Chapter 35
Republic of South Korea

Dong-Hyuk Kim, Sang-Hyun Lee and Kwang-Su Ryu

35.1 The South Korean National Forest Inventory

35.1.1 History and Objectives

The South Korean National Forest Inventory (NFI) is carried out by the Forest Resource Information Division of the Korean Forest Research Institute. The institute is a division of the Korea Forest Service (KFS). The NFI has been conducted on a regular basis since 1972 at approximately 10 year intervals: NFI1 from 1972 to 1975 (first cycle), NFI2 from 1978 to 1981 (second cycle), NFI3 from 1986 to 1992 (third cycle), and NFI4 from 1996 to 2005 (fourth cycle). In past NFIs, the provincial based inventory results were reported to the KFS at the end of the year. The KFS collates the inventory data and publishes annually the Statistical Yearbook of Forestry.

The purpose of the NFI is primarily to provide basic information on national forest resources. Each year one of the nine provinces are assessed. The provincial basis of field data collection causes some difficulty when producing forestry statistics for the whole country as the NFI can only provide sample based inventory

D.-H. Kim (✉)
Forest Inventory Center, National Forestry Cooperative Federation (NFCF),
Seoul, Republic of Korea
e-mail: dong77n@nfcf.or.kr

S.-H. Lee
Department of Forest Environment Science, Chonbuk National University,
Jeonju, Republic of Korea
e-mail: leesh@jbnu.ac.kr

K.-S. Ryu
Planning and Coordination Bureau, Korea Forest Service,
Daejeon, Republic of Korea
e-mail: r4361@korea.kr

C. Vidal et al. (eds.), *National Forest Inventories*,
DOI 10.1007/978-3-319-44015-6_35

data for one province per year. The periodic nature of the cyclical inventory can be problematic due to fluctuating NFI budgets and the fact that the survey results do not accurately reflect forest dynamics between measurements (Scott et al. 1998). From the early 1990s, NFIs in many countries began to improve by changing from periodic to a continuous annual inventory system to address international demands for forest resource information as well as to monitor and assess national forest resources and ecosystem. Most climate change and forest sustainability agreements require periodic reporting of forest statistics such as national forest area.

In NFI5 (2006–2010) the assessment timeframe of the South Korean NFI moved from a periodic to a continuous annual inventory. The Forest Inventory Center (FIC) conducts the continuous NFI over a 5 year period to obtain precise and up to date data necessary for the formulation of sound forest policies. Due to the robust sampling base and accurate field surveys, the statistics produced have international credibility.

For NFI 6, the re-measurement of permanent plots began in 2011 and is due for completion in 2015. Prior to 2011, the FIC carried out two major assessments of the nation's forest resources: the NFI program and the Forest Health Monitoring (FHM) program. As a result of new legislation and a revised implementation strategy in 2011, these two programs are now being merged, whereby more intensive measurements using the former FHM indicators and methodology are now being applied to a subset of NFI plots.

The FHM program is a national initiative designed to determine the current status, change, and trends in indicators related to forest condition on an annual basis. In South Korea, several sources of forest damage have been identified during the last decades. These include; fire, wind, floodwater, insects, disease and climate change. In most cases, the damage at a national level has not been substantial. However locally, the impact has been severe in some instances. As a result of the sparse monitoring networks, it has been difficult to quantify the magnitude of damage and acquire useful data for mitigation programmes. Therefore, the forest health monitoring data needs to be multi-dimensional. The merging of the NFI and FHM has the potential to provide a comprehensive dataset to describe large forest damage outbreaks.

35.1.2 Sampling Design

Digital map information is used to separate forest land from other land classes, such as arable land, built-up areas, roads, urban areas and single houses (Tomppo et al. 2008). Panchromatic aerial photograph at a scale of 1:15,000 has traditionally been used in forest inventory for the initial assessment of the entire sampling grid and for the identification of plots to be surveyed in the field (FAO 2007). In addition, aerial photos are assessed to determine; forest types, primary tree species, diameter class, age class and crown cover. A digital forest type map is prepared for the whole country. While field plots provide detailed stand information such as volume, tree height, diameter at breast height (dbh), species composition and growth rate, the

forest type maps provide statistics on the area by major forest types. Both volume and forest area data are combined to calculate national forest statistics.

The sampling design adopted in NFI5 uses permanent sample plots for the continuous monitoring of forest resources and ecosystem. About 4000 permanent sample plots are systematically established over the country (Korea Forest Research Institute 2011). The field plot design is based on a cluster plot, consisting of four circular subplots. The subplots 2, 3, and 4 are 50 m away from the subplot 1 at azimuths of 360°, 120°, 240°, respectively (Fig. 35.1).

