KJOAS

ISSN (Print) : 2466-2402
ISSN (Online) : 2466-2410

REVIEW ARTICLE

Brief history of Korean national forest inventory and academic usage

Byung Bae Park[1], Si Ho Han[1], Afroja Rahman[1], Byeong Am Choi[2], Young Suk Im[3], Hong Seok Bang[4], Soon Jin So[5], Kyung Mo Koo[6], Dae Yeon Park[1], Se Bin Kim[1], Man Yong Shin[7]*

[1]Department of Environment & Forest Resources, Chungnam National University, Daejeon 34134, Korea
[2]Forest Protection Bureau, Korea Forest Service, Daejeon 35208, Korea
[3]Forest Recreation and Healing Division, Korea Forest Service, Daejeon 35208, Korea
[4]Forest Environment & GeoSpatial Technology Research Institute, Daejeon 34070, Korea
[5]Korea Forestry Promotion Institute, Seoul 07570, Korea
[6]Korea Mountaineering Support Center, Daejeon 34413, Korea
[7]Department of Forest, Environment, and System, Kookmin University, Seoul 02707, Korea

*Corresponding author: yong@kookmin.ac.kr

OPEN ACCESS

Citation: Park BB, Han SH, Rahman A, Choi BA, Im YS, Bang HS, So SJ, Koo KM, Park DY, Kim SB, Shin MY. 2016. Brief history of Korean national forest inventory and academic usage. Korean Journal of Agricultural Science 43:299-319.

DOI: http://dx.doi.org/10.7744/kjoas.20160032

Editor: Ju Hyoung Lee, Yeungnam University, Korea

Received: August 19, 2016

Revised: September 13, 2016

Accepted: September 19, 2016

Abstract

The National Forest Inventory (NFI) is important for providing fundamental data for basic forest planning and the establishment of forest policies for the purpose of implementing sustainable forest management. The purpose of this study is to present the development of Korea's NFI including legal basis, sampling design, and measured variables and to review the usage of NFI data. The survey methods and forestry statistics among the Unites States, Canada, Japan, China, and European countries were briefly compared. Total 140 publications utilizing NFI data between 2008 and 2015 were categorized with 15 subjects. Korea has conducted the NFI 6 times since 1971, but only the 6th NFI is comparable with the fifth, the previous NFI, because the permanent sampling plots have been shared between the periods. The Korean Forestry Statistics contains only half as many variables as that of advanced countries in Forestry. More researches were needed to improve consistent measurement of diverse variables through implementation of advanced technologies. Additional data for Forest Health Monitoring since the NFI 6th must be under quality control which will be an essential part of the inventories for providing the chronological change of forest health.

Keywords: forest health monitoring, Korea forest service, natural resources, periodic survey, sustainable forest management

Introduction

In order for a nation to efficiently manage and preserve its natural resources using scientific methods, the detailed state of the resources and any changes that occur must be surveyed and analyzed periodically. Many countries, including South Korea, have surveyed forest resources with scientific methods suited to the environment in order to generate national statistics, support policy

makers, and maintain sustainable forest management. Furthermore, various intergovernmental organizations (IGOs) and treaties, of which South Korea is a member, require the periodic submission of forest statistics and other related national reports.

The National Forest Inventory (NFI), conducted by the Korea Forest Service (KFS), aims to "survey and evaluate forests nationwide using scientific methods, in order to acquire basic national statistics on forest resources and regularly monitor trends; thereby providing fundamental data for basic forest planning and the establishment of forest policies for the purpose of implementing sustainable forest management" (KFS, 2010). Recently, South Korea expanded the range of variables investigated in field surveys from that of previous surveys, which centered on timber resources, in order to enable the evaluation of multi-purpose forest resources (KFRI, 2014). Using data from the NFI to calculate forest resource statistics and increase utilization will enhance the validity of the NFI. This requires expert knowledge about the forest resources statistics; required by the IGOs and treaties as well as case studies from overseas including countries with advances in forestry. These countries have implemented systematic national forest inventories and calculated diverse forest statistics, having adapted their survey systems to generational changes.

The purpose of this article is to describe the development of Korea's NFI and summarize its academic uses. Comparing the survey systems and state of forest resource statistics to countries with advancements in forestry would contribute significantly to qualitative improvements to Korea's NFI. To this end, survey methods and forestry statistics among the Unites States, Canada, Japan, China, and European countries, such as Germany and Finland, were briefly compared. The uses of NFI data were analyzed: various studies collected from journal articles, conference papers, theses, and research reports between 2008 and 2015 within domestic universities and related research institutes.

Development of NFI in South Korea

In South Korea, the Division of Forest Resources Information, Korea Forest Research Institute (the name was changed into "National Institute of Forest Science") carried out national forest inventory under Korea Forest Service (FAO, 2007c). The main objectives of forest inventory is to estimate the present state and the changing trends of national forest resources (Kim et al., 2015). Additional purposes of forest inventory are to measure the volume, biomass, carbon stocks and characteristics of trees and stands including forest land area (Kim et al., 2008). From 1971, South Korea conducted national forest inventory 6 times with a time interval. The 2^{nd}, 3^{rd}, 4^{th} and 5^{th} inventory was done in the period of 1978 - 81, 1986 - 92, 1996 - 2005 and 2006 - 2010 (Table 1). Last one is done from 2010 - 2015 (FAO, 2014).

At the fifth NFI, a change in inventory system was created (FAO, 2014): At the 4^{th} NFI, forest inventory was conducted for 10 years, but from the fifth inventory (2006 - 2010) 5 years interval was implemented. In new system, 20% of permanent plot through the country was inventor every year (Kim et al., 2008).

The legal basis of Korea's NFI

The Korean NFI is conducted on the basis of Article 32 ('Surveys of Forest Resources'), Clause 1 of the Creation and Management of the Forest Resources Act, which states that "the Minister of the Korea Forest Service shall survey forest resources on a regular basis, as prescribed by Ordinance of the Ministry of Agriculture, Food, and Rural Affairs," and that "the Minister of the Korea Forest Service shall publish the results of [these] surveys." Furthermore, in the Enforcement Regulations for the Creation and Management of Forest Resources Act, the following specific regulations

Table 1. The development of Korea's NFI since 1971.

Phase	Years	Sampling design	Number of plots	Shape of plot
1st	1971 - 1975	Stratified systematic sampling	7,051	Circular
2nd	1978 - 1981		4,839	Circular
3rd	1986 - 1992		14,474	Cluster
4th	1996 - 2005		2,788	Cluster
5th	2006 - 2010	Systematic sampling	14,164	Cluster and multiplex circular
6th	2011 - 2015		16,280*	Cluster and multiplex circular

*The number of sampling cluster is 4,070. One cluster is composed of 4 circular plots.

are included:

Article 1 (National Forest Inventory)

- In accordance with the regulations in Article 32, Clause 1 of the act, the nation's forest resources shall be surveyed every five years.
- The content of the surveys prescribed in Clause 1 includes the following: herbaceous vegetation survey, shrub/sapling survey, survey of forest damage, including dead and felled trees, survey of timber resources, soil survey, and other articles considered necessary by the Minister of the Korea Forest Service.
- Requirements for the survey prescribed by Clause 1, including survey methods, shall be determined by the Minister of the Korea Forest Service.

Sampling design of Korea's NFI

The 5th NFI, which began in 2006, resulted in data collection from sample points that were allocated by hierarchical clustering. The country was divided into 4 × 4 km squares and a sample point was placed at each intersection on the grid. The design included the flexibility to acquire sufficient sample points, such as using a 2 km or 1 km grid in large cities, where it is difficult to acquire a suitable sample point because of the lack of forest area. Sample points were only selected when the intersection of the grid landed on a forested region, and this hierarchical sampling method was used to allocate approximately 4,000 sample points across the entire country (FAO, 2007c).

From each sample point centered on an intersection, identical sample points were allocated at a distance of 50 m in three directions (true north, 120°, and 240°), such that each cluster consisted of a total of four sample points (Kim et al., 2008).

Measured variables in Korea's NFI

The 5th NFI consisted of 32 measured variables. In the 6th NFI, the Forest Health Monitoring (FHM) survey was integrated at the same sample points, causing the number of measured variables to increase to 52. In 2013, additional categories of rock exposure, state of erosion, soil consistency, soil moisture, and organic layer thickness were added to the FHM survey resulting in 59 measured variables.

The Korea's forest health monitoring

Forest health refers to the healthy and diverse maintenance of the forest ecosystem to promote its ecological function.

In order to analyze and evaluate changes in forest ecosystems for healthier forest management, Korea legislated Article 19 of the Forest Protection Act in October 2010, thereby providing a legal basis for diagnosing and evaluating forest health and vitality.

The purpose of the FHM is to collect objective data regarding the current state of and potential trends in the health of the Korean forest ecosystem, and to explore countermeasures based on the analysis and evaluation of patterns of weaknesses in forest health.

As mentioned above, the FHM has shared some of sample points with the 6th NFI since 2011, which implies that the survey is being conducted systematically across the whole country. However, only the central sample point (S1) was investigated in the FHM (Fig. 1).

Five variables are measured for only assessment of FHM, constituting 12 indicators in four categories of 'tree health,' 'vegetation health,' 'soil health,' and 'atmospheric health.' Lower strata vegetation was surveyed in a 2 × 2 m survey area. The coordinates of target standing trees were measured within the central sample point (S1).

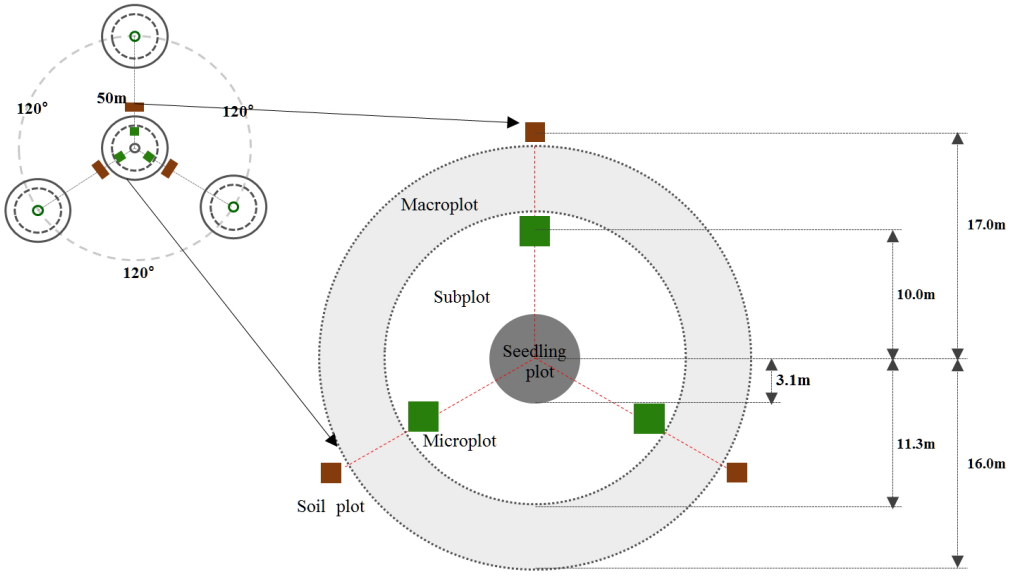

Fig. 1. Plot diagram of Korea's NFI 6th.

The state of NFI in other countries

United States

Led by the USDA, the Forest Inventory and Analysis (FIA) is conducted from four regional centers across the United States with the goal of conducting surveys and statistical analysis for the nation's forest resources. The US National Forest Inventory is repeated every five years, reporting on the current state of forest resources, previous usage, future prospects, and supply and demand of renewable resources (Table 2).

US congress established national forest inventory by the McSweeney-McNary Act of 1928 for estimating the national and regional timber supply (Zeng et al., 2015). FIA research program has been in continuous existence since mandated by Congress in 1928. FIA program has been monitoring and reporting on status, condition, and trends in the nation's forests for over 70 years and FHM program for the last 11 years (Smith, 2002). First 50 years forest inventory

Table 2. The comparison of sampling design for national forest inventory among selected countries.

Country	Sampling parameters			
	1st year of inventory	Survey interval (yr)	Sampling distance (km)	Plot shape
Korea	1971	5 (Since 5th NFI)	4	Cluster and multiplex circular
United States	1928	5	1 - 22 (depending on the phase)	Circular
Canada	1951	10	20	Circular
Japan	1999	5	4	Circular
China	1973	5	2 - 8	Square, rectangular, circular
Europe	1900	Depending on the countries	5 - 20	Depending upon the countries

by FIA estimated the timber resources (Van-Hooser et al., 1992; Powell et al., 1993).

Since the 1930s, FIA has provided 225 state wide forest inventories; seven national assessments (USDA, 1958, 1965, 1973, 1982; Waddell et al., 1989; Powell et al., 1993; Smith et al., 2001); two national biomass studies (USDA, 1981; Cost et al., 1990); two national private forest land ownership studies (Birch, 1996); a national satellite forest cover map of the USA (Zhu and Evans, 1994); hundreds of primary mill, utilization, and residential fuelwood studies (Smith, 1991; May, 1998); over 300 reports on non-timber issues (Rudis, 1991).

Three phase sample design has been used: 20% of the field samples are measured annually, with a completion of a measurement cycle every 5 years. Each sample plot is randomly located inside a matrix of non-overlapping hexagons (approximately 2,400 ha per hexagon) (Magnussen et al., 2007). Common sampling approaches- double sampling for stratification are used for data collection.

In 1999, FIA and FHM fully integrated the detection monitoring plots of FHM into the FIA program. These plots became Phase 3 of the enhanced FIA program. Approximately 8,000 Phase 3 plots are located in whole country (Smith et al., 2001). Plots are measured rotationally every year. Depending on the state the remeasurement cycle is 5 - 10 years (Zeng et al., 2015).

Canada

First national forest inventory in Canada was carried out in 1951 (Paille, 2013). Questionnaires based inventory was conducted before 1981. After 1981, national inventories were done by sampling methods (Gills et al., 2005). After that in 1986 NFI gave information about productivity, size and volume of a species, in 1991 NFI includes all major forest areas across the country and in 1994 NFI gave information about water bodies. Canadian Forest Inventory Committee (CFIC) create a new approach for national forest inventory. This committee applied a new design that was using plot based design consisting of permanent unit. NFI programmed to estimate the state, sustainability and health of forest in 10- to 20-year cycles (Power et al., 2001; Gills et al., 2005).

A sample design was described in *A Plot-based National Forest Inventory Design For Canada* (Natural Resources Canada, 1999). First, it build a systematic network of plots in Canada and then stratified the sampling plot within terrestrial ecosystem with varying strata. After that, photo plots lies on permanent plot and also estimate the ground

sample plot (Gills, 2001; Gills et al., 2005). Plot size vary in shape and size but the attributes should be same and sampling intensity is 20 × 20 km (Gills et al., 2005). All the sample location are within 4 × 4 km network in whole country. National forest inventory plots are permanent but data is collected from photo and ground plot (Gills, 2001). Permanent photo plots have 2 × 2 km sample grid located in each sample plot. Photo plots provide basic data and use to estimate 1% of sample mass. Approximately 18,850 photo plots (1:53,000 ha) are present in forested area (Gills et al., 2005). Ground plot measured synchronizing with photo plot and provide detailed data. 50 ground plots are located in each ecozone (Gills, 2001).

Japan

In 1897, a forest law regarding with establishment of nationwide protection system was created. After that on 1900, a survey was conducted in 1905 to estimate the forest resources. In 1990 - 2000 total national land area was estimated (FAO, 2007b). Japan conducted preliminary monitoring of forest resources for three years from 1991 to 1993. Based on this, they have conducted a national forest inventory at five-year intervals from 1999 to the present. The Japanese National Forest Inventory is managed by the Japan Forest Technology Association (JAFTA), whereas field surveys are the responsibility of approximately 14 companies in the forest industry.

The purpose of inventory is to evaluate the various aspects of forest throughout the country (Kitahara et al., 2009). Japan used two types of forest inventory system: first inventory is conducted by forest law, require forest planning system and another is to monitoring forest resources (Hirata et al., 2006). Every five years national and sub national inventories are conducted in Japan (FAO, 2007b).

From 1999 systematic sampling design is used in Japan. Sampling design is applied with 4x4 km ground grid. Total number of sample plot is 15,675. Every sample plot is composed by three overlapping subplots which are of different radius (FAO, 2007b). Each plot consists three concentric ring with various diameter of 5.64 (0.01 ha), 11.28 (0.04 ha) and 17.84 m (0.1 ha) (Kitahara et al., 2009). Remote sensing was also used in Japan from 1960s within the forest register system (FAO, 2007b). The main purpose was to classify the forest type (Hirata et al., 2006). In 2006 remote sensing was used in NFI with a view to estimate the forest boundaries (FAO, 2007b).

The results of the National Forest Inventory are used to calculate the forest resource statistics required for the compilation of the Statistical Yearbook for the forest industry and the Montreal Process report. Japan's Statistical Yearbook for the forest industry consists of a total of 190 variables in the eight categories of 'national economy,' 'forest resources, maintenance, and preservation,' 'forest industry,' 'forest production,' 'timber production,' 'finance,' 'overseas forests and forest industry,' and 'other.' This means they measure twice as many variables than does South Korea, with the main difference being that Japan's Statistical Yearbook includes various sociological statistics related to the forest industry.

China

The first inventory was carried out from 1973 - 1976 in China with the help of Ministry of Forestry. The purpose was to estimate the micro change in forest land and also the volume of forest. After 1973 NFI was carried throughout the country with five years interval (FAO, 2007a). Until now eight NFI was conducted in China: the periods are 1973 - 1976 (first), 1977 - 1981 (second), 1984 - 1988 (third), 1989 - 1993 (fourth), 1994 - 1998 (fifth), 1999 - 2003 (sixth), 2004 - 2008 (seventh) and 2009 - 2013 (eighth). China includes three stages of forest inventory systems: the National

Forest Continuous Inventory (NFCI); the Forest Management Planning Inventory (FMPI); and the Forest Operation Design Inventory (FODI) (Xie et al., 2011).

From first inventory, China used a systematic sampling design (FAO, 2007a) and a parameter field plot. Commonly two dimensional sample grid is used but sample grid varies from province to province (Zeng et al., 2015). Plot size is varied from 2 × 2 km to 8 × 8 km and approximately 415,000 fixed ground plot was established in 7th NFI across the whole country (FAO, 2007a). Plots shape also varies such as square, circular, and rectangular. More than 90 % of the provinces used square plots, but Tibet used circular plot, while rectangular plots are used in inner Mongolia and in one sub-population of Heilongjiang (Zeng et al., 2015). Sample plots are systematically laid out on the grid dots of topographic maps (scale 1:50,000) (FAO, 2007a).

Remote sensing is used in forest inventory at the middle of 1950s (Zeng et al., 2015). Remote sensing is using to know the geo-spatial distribution of forest and also to prevent biased estimation of field measurement (FAO, 2007a). 1:500,000 scale and aerial photos of small scale were used to determine forest area (Zeng et al., 2015). Remote sensing plot is set with equal distance systematic sample and the distance is mostly less than 2 × 2 km (FAO, 2007a).

Europe

In Europe first forest inventory was conducted on 14th and 15th century. In 19th century forest inventory was started to use as a tool for forest management. On that time only data was gathered but there was no statistical analysis. The purpose of national forest inventory was to provide information regarding timber resources, forest land and type for forest authorities, timber users, and planners (Zeng et al., 2015). Different countries have different purposes for forest inventory.

Lund (2009) reported that Norway started its first national forest inventory on 1910s. Whereas Sweden started its NFI on 1923 (Fridman et al., 2014). In the late 1940s in the German Democratic Republic; in 1958 in France; in the 1960s in Austria; and in the 1980s in Switzerland national inventory was conducted (Zeng et al., 2015). The Austrian National Forest Inventory (AFI) started in at 1961 with a systematic grid and a period of 10 years (Schadauer et al., 2005). European national forest inventory has been carried out since 1993 (Bastrup-Birk, 2010). It has five regional office (Spain, Germany, France, Croatia and Sweden) and three projects center. The time interval for inventory depending on the countries requirements (Zeng et al., 2015).

Germany's first systematic survey of the nation's forest resources was conducted in West Germany, before unification, from 1986 to 1990. A national forest inventory with statistical samples taken from the entirety of Germany was conducted for two years from 2001 to 2002, and will be conducted every 10 years thereafter, with the 3rd National Forest Inventory recently completed. The German National Forest Inventory is led by the Federal Research Institute for Rural Areas, Forestry, and Fisheries and state forestry research institutes. The Federal Research Institute gathers data that have been collected from surveys across 16 states, analyzes these data, and compiles the National Forest Inventory Report.

The German National Forest Inventory Report is characterized by a large number of statistical variables related to forest changes, which allows them to make forecasts about future changes. A total of 168 detailed statistics are reported for 16 categories, with 51 of the detailed statistics relating to change in area, timber stocks, harvest-related variables, and forest damage.

Finland's 1st National Forest Inventory began in 1921 (Tomppo et al., 1999), and in 2011, they began the 11th

National Forest Inventory. The Finnish Forest Research Institute (METLA) is the lead organization responsible for field surveys and statistical analysis. Based on these data, the 'Forest Resources' section of the Finnish Statistical Yearbook of Forestry is revised every year.

The Finnish Statistical Yearbook of Forestry contains 201 statistics in the categories 'forest resources,' 'forest biodiversity and health,' 'silviculture,' 'roundwood trade,' 'removals and transportation of roundwood,' 'multiple-use forestry,' 'forest sector labor force,' 'wood consumption,' 'energy,' 'forest industries,' 'foreign trade by forest industries,' 'forest sector in Finland's national economy,' and 'international forest statistics.' This is the most diverse collection of forest statistics among countries with advanced forest industries, taking a broad interpretation of the scope of forest industry and providing statistics that treat forest-derived industries as part of the forest sector.

The forest statistics of advanced countries in forestry include diverse statistical variables related to the entire industry including forest resources. However, the Korean Statistical Yearbook of Forestry contains only half as many variables as that of Japan and Finland, and there are fewer variables related to forest resource statistics. Those forest resource statistics that are included in the yearbook primarily relate to forest area and timber stocks, but more detailed information needs to be collected.

Finland includes trends in their statistics in addition to the current state of the forest area and timber stocks, as well as statistics relating to growth volume and rate. The United States and Germany are also not limited to the current state of variables but also describe forecasts. In South Korea, because the 6th NFI is comparable with the NFI of five years earlier, it should be possible to extract useful information for establishing future forest policies by examining changes in statistical variables over time, as is done in countries with advanced forestry, and predict trends in forest resources based on these changes.

The use of national forest inventory data in academic areas

The outputs of domestic research by using NFI data between 2008 and 2015 were classified into scientific journal articles, conference papers, theses, and research reports. Furthermore, these publications were grouped by subject (Table 3).

Scientific journal articles

A total of 39 articles were published, at an average of 4 - 5 per year. The content of the articles was diverse: including timber stocks, forest growth, forest biomass, forest carbon, thematic maps, statistical methodology in small forest area, and methodology for estimating forest statistics. The majority of articles suggested efficient, scientific methods to enable the calculation of relevant forest statistics based on partial data from specific regions.

Conference papers

A total of 74 conference papers were published, at an average of 9 per year. The subjects covered were more diverse than journal articles: including timber stocks, forest growth, forest biomass, forest carbon, forest vegetation, statistic methodology in small forest area, methodology for estimating forest statistics, thematic maps, stand density, dead trees, site index, survey methodology, forest health, and forest changes.

Table 3. The current state of research utilizing national forest inventory data.

Subject	Classification				Total
	Scientific journal papers	Conference papers	These	Research reports	
Timber stocks	Han et al., 2010b Kim and Kim, 2015 Kim et al., 2014c Park et al., 2012b Seo et al., 2015a Yim et al., 2011h Yim et al., 2012a Yim et al., 2012d	Chung et al., 2009d Han et al., 2011b Han et al., 2012 Nam et al., 2013 Yim et al., 2010a Yim et al., 2011e Yim et al., 2012b Yim et al., 2012c	Jang, 2012 Nam, 2013	-	18
Forest growth	Byun et al., 2010a Choi et al., 2014a Kim et al., 2014b Seo et al., 2009b Seo et al., 2011 Shin et al., 2008b	Byun et al., 2010b Choi et al., 2014b Han et al., 2009 Jang et al., 2011 Kim et al., 2009a Ko et al., 2012 Ko et al., 2013a Ko et al., 2013b Ko et al., 2014 Lee et al., 2009a Lee et al., 2009b Lee et al., 2011a Lee et al., 2011b Lee et al., 2012 Lee et al., 2013a Lee et al., 2013b Namgung et al., 2014 Nor et al., 2011 Seo et al., 2009a Seo et al., 2010 Shin et al., 2007 Shin et al., 2008c Shin et al., 2011	Byun, 2011 Choi, 2014 Kim, 2015a Park, 2011	KFS, 2012b	34
Forest vegetation	-	Choi et al., 2013 Jung et al., 2011c Jung et al., 2013a Kim et al., 2011c Song et al., 2009 Song et al., 2011	-	-	6
Forest carbon	Jeong et al., 2013 Jung et al., 2010b Jung et al., 2013b Kim et al., 2014a Kim et al., 2015 Lee et al., 2015a Lee et al., 2015b Lee et al., 2015c Park et al., 2012a	Kim et al., 2009b Kim et al., 2012a Kim et al., 2013a Kim et al., 2013b Lee et al., 2010 Nam et al., 2012 Yim et al., 2010c Yim et al., 2011a Yim et al., 2011b Yim et al., 2011c	Jeong, 2013 Kim, 2012 Kim, 2015b Lee, 2012 Pyo, 2013 Seo, 2013a Shin, 2012a	KFS, 2012a	27

Table 3. The current state of research utilizing national forest inventory data (Continued).

Subject	Classification				Total
	Scientific journal papers	Conference papers	These	Research reports	
Forest biomass	Chung et al., 2009a Jung et al., 2014 Kim et al., 2011b Kim et al., 2013c Kim et al., 2014d Shin et al., 2013 Son et al., 2014 Yim et al., 2009b	Chung et al., 2009b Kim et al., 2011a	Seo, 2013b Shin, 2012b	-	12
Statistical methodology in small forest area	Yim et al., 2010b Seo et al., 2015b	Han et al., 2011a Hwang et al., 2009 Jung et al., 2011a Jung et al., 2011d Kim, 2013a Kim and Lee, 2013 Shin et al., 2008a	Han, 2011	-	10
Estimating forest statistics	Lam et al., 2013	Han et al., 2010a Han et al., 2011c Jung et al., 2011b Park et al., 2011 Yim et al., 2009c Yim et al., 2011g	Hwang, 2009	KFS, 2010	9
Thematic maps	Jung et al., 2010a	Chung et al., 2009c Kim et al., 2012c Yim et al., 2011f	-	KFRI, 2014	5
Site index	-	Choi et al., 2012b	-	-	1
Survey methodology	-	Kim, 2013b Yim et al., 2009a Yim et al., 2011d Yim et al., 2013b	-	-	4
Forest changes	Chun et al., 2015a Chun et al., 2015b Yim et al., 2015a Yim et al., 2015b	Yim et al., 2013a	You, 2015	KOFPI, 2013a	7
Forest resource statistics	-	-	-	KFRI, 2011 KFS, 2014a KFS, 2014b KOFPI, 2013b	4
Forest health	-	Choi et al., 2012a	-	-	1
Dead trees	-	Namgung and Jeong, 2012	-	-	1
Stand density	-	Kim et al., 2012b	-	-	1
Total	39	74	18	9	140

Theses

Of the 18 total theses, master's theses were double of those of doctorate theses. The most common subject matter was forest carbon, occurring in seven theses, followed by forest growth, timber stocks, and forest biomass, and finally methodology for estimating forest statistics and statistical methodology in small forest area was the subject of the thesis. Forest carbon and forest biomass are both related to greenhouse gas statistics, and these two fields accounted for eight of the theses, more than half. This is related to the growing interest in estimating carbon storage capacity and carbon absorption in the forest sector in relation to climate change.

Of doctorate theses, three were on the estimation of forest carbon storage capacity and uncertainty, demonstrating the urgency and importance of research in this area. The other doctorate thesis was on methodology for estimating forest statistics. Forest carbon was the most common subject among the master's theses, occurring in three theses, followed by forest growth, forest biomass, and timber stocks, in two theses each. There was also one thesis on methodology for estimating forest statistics. In the future, if data can be accumulated from monitoring surveys at fixed sampling points, research results could be obtained for more diverse fields, such as forest change and forest health assessment. This is expected to diversify the subject matter of theses.

Research reports

Nine reports were related to NFI research projects. Each subject, such as forest growth, forest carbon, methodology for forest statistics, survey method and the change of forest, has been reported. Recently, the suggestion of utilization of NFI data and extended forestry statistics using NFI data were published.

Outputs of researches utilizing NFI data were broadly categorized into 15 areas (Table 3). Journal articles have been published in seven areas, including timber stocks, forest biomass, and forest growth; theses and research reports each deal with six areas of research. In addition, conference papers were concerned with the most diverse subjects, covering 14 out of the 15 areas, with a high number of publications. The most common research area among all publications was on forest growth, with a total of 34 papers, followed by 27 papers on forest carbon storage capacity. Timber stocks, which, together with forest area, is one of the most important items in forest resource statistics, and is covered relatively often, with a total of 18 publications among journal articles, conference papers, and theses, although not among research reports.

In terms of other areas, there were twelve publications for forest biomass, ten for small forest area statistics, and nine for methodology to estimate forest statistics. Similar to forest carbon, forest biomass is related to greenhouse gas statistics, and as such research will be conducted in this area in the future because of the significance of climate change. Methodology for estimating forest statistics dealt with overall measures for calculating forest statistics, including the calculation of small forest area statistics, calculation of annual forest statistics, re-calculation of past forest statistics, and algorithms for calculating individual forest statistics.

Concerning forest health and vitality, research was conducted in the areas of forest vegetation, forest health, and dead trees. A total of five publications, consisting of conference papers and research reports, were found on the compilation of thematic maps that provided information about the spatial distribution of forest statistics.

Although there have been five publications on forest change, because the NFI is repeated every five years at the same sampling points, we expect this area of research to become more active in the future. In particular, analysis of forest change is anticipated to provide information not only on changes in the usage of forestland and in forest type, diameter

structure, and age structure, but also on changes in forest growth, including growth rate.

Application of NFI data

Because the majority of studies have typically been conducted in restricted regions, rather than providing data for the country as a whole, there are tasks that need to be completed in order to use research results in applicable forestry practice. In the case of forest growth estimating the tree diameter, tree height, growth volume, and growth rate by region is an important task; it should be possible to calculate statistics using the NFI monitoring data. At the same time, it would be possible to calculate growth volume and growth rate by region and by tree species.

In the areas of forest biomass and forest carbon, which are related to greenhouse gas statistics, various studies have been conducted on estimating forest biomass, carbon storage capacity, and carbon absorption for different types of forest, as well as employing classifications used in the estimation of timber stock, such as region, forest type, and age class. Therefore, it should be possible to calculate these statistics using NFI data, and it will also likely be necessary to calculate statistics by species.

In the area of forest vegetation, research has been conducted on vegetation distribution, the distribution of dominant species, evaluating species diversity, and classifying types of forest vegetation. If the regional and topographical distribution of forest vegetation were categorized by type, it would be possible to calculate statistics related to the distribution of forest vegetation.

The field of forest health has relatively little research. If more data were accumulated in the future, it would be possible to calculate statistics related to the change of forest health and vitality. In terms of dead trees, it should also be possible to develop dead tree models that could estimate dead trees and their distribution based on NFI sampling point data. Similarly, as described above, because repeated measure is conducted every five years at fixed sampling points, it should be possible to calculate various statistics for forest changes. It will be possible to calculate statistics that enable assessment not only of changes in forestland usage, but also of changes in timber stocks and other forest resources, such as standing tree structure and forest growth.

With regard to thematic maps, studies have been conducted using NFI data to construct maps for the distribution of timber stocks, forest biomass and forest carbon, and species diversity. Although Korea has existing thematic maps for forest type and forest soil, a more diverse array of thematic maps is required, depending on the intended use. If numerous variables could be measured regularly throughout the country, as is done in the NFI, it should be possible to construct various thematic maps that are suited to particular needs.

Conclusion

Korea conducted the national forest inventory 6 times with a time interval from 1971 with legal basis, but the 6^{th} NFI is only comparable with the NFI of five years earlier. Outputs of researches utilizing NFI data have been broadly used in academic area which can be categorized into 15 areas. Although the forest statistics of advanced countries in forestry include diverse statistical variables, the Korean Forestry Statistics contains only half as many variables as that of advanced countries in Forestry.

There could not be overemphasized in the importance of the quality control of NFI data. Although scientists and working groups supported by Korea Forest Service have been substantial efforts to find more efficient sample designs,

get consistent measurement, and implement advanced technologies to measure diverse variables, additional data for FHM since 6th NFI must be under quality control. This will be an essential part of the inventories which can provide the chronological change of forest health. Furthermore, this will be closely related to the indexes of forest ecosystem service and sustainable forest management.

Acknowledgements

We appreciate Tom J. Kim's helpful comments and valuable suggestions to improve our manuscript as well as to correct of English writing. This project was carried out with support of 'Forest Science & Technology Projects (Project No. S211416L010110)' provided by Korea Forest Service.

References

Bastrup-Birk AM. 2010. European national forest inventory network. Forest protection conference.

Birch TW. 1996. Private forest-land owners of the United States, 1994. pp. 64. DIANE Publishing.

Byun JG. 2011. Radial growth model for *Pinus densiflora* and *Quercus* spp. using tree ring and climate data in South Korea. Ph.D. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Byun JG, Lee WK, Nor DK, Kim SH, Choi JK, Lee YJ. 2010a. The relationship between tree radial growth and topographic and climatic factors in Korea. Proceedings of the 2010 Meeting of the Korean Forest Society 2010:437-440.

Byun JK, Lee WK, Nor DK, Kim SH, Choi JK, Lee YJ. 2010b. The relationship between tree radial growth and topographic and climatic factors in red pine and oak in central regions of Korea. Journal of Korean Forest Society 99:908-913.

Choi KM, Jeong JH, Jung DJ, Sung JH, Kim SH, Song YH, Yang YJ. 2013. Ecological characteristics of the forest vegetation by forest health monitoring in Korea. Proceedings of the 2013 Meeting of the Korean Forest Society 2013:299-302.

Choi KM, Jung DJ, Jeong JH, Sung JH, Lee WK. 2012a. Analysis of forest health monitoring using national forest inventory data in Korea. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:645-648.

Choi KM, Kim MI, Lee WK, Chung DJ, Yun BH, Kim CH. 2014a. Estimating the radial growth response of *Quercus mongolica* using climatic and topographic condition in South Korea. Proceedings of the 2014 Meeting of the Korean Forest Society 2014:185.

Choi KM, Kim MI, Lee WK, Kang HU, Cheong DJ, Ko EJ, Kim CH. 2014b. Estimating radial growth response of major tree species using climatic and topographic condition in South Korea. Journal of Climate Change Research 5:127-137.

Choi KM. 2014. Research diameter growth response of major tree species to climatic and topographic condition using tree-ring data of National Forest Inventory. Ph.M. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Choi YJ, Kim DS, Lee DS, Choi JK, Lee WK, Lee YJ, Jung DJ, Kim SH. 2012b. Comparison of forest productivity for *Pinus koraiensis* using information of national forest inventory. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:464-467.

Chun JH, Lee CB, Yoo SM. 2015a. Shifts of geographic distribution of *Pinus koraiensis* based on climate change scenarios and GARP model. Korean Journal of Agricultural and Forest Meteorology 17:348-357.

Chun JH, Lee CB, Yun SJ. 2015b. Effects of climate change on the geographic distribution of *Quercus acuta* Thunb. Journal of Agriculture and Life Science 49:47-57.

Chung SY, Kim JS, Cho HK, Jeong JH, Kim SH, Shin MY. 2009a. Estimation of forest biomass for Muju County using biomass conversion table and remote sensing data. Journal of Korean Forest and Society 98:409-416.

Chung SY, Yim JS, Cho HK, Shin MY. 2009b. Comparison of forest biomass estimation methods by combining satellite data and field data. Proceedings Extending Forest Inventory and Monitoring 2009:114.

Chung SY, Yim JS, Hwang JH, Cho HK, Shin MY. 2009c. Forest biomass estimation and mapping for Muju county using BioCLUST method. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:443-446.

Chung SY, Yim JS, Kim SH, Jeong JH, Lee KH, Shin MY. 2009d. Application of the overlap technique for the recalculation of forest growing stocks of the past in Korea. Proceedings of International Symposium on National Forest Inventory 2009:65.

Cost ND, Howard J, Mead B, McWilliams WH, Smith WB, Van Hooser, DD, Wharton EH. 1990. The biomass resource of the United States. pp. 18. US Department of Agriculture Forest Service,Washington Office, Washington, DC.

FAO 2007a. Forest Resources Assessment 2007 - Country Report-China.

FAO 2007b. Forest Resources Assessment 2007- Country Report-Japan.

FAO 2007c. Forest Resources Assessment 2007- Country Report-Republic of Korea.

FAO 2014. Forest Resources Assessment 2014- Country Report-Republic of Korea.

Fridman J, Holm S, Nilsson M, Nilsson P, Rigvall H, Stahl G. 2014. Adapting national forest inventories to changing requirements- the case of the Swedish national forest inventory at the turn of the 20th century. Silva Fennica 48:1-29.

Gills MD, Omule AY, Brierley T. 2005. Monitoring Canada's forests: The national forest inventory. The Forestry Chronicle 81:214-221.

Gills MD. 2001. Canada's national forest inventory (Responding to current information needs). Environment Monitoring and Assessment 67:121-129.

Han SH, Jeong JH, Shin MY, Yim JS, Jung IB. 2012. Selection of methods for estimation of growing stock volumes in Chungcheongbuk-do based on national forest inventory. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:172-175.

Han SH, Nor DK, Jeong JH, Kim SH, Jung DJ. 2009. Estimation of height-DBH models for *Ulmus davidiana* by national forest inventory data. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:432-434.

Han SH, Nor DK, Jung DJ, Kim SH, Shin MY. 2011a. Comparison of small area estimation by national forest inventory data. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1131-1133.

Han SH, Nor DK, Jung DJ, Kim SH, Yim JS, Shin MY. 2011b. Estimating forest growing stock volume using the *k*-nearest neighbor technique for Chungcheongbuk-do by national forest inventory data. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1106-1107.

Han SH. 2011. Selection of methods for estimation of forest statistics in small area district. Ph.D. dissertation, Kookmin Univ., Seoul, Korea. [in Korean]

Han WS, Kim JC, Kim SH, Jung IB, Shin MY, Yim JS. 2010a. Estimation of annual forest statistics by volume growth rates and moving average. Proceedings of the 2010 Meeting of the Korean Forest Society 2010:417-420.

Han WS, Kim JC, Kim SH, Yim JS, Jung IB, Shin MY. 2011c. Analysis of annual forest statistics per cluster plot and permanent sample plot. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1059-1062.

Han WS, Kim SH, Kim CC, Shin MY. 2010b. Analysis of difference in growing stock volume estimates by the changes of cluster plot design and volume equation. Journal of Korean Forest Society 99:304-311.

Hirata Y, Mitsuo M, Iehara T. 2006. Japanese national forest inventory and its spatial extension by remote sensing.

Hwang JH, Yim JS, Jeong JH, Kim SH, Shin MY. 2009. Estimation of forest statistics for small areas from digital satellite data and national forest inventory data. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:454-457.

Hwang JH. 2009. Method of forest statistics estimation using national forest inventory data. Ph.M. dissertation, Kookmin Univ., Seoul, Korea. [in Korean]

Jang KU. 2012. Comparing the precision of two growing stock volume estimation methods. Ph.M. dissertation, Kookmin Univ., Seoul, Korea. [in Korean]

Jang MN, Seo YO, Kim SY, Kim SH, Choi JK, Lee WK, Jung DJ, Nor DK, Lee YJ. 2011. Comparison of non-linear growth functions for major tree species in Korea. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1129-1130.

Jeong HY, Lee WK, Nam KJ, Kim MI. 2013. Estimating the change of potential forest distribution and carbon stock by climate changes - Focused on forest in Yongin-city. Journal of Climate Change Research 4:177-188.

Jeong HY. 2013. Estimating the change of potential forest distribution and carbon stock by climate changes: focused on forests in Yongin-city. Ph.M. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Jung DJ, Choi KM, Song YH, Kim CH. 2013a. Vegetation type and ecological characteristics of Ulleung-do. Proceedings of the 2013 Meeting of the Korean Forest Society 2013:67-69.

Jung DJ, Kang KH, Heo J, Kim CJ, Kim SH, Lee JB. 2010a. Mapping for biodiversity using national forest inventory data and GIS. Journal of Environmental Impact Assessment 19:573-581.

Jung IB, Yim JS, Han WS, Kim SH, Kim JC, Shin MY. 2011a. Estimation of forest growing stock volumes at county level by using geo-spatial statistics analysis. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1068-1071.

Jung IB, Yim JS, Kim JC, Kim SH, Shin MY. 2011b. Verification of annual forest statistics in 2010. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:164-167.

Jung IB, Yim JS, Kim JC, Shin MY. 2011c. Standard criteria to identify dominant species for NFI data collected by sampling method. Symposium of Korean Society of Forest Measurements 2011(Poster presentation).

Jung IB, Yim JS, Kim SH, Kim JC, Shin MY, Han WS. 2011d. Comparison of small-area estimation techniques for providing forest growing stock volume from NFI5 field data. International Forest Fire Symposium 2011:327-331.

Jung JH, Heo J, Yoo SH, Kim KM, Lee JB. 2010b. Estimation of aboveground biomass carbon stock in Danyang area using *k*NN algorithm and Landsat TM seasonal satellite images. