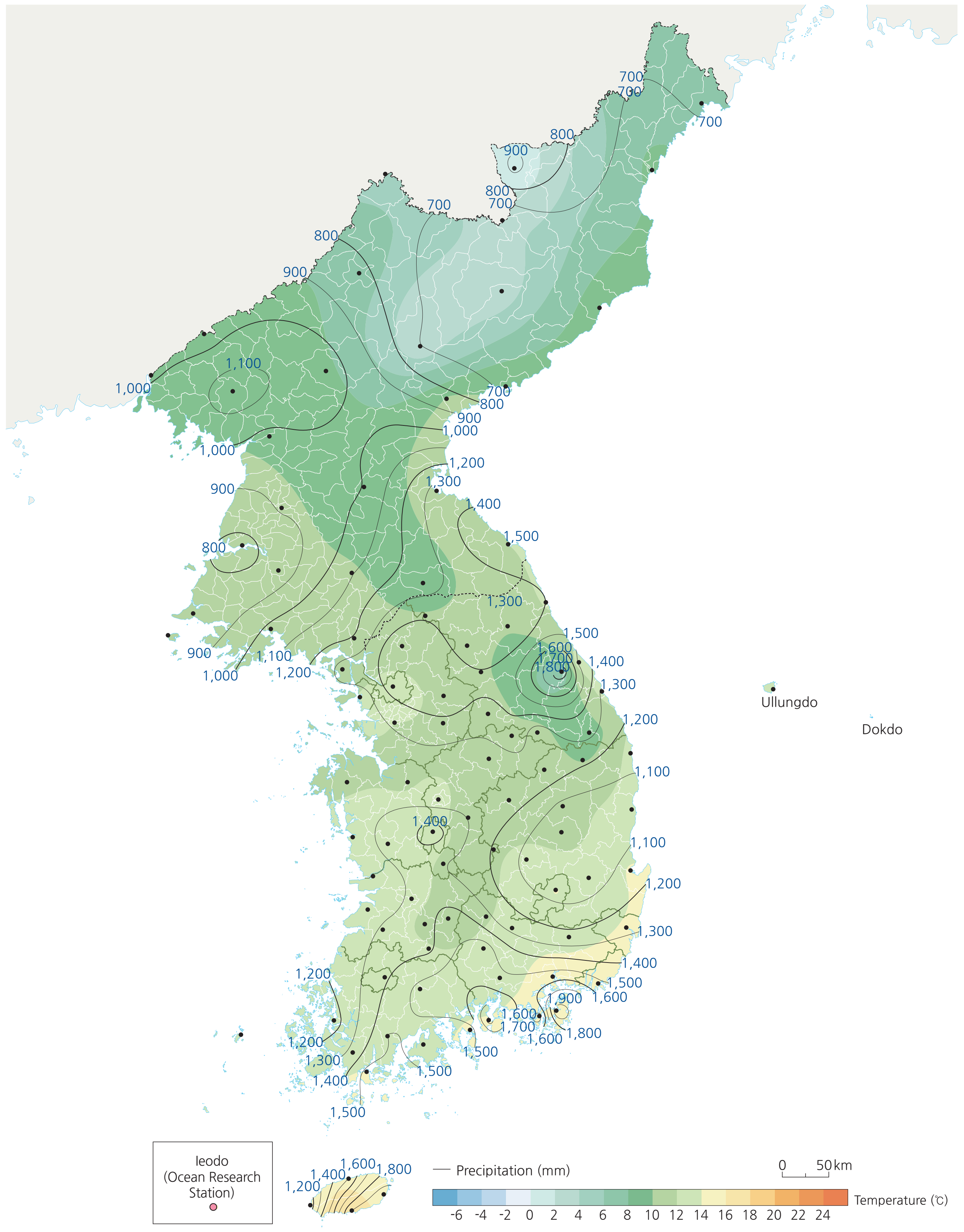
The Korean Geographical Society (1979)

Classification of Natural Seasons by Region



Korea Meteorological Administration (2012)

Annual Mean Air Temperature and Precipitation (1981-2010)



The spatial distribution of climate in Korea is determined by key climate factors such as latitude, elevation, geographical location, land/sea heating properties, ocean current, the East Asian Monsoon system, and air mass. During the summer, it is hot and humid in response to the East Asian Monsoon, but during the winter, it is cold and dry.

The Asian Monsoon system over East Asia (including Korea, China, and Japan) is formed by the land-sea distribution and the associated difference in heating properties. While cold, dry wind from the northwest blows into the Korean Peninsula in the winter as a result of the continental effect, hot and humid southeasterly wind blows into Korea during the summer from the North Pacific. The climate of Korea is also under the influence of various air masses such as the Siberian, the North Pacific, the Okhotsk Sea, and equatorial air masses.

The difference in temperature between the northern area and the southern area is clear. This is because of the amount of solar energy received and the difference in length of daylight that varies with latitude. The difference in annual mean air temperature between Seogwipo (16.6ºC), located near the southernmost tip of South Korea (33° 14' N), and Cheorwon (10.2ºC), located at the northernmost tip (38° 08' N) of South Korea, demonstrates a wide variation in air temperature because of latitude.

The climate features also vary with elevation. The annual mean air temperature at Daegwallyeong (773 m), the highest observation station in South Korea, is 6.6ºC, which is 3.7ºC lower than that at Hongcheon (10.3ºC) at an elevation of 141 m even at a similar latitude. The difference in the mean air temperature is also found in the southern area between Imsil (248 m) and Jeongeup (45 m), with 11.2ºC and 13.1ºC, respectively.

Geographic location can also affect climate. As an example, we examine two locations: Yeondong (east of the Taebaek Mountain Range) and Yeongseo (west of the Taebaek Mountain Range). During winter when a cold northwesterly wind dominates over the Korean Peninsula, the temperature at Chuncheon, a city in the Yeongseo area, is low because it is in the windward side of the winter wind direction. Sokcho, a city in the Yeongdong area, is warmer because it is in the leeward side. However, the situation reverses if the winter wind comes from the northeast; Sokcho is now in the windward side and will have a colder temperature than Chuncheon, which is now in the leeward side. Because the northeasterly wind comes in over the East Sea after picking up moisture from the warm currents, heavy snow occasionally falls in the Yeongdong area as the wind ascends the cold Taebaek Mountain top.

Korea is largely characterized by a continental climate due to the effects of the Eurasian continent. However, the climate of the coastal areas, which is mostly affected by the ocean, differs from that of the inland areas. The annual mean temperature range for Daejeon is only 0.3ºC greater than that of Boryeong, which is adjacent to the coast. The average temperature during the summer (months of June, July, and August) in Daejeon is approximately 1.3ºC higher than that in Boryeong.

Ocean currents can also affect the climate of Korea. East Korean Warm Current and North Korean Cold Current in the East Sea as well as the Yellow Sea Warm Current all play a role in affecting Korea's climate (see maps on page 57).

The classification of natural seasons based on the criteria of daily mean air temperature, daily maximum air temperature, and daily minimum air temperature results in regional differences in beginning dates of the year and number of days for each season. Spring comes the earliest to the Korean mainland in Busan (February 10) while it comes latest in Daegwallyeong (April 10). Except for Daegwallyeong (August 8) and Sokcho (July 8), summer mostly begins between late May and early June and lasts about 70 – 120 days. Autumn starts around the middle of September, with shorter duration (60 – 80 days) than spring and summer. Winter generally commences around late November, lasting about 100 – 130 days.

Brief Interpretation of the Maps

The patterns of precipitation and temperature in the different seasons in South Korea provide an additional element to the perception of Korea' landscape that helps to develop a more detailed mental image of the geography of Korea's different districts and provinces. Without the seasonal elements of climate to add visual depth to the different areas, South Korea seems to appear quite similar throughout based on location relative to the sea and elevation.

The island of Jeju, about 100 km south of the south coast of Korea, has quite a distinctive pattern of temperature and rainfall. As expected except in the summer, it reflects the influence of the ocean. In the summer it has an average temperature of about 25ºC (75ºF) and receives an average of approximately 700 mm (25 in) of rain from June to September. In the spring, Jeju's temperatures of 13ºC are similar to those in southeast Korea, also reflecting the influence of the sea. In the autumn and winter Jeju is warmer than the mainland with somewhat more precipitation.

Year round there is one area that shows distinctive weather patterns. About 25 km west of Sokcho, the mountainous region that reaches to 1,300 m displays colder temperatures and is associated with greater precipitation than its lower areas nearby.

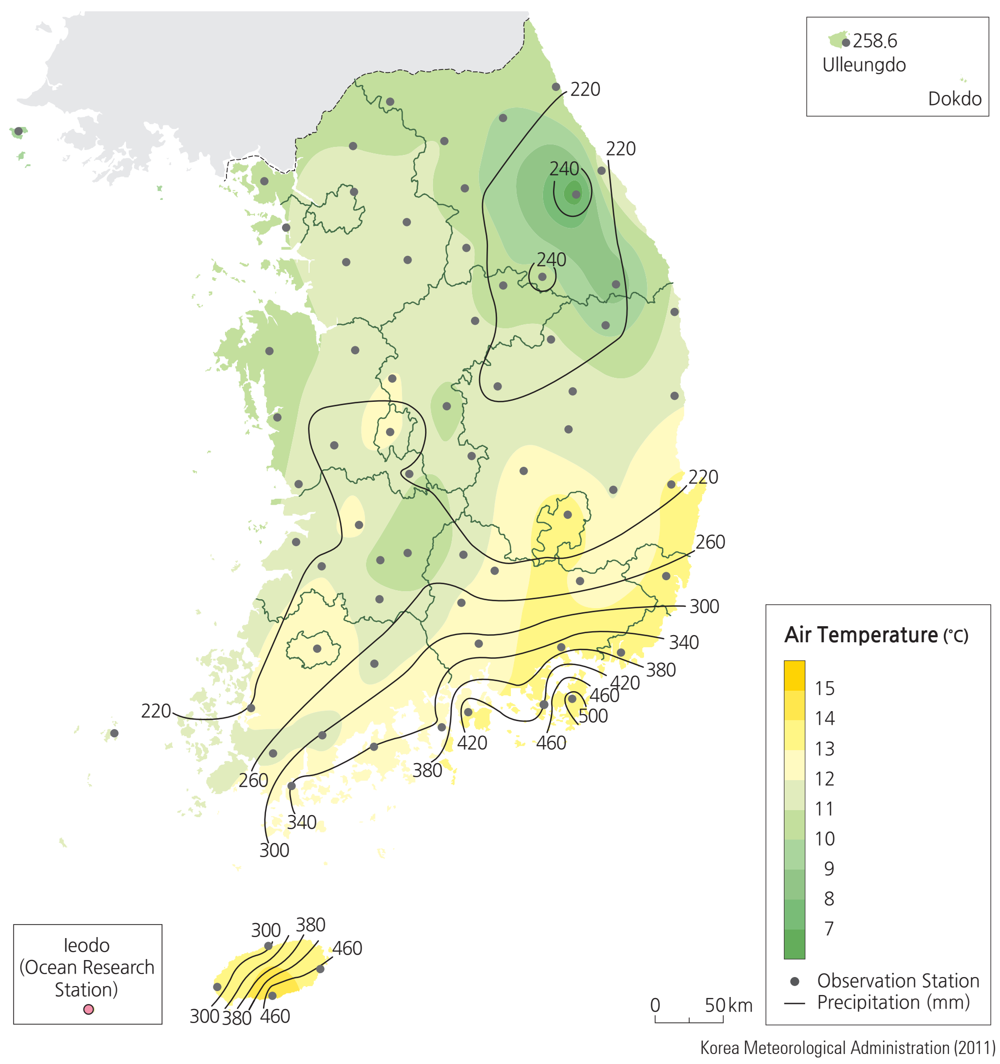
In general, on the South Korea mainland, there are two main types of weather: the coastal region, which is wide in the west, narrow in the east, and about 100 km wide in the south, and the higher, more dissected areas in the center. The central part of the Peninsula, lower on the south and higher and closer to the coast on the northeast, is cooler and associated with more precipitation in most seasons in the form of rainfall. In the spring, the coastal areas are warmed more by the coastal sea, ranging from 15ºC (59ºF) in the south to 7ºC (45ºF) in the north, with precipitation of 450 mm (17 in) on the south coast to 240 (9 in) on the north. In the summer the temperature is more similar throughout, with various high points ranging from 25ºC (77ºF) to 22ºC (71ºF) in the higher central zone, a pattern more like Jeju than any other season.

The rainy season is the summer, ranging from 900 mm (35 in) to 600 mm (23 in), with less rain in the northeast. In the autumn and winter, as to be expected, the temperatures are cooler across the Peninsula. In the autumn the higher mountain areas fall to 10ºC (50ºF) and to around freezing in the winter in the higher areas, with the south coast warmer to around 15ºC (59ºF). Precipitation decreases in both autumn and winter to 150 to 200 mm (6–17 in) at the higher elevations, to 50 to 60 mm (2–2.5 in) nearer the coast. The winter shows temperatures from 0ºC (32ºF) to -4ºC (28ºF) and much less precipitation throughout.

Almost all of the temperatures and precipitation values on these maps are 30-year averages. There are local highs and lows that are much more variable from year to year and in different seasons. However, it is the stability of these values that provides a critical baseline for the evaluation and prediction of the effects of changes in the climate due to human and environmental conditions.

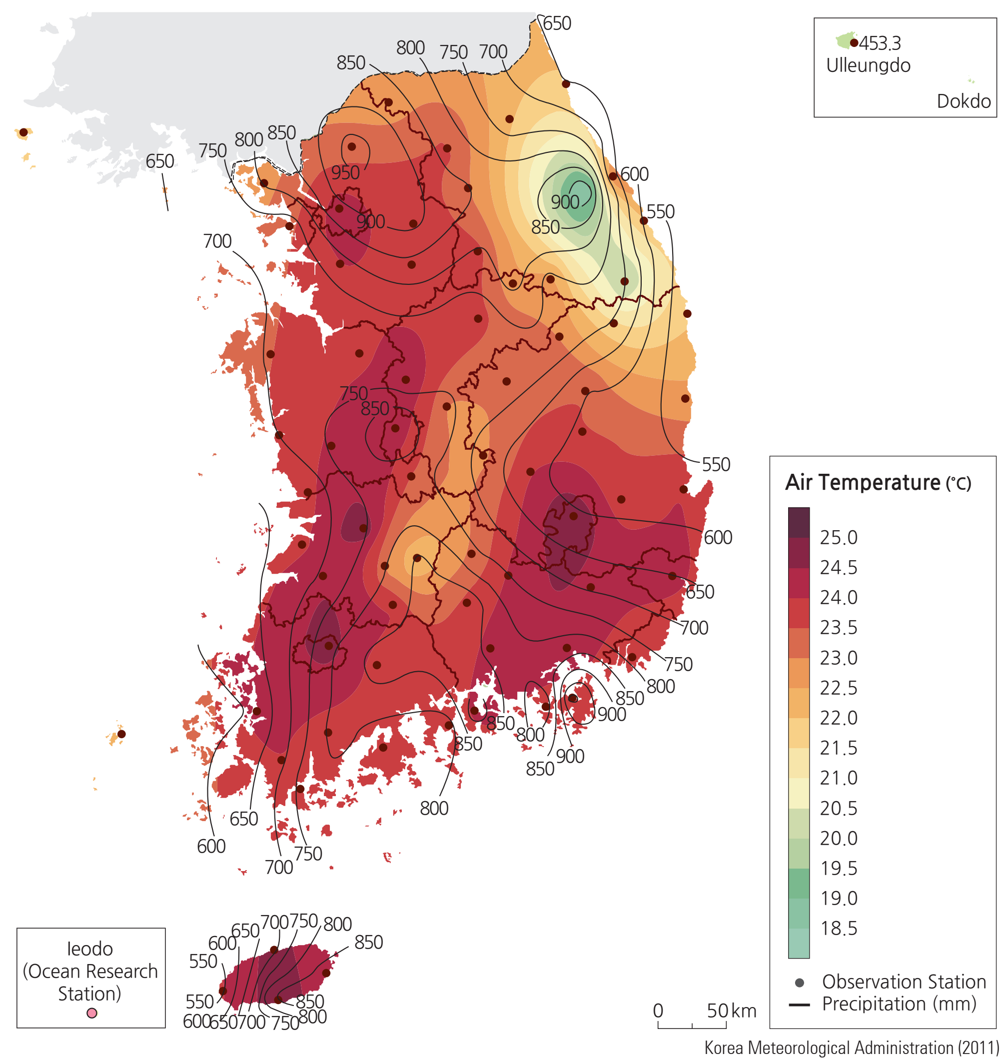
The area just to the east of Seoul shows a much higher average zone of rain in autumn, 200 mm (8 in) more, than the surrounding lowlands. What could account for this difference in that urban area? If one were studying the average rainfall for the period of 1890 to 1920, would a similar pattern exist? Do other urban areas in South Korea show a similar pattern? If Jeju showed that in a five-year period from 2020 to 2025, there were three abnormally warm winters with a 50% increase in rainfall, would this be clear evidence of global warming?

Spring Mean Air Temperature and Precipitation (1981-2010)



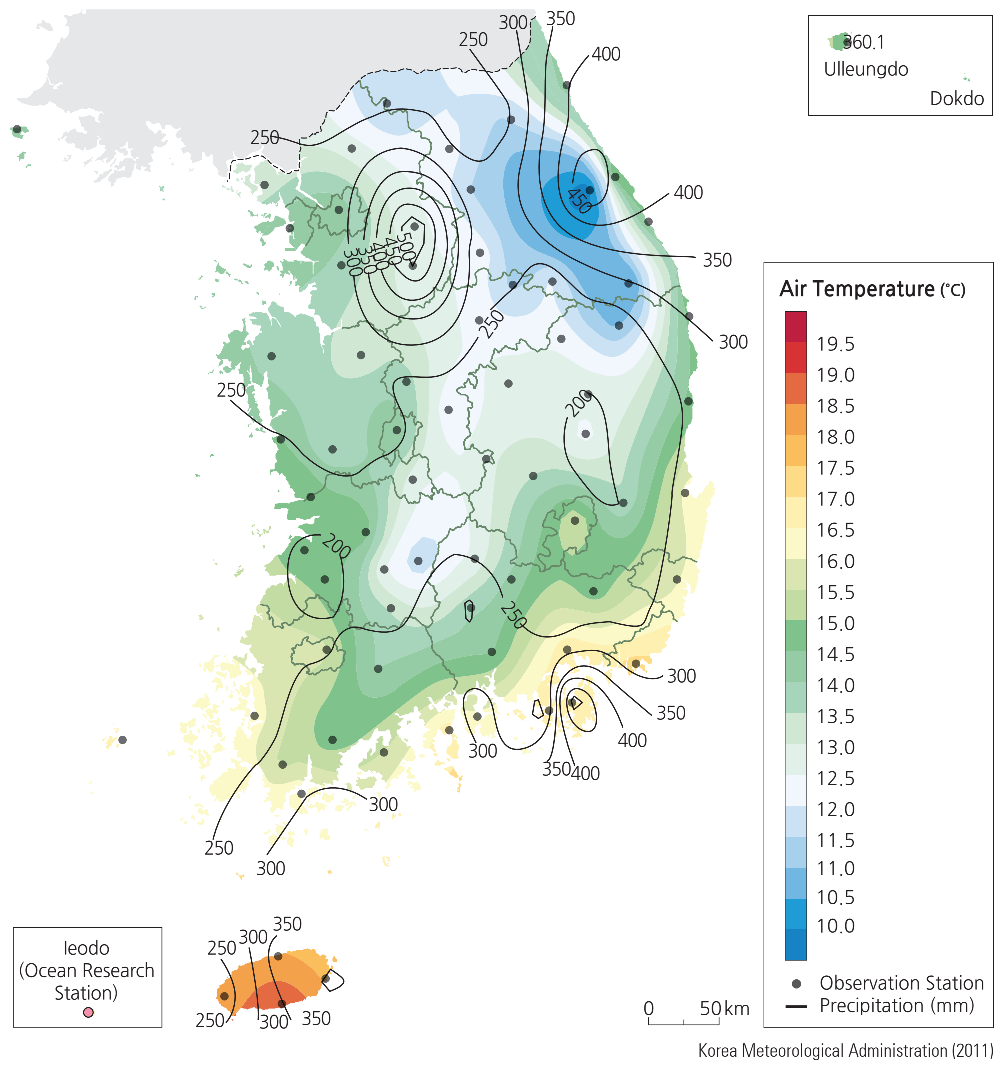
Korea Meteorological Administration (2011)

Summer Mean Air Temperature and Precipitation (1981-2010)



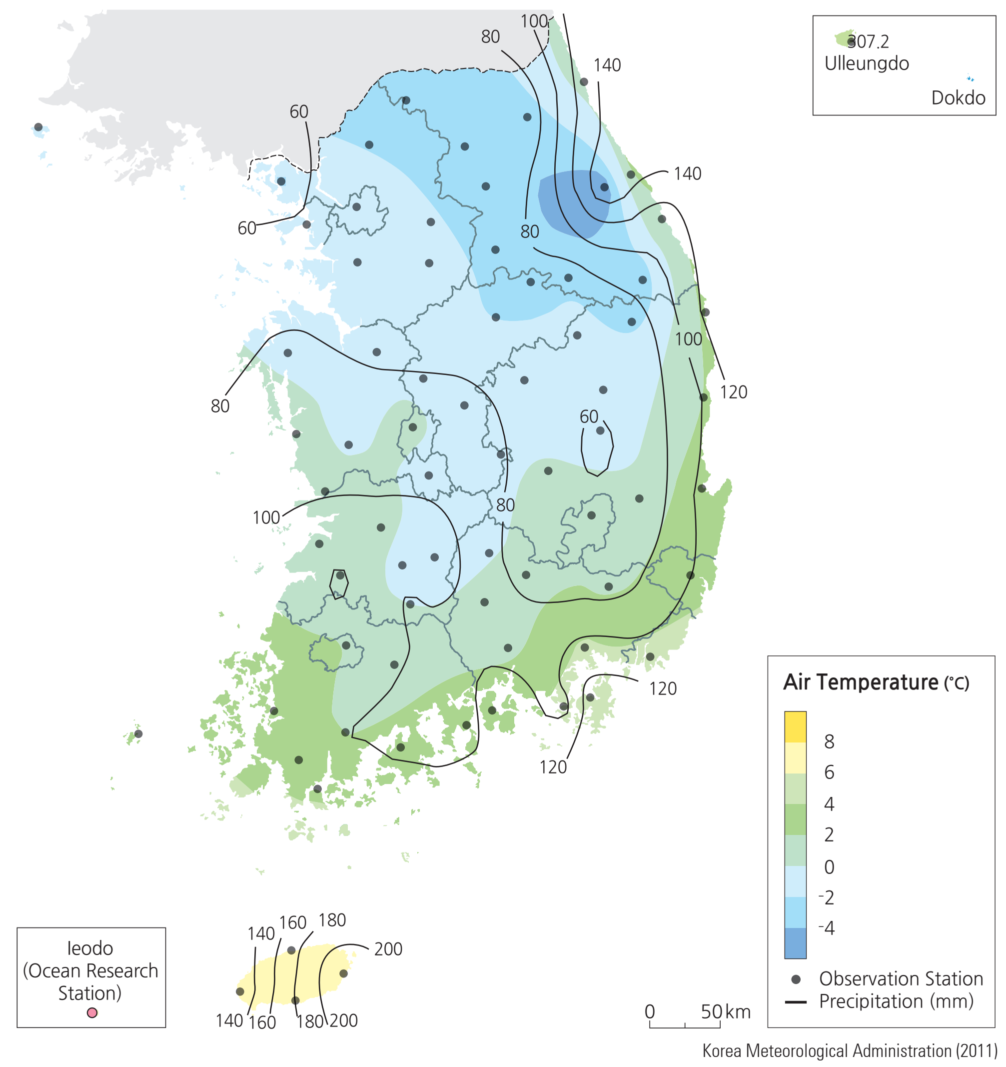
Korea Meteorological Administration (2011)

Autumn Mean Air Temperature and Precipitation (1981-2010)



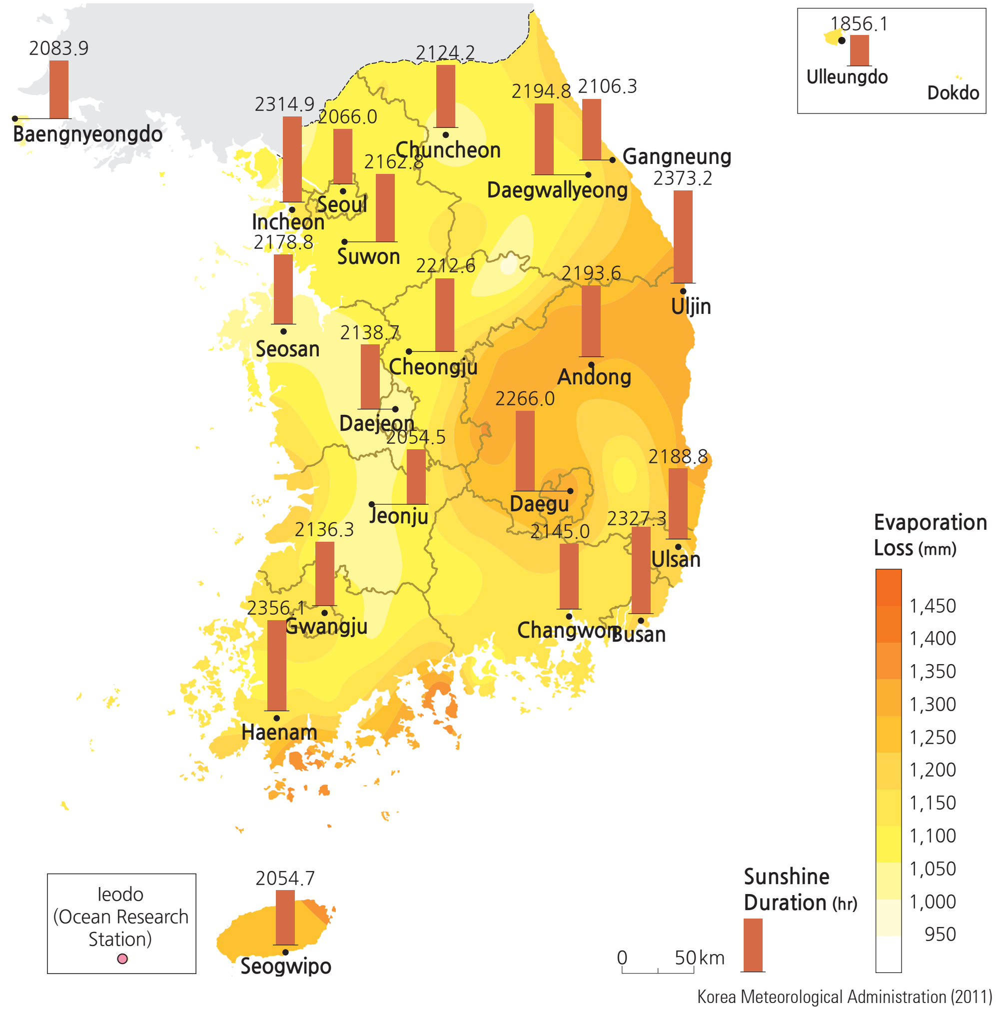
Korea Meteorological Administration (2011)

Winter Mean Air Temperature and Precipitation (1981-2010)

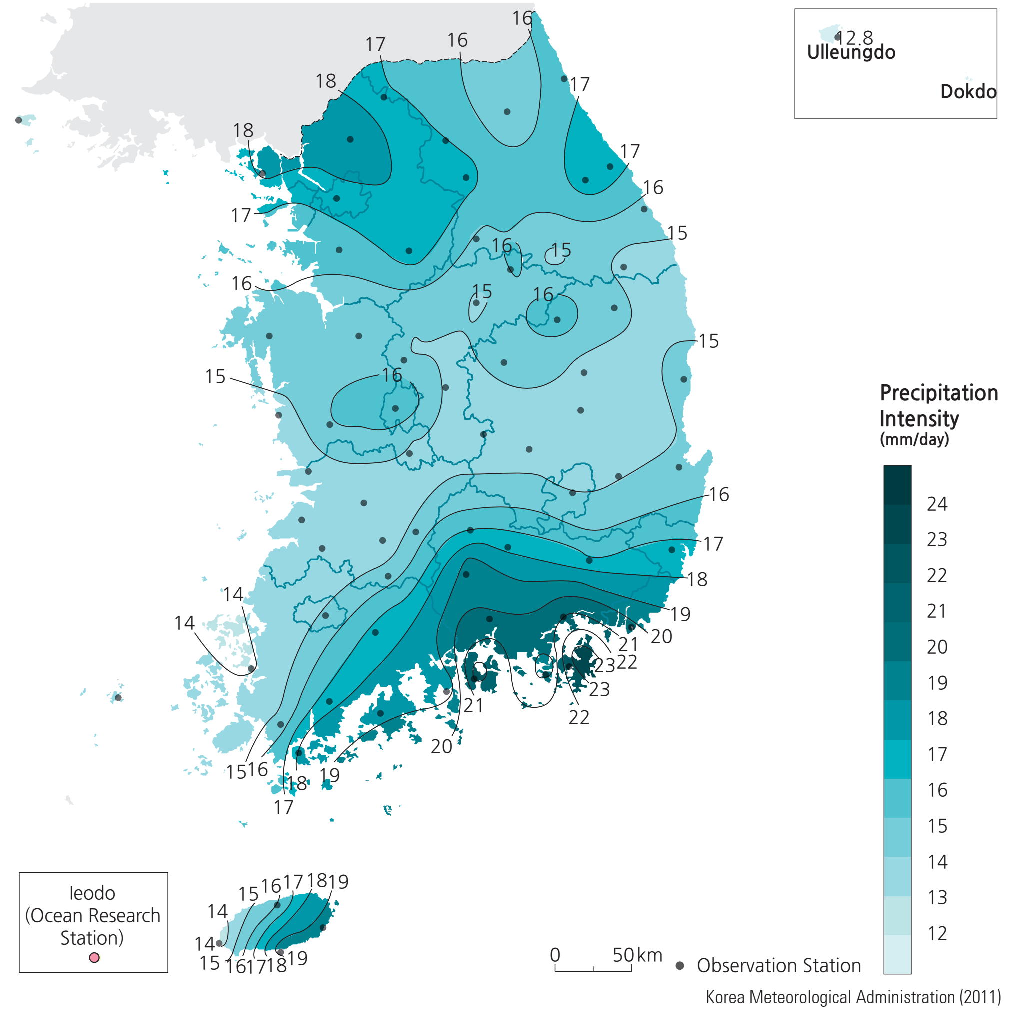


Korea Meteorological Administration (2011)

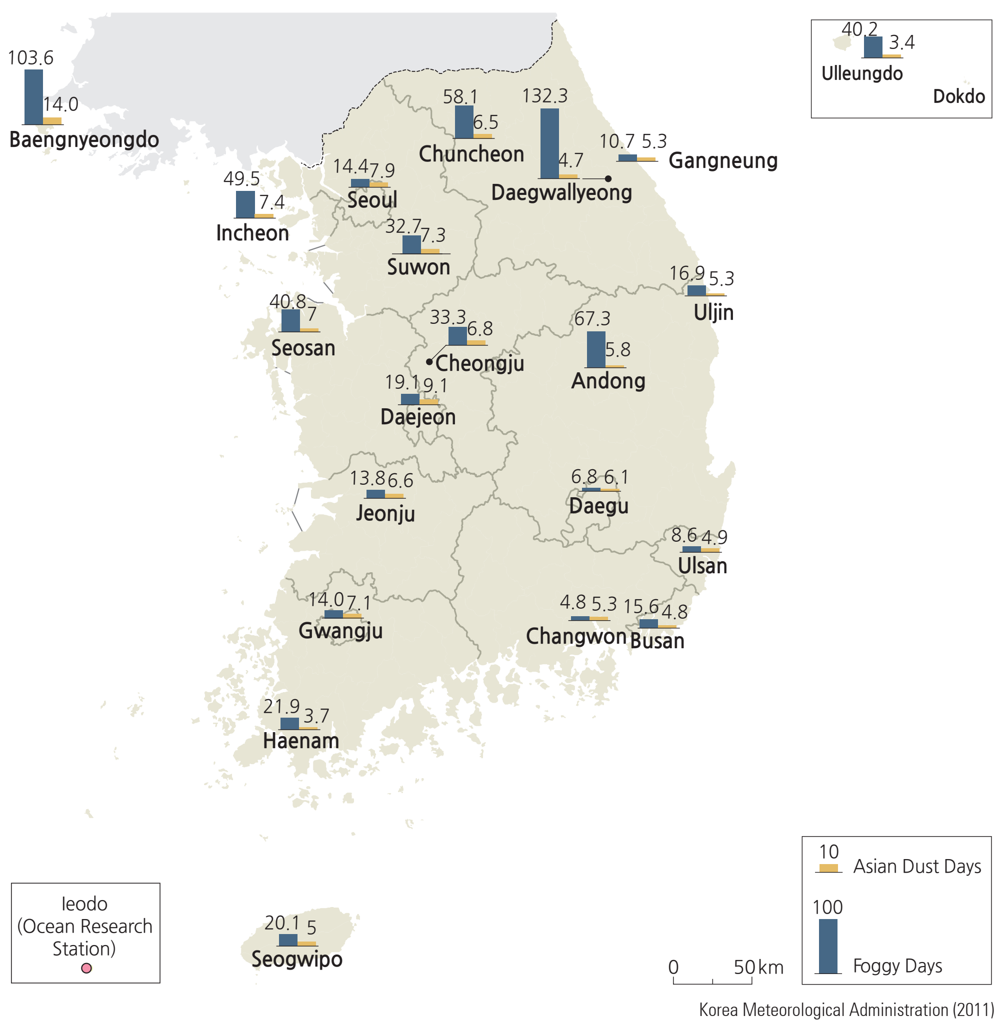
Annual Mean Sunshine Duration and Annual Mean Amount of Evaporation (1981-2010)



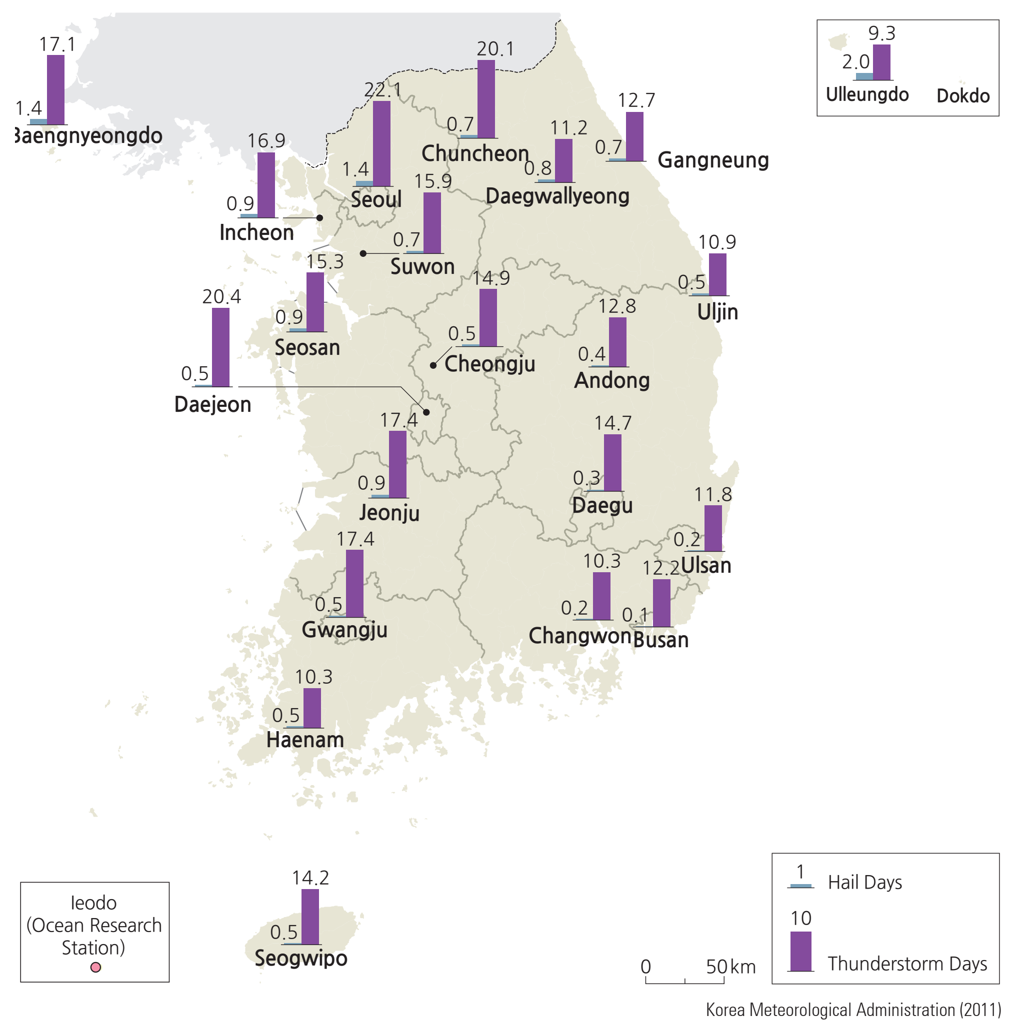
Annual Precipitation Intensity (1981-2010)



Annual Mean Number of Foggy Days and Asian Dust Days (1981-2010)



Annual Mean Number of Hail Days and Thunderstorm Days (1981-2010)



The annual mean sunshine duration is short in island areas such as Seogwipo City on Jeju Island (2,054.7 hrs), Ulleungdo (1,856.1 hrs), and Baengnyeongdo (2,083.9 hrs). On the other hand, the annual mean sunshine duration is long in the Yeongnam inland areas, the southeastern coastal areas, and the southernmost parts of the Taebaeksanmaek. Uljin on the east coast has the longest duration (2,373.2 hrs), followed by Haenam (2,356.1 hrs), Busan (2,372.3 hrs), Daegu (2,260.0 hrs), and Andong (2,193.6 hrs). In terms of amount of evaporation loss, Yeosu, south-central coast, has the highest (1377.6 mm) while Ganghwa, a district in Incheon, has the lowest (956.8 mm).

Annual precipitation intensity is a climate index, calculated by dividing annual precipitation by the annual mean number of precipitation days. The precipitation intensity appears relatively strong in the southern region, including Jejudo and the northern part of Gyeonggi-do. For instance, the southern coastal region has a precipitation intensity greater than 20 mm/day in general. The precipitation intensity appears relatively weak in the middle section of the country around the inland areas of Gyeongsangbuk-do, the western coastal areas of both Jeollanam-do and Jeollabuk-do, and Ulleungdo. Annual Precipitation Intensity increases slightly towards the northern third of the nation.

Daegwallyeong experiences the highest annual mean number of days with fog (132.3 days) due to high altitude. On average, the eastern coast has more foggy days than the western coast. Low numbers of foggy days are found in Changwon (4.8 days) and Daegu (6.8 days). The annual mean number of Asian dust days varies from 3.4 to 14 days. The number of Asian dust days decreases from the west coast to the east coast because the dust moves along with the westerlies. Baengnyeongdo, a western island, has the most number of days (14 days) while Ulleungdo, an eastern island, has the fewest (3.4 days).

The greatest annual mean number of days with hail occurs in Ulleungdo (2 days). Baengnyeongdo and Seoul have the second greatest number of hail days (1.4 days). The maximum annual mean number of days with thunderstorms occurs in Seoul (22.1 days), followed by Daejeon (20.4 days) and Chuncheon (20.1 days). It decreases from the west coast to the east coast. Ulleungdo has the lowest number of thunderstorm days (9.3 days).

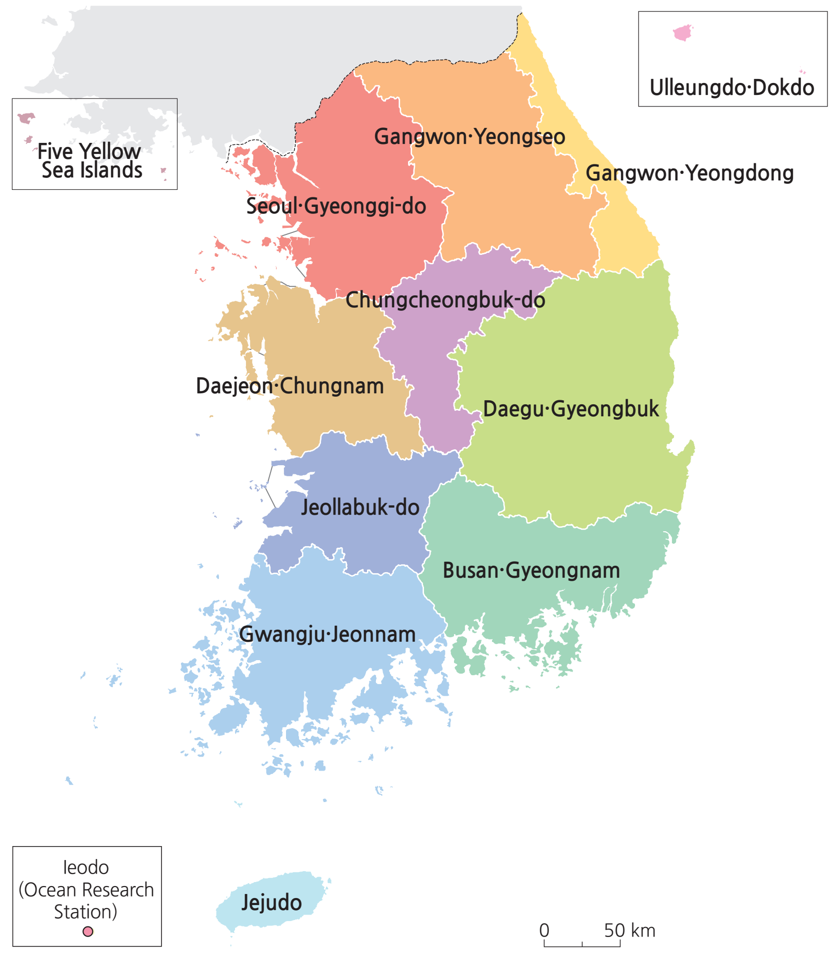
Brief Interpretation of the Maps

In the Core Map Skills section, one of the caveats about map accuracy is the adequacy of having enough data points to generate a map pattern. On this page of four maps, three were based on data recorded in only 20 stations (including Ulleungdo) for the whole country. One may argue that twenty data points may not be adequate for accurate patterns for sunshine duration and evaporation, foggy days and dusty days, and hail and thunderstorm days. The precipitation intensity map, however, does have enough data points to generate an accurate geographic pattern, which shows concentrations in both the north and the south of the country with the mid-section receiving substantially lower amounts of intense precipitation.

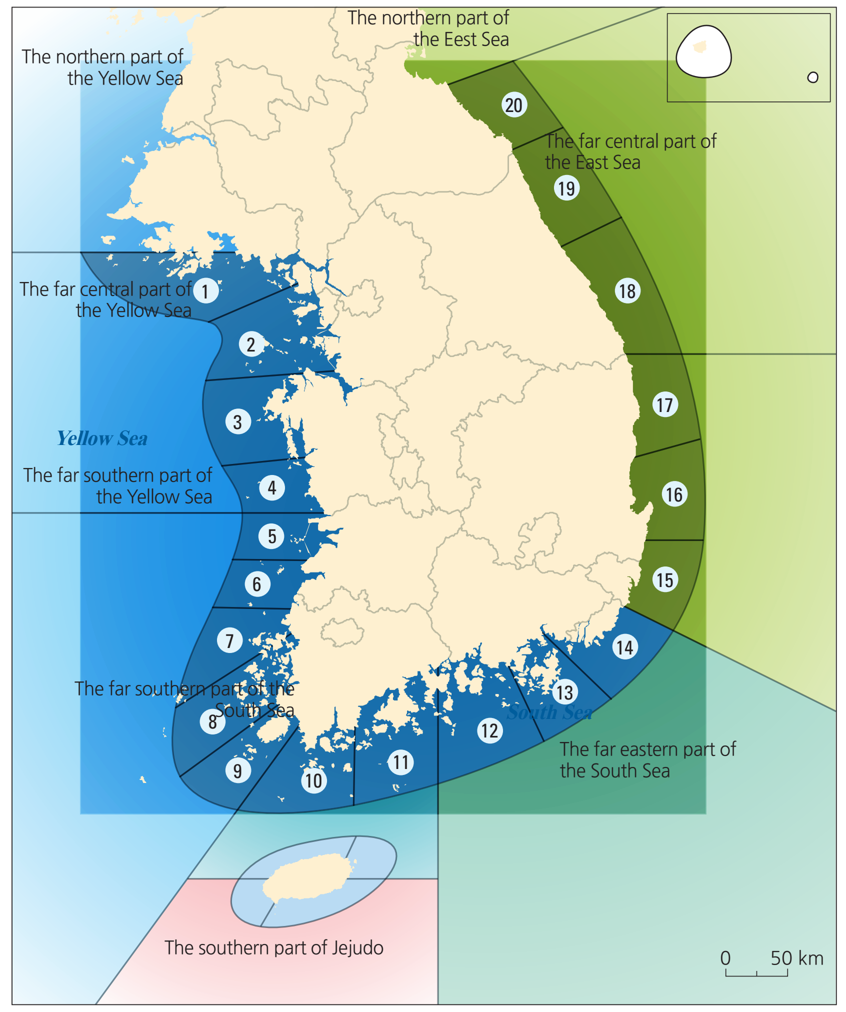
Considering that urban heat islands create lower air pressure, why do you think that the maximum number of thunderstorms occur in inland large cities such as Seoul, Daejeon, and Chuncheon?

Process of Meteorological Service Weather Forecasting

Terrestrial Weather Forecast Area Map



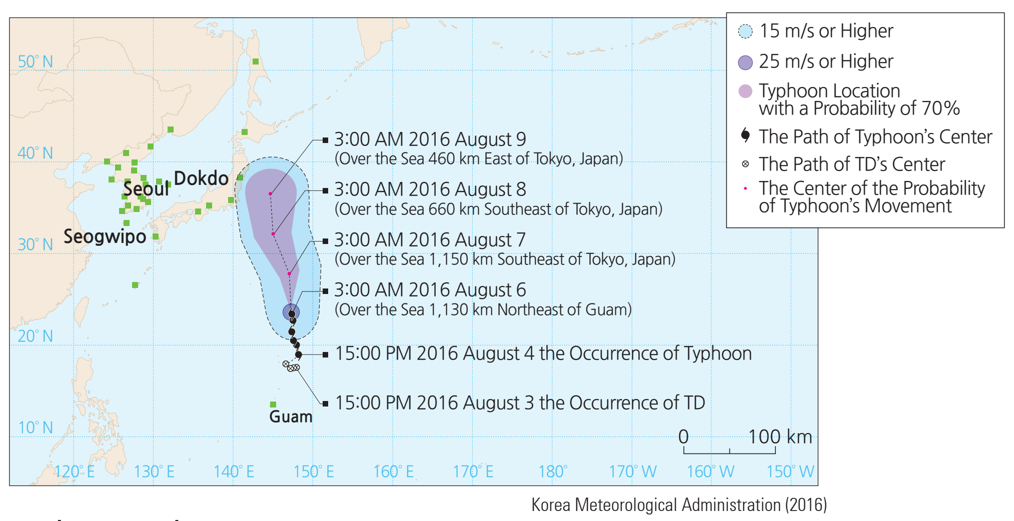
Marine Weather Forecast Area Map



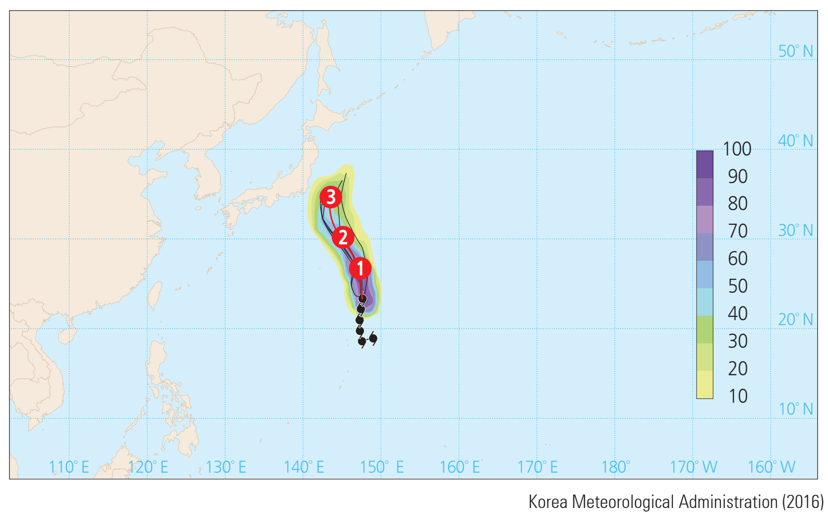
Coast of the Central Yellow Sea	① Northern Gyeonggi-do ② Southern Incheon/Gyeonggi-do	③ Northern Chungcheongnam-do ④ Southern Chungcheongnam-do
Coast of the Southern Yellow Sea	⑤ Northern Jeollabuk-do ⑥ Southern Jeollabuk-do ⑦ Northern Yellow Sea off Jeollanam-do	⑧ Central Yellow Sea off Jeollanam-do ⑨ Southern Yellow Sea off Jeollanam-do
Coast of the Western South Sea	⑩ Western South Sea off Jeollanam-do ⑪ Eastern South Sea off Jeollanam-do	
Coast of the Eastern South Sea	⑫ Western South Sea off Gyeongsangnam-do, Eastern Geoje ⑬ Central South Sea off Gyeongsangnam-do	⑭ Busan
Coast of the Southern East Sea	⑮ Ulsan ⑯ Southern Gyeongsangbuk-do	⑰ Northern Gyeongsangbuk-do
Coast of the Central East Sea	⑱ Southern Gangwon-do ⑲ Central Gangwon-do	⑳ Northern Gangwon-do

Korea Meteorological Administration (2016)

Typhoon Forecast



Typhoon Path Forecast



Process of Meteorological Service Weather Forecasting

Korea's Meteorological and Weather Forecasting Service is a very important entity. It helps to save lives, issuing warnings and advice for preparedness that can minimize the amount of destruction prior to or during catastrophic weather events.

National weather data are collected in a central server of supercomputers and shared with member nations of the World Meteorological Organization in real time. These data are assimilated for the production of various numerical, analytical models through the super computers. Then trained forecasters with expertise and experience examine current atmospheric conditions based on the observations, and analyses of the numerical weather prediction models. Finally, forecasters across the country consult and exchange opinions via videoconference to make a final forecast decision. Area forecasts are provided on both a regional scale (12 overland areas and 14 marine areas) and at the local scale (about 3,500 towns). Special weather reports are issued, as needed, to provide weather advisories for possible natural disasters. The report is issued as either a watch or a warning, depending on the risk level of the following 11 natural disasters: heavy rainfall, heavy snowfall, storm surge, tsunami, typhoon, strong winds, high seas, Asian dust, drought, cold surge, and heat wave. A preliminary weather advisory is issued ahead of a special weather report in order to help people to prepare for meteorological disasters.

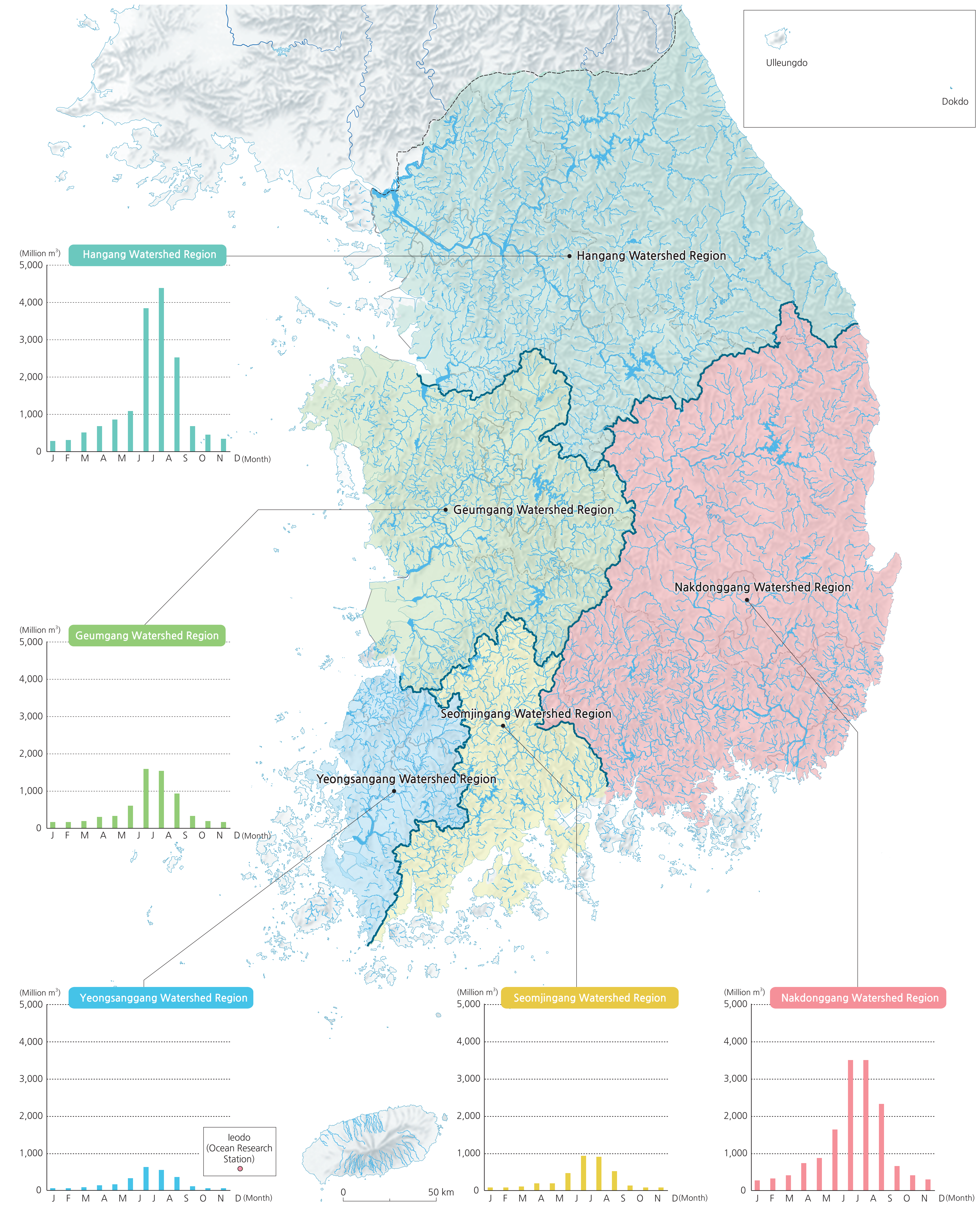
Brief Interpretation of the Maps

Both the terrestrial and marine weather forecast area maps do not strictly follow provincial boundaries, especially the marine map since its major concern is over water. Special boundaries are created for these maps that are based on projected weather conditions and specialized local weather variations, such as the long and narrow area along the east coast of Gangwon-do Province labeled as Gangwon Yeongdong. This strip of land is actually the windward side of the eastern mountain chain; thus, its weather conditions are very different from the leeward side. The marine weather forecast map divides the entire coastline of South Korea into 20 different zones plus Jeju Island, giving the nation a more accurate forecast based on localized coastal configurations as well as easier dissemination of weather conditions to localized fishermen and seafarers.

Because weather forecasting involves a very complex set of weather variables, the accuracy of weather forecasts, even though performed in supercomputers, may not always achieve precise and pinpoint accuracy. Observe and think about the spatial accuracy of weather forecasts around your home to get a sense of weather forecast accuracy that may affect people's daily lives.

Rivers and Watersheds

River Networks and Monthly Discharge of Major Watershed Region



The terrain of Korea is characteristically high along the east coast and low along the west coast. Consequently, most of the rivers flow into the Yellow Sea and the South Sea. The shoreline of the east coast is smooth and rivers flowing into the East Sea are relatively short and steep-sloped. On the other hand, the shoreline of the west coast is more complex with lots of indentations, offshore islands, and deltas. Many rivers flowing to the western and southern coasts are relatively long; they have gentle slopes and wider basins that result in higher amounts of discharge. In these areas, river sediments shape extensive alluvial plains and alluvial basins; meandering channels are often formed as well.

In Korea, there are five large rivers: Nakdonggang, Hangang, Geumgang, Seomjingang, and Yeongsangang ("gang" is the Korean word for rivers). Several mid- to small-scale rivers are also found in the country, including Anseongcheon ("cheon" is the Korean word for mid- to small-scale rivers), Sapgyochun, Mangyeonggang, Dongjingang, and Hyeongsangang. In order to systematically manage river and water resources, the rivers have been divided into 117 sub-basins. Hangang has the largest drainage area of 35,770 km^2 (including its portion in North Korea). It also has an annual runoff volume of 16 billion cubic meters, which constitutes 35.1% of the nation's total runoff volume. The longest river in Korea is Nakdonggang, with a length of 510 km.

From 2005 to 2014, the average annual precipitation in Korea was approximately 1,323.7 mm, which is equivalent to about 1.6 times the world average. This is enough to classify Korea as a high rainfall region even though seasonal variability is extremely high. Due to seasonal rain and typhoons, 735.8 mm of rainfall (55.6% of the annual rainfall) occurs in the summer and often causes floods. Furthermore, rainfall has the tendency to quickly collect in rivers as over 70% of the land is mountainous with an average slope of about 20%. These geomorphic and climatic characteristics cause high fluctuations in the discharge rate of rivers throughout the year, often causing extensive floods and severe droughts.

The coefficient of river regime indicates the ratio between the maximum and minimum flow of a river. Seomjingang currently has a coefficient of river regime of 270, which is the highest among the five large rivers of Korea. Before the installation of dams, each of the five large rivers had coefficients of river regime that were higher than 300. In particular, Seomjingang and Yeongsangang displayed extremely high levels at around 700. Consequently, dams and reservoirs were actively constructed to ensure the reliability of water resources, reduce flood damage, and mitigate the effects of drought. Intensive plans were also implemented to conserve river banks and their surrounding areas.

As the nation grows, accompanied by population increases, the need for transportation infrastructure, and high rates of urbanization, rivers and watersheds need to be protected. Given the complex nature of human interaction with the land that involves the building of dams and usage of water for home consumption, agriculture, and industry, water resources need to be sustained. The government proceeded to develop policies on the usage of water, river management efforts, and plans for maintenance.

A River Master Plan is a comprehensive river maintenance, conservation, and utilization plan for the functional sustenance and prevention of natural disasters in river systems.

Based on the River Master Plan, river banks are established to prevent flooding by calculating the area of cross-section depending on flood discharge standards for each river. By December 2013, 52.1% of the total length of legally designated rivers had completed river bank maintenance. Newly established banks are required by 23.1% of all river areas, among which 3.8% are for national rivers, while 48.9% are for local rivers.

Among the five major rivers, Hangang displays the highest percentage of maintenance completion at 56.9%, followed by Yeongsangang at 56.3%. Geumgang has the highest percentage of reinforcement needed (28.9%), while Yeongsangang comes last (21.6%). Seomjingang requires the most new infrastructure (31.8%), while Hangang needs the least (18.7%). By municipal district, Seoul has the highest percentage of maintenance at 95.8%, followed by Gwangju (87.1%) and Daegu (76.3%). Sejong shows the highest percentage of reinforcement needed at 34.4%, followed by Chungcheongnam-do (30.8%) and Jeollabuk-do (29.2%). Districts that need the most new infrastructure are Incheon (45.6%), Jeollanam-do (32.2%), and Jeju Special Self-Governing Province (31.5%).

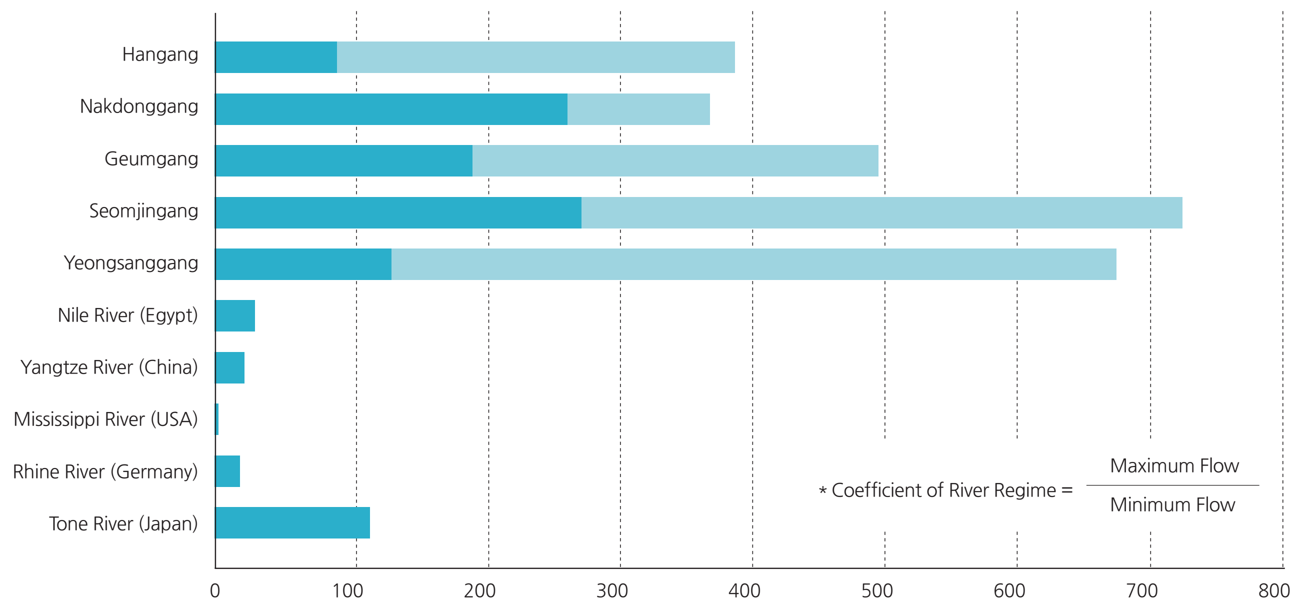
In terms of small-scale rivers, records indicate that 43.1% of a total of 22,823 rivers in Korea have been maintained. Daegu had the highest rate of small-scale river maintenance at 67.5%, followed by Daejeon (60.1%), Gwangju (60.1%), and Seoul (54.1%). On the other hand, Jeju Special Self-Governing Province has a small-scale river maintenance rate of only 20.9%.

Brief Interpretation of the Map

With a high average rainfall (1.6 times the world average) and a river ratio of over 700 (ratio of maximum to minimum flow), watershed management is of critical importance to South Korea. The primary reasons for watershed management are to decrease the effects of flooding in the mainly summer rains and to provide a stable water supply for Korea's increasing population. The development of adequate watershed management systems is a large task that is accomplished over many years. Each of the regions judge that their management process is just over half complete and well maintained with the balance about evenly divided between needing maintenance and needing reinforcement stages.

Each of the five major watershed management regions contains at least one major dam. The dams in these regions are located in different areas of the region. Some are nearer the headwaters and some very near the coast. Can you project the different functions of the dams by the geographic locations? Flooding in Korea is a major concern because of the concentration of rainfall in the late spring and summer. In addition the rivers on the east side of the country are shorter and rise nearer the coast, while on the west side they are longer and display a much more complex drainage system. If you were charged with proposing a new flood control dam in each management region, where you chose to construct it?

The Coefficient of River Regime



Ministry of Land, Infrastructure and Transport (2011)

River Master Plans by Class

Class	With Plan		Without Plan		Completion Rate by Length (%)
	Number of Channels	Length (km)	Number of Channels	Length (km)	
National Rivers	62	2,969.1	3	26.3	99.1
Local Rivers	3,082	21,362.2	1,664	5,460.0	79.6
Total	3,144	24,331.3	1,667	5,486.3	81.6

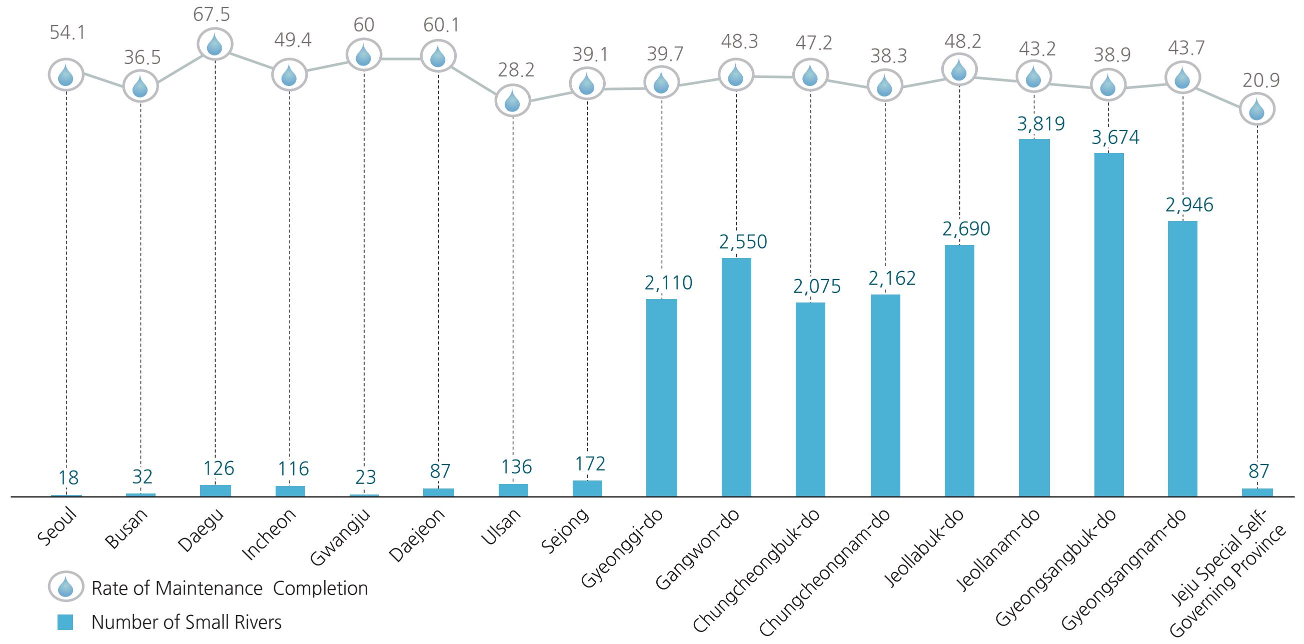
Ministry of Land, Infrastructure and Transport (2013)

River Maintenance by Class

Class	Maintenance Completed		Reinforcement Needed		Infrastructure Needed		Total (km)
	(km)	(%)	(km)	(%)	(km)	(%)	
National Rivers	2,561.5	80.4	505.0	15.9	119.5	3.8	2,995.4
Local Rivers	13,992.4	48.9	7,403.7	25.9	7,223.9	25.2	26,822.2
Total	16,553.8	52.1	7,908.7	24.9	7,343.4	23.1	29,817.6

Ministry of Land, Infrastructure and Transport (2013)

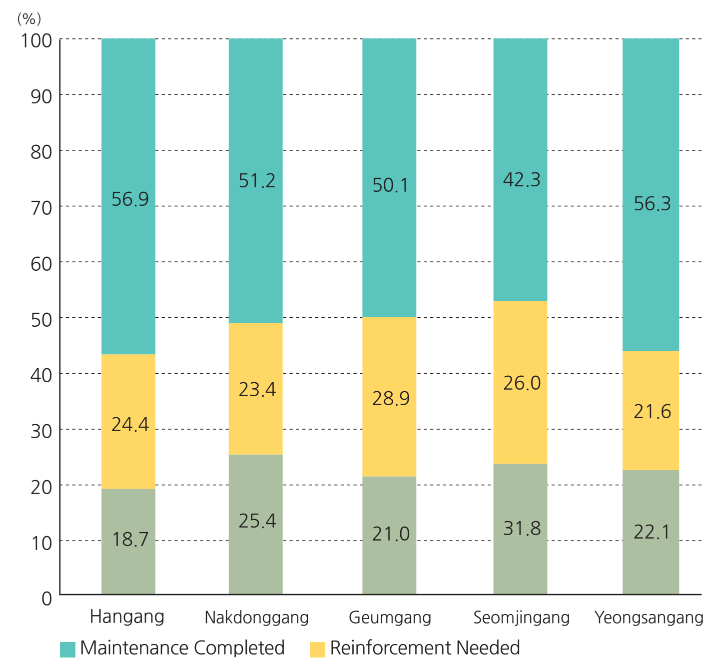
Maintenance of Small Rivers by Province



* Small rivers are not subject to the application of the River Act, and the maintenance of small rivers is aimed at preventing disasters and creating a hydrophilic environment.

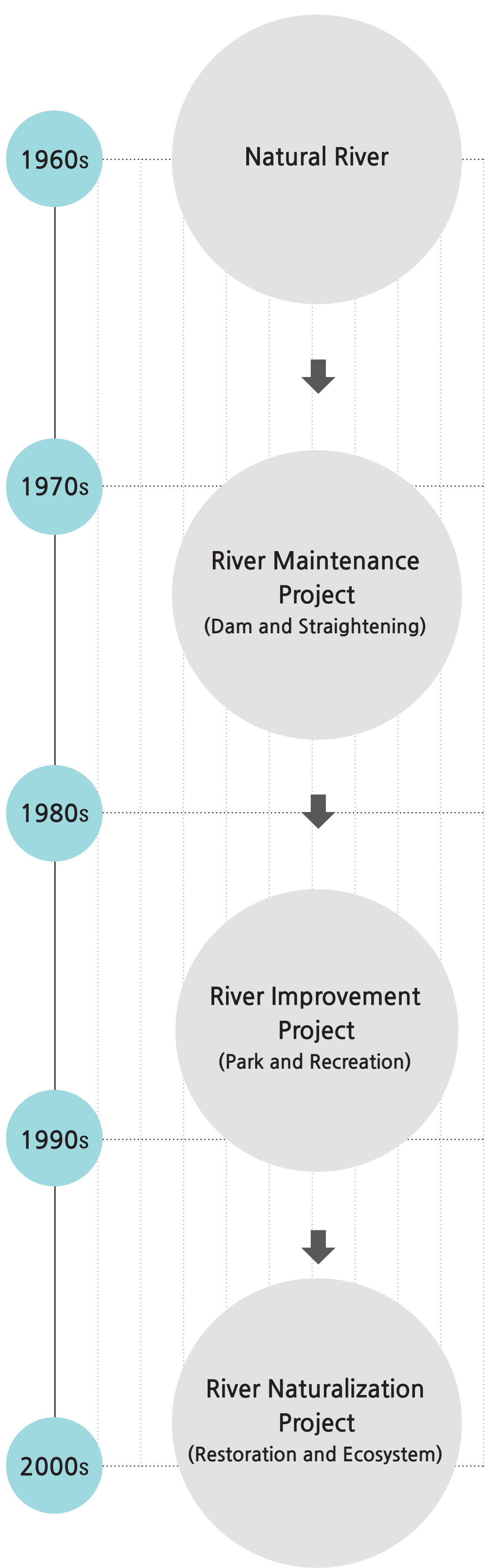
National Groundwater Information Center (2015)

Maintenance of the Five Major Rivers

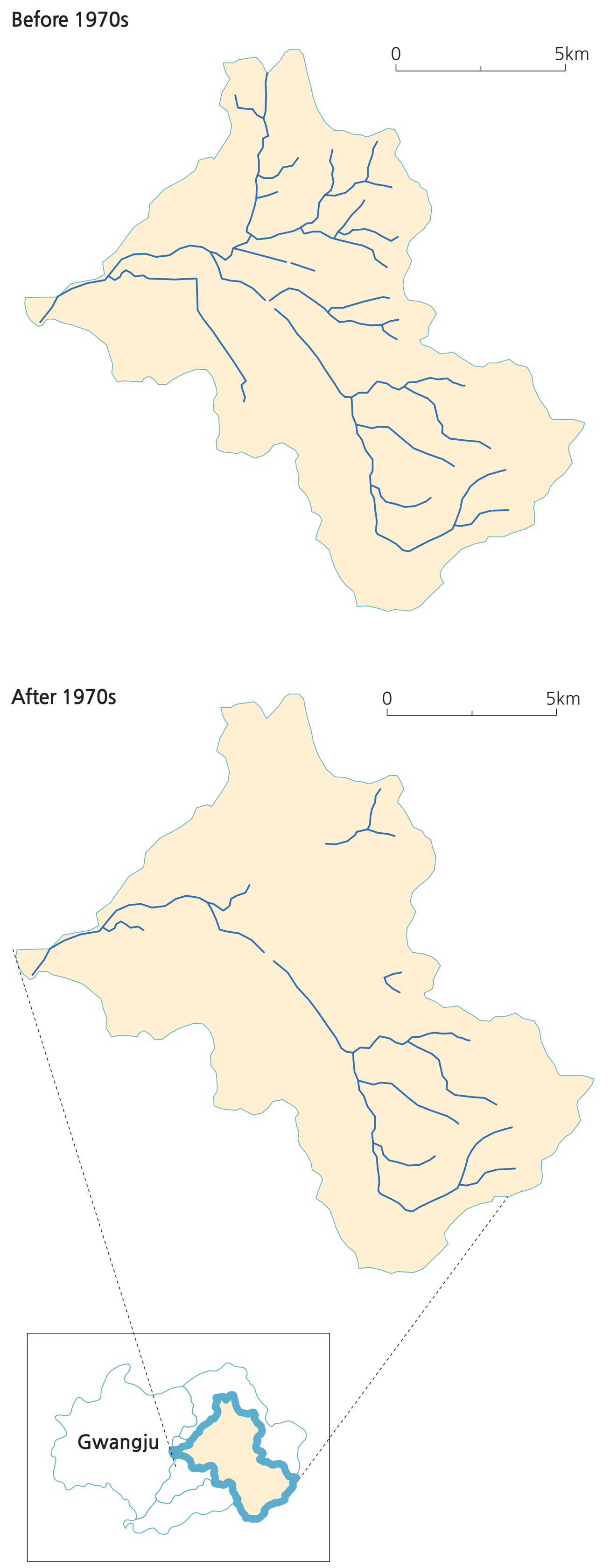


Ministry of Land, Infrastructure and Transport (2013)

River Management Policy



Covered Channels in Gwangjucheon



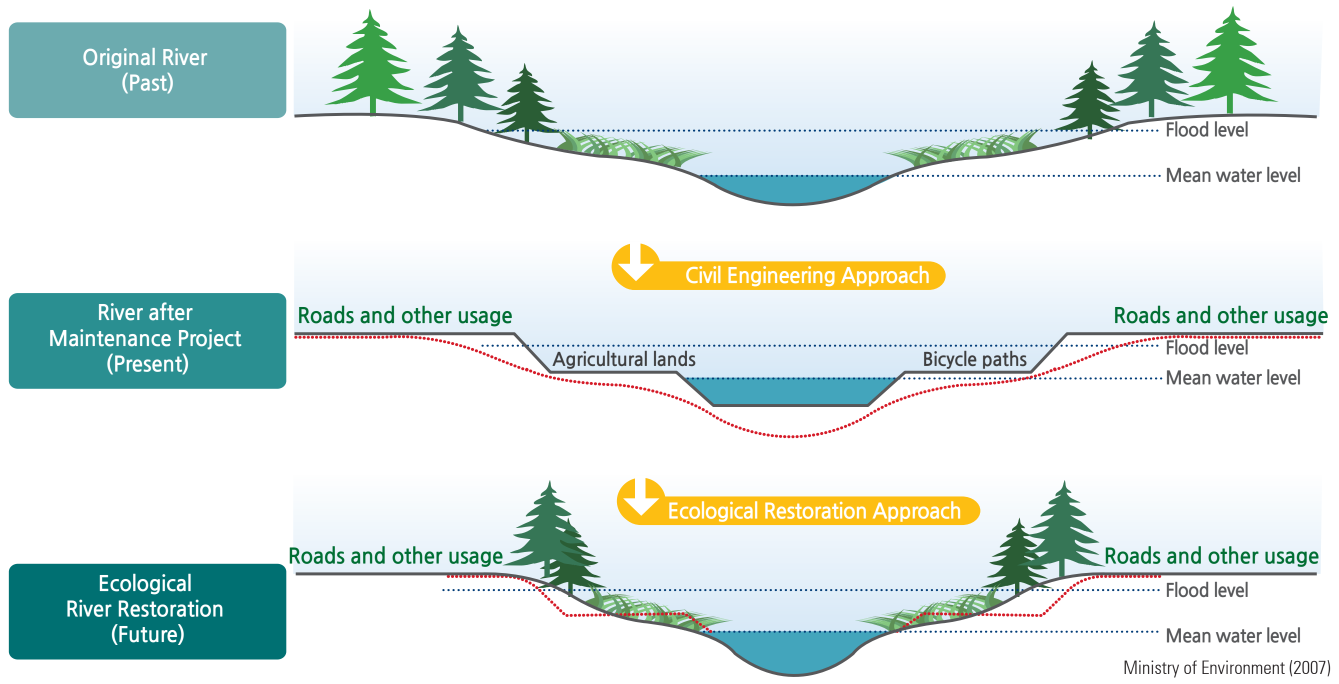
River Maintenance Project: Initiated around the 1970s, the river maintenance project mostly focused on straightening river channels and building concrete levees for flood control. By the 2000s, 80% of the river maintenance had been completed, and many river reservations were turned into farmland. However, such vigorous development involving artificial structures resulted in an increase in stream velocity rates and a devastation of ecological functions and self-restoration abilities.

Before the Cheonggyecheon Restoration Project

After the Cheonggyecheon Restoration Project

River Restoration Projects (Seunggicheon, Incheon): As part of the rapid urbanization that followed the 1970s, many rivers surrounding cities were covered to make way for roads and parking lots. Beginning in the 1990s, projects were initiated to convert rivers into parks, fueling discussions to restore rivers that were previously covered. A major example is the Cheonggyecheon Restoration Project, completed in 2005.

Ecological River Restoration



Ministry of Environment (2007)

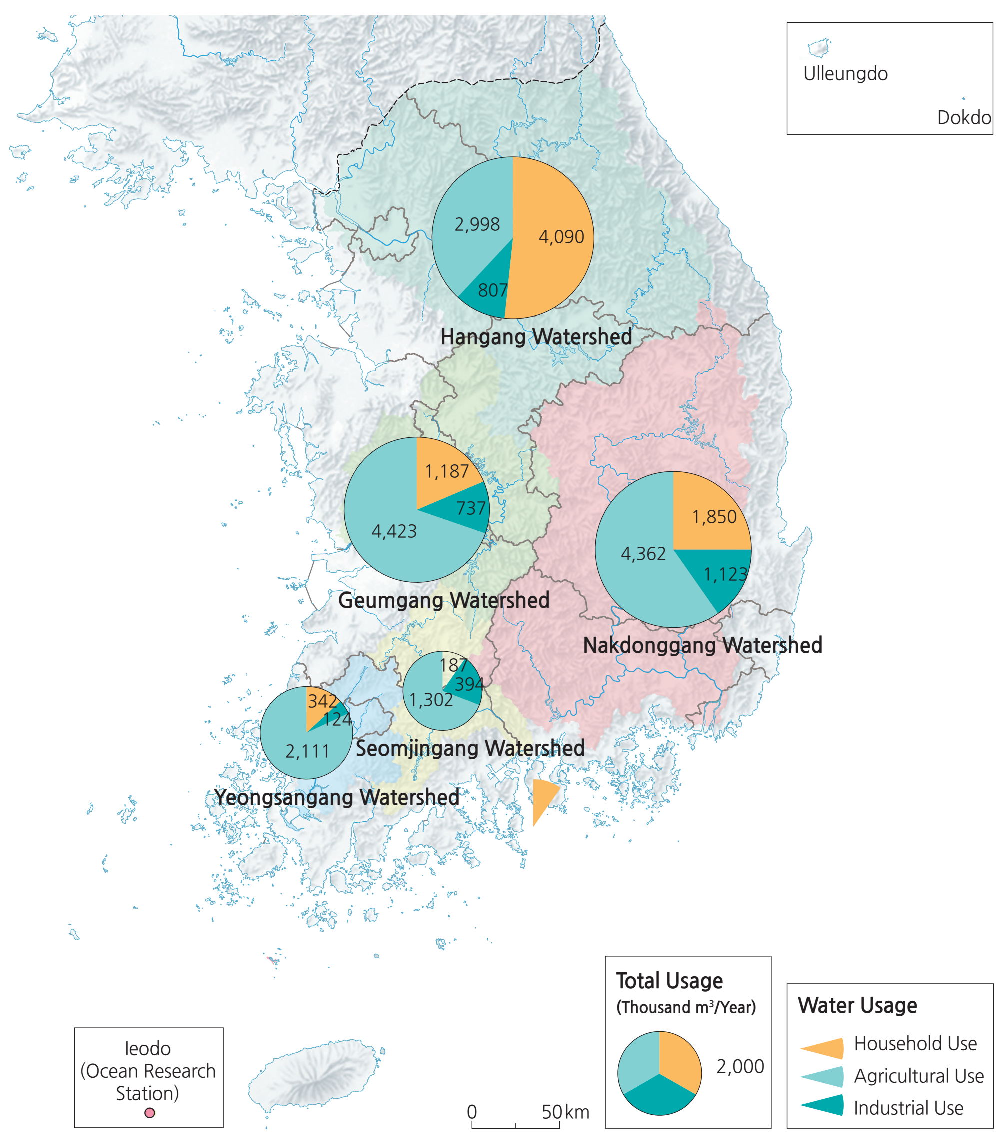
River Management

Up until the 1950s and 1960s, most rivers in Korea were in their natural form. However, due to the rapid urbanization of the 1970s, many tributaries were covered or revamped and meandering channels were straightened out in rural areas. As a result, the rate of water flow and discharge become more rapid and large amounts of sediments are washed downstream. As such environmental issues gained light in the 1990s, various environmental improvement projects (such as the construction of waterfront parks and promenades) were launched in areas around rivers. In the 2000s, the concept of improvement evolved beyond the simple concept of parks to recognize the ecological and scenic conservation value of rivers for ecosystems and humans.

From the before and after photos of the Cheonggycheon Restoration Project, what can you see as the major difference between the before and after photos pertaining to the center of the photos? Discuss the economic, environmental, and public health ramifications of changing a freeway back to a river channel. What are the ecological gains and what are the environmental degradations? Discuss the pros and cons of this project and the gains and losses.

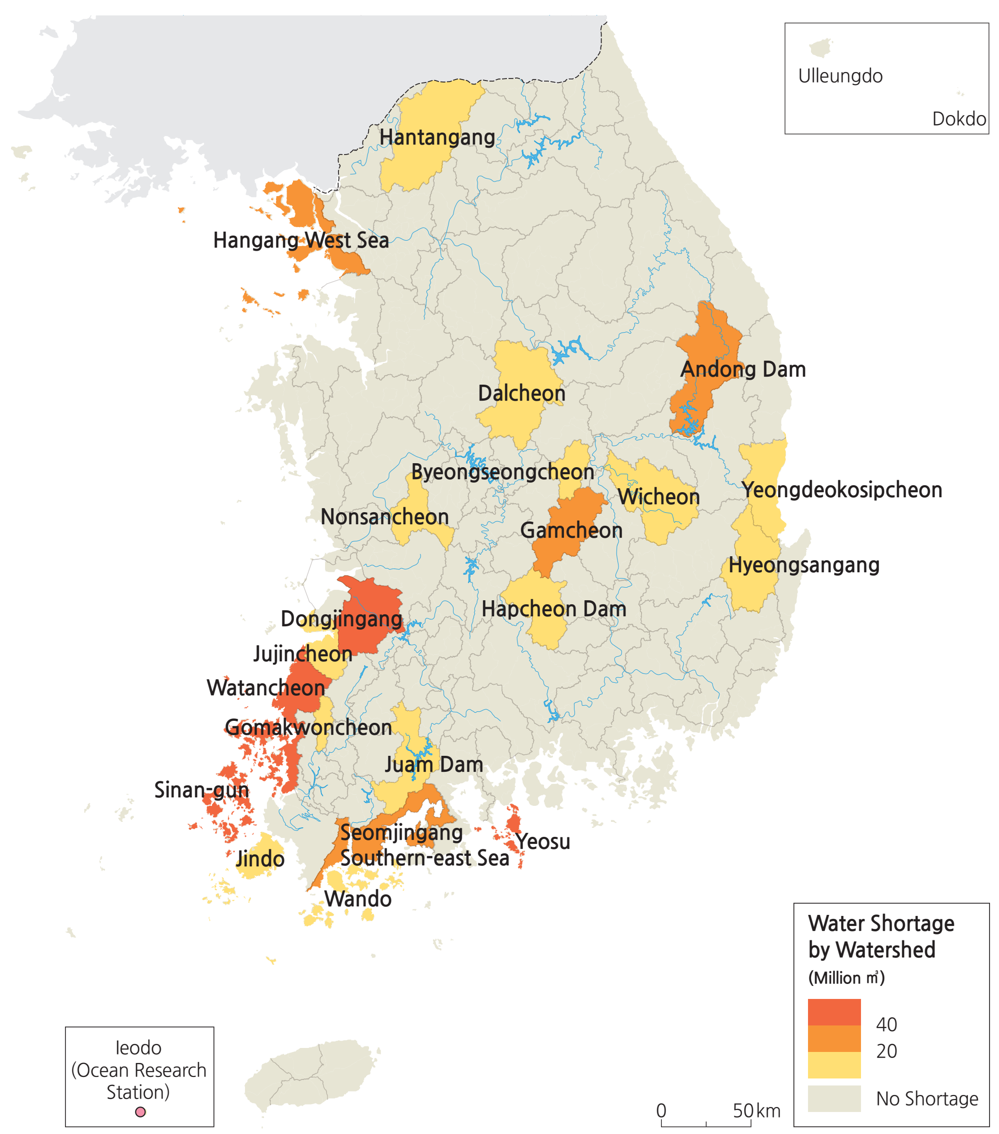
Water Distribution and Usage

Water Usage by Watershed



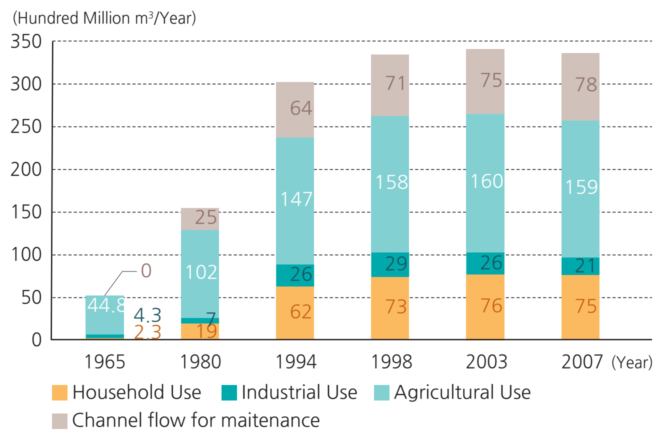
Ministry of Land, Infrastructure and Transport (2013)

Water Shortage by Watershed



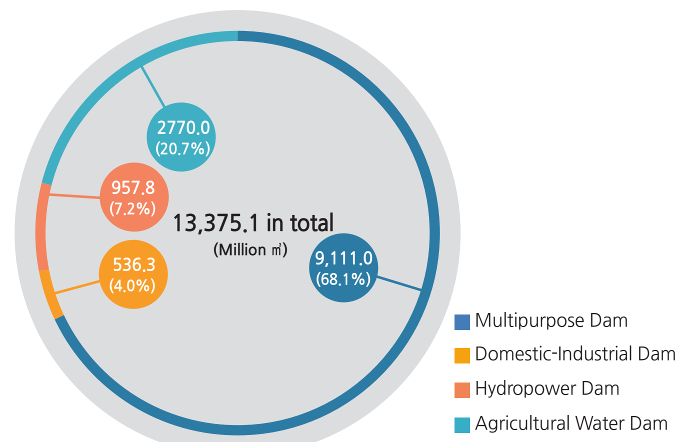
Ministry of Environment (2014)

Water Usage by Year



Ministry of Land, Infrastructure and Transport (2013)

Available Reservoir Storage



Potential Hydropower Generation by Watershed

Potential Volume (Million m³)	Theoretical Potential Volume	Geographical Potential Volume	Technical Potential Volume
Hangang	14,262	7,796	2,496
Nakdonggang	14,502	7,782	2,490
Geumgang	6,770	3,436	1,099
Seomjingang	4,034	2,074	650
Yeongsangang	2,187	1,338	428
Jeju Special Self-Governing Province	1,672	272	87
Total	43,427	22,698	7,250

Water and Future (2015)

The total water use in Korea increased more than six times from 5.12 billion cubic meters in the 1960s to 33 billion cubic meters in the 1990s. This steep rise can be attributed to population growth, economic advancement, increased industrial development, and an increasing number of irrigation facilities. Accordingly, channel maintenance flow also increased to protect water quality, ecosystems, and landscapes. Since the 2000s, however, the rate of increase for water usage has been slowing down.

In 2007, agricultural use accounted for the largest proportion of total water use at 48%, followed by domestic use (23%), channel maintenance flow (23%), and industrial use (6%). Domestic and industrial water usage has remained about the same since 1998, while agricultural use experienced a decrease over the same time period. On the other hand, channel maintenance flow—which is used for maintaining river functions—has gradually increased.

As of 2011, the Hangang Watershed was recorded as the largest area of water use at 5.23 billion cubic meters, followed by the Nakdonggang Watershed (5.1 billion cubic meters), Geumgang Watershed (2.61 billion cubic meters), Yeongsangang Watershed (1.5 billion cubic meters), and Seomjingang Watershed (0.9 billion cubic meters).

In the Hangang Watershed, domestic water use accounted for the highest proportion of water use nationwide at 54.4% due to the large population that inhabits the area, while agricultural and industrial water use amounted to 44% and 1.6%, respectively. For all other watersheds, agricultural water use had the highest proportion, followed by domestic and industrial water use. Large industrial complexes contribute to the relatively high rate of industrial water use in the Nakdonggang Watershed (6.4%), while a smaller population and fewer industrial facilities are responsible for the relatively high rate of agricultural water use in the Seomjingang Watershed (88.1%).

As of 2014, Korea has a total of 17,735 dams and reservoirs, including those under construction. This number includes 20 multipurpose dams, 54 domestic and industrial dams, and 12 hydroelectric dams, with the rest being small-scale agricultural dams. In terms of hydropower capacity, multipurpose dams account for 68.1% of all structures. There are also three dams for flood control: "Dam for Peace," Gunnam Flood Control Reservoir, and Hantangang Dam.

The "Four Major Rivers Restoration Project" was launched in February 2009 with the aim to promote local development by building weirs, thus securing water resources, enhancing water quality, and developing the leisure industry. A total of 16 weirs were newly installed on the four major rivers (Hangang, Nakdonggang, Geumgang, and Yeongsangang), and various leisure facilities such as riverside parks and bicycle paths were created as well. However, there are serious ongoing debates concerning water quality degradation and the effectiveness of the project.

Brief Interpretation of the Maps

The Hangang and Nakdonggang Watersheds comprise almost two-thirds of the managed watershed land in South Korea, encompassing both mountainous and urban lowland provinces and cities. The remaining three watershed regions are smaller and located in the south and west lowland and coastal areas. Different geographic processes are at work when comparing watershed management and use patterns to the distribution of water shortages by management area.

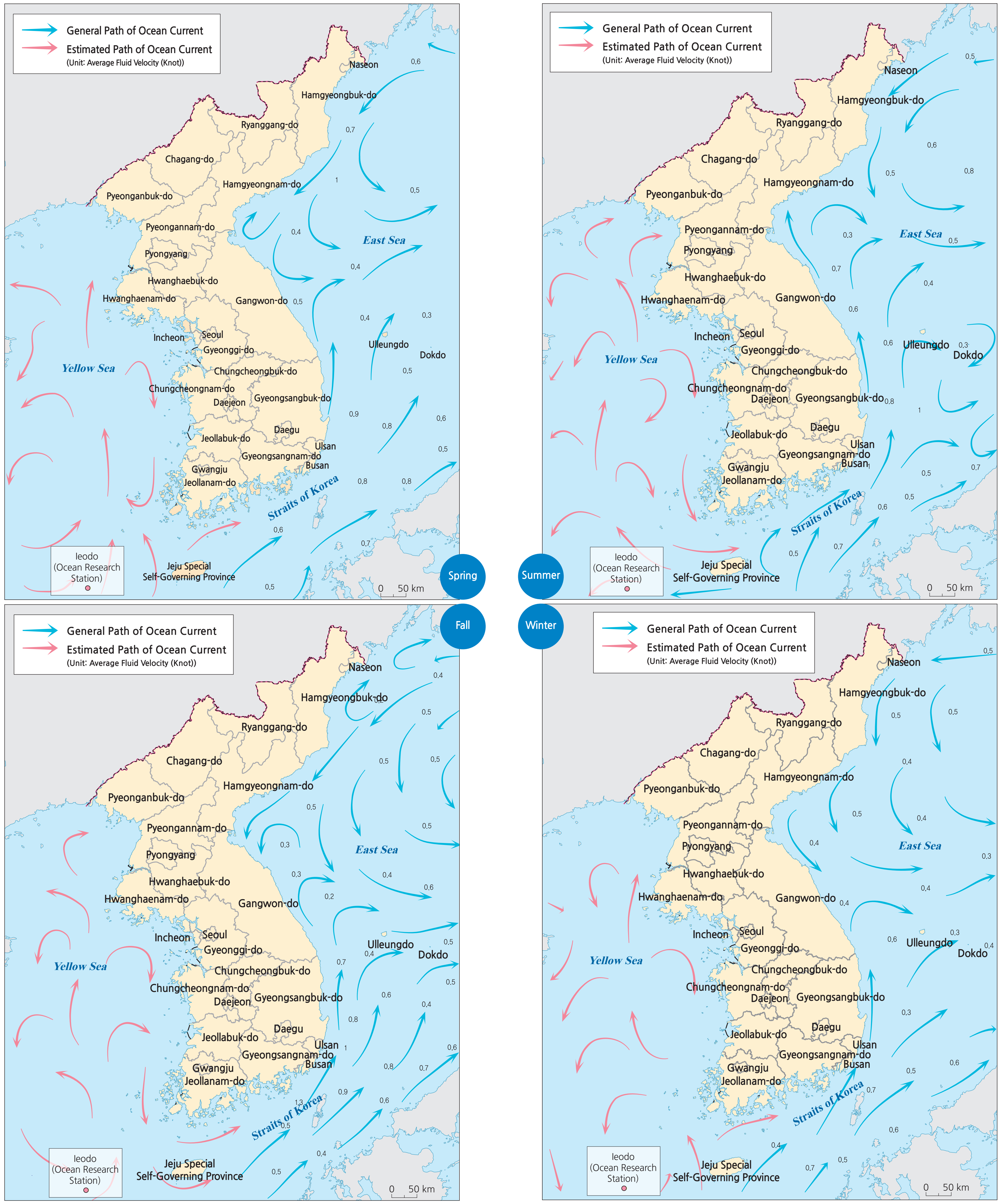
Over half the Hangang Watershed water usage is devoted to domestic use; this is not unusual because this management area includes the large metropolitan areas of Seoul and Incheon. However, the coastal area surrounding Incheon shows a shortage of water that is suggested by deterioration of water quality due to resources and distribution systems. This coastal pattern of water shortage continues on the southwest part of the coast, especially in the island areas surrounding the coast. The islands obviously do not have an extensive riverine catchment to draw upon for their water resources.

The four watershed management areas other than Hangang are dominated by agricultural water use and while they include urban areas, the impact of the water shortages primarily affect agricultural usage. Patterns of water use and associated shortages in different applications are needs that are not easily remedied. The overall water budget for human consumption is largely supplied by natural processes on the supply side and population growth on the consumption side. Efforts at increasing water conservation are important but can only slow demand, and developments in desalinization are prohibitively expensive for agriculture use.

The impact of global warming on rainfall is not well documented other than anecdotal associations with an apparent increase in storms in some areas. If there is actually an increase in major storms, the effect of flooding may offset the usual absorption of water into the soil needed for agricultural production. With an increase in major cyclonic events, how would their frequency affect water availability for agricultural, domestic, and industrial use? With the increasing land reclamation on the west coast of South Korea, how would this process affect the water utilization for domestic uses?

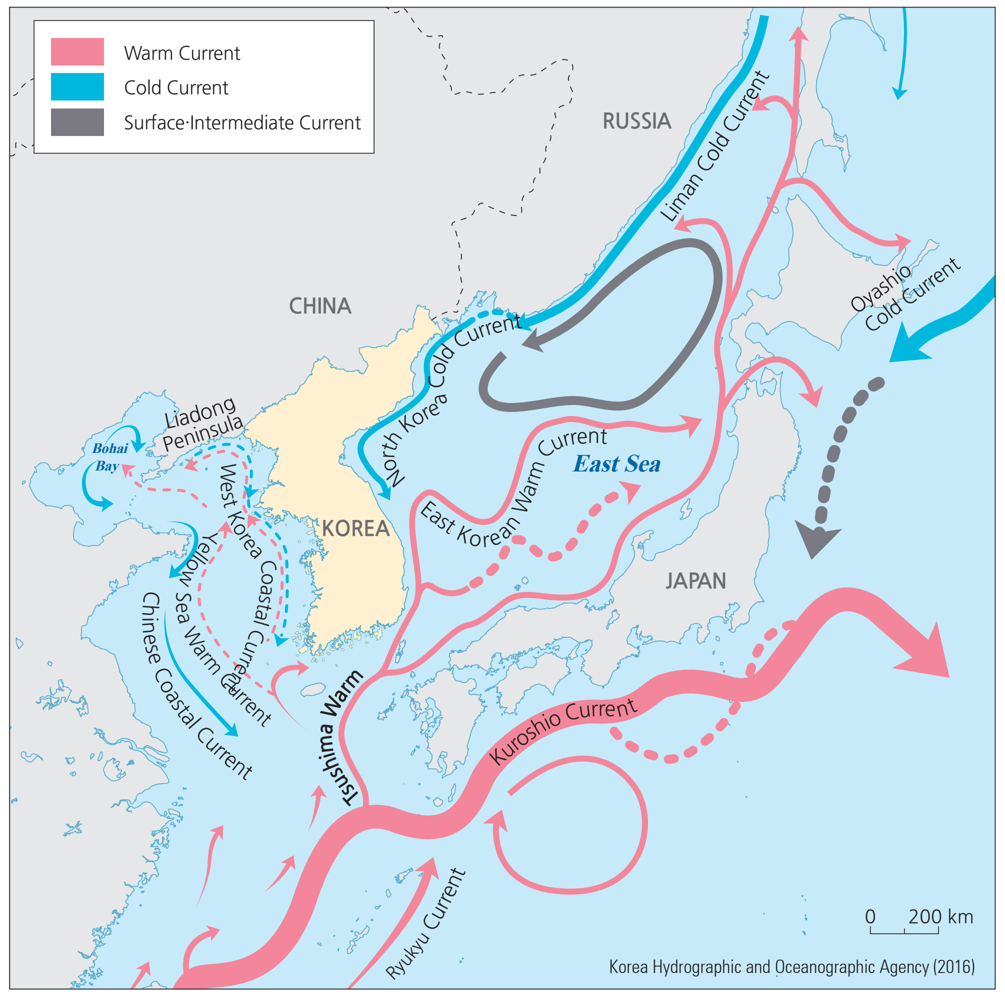
Ocean Currents

Ocean Currents



Ministry of Oceans and Fisheries, Korea Hydrographic and Oceanographic Agency (2006)

Ocean Currents around the Korean Peninsula



Korea Hydrographic and Oceanographic Agency (2016)

Ocean Currents

The Korean Peninsula is influenced by the Yellow Sea Warm Current, East Korean Warm Current, and Tsushima Warm Current, which are all branches of the Kuroshio Current. The Kuroshio Current is a western Pacific boundary current that is the second largest warm current after the Atlantic Gulf Stream. It starts at the eastern part of Taiwan in the western Pacific Ocean and flows to the north of Japan. It has high water temperatures of 20 – 30˚C and high salinity of 34–34.8‰.

The Yellow Sea Warm Current passes through China's Liaodong Peninsula via Heuksando and Baengnyeongdo of Korea, and reaches Bohai Bay of China when it becomes stronger in the summer. It becomes weaker and changes into coastal water during autumn, then heads south, and finally flows east along the Jeju Strait.

The Tsushima Current branches off the Kuroshio Current in the East China Sea and flows north along the East Sea. Characterized by high water temperature and high density, it lacks the original black color of the Kuroshio Current and is instead tinged cobalt-blue. It serves as the main factor of the snow that falls in the Yeongdong area of Korea in winter as the cold easterlies pick up its moisture before reaching the Korean coast. The East Korean Warm Current branches off the Tsushima Warm Current at the east end of the Korea Strait and flows north along the southeast coast of the Korean Peninsula. It mixes with the North Korea Cold Current at the northern latitudes of 36 – 38˚ and changes direction toward the open sea to the southeast. The boundary between the two currents changes continuously and forms a large eddy in the East Sea. Afterwards, the current changes direction to flow northeast and finally rejoins the Tsushima Warm Current.

The Liman Cold Current begins in the vicinity of the Russian Tatar Strait and flows south along the Eurasian continent to the East Sea. While there are several theories on its formation, it is most commonly considered that the Tsushima Current cools as it flows north through the East Sea and mixes with the freshwater of the Amur River as it flows south. The Liman Cold Current, which gets its name from the Russian term that refers to the mouth of a great river, has a low temperature and low salinity and is inhabited by an abundance of cold sea fish species.

The North Korea Cold Current is an extension of the Liman Cold Current that flows southwest along the east coast of North Korea. During the summer, it reaches the Wonsan area of North Korea. The current is strengthened during the winter and affects as far south as Gangwon-do of South Korea.

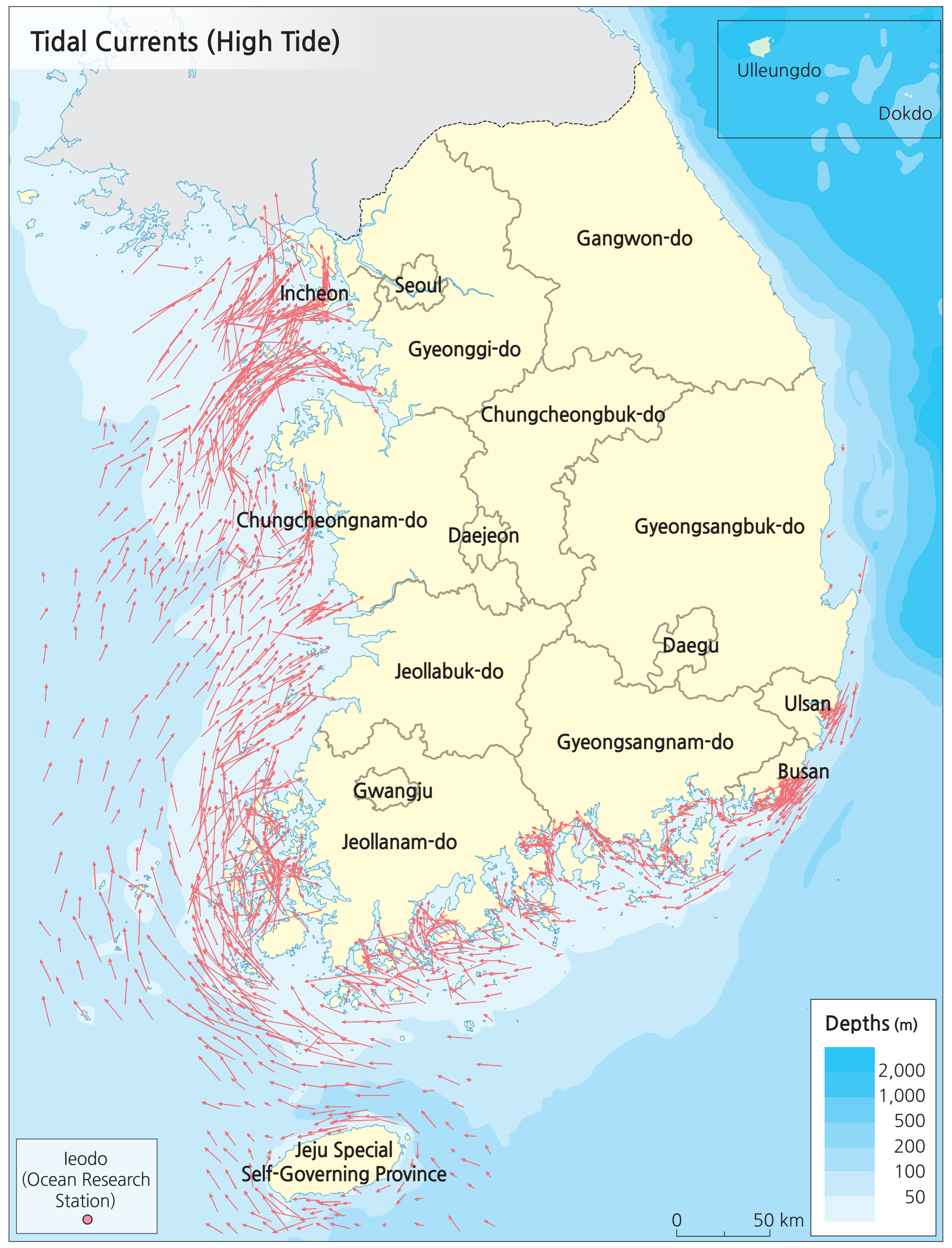
Brief Interpretation of the Maps

Ocean currents are elusive parts of the environment because at most times they are invisible except when the tide changes or there is a lot of extra sediment runoff from rivers discharging into the sea. In all seasons, the current pattern on the east side of the Korean Peninsula is a counter pattern of a northward warm current from the south and a cold southward current meeting it from the north. In the Yellow Sea the general current pattern is circular in most seasons. The interesting pattern relates to the shape of the Yellow Sea that is bounded on three sides by land. This geographic shape allows a water buildup that creates a strong tidal pattern in contrast to the East Sea on the other side of the Peninsula that has many opportunities for current flows to flow freely with very little tidal range on the south and southeast.

The tide range on the west is quite large with a maximum tide at Incheon of 10.5 m (34 ft), one of the largest in east Asia. At the southeast side of South Korea at Jinhae, the maximum range is 2.3 m (7.5 ft). At Pusan on the southeast side of the Peninsula the maximum range is 1.6 m (5.2 ft). This large range from the northwest side to the southwest side provides the opportunity for the development of tidal power generation. The world's largest operating tidal power station at Shiwa Lake uses a seawall constructed in 1994 near Incheon. Shiwa's mean tidal range is 5.6 m with a spring tide of 7.8 m.

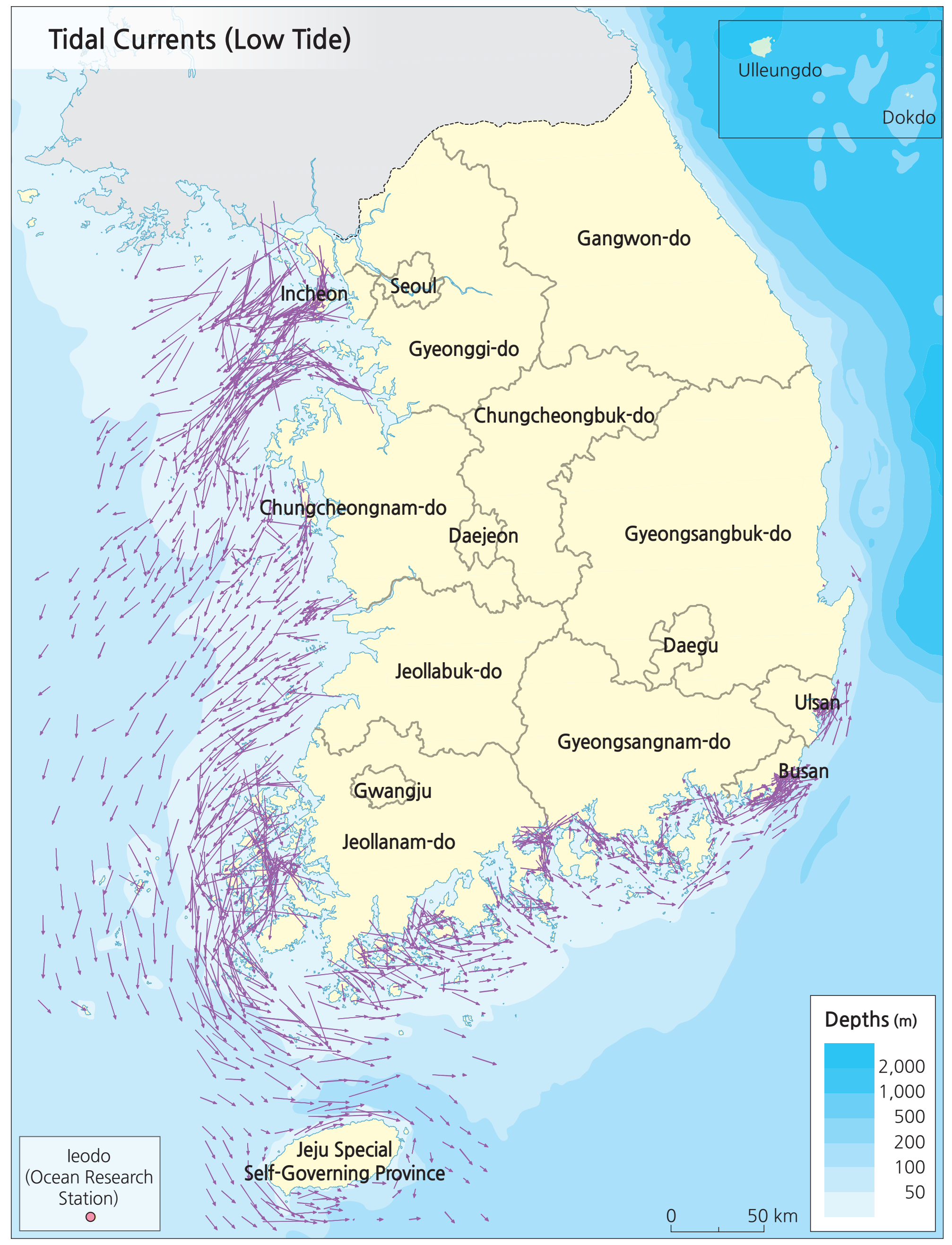
The Shiwa Lake Tidal Station makes use of only the incoming tidal race to generate power. Why would the station only use half of the potential energy stored in the tidal difference? The Shiwa Lake station has a projected life that is continually decreasing. Postulate why this station might be losing power potential. Current scientific investigations project that an area needs a 4-m tidal range to locate an economically viable power station. Estimate where other locations on the west coast of South Korea might be possible for the construction of tidal power stations.

Tidal Currents (High Tide)



Ministry of Oceans and Fisheries, Korea Hydrographic and Oceanographic Agency (2006)

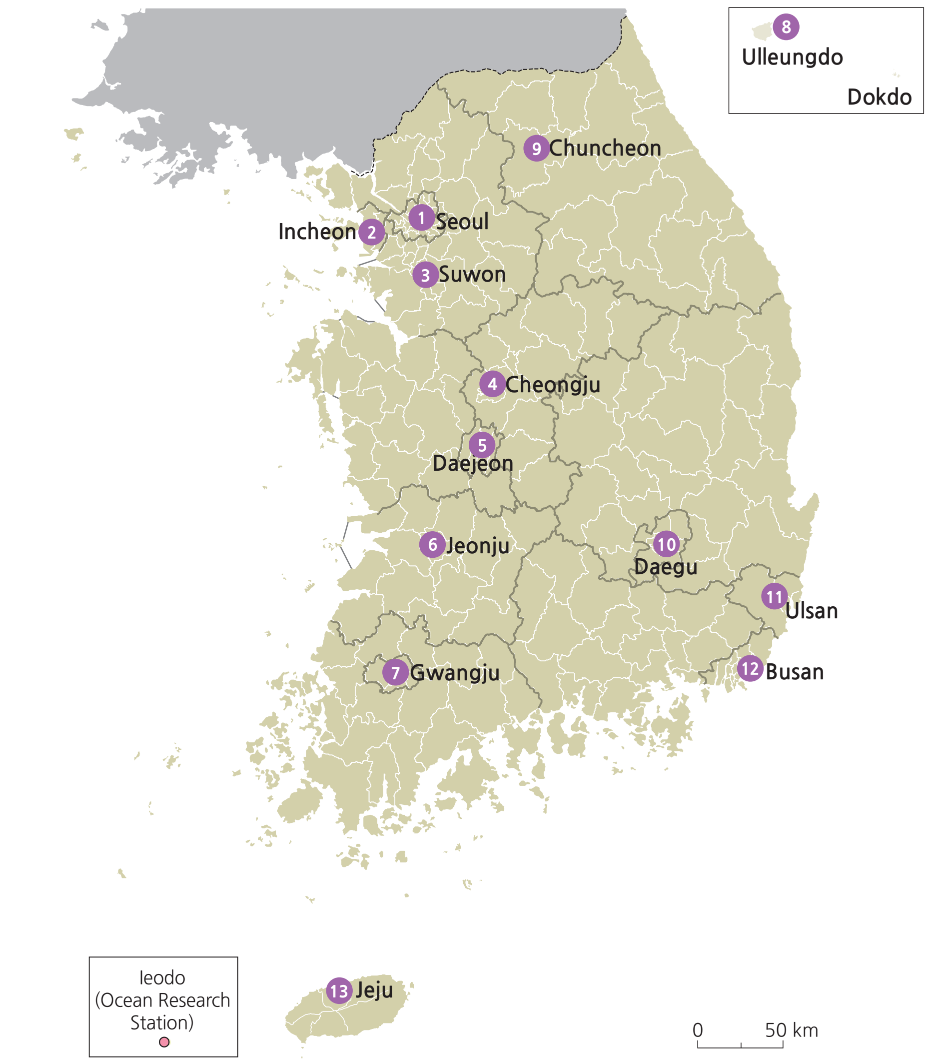
Tidal Currents (Low Tide)

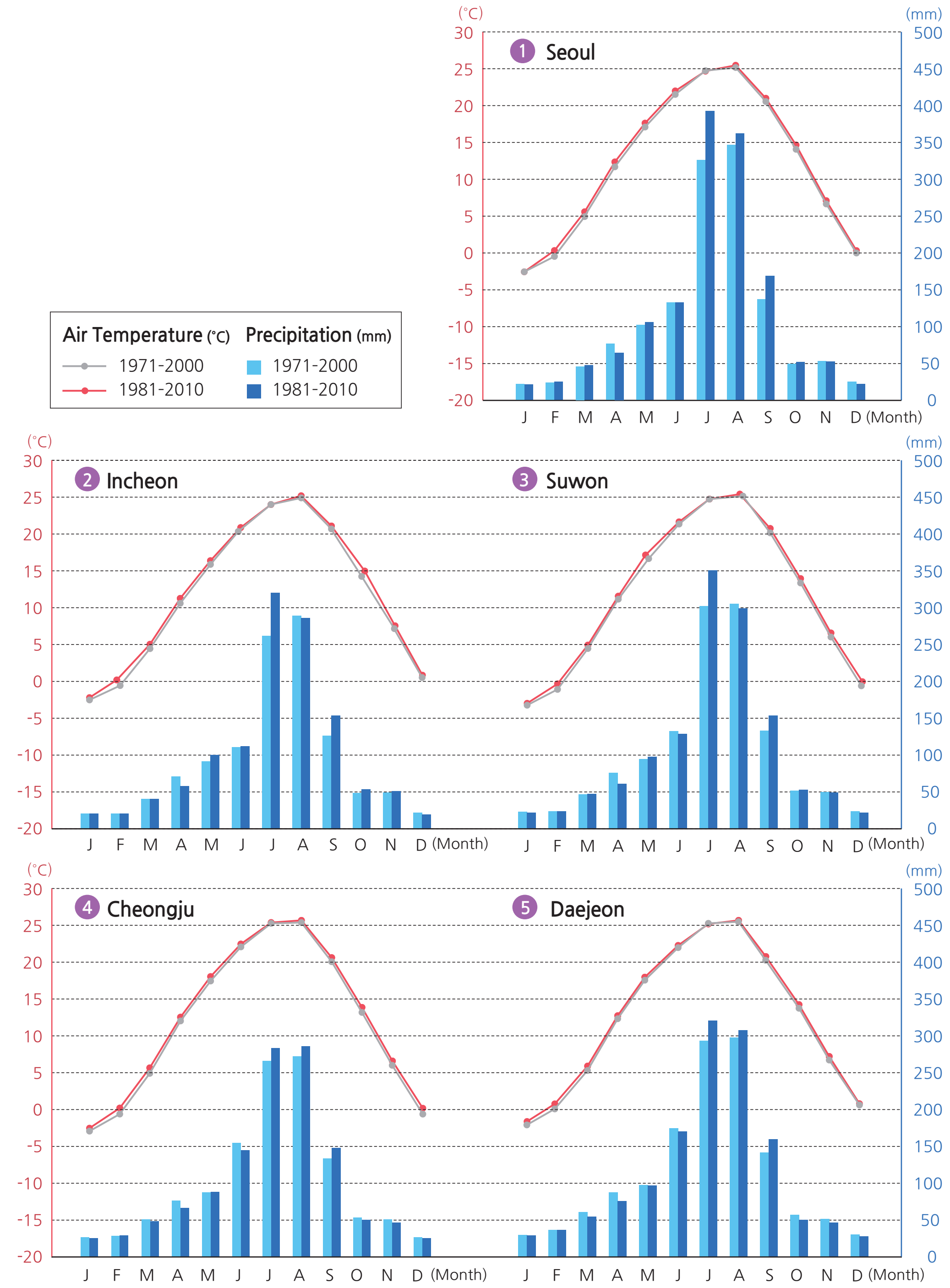


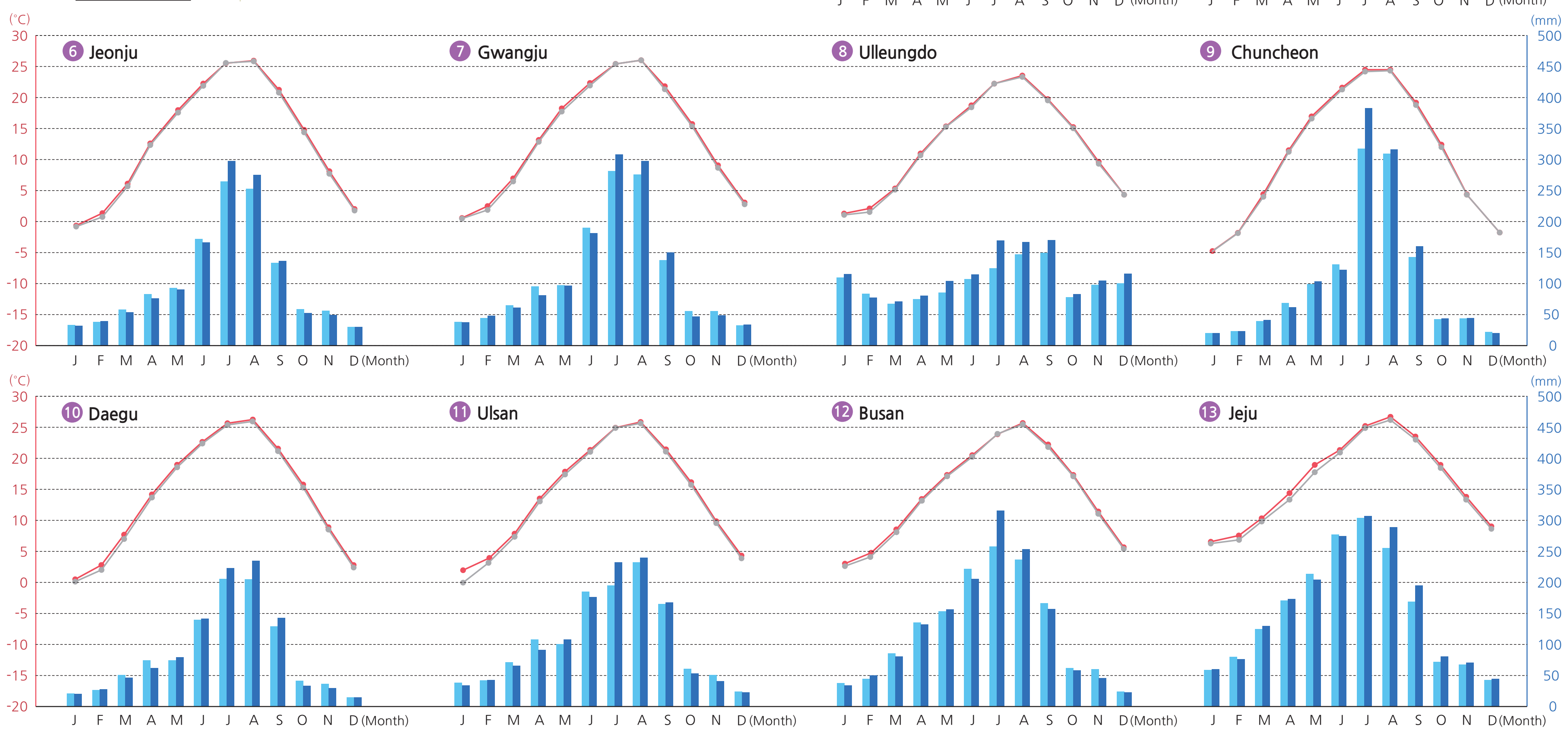
Ministry of Oceans and Fisheries, Korea Hydrographic and Oceanographic Agency (2006)

Climate Change

Changes in Climographs at Selected Stations







Korea Meteorological Administration (2011)

Increasing temperatures

There has been an increasing trend in temperature over the past 30 years. According to the climographs, average monthly temperatures of the recent 30-year period between 1981 and 2010 are greater than the 30 year period between 1971 and 2000. With the exception of the month of July, most other months of the year recorded higher average temperatures.

The annual precipitation of South Korea experienced a slight increase of 50 mm on average in the 30-year period of 1981–2010. The annual precipitation recorded at 13 observation stations increased by about 3.9% on average compared to the past, while Ulleungdo experienced an 11% increase in precipitation. In most areas, summer precipitation has increased, while spring and autumn precipitation have decreased.

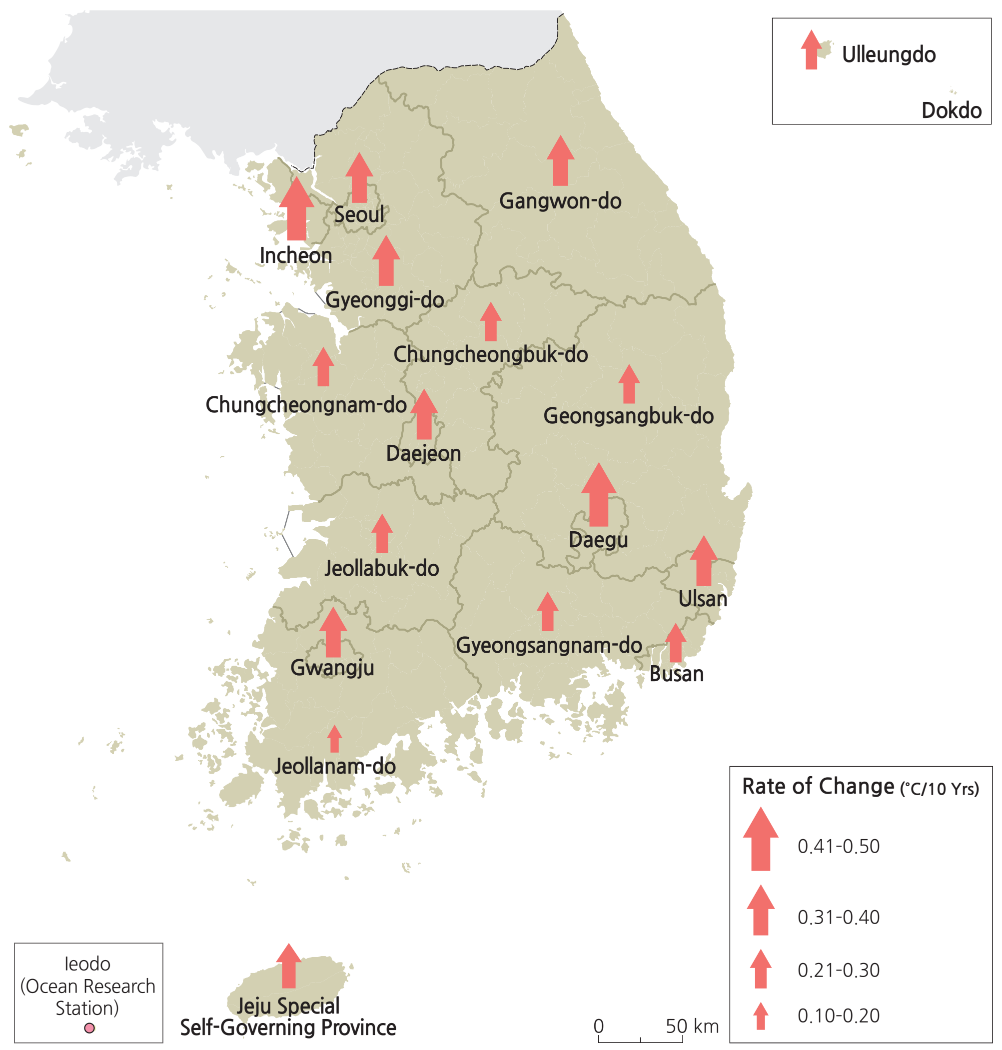
Brief Interpretation of the Map and Charts

The map shows the location of the weather stations. One may use it to associate location with characteristics of the climographs. Between 1971 and 2000, stations with both July and August precipitation over 300 mm are Seoul, Suwon, and Chuncheon, all of which are inland cities. Seoul has by far the highest July and August precipitation. For the period between 1981 and 2010, stations with both July and August precipitation over 300 mm are Seoul, Suwon, Daejeon, and Chuncheon; once again all are located inland. Stations with only July precipitation over 300 mm are Incheon, Gwangju, Busan, Jeju, and Gwangju; of these four cities, only Gwangju is an inland city.

Comparing the light blue bars (1971–2000) with the dark blue bars (1981–2010) in the climographs reveals that precipitation has increased in all summer months in all thirteen stations, while winter months remain relatively equal during the 1981–2010 period.

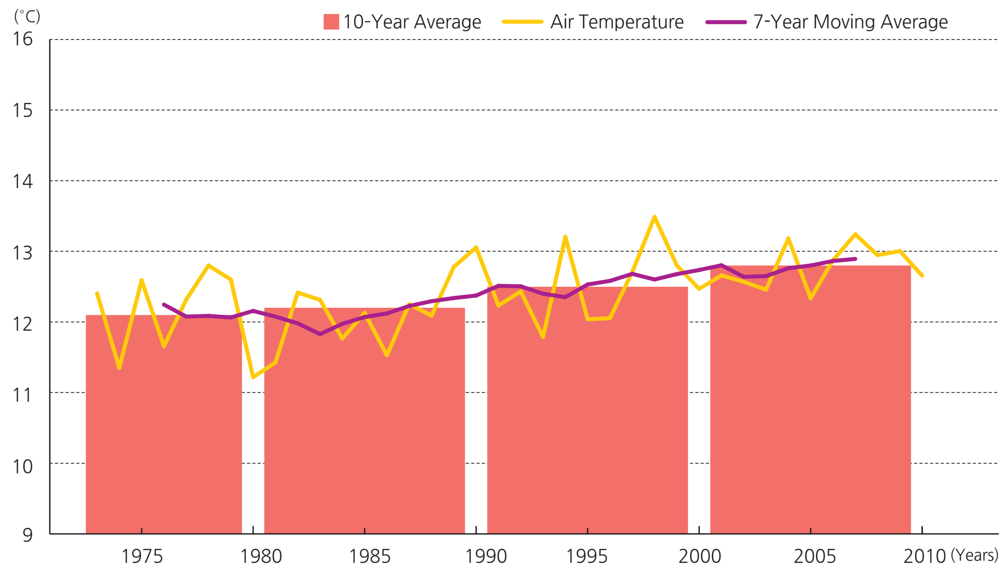
Can you suggest a reason why inland cities have a higher precipitation in general? Size and elevation of an island influences its climate. Study the climographs for Jeju and Ulleungdo. They are both far offshore islands, but Ulleungdo has a much milder climate with less precipitation that is more even distributed monthly. Can you suggest a reason why?

Rate of Change in Annual Mean Air Temperature (1973-2010)



Korea Meteorological Administration (2011)

Change in Annual Mean Air Temperature (1973-2010)



Korea Meteorological Administration (2011)

Rate of Change in Annual and Seasonal Mean Air Temperature (1973-2010)

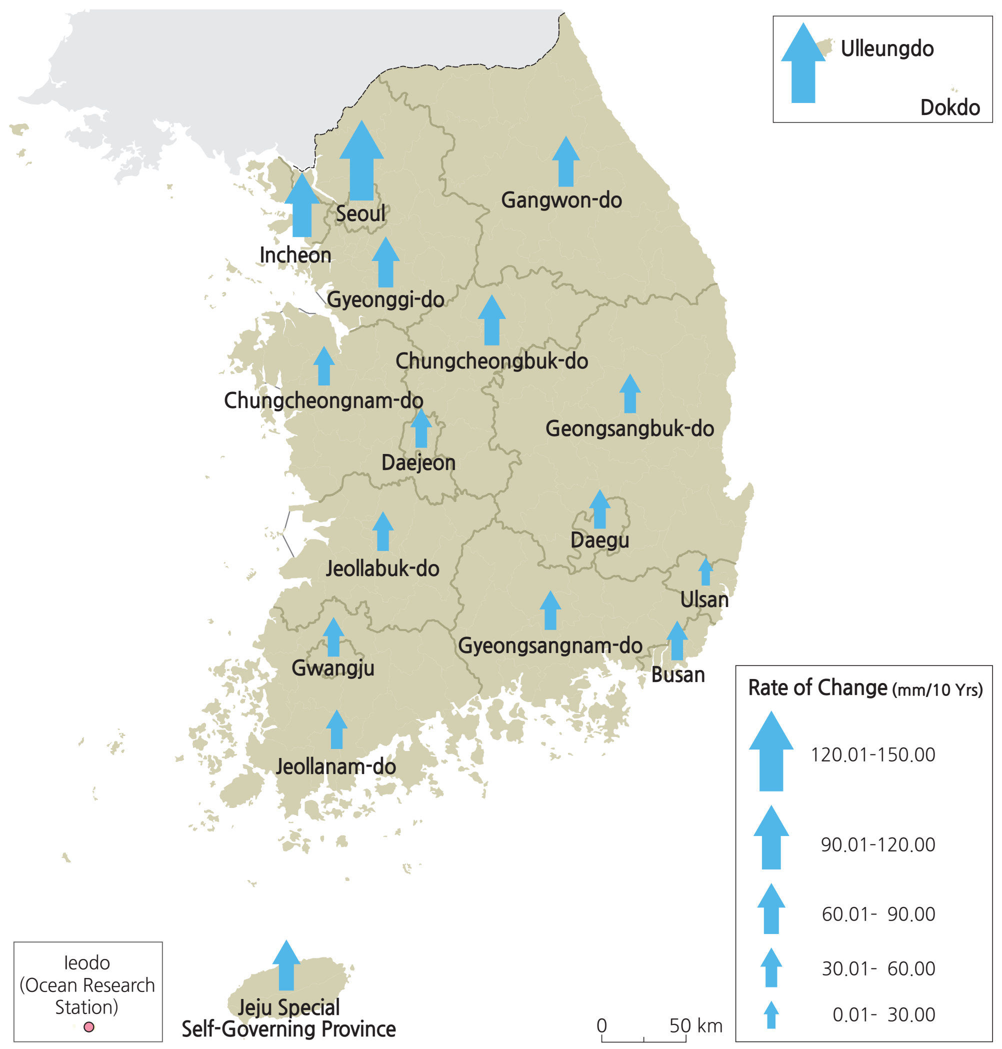
Unit (°C/10 yrs)

Classification	Annual	Spring	Summer	Autumn	Winter
Mean Temperature	0.27**	0.24**	0.1	0.31**	0.53*
Maximum Temperature	0.27**	0.26 **	0.08	0.29*	0.51*
Minimum Temeperature	0.30**	0.25*	0.18	0.38**	0.52*

* Significant at α=0.05 / **Significant at α=0.01

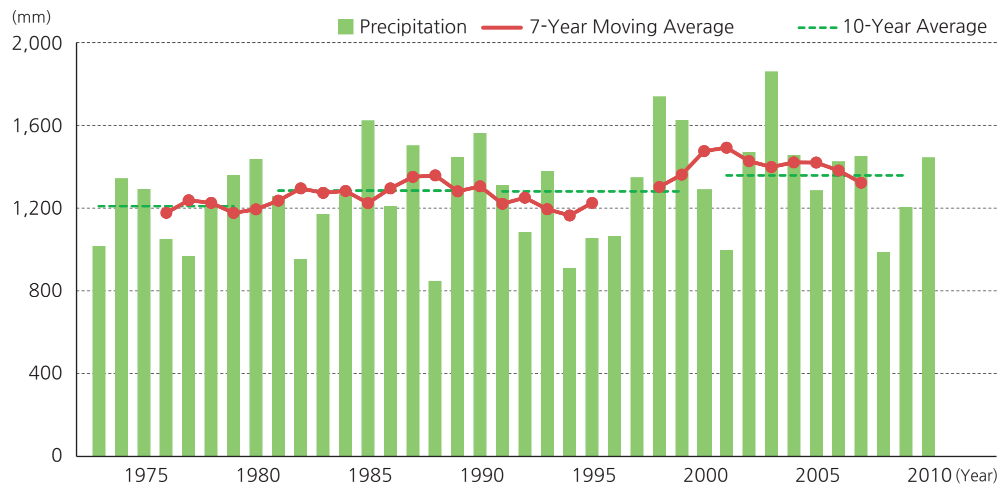
Korea Meteorological Administration (2011)

Rate of Change in Annual Mean Precipitation (1973-2010)



Korea Meteorological Administration (2011)

Change in Annual Mean Precipitation (1973-2010)



Korea Meteorological Administration (2011)

Rate of Change in Annual and Seasonal Mean Precipitation (1973-2010)

Unit (mm / 10 yrs)

Classification	Annual	Spring	Summer	Autumn	Winter
Precipitation	55.45	-5.75	55.20 *	6.89	0.15

* Significant at α=0.05 / **Significant at α=0.01

Korea Meteorological Administration (2011)

The rate of change in annual mean temperature at 0.27˚C/10 years clearly shows a warming trend in Korea. On average, all the areas except Mungyeong have experienced a rise in annual mean temperature between 0.09˚C and 0.57˚C for every 10 years. Cheongju and Suwon have experienced the greatest increase in temperature for the most recent 10-year period. Also, the annual mean temperature increases at a greater rate in metropolitan areas than the national average rate of change. The highest rate of change in annual mean temperature occurs in Daegu and Incheon (0.46˚C/10 years). Winters (0.53˚C/10 years) have experienced the greatest increase in air temperature, while summers (0.1˚C/10 yrs) have experienced the lowest temperature increase, but nonetheless significant increases.

The rate of change in annual precipitation, 55.45 mm/10 years, represents an increasing trend in most areas. Seoul has seen the biggest increasing rate of precipitation at 147.16 mm/10 years while Goheung has experienced a changing rate at -18.95 mm/10 years. Throughout all seasons, the summer has the highest rate of change (55.2mm/10 years) and this trend is analogous to that of annual precipitation. However, the rate of change in annual precipitation is quite low throughout the year except the summer. Also, the concentration ratio of precipitation in the summer has increased as a response to reduced rainfall in other seasons across large parts of the Peninsula.

Brief Interpretation of the Maps

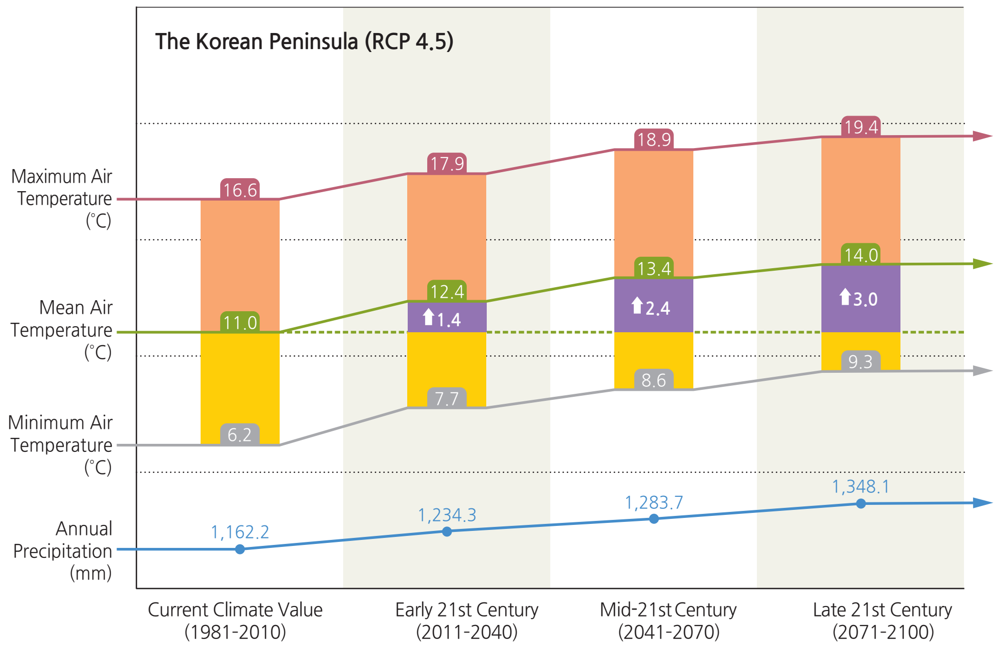
For both maps, each arrow symbol represents the cumulative mean data for that particular area. For instance, the arrow that represents Gangwon-do Province show the collective mean of data collected from 24 weather stations in mainland Gangwon-do Province plus 8 stations in Ulleungdo and Dokdo. Likewise for Seoul, Incheon, and Gyeonggi-do Province, or any other province, the arrows also represent cumulative means of several respective stations within their domains.

The map for the rate of change in annual mean air temperature (1973–2010) indicates a strong confirmation of the rise in temperature within these 37 years. It is not a short-term weather increase but a definitive long-term warming trend. The size of the arrows gauges at levels of a range between 0.1 and 0.5 degree Centigrade per ten years. Although the numbers may appear small, the climatic effects on the biosphere can be tremendous. Cumulative through decades, the effects can become devastating. They can change the distribution of vegetation, alter seasonal rainfall patterns and intensity, and affect our daily lives.

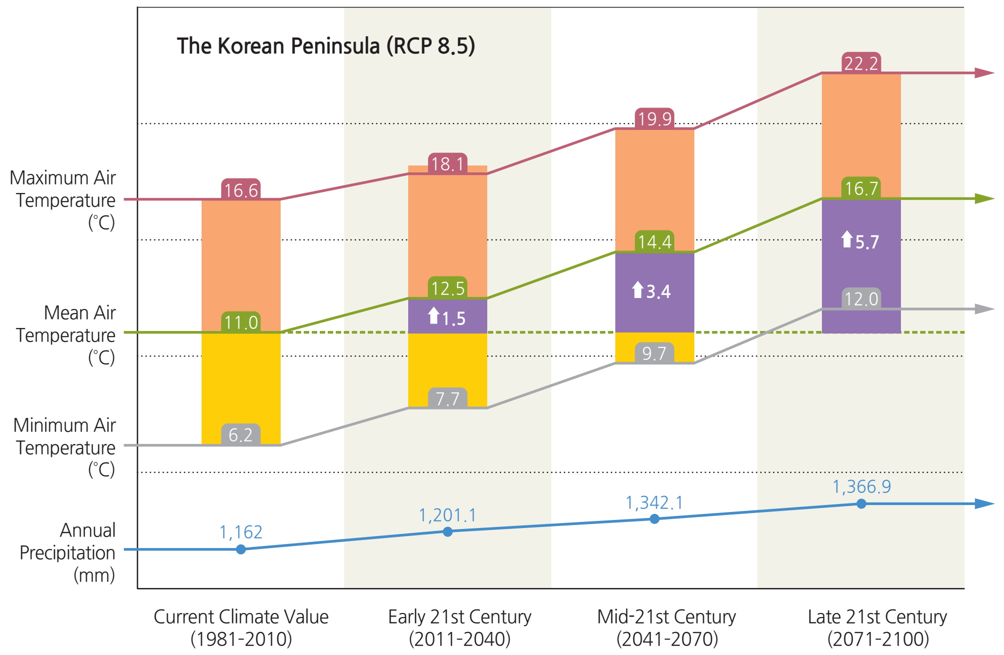
The map on the rate of change in annual mean precipitation (1973-2010) shows both significant (solid arrows) and insignificant (open arrows) changes in precipitation. The pattern here is very clear: in the northern third of South Korea, precipitation increase is significant, while in the southern two-thirds of the nation, it is not. The reasons for this interesting and definitive pattern should be open to investigation as to why such a pattern occurs.

The smallest annual mean air temperature increase as symbolized by the smallest red arrow is found in Jeollanam-do. On a map from page 124 of The National Atlas of Korea Volume 2 that shows the distribution of weather stations, it is obvious that most of the stations in this southwestern province are located along the coast; only one or two are located inland. How does the distribution of weather stations affect the data they collect? Are the majority of coastal stations truly representative of Jeollanam-do Province? If there were more inland stations, would they change the annual mean temperature data?

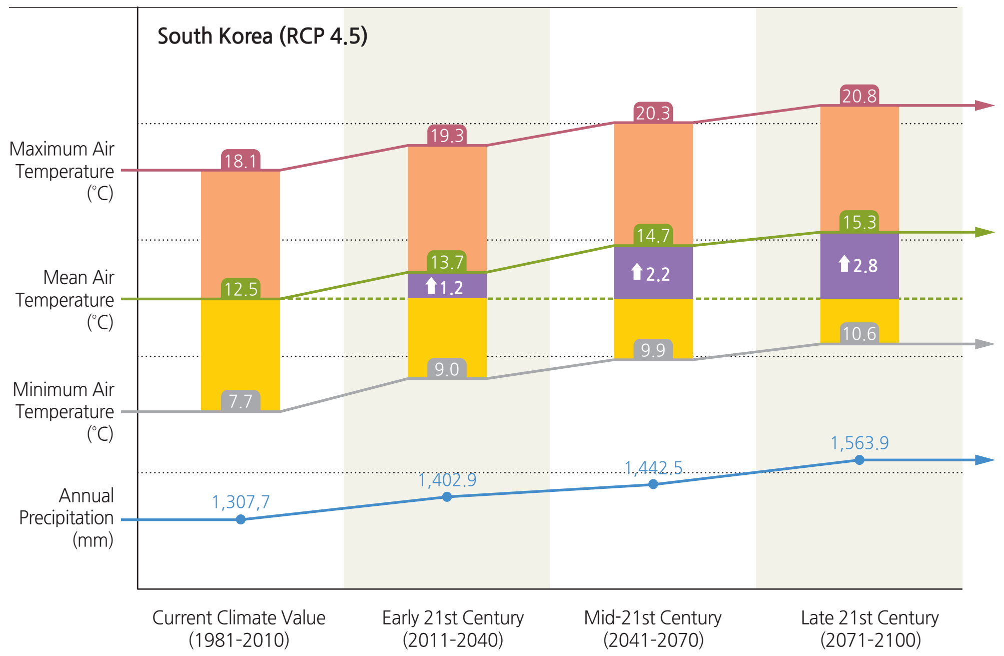
Projection of the 21st Century Air Temperature and Precipitation over the Korean Peninsula under RCP Scenarios



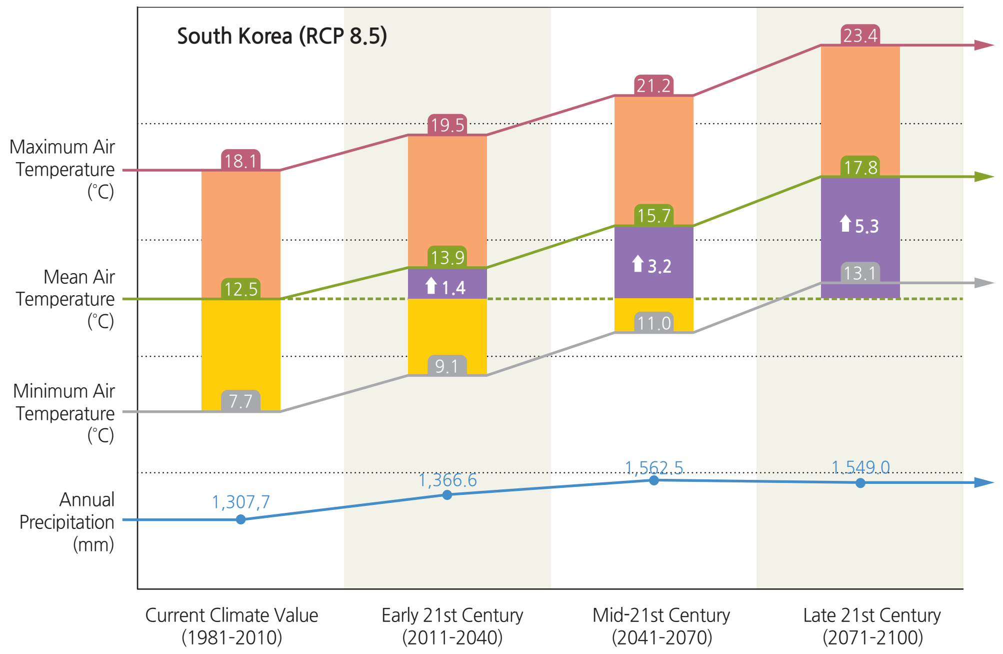
Korea Meteorological Administration (2012)



Korea Meteorological Administration (2012)



Korea Meteorological Administration (2012)



Korea Meteorological Administration (2012)

The information portrayed on the maps and graphs associated with this section are an attempt to glimpse into the future. These views are based upon different scientists' interpretation of hundreds of data sets developed worldwide for many years. Their models are not definitive predictions but ideas on what may happen to the climatic environment if different elements of the physical, social, and political world come together over the next 80 years. The projections are based on scenarios produced by an international group of specialists who have developed four different models. These scenarios are termed Representative Concentration Pathways (RCPs). Briefly these RCPs are probable trajectories of changes of the world environment. These changes may happen if different conditions of atmospheric warming at the upper boundary of the troposphere are fulfilled. The models are of climatic conditions and are tied to alternate patterns of radiative forcing (atmospheric warming) resulting from the emission of greenhouse gases.

The baseline value or starting point for the atmosphere warming used in RCPs is the radiative forcing assumed at the top of the troposphere. Each of the RCPs is based on a different pattern of the radiative forcing that considers socioeconomic conditions, measured atmosphere conditions, and the projected control of gaseous emissions. The number associated with each RCP is the projected watts/square meter in 2100.

RCP 2.6 assumes that the forcing level will rise to 3.1 in mid-century and decline until 2100.

RCP 4.5 assumes that the forcing level will be stabilized at 4.6 by 2100 and remain stationary after that.

RCP 6.0 assumes that the forcing level will be stabilized shortly after 2100 and be maintained at that level.

RCP 8.5 assumes that the forcing level will continue to increase with increasing gaseous emission levels.

The annual mean temperature of the Korean Peninsula is expected to rise steadily throughout the 21st century. In the Representative Concentration Pathways (RCP) 4.5 scenario, the increasing trend projected from the 1981-2010 mean temperature of 11˚C to the early 21st century (2011-2040) is similar to that in the RCP 8.5 scenario. However, the increasing rate is expected to slow down during the mid-21st century (2041–2070). The annual mean temperature in the late 21st century is projected to be 14.0˚C in the RCP 4.5 scenario, corresponding to the 1981-2010 average temperature in the southeastern coastal region.

According to the RCP 8.5 scenario, the magnitude of the increase in annual mean temperature becomes greater after the early 21st century. The annual mean temperature in the late 21st century is projected to be 16.7˚C, corresponding to the 1981-2010 average temperature in the southernmost tip of Jejudo.

The annual mean maximum and minimum temperatures are expected to increase constantly. Based on the RCP 4.5 scenario, the increasing rates of the maximum and minimum temperatures are projected to decrease during the mid-21st century and beyond. Since the magnitude of the increase in the daily maximum temperature is smaller than that in the daily minimum temperature, the daily temperature range is projected to decrease gradually. The RCP 8.5 scenario indicates that the increasing trends for the maximum and minimum temperatures accelerate toward the late 21st century.

The annual precipitation is projected to rise until the late 21st century. The RCP 4.5 scenario expects the annual precipitation in the late 21st century to be 1,348.1 mm, while the RCP 8.5 scenario predicts it to be 1,366.9 mm. The annual mean temperature in South Korea is projected to continue to increase along with the increasing trend for annual mean temperature of the entire Peninsula. The RCP 4.5 scenario predicts the increasing trend in the early 21st century will have a rate similar to that of the RCP 8.5 scenario, but it will slow down over time. The annual mean temperature in the late 21st century is predicted to be 15.3˚C, corresponding to the 1981-2010 value of Jejudo. According to the RCP 8.5 scenario, the increasing trend for temperature accelerates from the mid-21st century to the late 21st century. In the scenario, the annual mean temperature in the late 21st century is projected to be 17.8˚C, which exceeds the 1981-2010 annual mean temperature of Seogwipo (16.6˚C). The annual mean maximum and minimum temperatures are also expected to increase steadily until the late 21st century. In the late 21st century, the increasing trend for the minimum temperature is slightly greater than that for the maximum temperature for the same period based on the RCP 4.5 and RCP 8.5 scenarios.

Annual mean precipitations in the late 21st century projected in the RCP 4.5 and RCP 8.5 scenarios are 1,563.9 mm and 1,549.0 mm, respectively, which correspond to the 1981-2020 mean amount for the southern coastal region of the Peninsula. Although the RCP 4.5 scenario shows a greater increasing rate in the annual mean precipitation during the early 21st century than the RCP 8.5 scenario, the increasing trend for precipitation appears to be low for the beginning of the mid-21st century. However, during the mid-21st century, the magnitude of the increase in annual mean precipitation becomes greater once again, resulting in the average amount predicted in the RCP 4.5 model to exceed that predicted in the RCP 8.5 scenario.

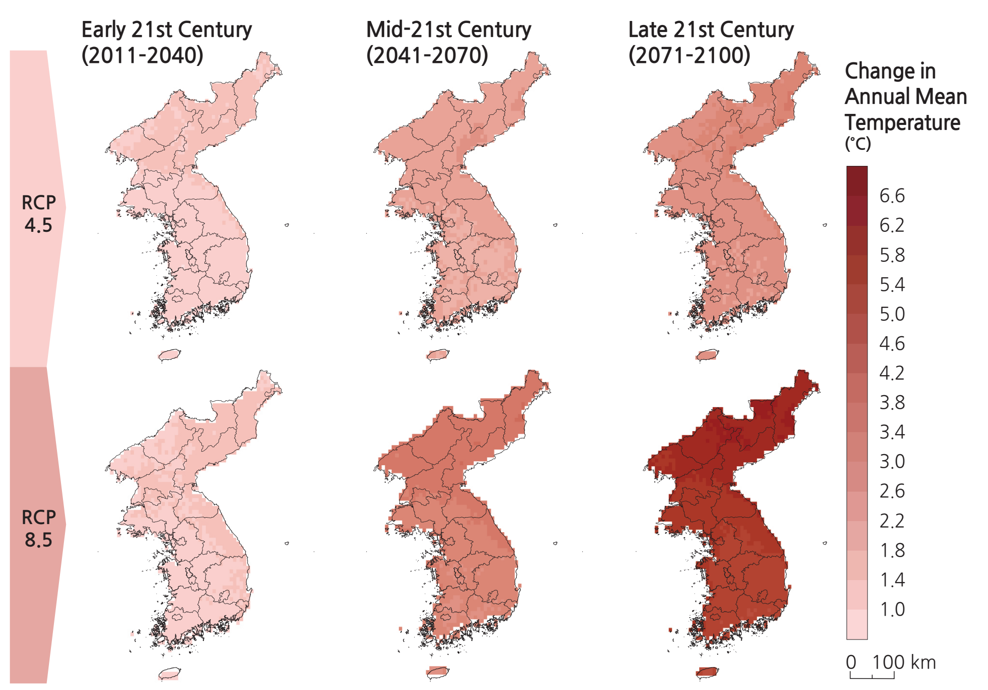
Based on the RCP 8.5 scenario, the early 21st century begins with a small increase in annual mean precipitation. Then, the annual mean precipitation appears to increase largely right after the early 21st century. However, the increasing trend for precipitation slightly decreases during the mid-21st century.

Using the Trewartha climate classification, the southern coast of the Korean Peninsula, including Jejudo, is classified as a humid subtropical climate region. As global warming accelerates, the boundary of the subtropical climate region is projected to move gradually to the north. With the RCP 4.5 scenario for the late 21st century, Jeollanam-do, Jeollabuk-do, the west coast of Chungcheongnam-do, the west coast of Gyeonggi-do, and Gyeongsangnam-do are expected to become subtropical climate regions, while the RCP 8.5 scenario predicts most of South Korea, except the mountainous region, to be classified as subtropical climate regions in the late 21st century.

With global warming, the annual mean number of tropical nights is expected to increase, which can be attributed to the trend of increasing air temperature over the Korean Peninsula. According to the RCP 4.5 and 8.5 scenarios, the annual mean number of tropical nights in the late 21st century is expected to increase substantially. In the RCP 4.5 scenario, the annual mean number of tropical nights increases far more in South Korea than in North Korea from the mid-21st century to the late 21st century. However, from the RCP 8.5 scenario for the late 21st century, most areas of the Peninsula, except some major mountainous regions with high elevation, will have a much greater annual number of tropical nights than during the 1981–2010 period. After the late 21st century, as climate change becomes more intensified, it is anticipated that areas with tropical nights shall also expand to the high mountainous regions.

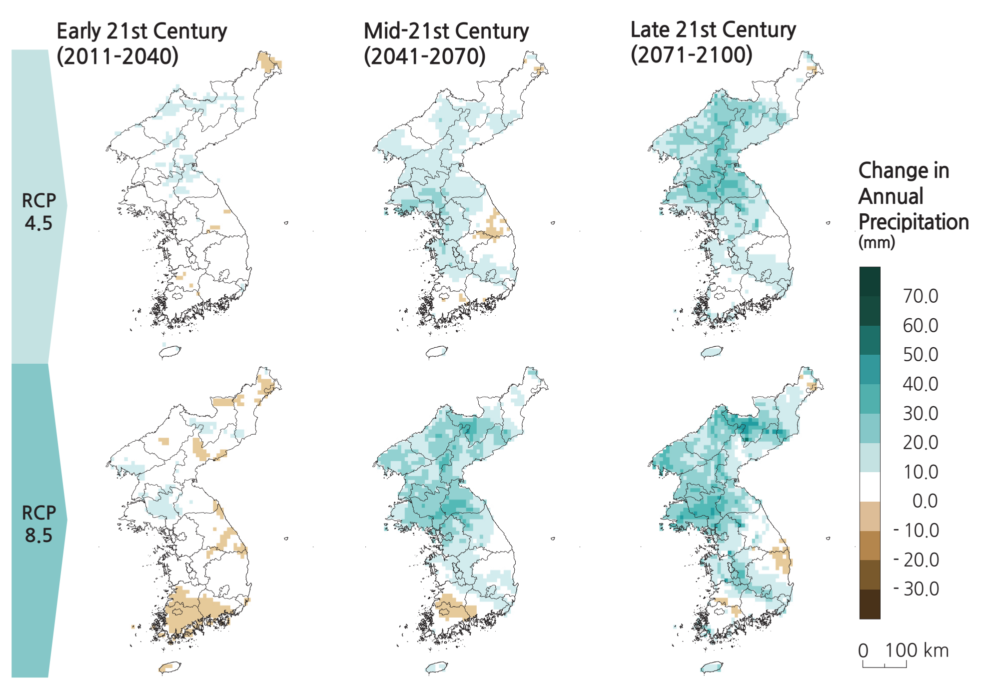
The RCP 4.5 and 8.5 scenarios predict that the annual mean number of heat wave days starts to increase in the lowlands. In the RCP 4.5 scenario, the Korean Peninsula is unlikely to see a large increase in the annual mean number of heat wave days; but in the RCP 8.5 scenario, the increasing trend for heat wave days is likely to accelerate. The number of heavy precipitation days is projected to increase in most parts of the Korean Peninsula with wide variations, depending on time, region, and scenario used.

Projection of Air Temperature over the Korean Peninsula under RCP 4.5/8.5 Scenarios



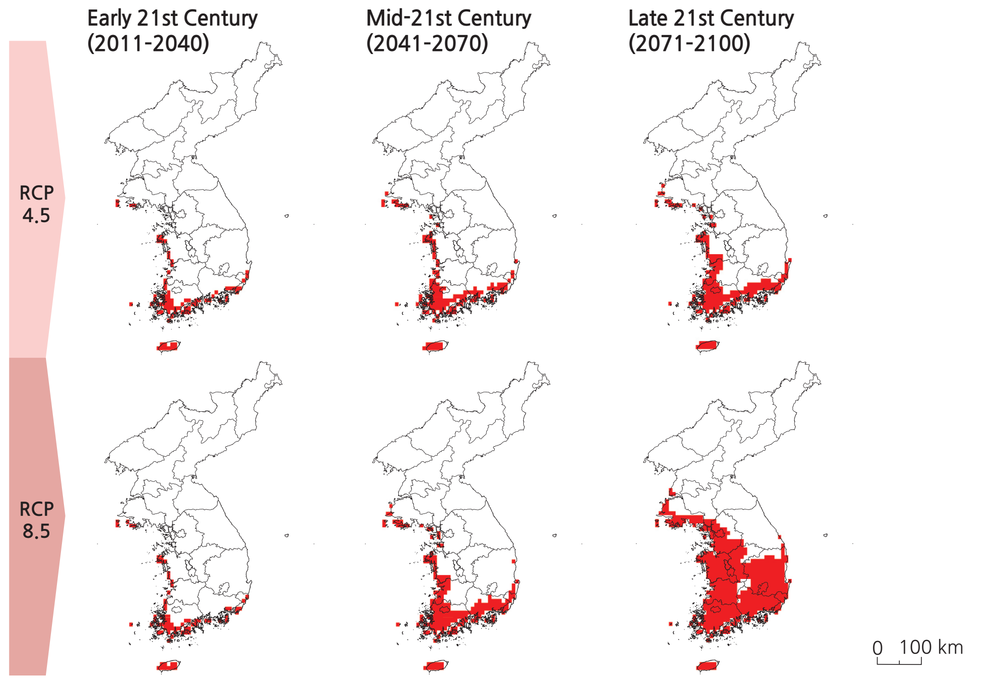
Korea Meteorological Administration (2012)

Projection of Precipitation over the Korean Peninsula under RCP 4.5/8.5 Scenarios



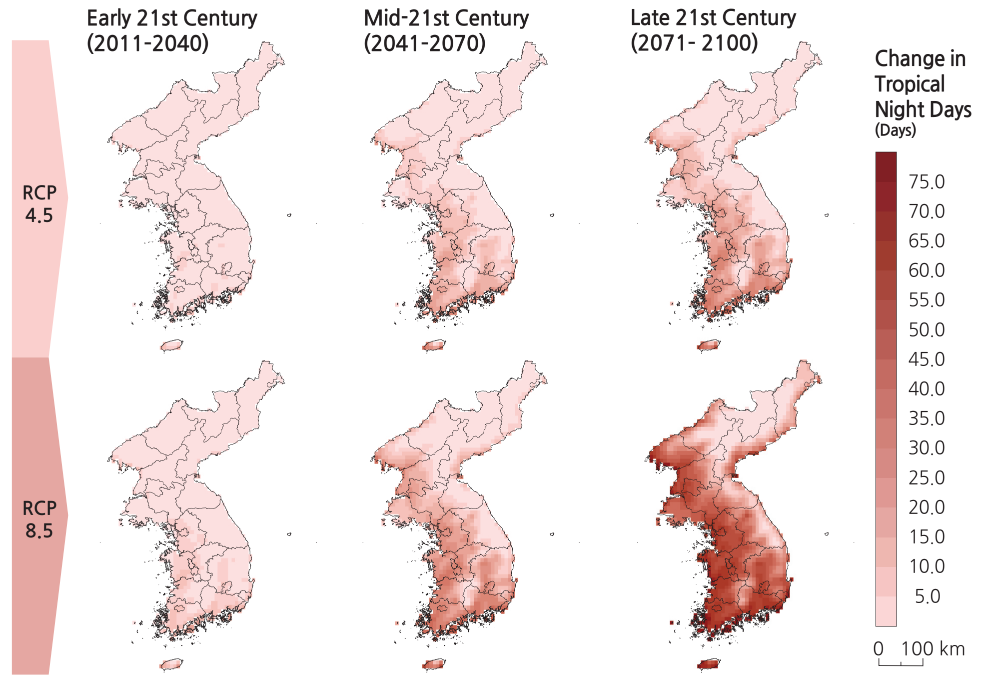
Korea Meteorological Administration (2012)

Projection of Subtropical Regions over the Korean Peninsula under RCP 4.5/8.5 Scenarios



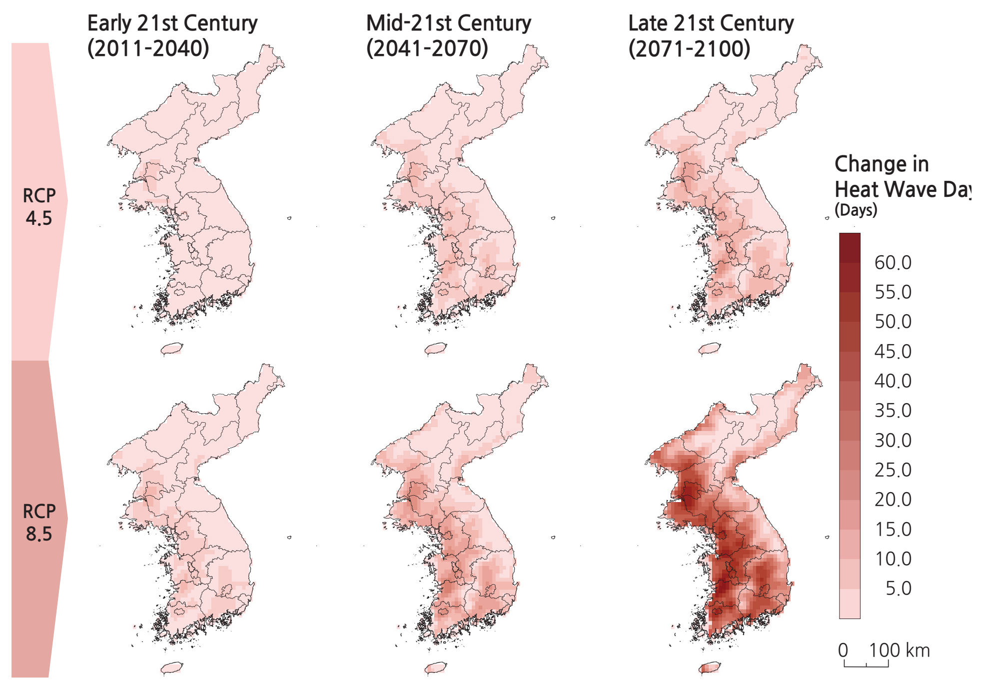
Korea Meteorological Administration (2012)

Projection of Number of Tropical Nights over the Korean Peninsula under RCP 4.5/8.5 Scenarios



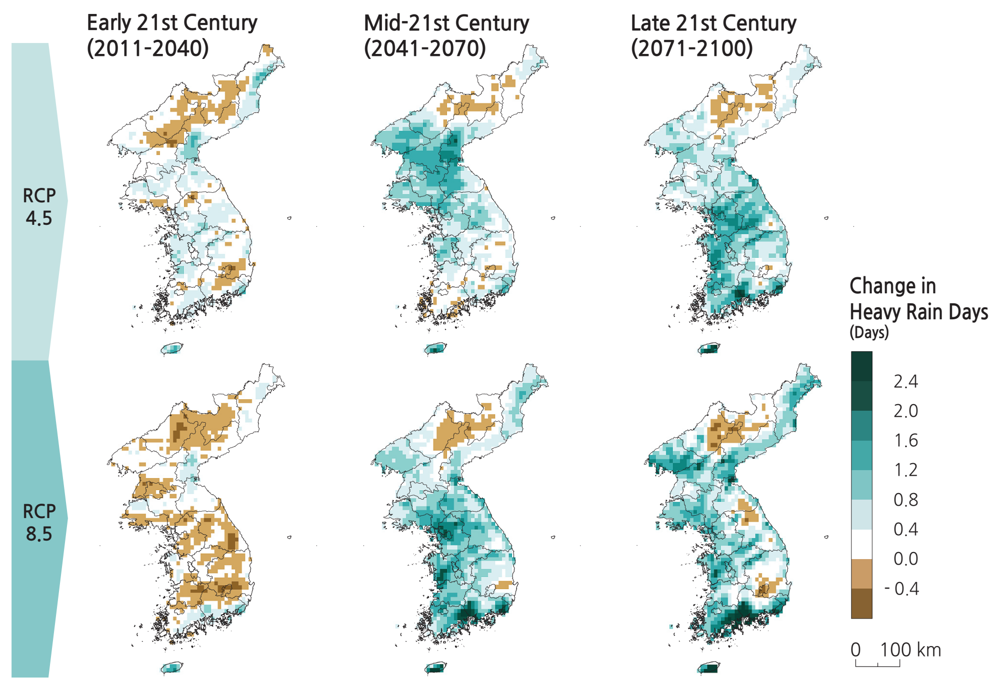
Korea Meteorological Administration (2012)

Projection of Number of Heat Wave Days over the Korean Peninsula under RCP 4.5/8.5 Scenarios



Korea Meteorological Administration (2012)

Projection of Number of Heavy Precipitation Days over the Korean Peninsula under RCP 4.5/8.5 Scenarios



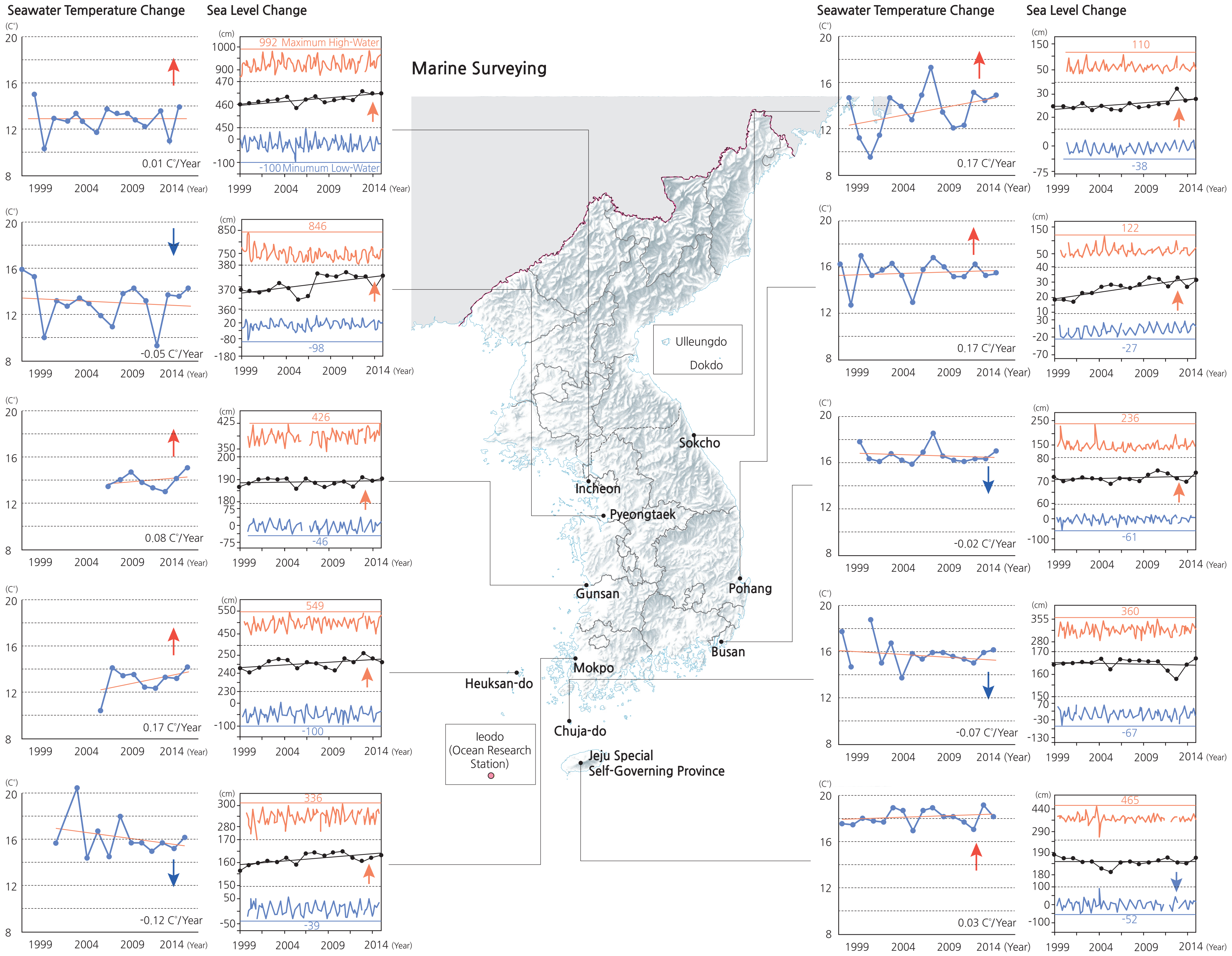
Korea Meteorological Administration (2012)

Brief Interpretation of the Maps

The RPC 4.5 and 8.6 graphs of precipitation and temperature show a rise into the late 21st century; however, the precipitation increases at a slower rate. As would be expected the RCP 8.6, rate of temperature increase throughout the century shows a more rapid rise in temperature than the more conservative RCP 4.5. The geographic increases in temperature are evenly distributed while the increases for the sub-tropical region are concentrated in the south and west coast areas. The increase in heat wave days is concentrated in the lower west and central mountainous areas, extending (with minimum increases) to the east coast.

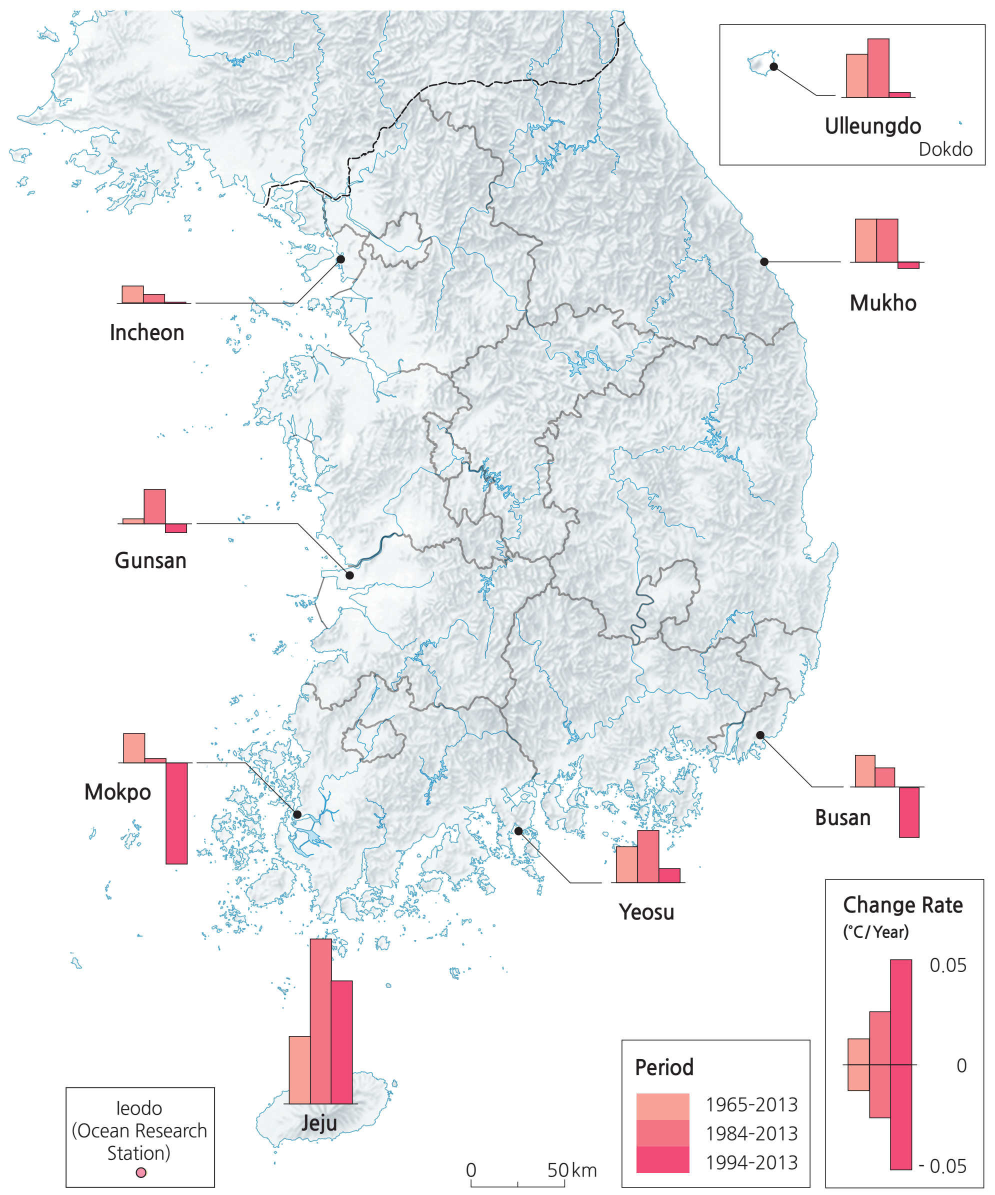
The increase in precipitation associated with the RCPs of 4.5 and 8.6 is located in the north central areas of the Peninsula. The projected increase in heavy precipitation is throughout Korea.

Given the coastal region expansion of sub-tropical regions, project the effect that these temperature changes would likely produce on agriculture crop composition and rates of agricultural production. The changing pattern of heavy precipitation events throughout the century shows a curious pattern later in the century—in general, the events are moving southward and toward the west coast. Can you think of how this change might affect the design of urban housing in the areas of heavier rain?



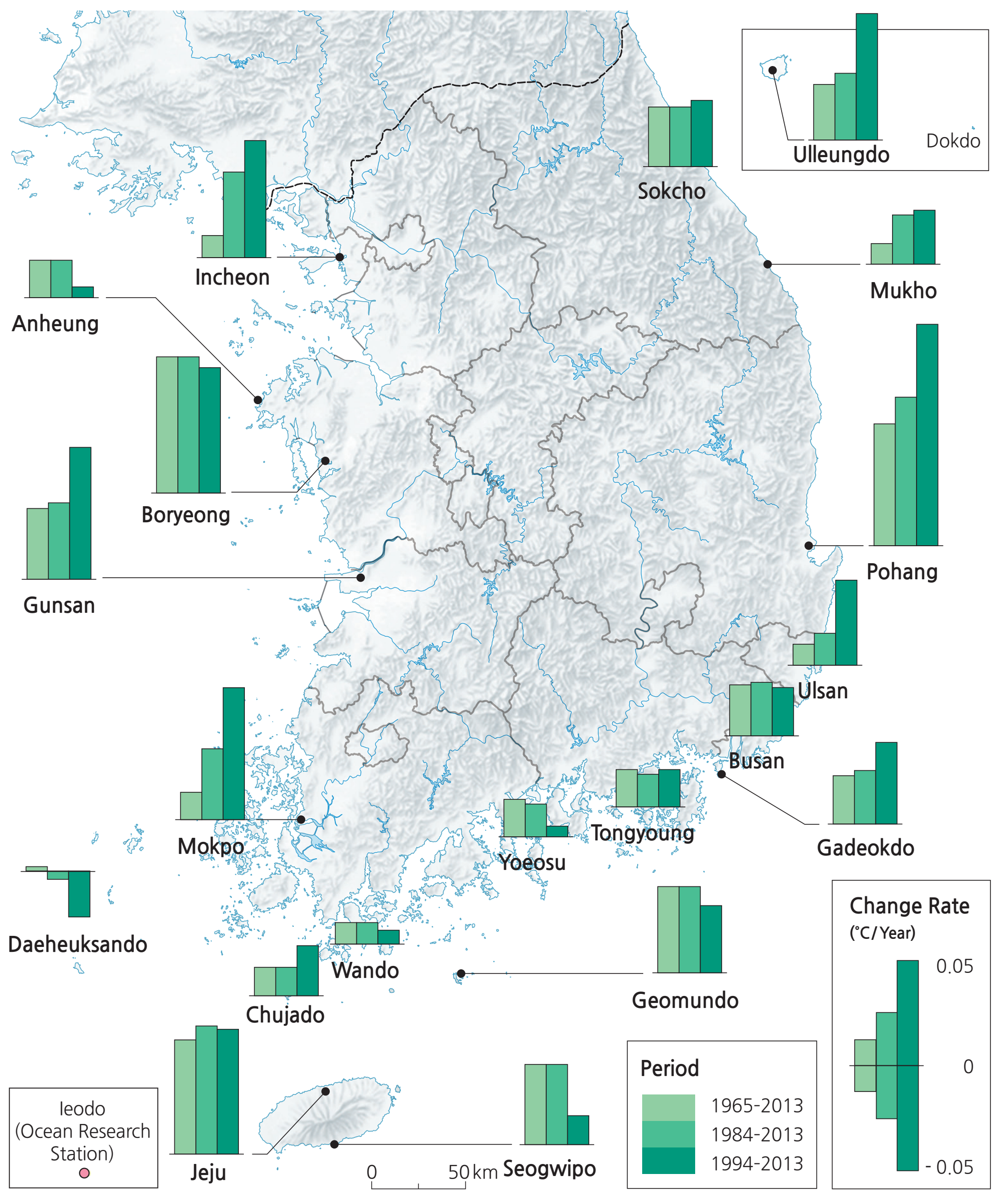
Korea Hydrographic and Oceanographic Agency (2014)

Long-Term Change Rate of Sea Surface Temperature by Period



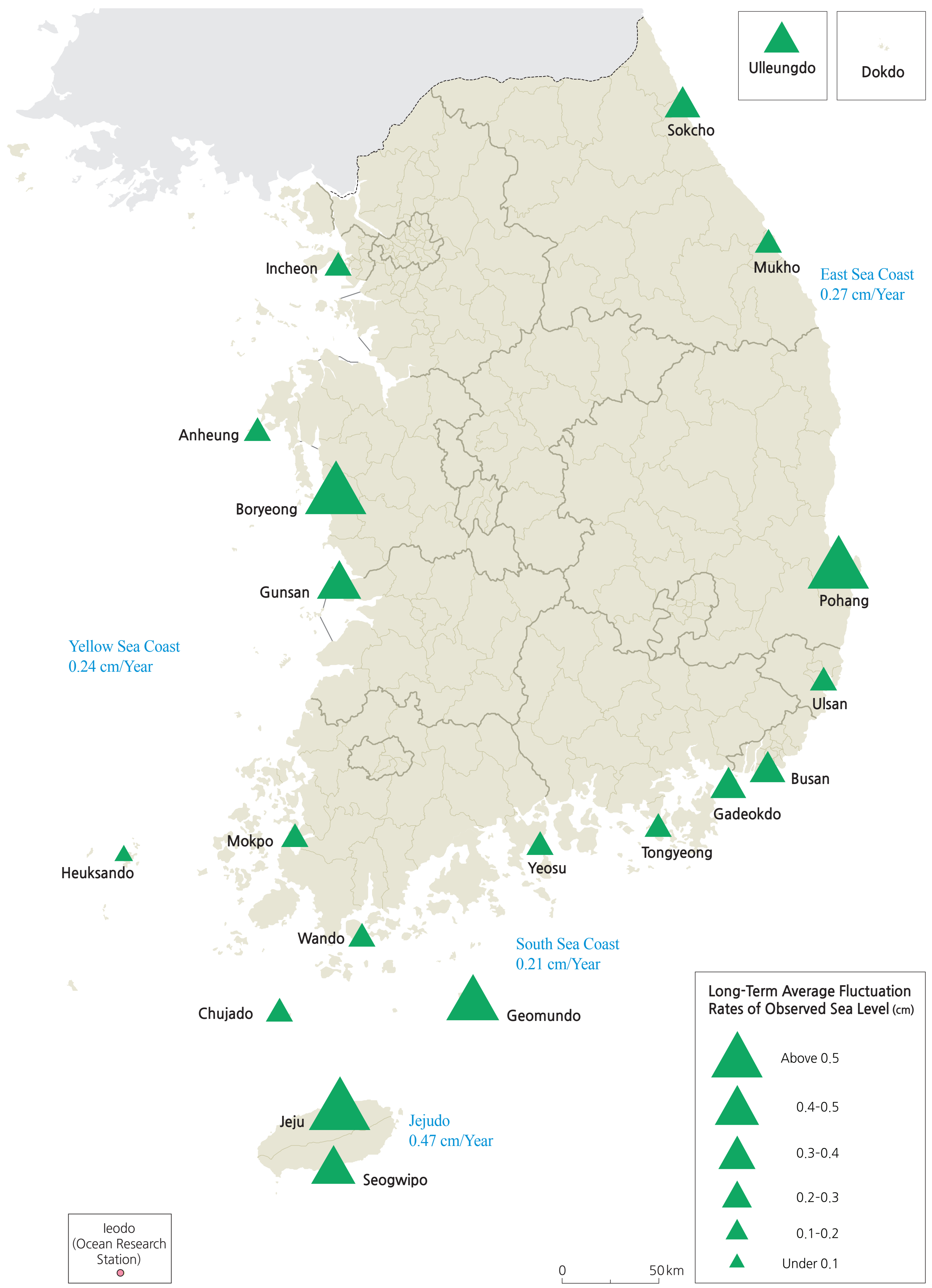
Korea Hydrographic and Oceanographic Agency (2014)

Long-Term Change Rate of Average Sea Level by Period



Korea Hydrographic and Oceanographic Agency (2014)

Long-Term Average Fluctuation Rates of Observed Sea Level



Korea Hydrographic and Oceanographic Administration (2014)

Marine Surveying

Marine surveying by domestic explorers began in the mid-1900s with the founding of the Department of Hydrography in the Operation Agency of Navy Headquarters (currently the Korea Hydrographic and Oceanographic Agency: KHOA). The Ocean Development Institute, affiliated with the Korea Institute of Science and Technology (currently the Korea Institute of Ocean Science and Technology: KIOST) was established in 1973 and introduced active ocean exploration and research. Today, extensive exploration and research continues to be carried out along the coastal region of the Korean Peninsula as well as in other regions such as the Arctic and Antarctic.

Marine surveying can be defined as the collection of oceanic data through various observation techniques to help develop an understanding of ocean characteristics and phenomena. It includes marine physical surveys, marine geological surveys, marine biological surveys, marine chemical surveys, and remote sensing data. Marine surveys are either carried out regularly or specifically for particular purposes.

Data for sea level rise along Korean coasts are based on marine surveys. These surveys observe the physical properties of the ocean such as water temperature, salinity, waves, tides, inundation range, mean sea level fluctuations, and ocean currents.

Brief Interpretation of the Maps

Marine Survey data are detailed information determined over the 15 years from a variety of coastal sites in South Korea. Short-term stretches of data are always suspect in projecting long-term change. However, they are useful as starting points in environment analysis for baselines or monitoring special events. All the monitoring stations on the east and west coasts show a gradual increase in sea level rise in the range of 3 to 8 cm. These numbers are an average of the normal year-to-year fluctuations. The exceptions are the southerly island stations on Jeju and Chuja-do, which showed no or a small average decrease in sea level change. The measured temperature change of sea level was variable but exhibited a small average increase over the whole Peninsula.

When the length of the record is extended backward to the mid-1960s where data were available, the sea surface temperature showed a more variable pattern; also, the occurrence sea level rise was clearer, and the increase in sea level over the longer period showed the greatest increases in the last 15 years.

Working from these years alone, how long would one project it to take for the average sea level rise to double at the ongoing rate? Can you think of any environmental process that might reverse this trend in rate of increase?

Sea Level Rise

Sea level surrounding the Korean Peninsula has increased. The rate of sea level rise in the East Sea is relatively higher than that in the South and Yellow Seas; the rates of sea level rise for the South and Yellow Seas are similar. Observed mean sea level fluctuations around the Korean Peninsula are 0.24 cm/yr, 0.21 cm/yr, and 0.27 cm/yr in the Yellow, South, and East Seas, respectively. Mean sea level fluctuation in Jejudo is the highest at 0.47 cm/yr. Boryeong in the Yellow Sea recorded the highest sea level fluctuation among all the seas at 0.65 cm/yr. Areas with the highest sea level fluctuation recoded are Jejudo (0.55 cm/ yr in the Yellow Sea), Geomundo (0.41 cm/yr in the South Sea), and Pohang-si (0.58 cm/yr in the East Sea), respectively.

Compared to the other seas, the sea level rise in the East Sea is remarkable. It is due to an increase in the heat transport of the Kuroshio warm current and rise in the temperature of the warm current through the East Sea as a result of global warming. If global warming is accelerated, the coastal areas are expected to suffer great damage from coastal flooding due to sea level rise.

According to the RCP 4.5 and 8.5 scenarios, the sea level around Korea will rise by 53 cm and 65 cm respectively for both scenarios, for both the South Sea and Yellow Sea; and 74 cm and 99 cm respectively for the East Sea within the latter part of the twenty-first century (2071–2100). Meanwhile, global average sea level is expected to rise by 70.6 cm and 88.5 cm respectively, for the same time period. Also based on the RCP 4.5 and 8.5 scenarios, the sea level will rapidly increase by 2100, and the sea level around the Korean Peninsula will continue to rise by more than 65 cm and 85 cm, respectively, in both the South Sea and Yellow Sea, and 90 cm and 130 cm, respectively, in the East Sea. The RCP 8.5 scenario predicts a high risk of flooding due to rising sea level in coastal lowlands. (Please refer to Page 60 for explanation of the RCP scenarios.)

Brief Interpretation of the Map

The map on this page is of the type termed a graduated symbol map. The map symbols used (in this case triangles) are often scaled to make small differences in data more visible to allow the user to discern small variations in patterns rather than looking at numbers. However, interpretation of these scaled symbols can be tricky and the scales associated with the symbols need to be inspected carefully. In many cases, cartographers use this type of symbol to make better use of limited map space by using non-linear scaling – in effect compressing larger values and using different scales for smaller values to enhance visibility.

In this case the five categories of triangles use a preferred interval scale that is of equal size except for the two open-ended top and bottom values (above 0. 5 cm; 0.4–0.5 cm; 0.3–0.4 cm; 0.2–0.3 cm and below 0.2 cm). This linear scale makes direct size interpretations possible. However, the total range of the fluctuation is just over half a centimeter, which is not a large rate of increase and which begs one to assume that the precision of the instrumentation will be critical in the measurement with a relatively large possible error even if the values are based on hundreds of measurements. Nevertheless, the averaged values are all positive or increasing.

The data shows relatively high rates at Jeju and Geomundo (island data stations in the South Sea), Pohang (a 10-km bay) on the East Sea Coast, and Boryeong (an island/coastal environment) on the Yellow Sea west coast. If one accepts the RCP projections of sea level rise associated with the higher scenarios, these four locations and nearby locations might expect considerable coastal flooding by the end of the 21st century.

The coastal locations of all the data points suggest that considerable concern for planning for future sea level rise is wise under all the RCP scenarios in similar deep and shallow water environments. Locate an additional 10 locations that are at risk for urban flooding. What are their risk factors? What methods of mitigation might you suggest for the existing and projected urban risk areas?

Anthesis and Phenology

Anthesis and Phenology

Climate change can affect the growth of plants. Two phenomena related to the effects of climate change on plants are "anthesis" and "phenology." Anthesis is a botanical term that refers to the flowering period of a plant that begins with the opening of the flower bud. It is generally recorded as the number of days from January 1 of each year to the day of first budding. Due to global warming, the first opening day of the flower bud may come earlier than usual because of warmer temperatures in the spring, thus the number of days shall be shorter than normal. Phenology is the biological study of periodic phenomena such as flowering, budding, breeding, and spatial migration in response to climatic conditions.

Average global temperature has increased by about 0.7˚C over the last century; 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 Jejudo) 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 Jejudo 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, all north of their original sites. 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.

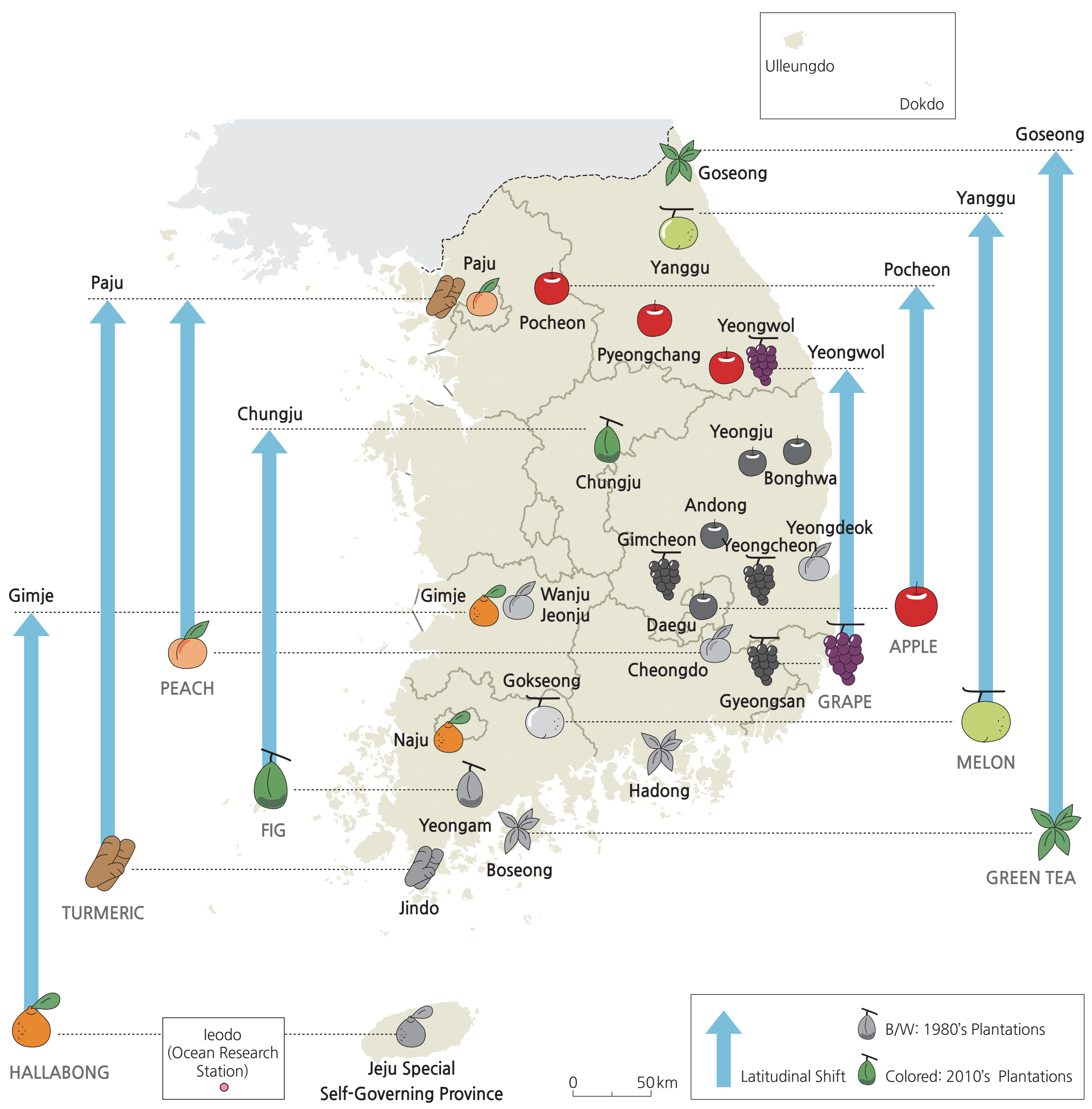
Brief Interpretation of the Maps

The map shows the shift of fruit growing plantations northward from the 1990s to 20 years later. It is very interesting but to a degree, oversimplified. The dramatic shift of fruit growing areas moving from 160 to 400 kms northward tells only part of the story. The map shows where the crops are actually grown, not necessarily where they could be grown. While active plantations are successful, there may be others that have failed or for other reasons may not be economical.

The shift of potential growing season with increasing average temperature is an important factor. However, there are other contributing factors in play as well, such as soil conditions, aspect (direction in relation to the sun), winds, and precipitation. The map showing the change in cultivation of alpine Chinese cabbage shows areas that are suitable for production in contrast to areas that are possible, not where the actual production exists. In the case of Chinese cabbage, elevation seems to be a significant controlling factor, which will have a temperature effect due to elevation in addition to global change. When global warming is factored into temperature decrease with elevation, the growing zones for the cabbage may have to be adjusted in projections.

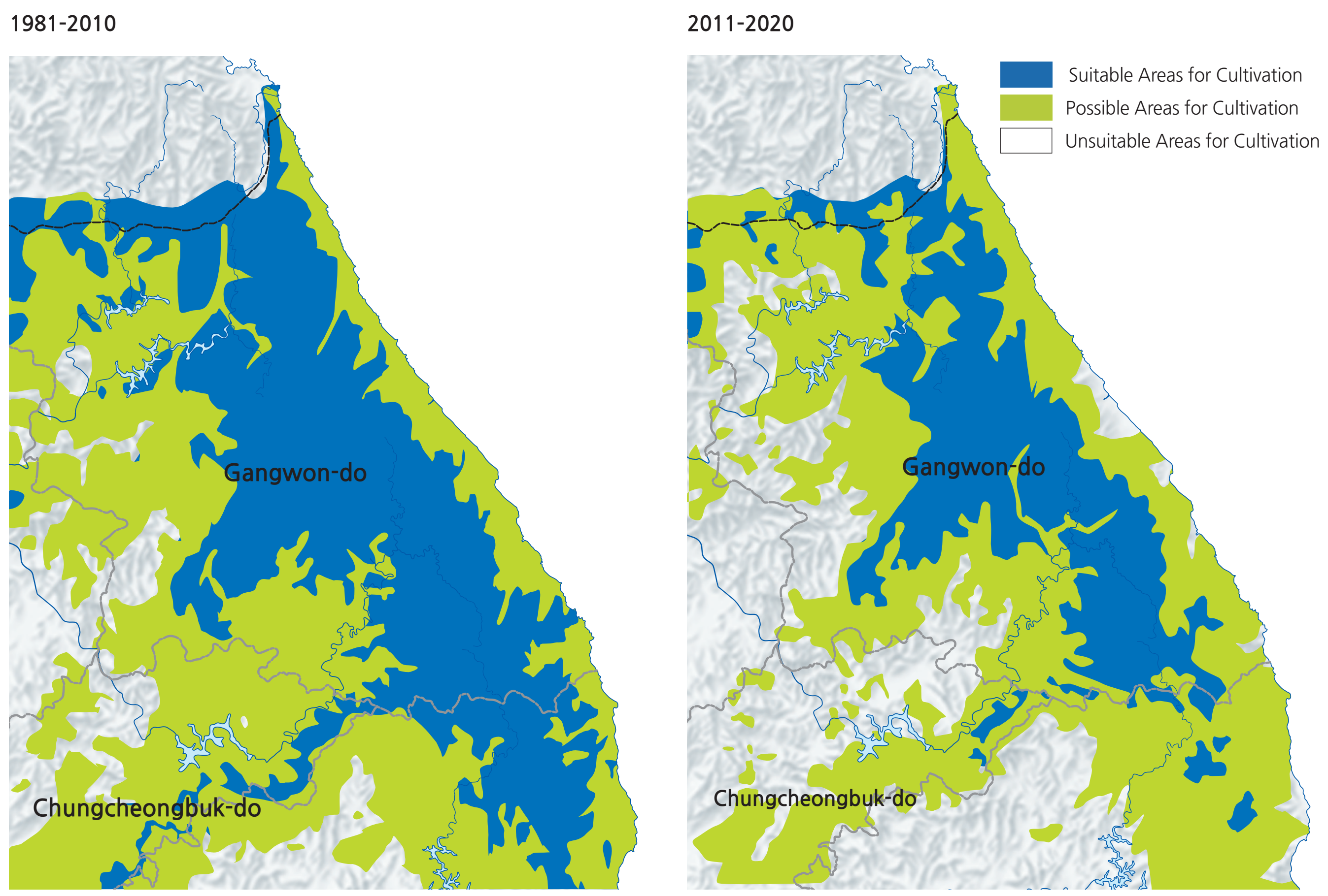
If the establishment of a new peach plantation were being planned by a local agricultural cooperative, list all the economic and physical factors that would have to be considered in alternate locations. Would there be a difference in location factors for grapes in contrast to peaches? Would the easily accessible modes of transportation or the run schedule regularity play a role in the location of a fruit plantation? Why or why not?

Geographic Shifts of Major Fruit Farmlands Affected by Climate Change



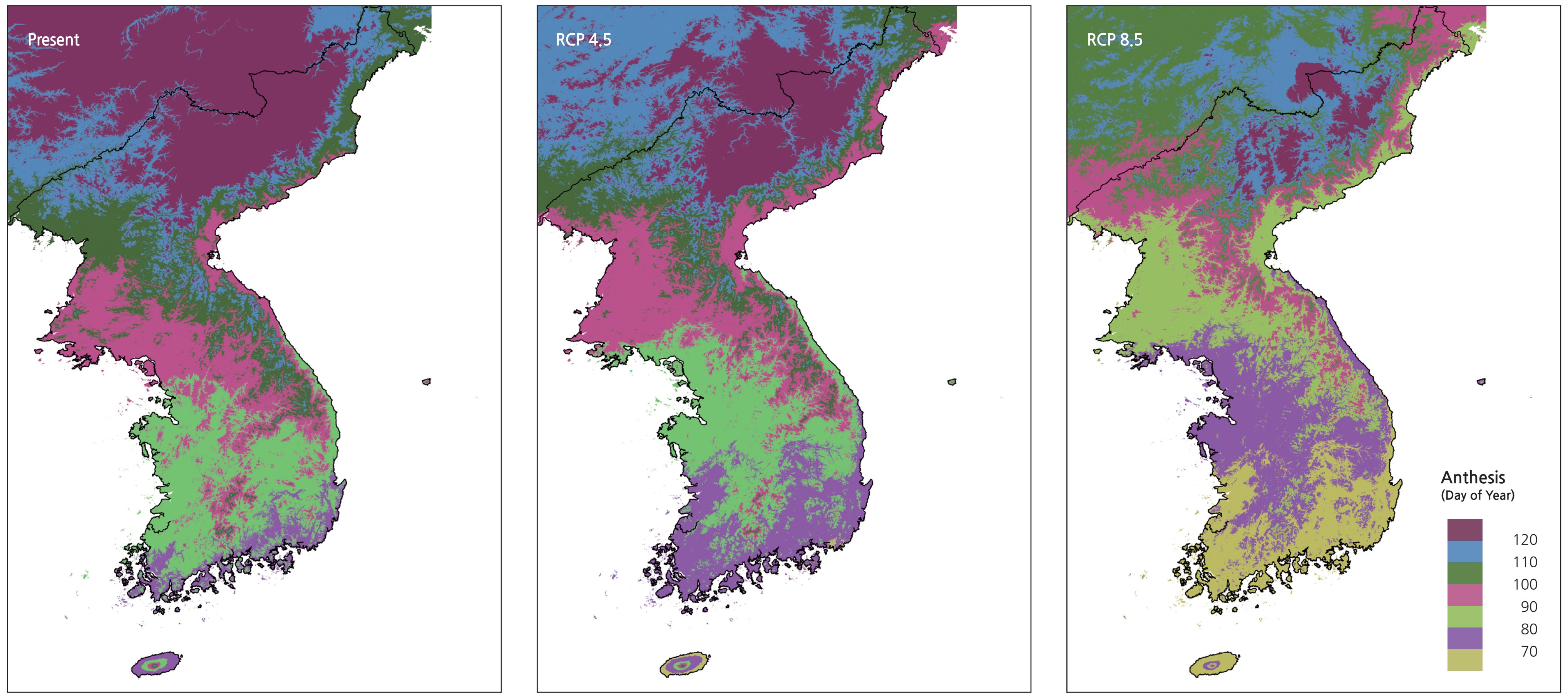
National Institute of Horticultural and Herbal Science (2010)

Change in Alpine Chinese Cabbage Cultivation Area



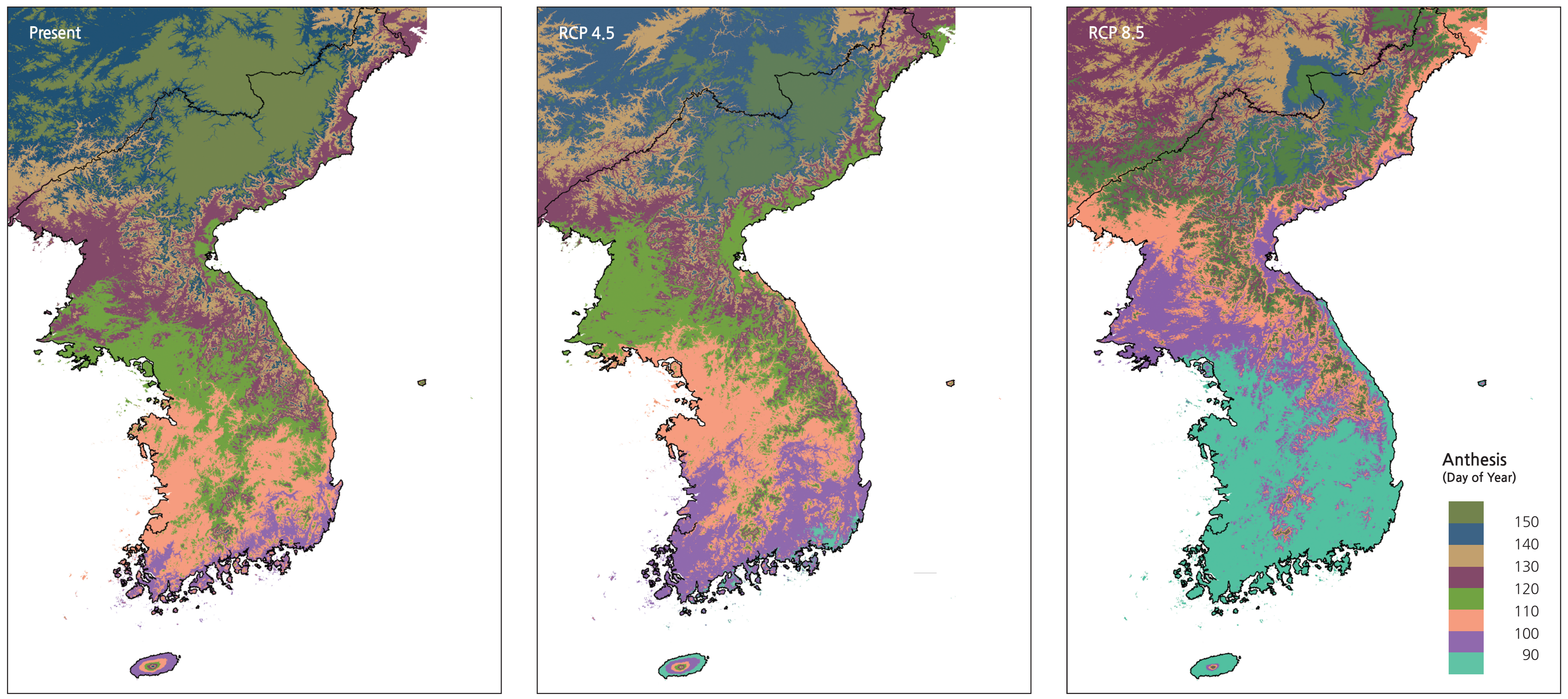
Rural Development Administration (2013)

Rigid-Branch Yew (Taxus cuspidata)



Korea National Arboretum (2012)

Korean Fir *(Abies koreana)*



Korea National Arboretum (2012)

Modeling Geographic Shifts

As the temperature increases, the vegetation zone of the Northern Hemisphere is moving from the south to the north and from lowlands to highlands. An increase by 1˚C is expected to cause a migration of plants of middle latitude by 150 km to the north and 150 m higher in altitude, making it difficult for most plant species to keep up with the speed of climate change. Thus, the chance of extinction or shrinkage of habitat for plants increases. Detection of changes is possible by observing the microclimate, seasonal variations, and physiological changes in plants' blooming and bearing of fruits through long-term monitoring.

Since 2009, the Korea National Arboretum has been implementing an adaptation plan for forest plant species that are susceptible to climate change. The plan, which builds datasets on regional microclimate change, designates 100 vulnerable species that will be physiologically influenced by climate change. They are carefully monitored after classifying them into either northern or southern species. Habitat change and spatial distribution change are predicted as consequences of inter-species competition. Thus, some species may likely become newly endangered because of global warming.

In the case of seasonal variation of plant phenology, the winter bud burst season and leaf unfolding season of rigid-branch yew (Taxus cuspidata) and Korean fir (Abies koreana) are expected to start earlier. Highland plants inhabiting the summits of Hallasan (on Jeju Island), Jirisan (south central), and Seoraksan (east coast) such as Korean fir (Abies koreana), dark-bark spruce (Picea jezoensis), Korean crowberry (Empetrum nigrum), rigid-branch yew (Taxus cuspidata), Khingan fir (Abies nephrolepis), and Korean arborvitae (Thuja koraiensis) are expected to decrease in population. Conservation of northern plants living in isolated environments such as alpine, sub-alpine, islands, and wind holes is becoming an important issue and a necessity. Once again, modeling of these species is based on the IPCC Representative Concentration Pathways (RCP) scenarios (see page 60).

Brief Interpretation of the Maps

The two sets of maps on this page show the anticipated change in when first buds appear and leafing starts in these two species (colors assigned to numbers are number of days after January 1). Each species shows quite different patterns that reflect their growth characteristics. The two sets of differing RCP scenarios are assigned as the results by the end of the century given different assumptions about global warming and socio-political controls of greenhouse gas emissions. RPC 4.6 projects a more conservation global warming effect and RCP 8.5 projects a worst-case scenario.

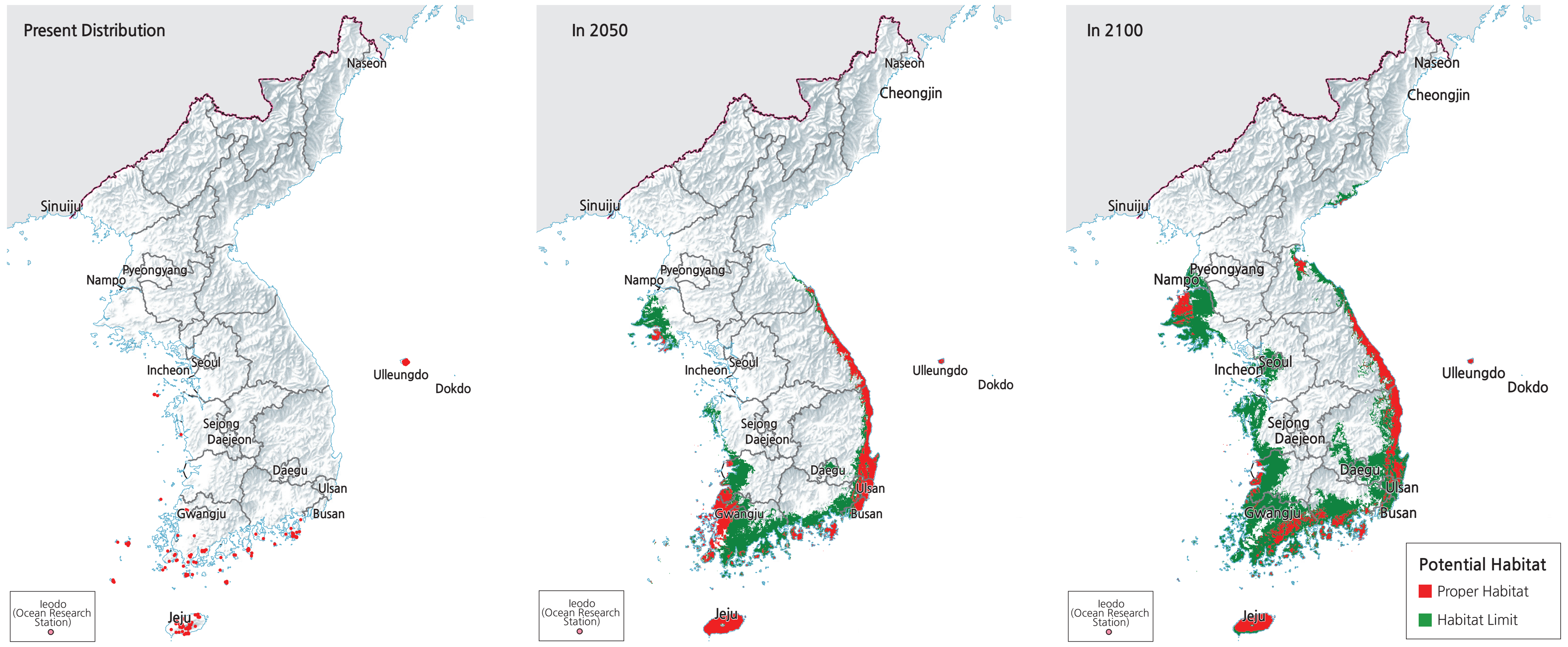
Please note that coloring across the map shows changes in anthesis where the species exists and should not imply that the species covers the landscape. Each species may be represented by relatively isolated groups of trees or concentrated forest stands. This means that the changes shown represent highly variable numbers of trees and a pixel of color may represent a small number of trees that are not representative of the population as a whole in the area. It would be very difficult cartographically to show the anthesis progress only on existing trees. To map the actual affected individual trees would represent a huge expenditure of time in locating the trees for analysis.

For example, a small group of trees in an urban park surrounded by high rise apartments that generate heat on their own may show a different anthesis color date than in a rural setting five km away. This would show a useful difference in average anthesis that would be invisible on a map of this scale. This situation should warn the reader that great detail on a small-scale map does not necessarily mean high precision.

The size of the anthesis color bands is important to give a general rate of progression of the global warming effect. In the Korean Fir RCP 8.5, the below-90 day band is much larger than the next two bands. What does this imply about the speed of annual maturing of the firs? Could this affect the dates of a fir forest being susceptible to lightning-caused forest fires?

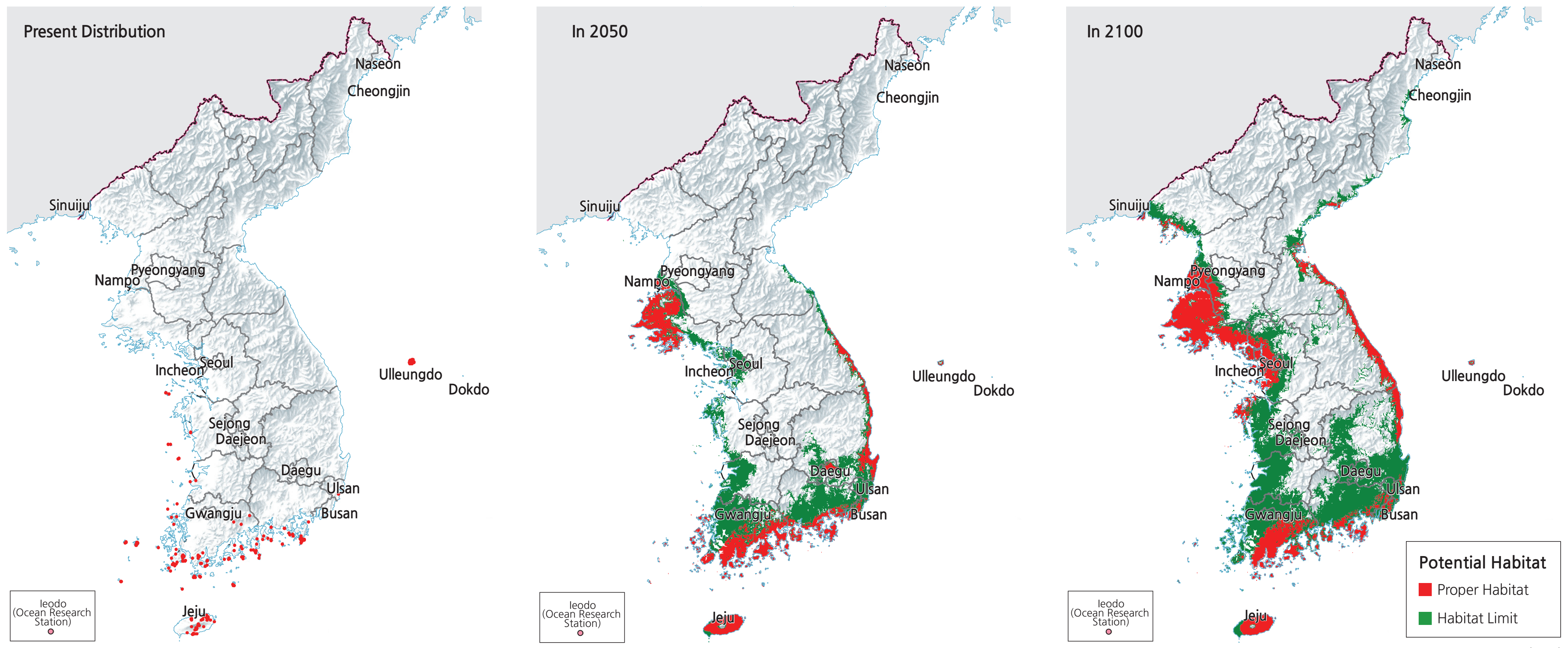
Climate Change

Distribution Change of Japanese Silver Tree (Neolitsea sericea) with Time



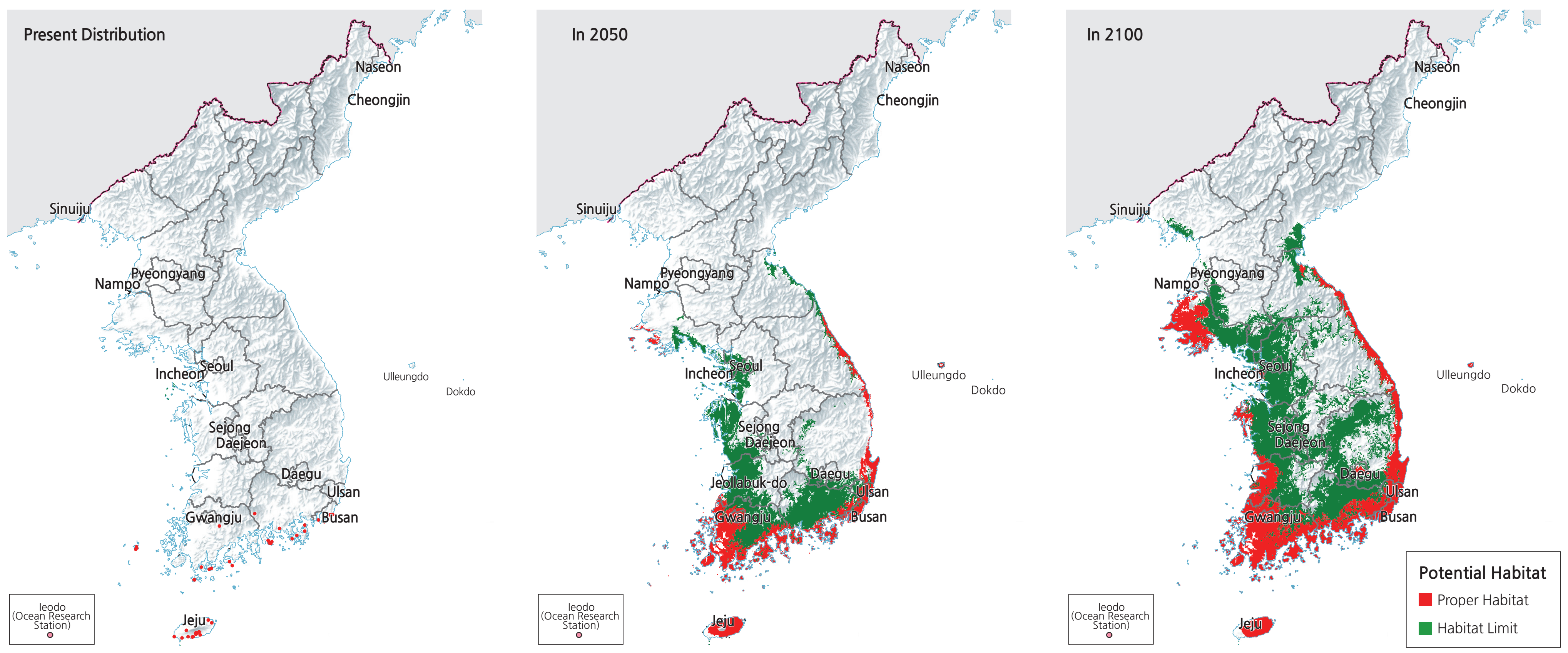
National Institute of Biological Resources (2014)

Predicted Distribution of Japanese Bay Tree (Machilus thunbergii) with Time



National Institute of Biological Resources (2014)

Predicted Distribution of Old World Forked Fern (Dicranopteris linearis) with Time



National Institute of Biological Resources (2014)

Concerns about the impacts of global warming and extreme weather events call for the preparation of adaptive measures against effects of climate change on the biota in Korea. As a result of these required measures, studies on future spatial changes of some species' distributions are being carried out to scientifically analyze and estimate the impacts and risks of such re-distributions. These studies also include the development of predictive habitat suitability maps for species that are Climate-sensitive Biological Indicator Species (CBIS) and candidates for CBIS. Future climate projections are based on Representative Concentration Pathway (RCP) scenarios defined by the Intergovernmental Panel on Climate Change (IPCC).

Japanese silver tree (Neolitsea sericea), Japanese bay tree (Machilus thunbergii), and Old World forked fern (Dicranopteris linearis) are some of the representative subtropical evergreen plants in the southern provinces of Korea. These subtropical species are expected to undergo a nationwide spread in their distribution due to accelerating global warming. Therefore, subtropical species are expected to result in a serious competition with the temperate plants inhabiting the region. Continuous monitoring and long-term research for future prediction are proposed to mitigate the expected damage to the biodiversity in Korea. The results of the study are expected to be implemented in the development of climate change adaptation policies for biodiversity in East Asia and in the establishment of the selection criteria for climate change index species.

Brief Interpretation of the Maps

The nine maps of three evergreen species portrayed on page 66 are labeled "Present," "2050," and "2100." The two future sets of maps are projections made from the RCP scenarios; however, the scenario number that was used in these projected patterns is not supplied as that makes it difficult to assign rates of projected changes to projected years. Ecosystems of specific species are very complicated combinations of environmental conditions. Some species are sensitive to very small changes in one element of those conditions and some can exist under very broad ranges of multiple conditions.

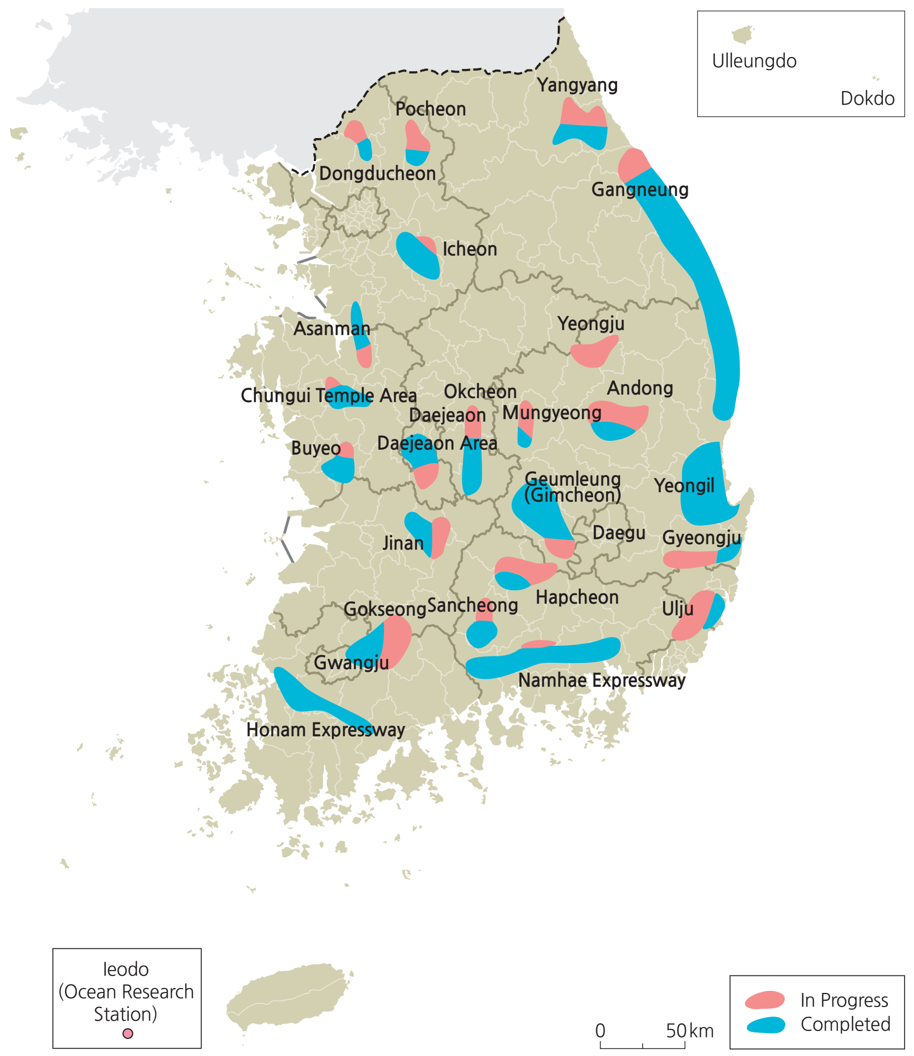
Notice the size of the three evergreen's ecosystems. They exist in very small island areas, but are variable in size even on small Jeju. However, when the size of the potential ecosystem is projected into the future, the evergreens are much larger on the mainland, but that does not mean they will actually occupy the possible environmentally fit areas in those projected years. Projecting the future is a fascinating process but also one that may not become a reality for many unforeseen reasons yet to be understood.

Almost all of the projected "proper" and "limits" habitats on the mainland are contiguous, postulating movement of the species in their habitats. If the first mainland "contact" or "origin" points did not occur in 2040, would that make the species extinct in 2050?

Afforestation

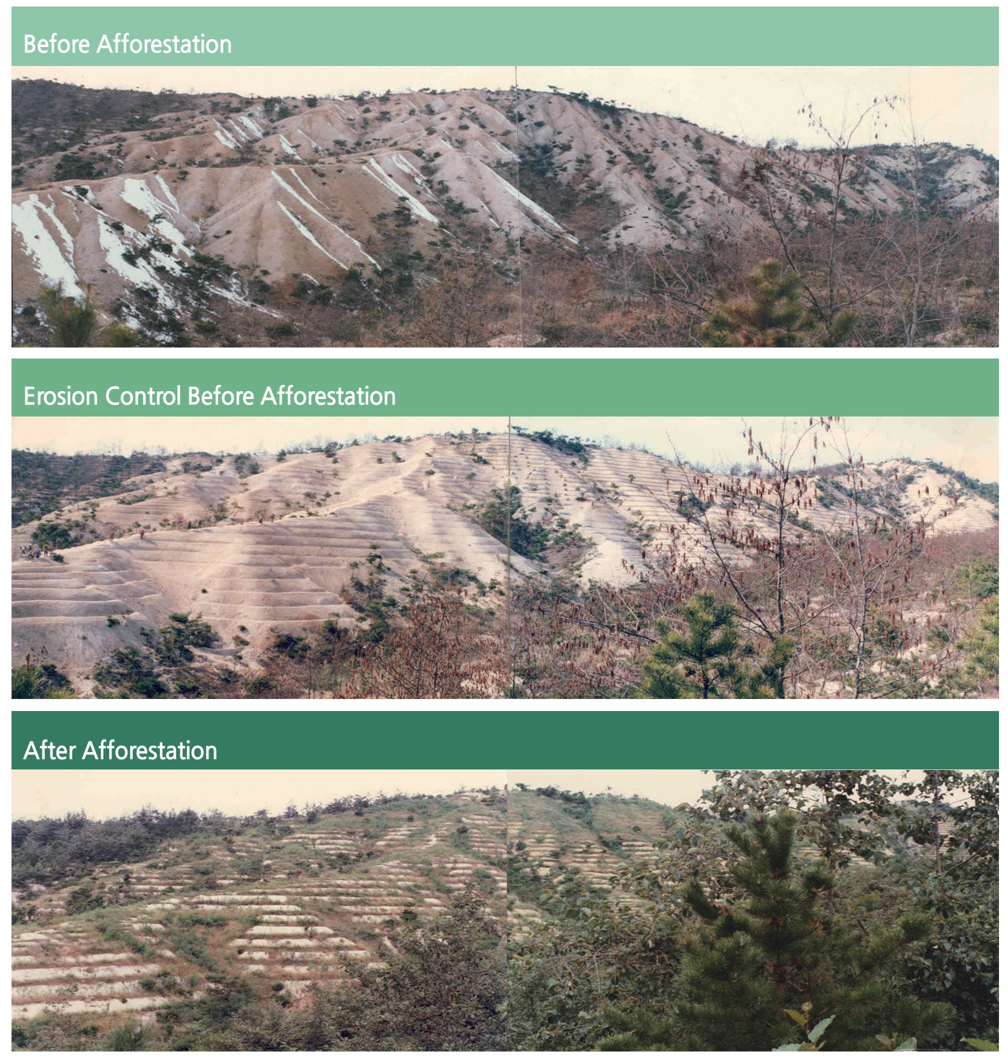
Overcoming Forest Soil Degradation

Major Afforestation Areas



Korea Forest Service (2006)

Example of Afforestation on Devastated Forest Land



Afforestation

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 remedy this situation, an afforestation project was planned and completed for deteriorated forests around Changuimun Gate in 1907. 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 prioritized the recovery of devastated land. Numerous projects for soil erosion control and reforestation were implemented. Planned restorations to remedy such large-scale devastation 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 green projects. Second, the strong social response from people who participated in tree planting and poverty relief activities supported the success of the afforestation projects. Third, the Korea Forest Service, established in 1967, played a critical role in organizing systems and regulations for forestry and planning restoration projects. Lastly, as most of the projects were systemized under the direct control of the government, officials took responsibility and worked hands-on to yield the best results by running operations in restoration fields.

Today, with the advent of climate change that results in global warming and the vast amount of carbon dioxide released into the atmosphere, reforestation is more important than ever before. It is hoped that the success Korea experiences will continue, and serve as a model for other nations to follow.

Brief Interpretation of the Map

The area of South Korea devoted to "complete" and "in progress" reforestation represents a significant percentage of the land area of the country. From the map, this percentage looks like it is approaching 10%, a major commitment to environmental restoration and carbon sequestration. Carbon sequestration is an especially important aspect of the global fight to offset global warming, especially in light of the huge current annual rate of deforestation in Southeast Asia and the Amazon Basin. It is estimated that every growing tree, especially young tropical trees, sequesters or stores 50 pounds of carbon per year that it removes from the atmosphere. Likewise, for every tree lost to deforestation, this amount of carbon still remains in the atmosphere without being removed. Today, 63.2% of South Korea's territory (100,266 square kilometers) is covered in forests. Given that Brazil's Amazon Basin is being deforested at a rate of 5830 square kilometers per year, how many years will it take for South Korea to be totally devoid of trees if deforestation is indeed allowed to take place at the Amazon Basin rate? On the contrary, how many square kilometers of forest can be added with a 10% afforestation in the Korean territory (when totally completed)?