Circular plots are easy to establish where the radius is not very large, and they are also less vulnerable to errors in plot area. The length of the perimeter increases as the radius increases, however so too will the number of trees on the edge of the plot. Thus circular plots with a large radius are not very efficient (Schreuder et al. 1993; Loetsch et al. 1973). In many cases combined circular plots can be established, i.e. plots that consist of several concentric circles, the smaller circles being used for smaller trees and the larger circles for larger trees (Annika and Matti 2009).

Each sub-plot has a concentric design, consisting of three different plots: a sapling plot of 30 m^2 (3.1 m radius), a small tree plot of 400 m^2 (11.3 m radius), and a large tree plot of 800 m^2 (16 m radius). The sapling plot is used to collect

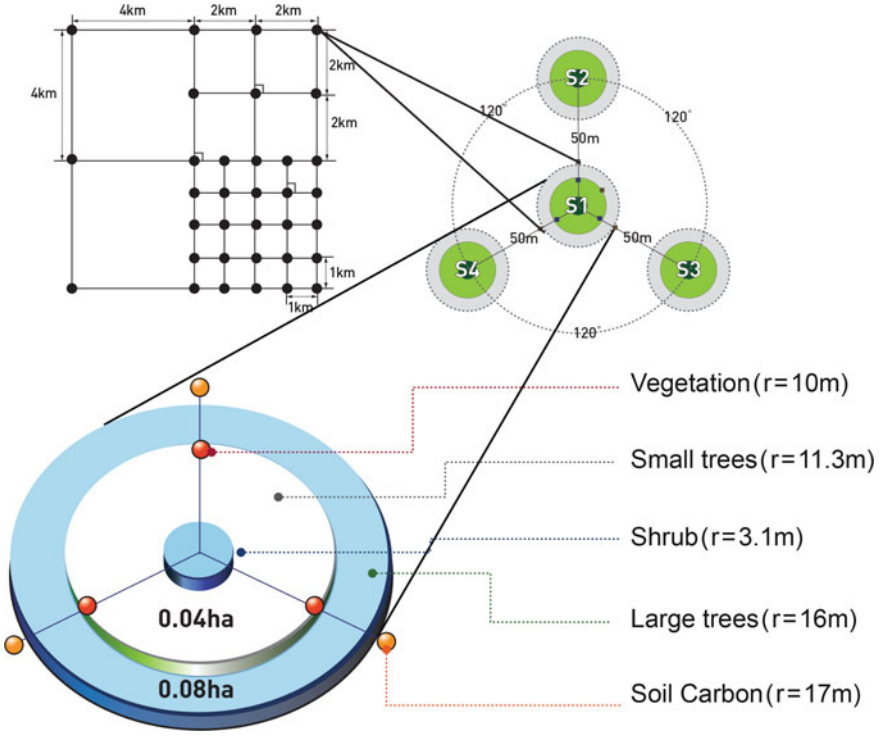

Fig. 35.1 South Korean NFI sampling design

data on trees with dbh less than 6 cm; the small tree plot assesses tress greater than 6 cm and large tree plot assesses trees with a dbh of more than 30 cm. In the new inventory system 25 % of the sample plots are permanent for the purpose of forest health monitoring. The centre sub-plot only contains six micro plots, three vegetation plots and three soil carbon plots, each with areas of 1 m^2. The centre of the micro plots are located at a distance of 10 and 17 m from the plot centre, on three lines radiating from the plot centre. These micro plots are only established on the 1000 permanent sample plots that are systematically sub-sampled from the total permanent sample plots for Forest Health Monitoring (Fig. 35.1).

35.1.3 Data Collection

During field data collection the following important attributes are assessed; forest type, species composition, diameter at breast height (dbh), age class, stand density, height, crown height, site quality, age class and defects of each sampling plot (Lee et al. 2014). From the data collected secondary attributes are calculated; the number of trees per ha, the basal area, the volume of trees in an area and the economic value of the timber. In particular, the biomass components of all living trees, in addition to the stem, were studied more intensively due to the increasing interest in using biomass as an energy source (Hakkila 1989). Also, the national forest inventory provides an overview of the resources available at a regional and national level, as well as information on the carbon balance of Korea's forests.

35.1.3.1 National Forest Inventory Variables

The field crews determine the location of the subplot geographic centre using GPS receivers. There are a lot of variables assessed on the plot, including; species, dbh, height, growth, soil, mortality, damage, management activity, etc. Additional NFI measurements relate to forest stand condition and site description; and may be grouped into three categories:

1. Forest stand condition
    - Forest type: Conifer, Broadleaf and Mixed forest
    - Crown density: Assessed using a densitometer
    - Stand DBH class: Sapling tree stand (<6 cm dbh), Small tree stand (6–17 cm dbh), Medium tree stand (18–29 cm dbh), Large tree stand (>30 cm dbh)
    - Stand age class: Five sample trees to measure age
    - Forest ownership: National, Public or Private
    - Stand origin: Natural or Artificial
    - Forest land class: Forest practice area i.e. area where forest management is permitted
    - Stand renewal (Afforestation, Natural seeding, Regeneration).

2. Site description
    - Altitude: Altitude measurement at the sample plot centre
    - Slope: Slope is measured from two points (15 m apart), which are generally in the direction of the slope line below the sample plot center
    - Aspect: Aspect is classified into one of eight classes N, NE, E, SE, S, SW, W, NW
    - Topography: Aerial photographs are used to measure the topography
    - Soil: Soil is separately described in terms of depth (0–10, 10–20, 20–30, 30–40, 40–50 cm).
3. For each tree Species (where tree dbh is greater than 6 cm):
    - Live/Dead status: To estimate biomass
    - Diameter: Tree-level dbh data
    - Height: Height is assessed on 10 well-grown trees
    - Crown ratio: Percent of tree height represented by crown
    - Crown class: For example; dominant, co-dominant, suppressed.

35.1.3.2 Forest Health Monitoring Variables

The measurement of FHM indicators can be grouped into Tree Health, Vegetation Health, Soil Health and Atmospheric Health. Each indicator is evaluated, classified and analysed to provide conclusive information on the health of South Korean forests. Additional measurements for FHM relate to forest ecosystem function, condition, and health. These measurements are generally acquired during summer months and may be grouped into four categories:

1. Tree health
    - Crown: Crown health, crown class, crown density
    - Stem: Quality of stem, damage to the stem, damage type and damage severity
    - Defoliation: Damage resulting in the loss of leaves or needles
    - Growth: Stand dynamics.
2. Vegetation health
    - Overstorey: Tree species, species diversity, density, cover cover, number of exotic tree species
    - Understorey: Cover of the herbaceous layer, shrub species, sapling species
    - Forest floor: Thickness of litter on the forest floor
    - Mortality: Mortality (in small tree plot).
3. Soil health
    - Chemical properties: pH, Nitrogen content, Organic content, Available phosphate, Cation Exchange capacity
    - Physical properties: effective soil depth, consistence, humidity.

4. Atmospheric health
   - Lichens; Number of epiphytic and ground lichens.

If multiple factors affecting forest health are identified on a plot, field crews assign tallied trees to the condition class in which they occur and record the necessary information for estimating the portion of the plot that is within each condition.

35.1.3.3 Land Use Information

Forest is defined as land spanning more than 0.5 hectare with trees higher than 5 meters and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. The width of the interpretation area is at least 20 m. It includes areas with bamboo and non-stocked forest land provided that height and canopy cover criteria are met. It excludes land that is predominantly under agriculture, building site, road (national highway, local road, railroad) etc. Forests are divided into stocked forest land, un-stocked forest land and Miscellaneous. Non-forests are divided into residential area, cultivated land, others and Marshy land (Korea Forest Service 2011a).

35.2 Land Use and Forest Resources

35.2.1 Classification of Land

The total land area in South Korea is 10,003,308 hectares with 64 % of forests and 36 % of other land. Between 1990 and 2010, the total land area of South Korea has increased from 9.927 to 10.003 million hectares. The area of stocked forests have slightly decreased with industrialisation and urbanisation after 1990s. However, the unstocked forest and other land have slightly increased over the same period of time (Table 35.1).

Table 35.1 Land area of South Korea (Korea Forest Service 2011b)

Year	Total land area (1000 ha)	Forest (1000 ha)			Other land (1000 ha)
		Sub-total	Stocked	Un-stocked	
1990	9927	6476	6302	174	3451
2000	9946	6422	6268	154	3524
2010	10,003	6368	6171	197	3635

35.2.2 Forest Land Classification

The total forest area of Korea is 6.3 million ha, about 64 % of the total land. In recent decades, Korea has undergone rapid urbanisation and industrialisation which has expedited a population influx into the cities. This has increased the demand in land for factories and housing. This increased demand in land for development has led to a decrease in the total forest area from 1990 to 2010. The forest land area decreased from 6.47 to 6.36 million ha between 1990 and 2010, continuing a slight downward trend in area beginning in the 1990s. The forest areas were predominately coniferous in the 1990s but now the area is more or less equally divided between coniferous, deciduous forest and mixed species forest (Table 35.2).

35.2.2.1 Reforestation

In the 1950s, the forest area was left in a state of extreme devastation as a result of excessive cutting during and after the colonial period of 1910–1945 and the Korean War of 1950–1953. In order to rehabilitate the degraded forests, the government initiated a large-scale reforestation program, and set up a national forest plan, which has been renewed every 10 years from 1973 to present.

In 1973, the first 10-year forest rehabilitation project (1973–1978) was launched and proved to be a turning point in the evolution of forest policy affecting the management of the nation's forests. The main goal of the plan was to restore 1 million ha of forest over a short time period. As a result, this 10-year project was completed in 1978, four years in advance of its target year 1982. During this project, 1.08 million ha of forest land was reforested, representing a significant achievement in the national forest rehabilitation plan.

The Second National Forest Plan (1979–1987) was devised to establish large-scale commercial forests. To achieve this objective, the government initiated various forest policies relating to the; improvement of the national rehabilitation project and forest protection, promotion of forest development fund to support private forest management, grouping and expansion of national forests. Forest conservation projects were also implemented to improve the ecological benefits of forests for society.

The objective of the third national forest plan (1988–1997) was to harmonise the goals aimed at enhancing economic capacity of forests and improving common

Table 35.2 Forest land area (1000 ha) by forest type (Korea Forest Service 2011b)

Year	Total	Conifers	Broadleaves	Mixed	Bamboo Stand	Un-stocked
1990	6476[a]	3079	1389	1810	7.98	174
2000	6422	2711	1666	1885	6.09	154
2010	6369	2581	1719	1865	7.04	197

[a]Un-surveyed area (15,386 ha) is excluded from the total forest land area in 1990

benefits of forests. The plan also aimed to promote the effectiveness of forest management practices. Although the reforestation target was nearly achieved by the end of the second 10-year forest plan, timber supply in Korea was still dependent on imports for about 90 % of the domestic demands.

The primary objective of the Fourth plan (1998–2007) was to establish a foundation for sustainable forest management. Key strategies were included aimed at developing valuable forest resource, fostering a competitive forest industry and enhancing forest health and vitality.

The fifth national forest plan (2008–2017) is the latest government-driven reforestation initiative, and sets out further goals towards the implementation of sustainable forest management in pursuit of maximising forest functions. In particular, the plan highlights the importance of forest functions with respect to climate change. The overall vision of the fifth plan is "to realise a green nation with sustainable welfare and growth" by sustainably managing forests as key resources for strengthening national economic development, land conservation and improved quality of life.

35.2.3 Wood Resources

Korea's forests were devastated in the 1950s due to the Korean War and land use change for industrialisation. The Korean government has made diverse efforts to rehabilitate the forest area. These efforts have resulted in the dramatic increase in the growing stock volume. Forest resources of South Korea have continuously improved in general condition and quality, as measured by increased average size and volume of trees. Tree volume is estimated on those trees that have a dbh of 6 cm or larger. The growing stock volume of South Korea increased from 38.36 to 125.62 m^3/ha between 1990 and 2010 (Table 35.3). Currently estimates of increment and drain are not available. However, following the completion of NFI6 (2011–2015), it will be possible to produce such statistics.

Table 35.3 Growing stock volume of the South Korea by forest type (Korea Forest Service 2011b)

Year	Growing stock per ha (m^3/ha)	Growing stock (1000 m^3)			
		Total	Conifers	Broadleaved	Mixed
1990	38.36	248,426	113,868	64,509	70,048
2000	63.46	407,575	174,941	110,129	122,504
2010	125.62	800,025	336,337	215,369	248,369

35.2.3.1 Commercial Tree Species

Over the last 40 years, comprehensive efforts were made to rehabilitate degraded forests, to expand protected land, and to implement sustainable forest management. About 730,000 ha of degraded land was restored and extensive plantations were afforested on over 350,000 ha by planting about 11 billion trees. This plan has succeeded in restoring forest cover nationwide and is internationally recognised as an exemplary case of forest rehabilitation. Following the large-scale afforestation of plantations and rehabilitation of degraded forests and through natural succession, red pines (*Pinus densiflora*) have become dominant as a pioneer species in natural forests (Table 35.4).

35.2.3.2 Forest Management and Cutting Systems

Following the civil war, excessive and illegal cutting of trees was more severe compared to the levels previously experienced. The Korean Government introduced a policy that legally harvested timber should be marked. However, illegal cutting did not markedly decrease until the 1980s when a prohibition order from entering into forest was introduced (Kim and Kim 2005). Between 2005 and 2008, the average annual cutting area was approximately 22,000 ha (Table 35.5). However,

Table 35.4 Commercial tree species for NFI5 (2006–2010) (Korea Forest Promotion Institute 2013)

Tree species	Area (1000 ha)	Growing stock (1000 m^3)
Red pine (*Pinus densiflora*)	2220	317,839
Korean pine (*Pinus Koraiensis*)	235	25,240
Japanese larch (*Larix leptolepis*)	280	44,303
Pitch pine (*Pinus rigida Mill*)	313	40,065
Japanese cedar (*Cryptomeria japonica*)	14	2891
Japanese cypress (*Chamaecyparis obtuse*)	24	2307
Oak (*Quercus* spp.)	1078	157,235
Total	4164	589,880

Table 35.5 Annual cutting area (ha) of South Korea (Korea Forest Service 2010)

Year	Total	Clear cutting	Selective cutting	Shelter-wood cutting	Other
2005	23,703	15,970	1358	2178	4197
2006	23,349	14,394	805	1042	7108
2007	24,078	15,181	512	1829	6556
2008	22,183	15,079	200	1260	5644
2009	57,677	17,939	1706	811	37,221

the level of cutting increased in 2009 due to the implementation of a new forest policy that focused on increasing the quantity of timber harvested using clear cutting and selective cutting. The policy to increase harvest levels was aimed at stimulating economic growth and promoting environmental benefits from the forests. As the stand age class increases, the cutting area is also expected to increase continuously in the coming years.

35.3 Conclusion

The National Forest Inventory (NFI) produces valuable information on South Korean forests. The NFI program of South Korea has been enhanced by moving from a periodic to annual system from 2006 to assess and monitor the status of forest resources and changes to the forest ecosystem over time. Since 2006, the NFI has undertaken to collect various information for wood resources as well as environmental conditions in forests. National forest statistics are generated for a number of forest variables using NFI data.

Many variables assessed during NFI5 and NFI6 were selected to address specific criteria outlined by the Montreal Process working group for the conservation and sustainable management of temperate and boreal forests and is based on the concept of indicator variables. The indicator variables represent an index of ecosystem functions that can be monitored over time to assess trends. Indicator variables are used to monitor the status of ecological attributes such as vegetation diversity, fuel loading, regional air quality gradients, and carbon storage. The enhanced NFI of South Korea is expected to provide accurate and timely forest information at national level and to satisfy increasing domestic and international reporting requirements. This information is important for the formulation of government policy, public administration, the private business sector, the general public and the research community.

References

FAO (2007) Brief on national forest inventory. NFI. South Korea. MAR-SFM Working paper 27

Hakkila P (1989) Utilization of residual forest biomass. Springer, Berlin, pp 352–477

Kim E, Kim D (2005) Historical changes and characteristics of rehabilitation, management and utilization of forest resources in South Korea. J Mt Scit 2(2):165

Korea Forest Promotion Institute (2013) Assessment of forest resources in Korea. Research Report 31 p (in Korean)

Korea Forest Research Institute (2011) The 5th national forest inventory report, Korea Forest Research Institute, Korea (in Korean)

Korea Forest Service (2010) Statistical yearbook of forestry, Korea Forest Service, Korea, 2010 (in Korean)

Korea Forest Service (2011a) NFI6 Field Manual Version 1.1 (Not published). 17 p (in Korean)
Korea Forest Service (2011b) Statistical Yearbook of forestry, Korea Forest Service, Korea, 2011 (in Korean)
Lee J, Yoon TK, Han S, Kim S, Yi MJ, Park GS, Kim C, Son YM, Kim R, Son Y (2014) Estimating the carbon dynamics of South Korean forests from 1954 to 2012. Biogeosci Discuss 11(3):4368
Loetsch F, Haller KE (1973) Forest Inventory, vol II. BLV Verlagsgesellschaft mbH, München, Germany
Schreuder HT, Gregoire TG, Wood GB (1993) Sampling methods for multiresource forest inventory. Wiley, New York
Scott CT, Köhl M, Schnellbächer HJ (1998) A comparison of periodic and annual forest surveys. For Sci 45(3):433–451
Tomppo E, Haakana M, Katila M, Peräsaari J (2008) Multi-source national forest inventory—methods and applications. Springer, Netherlands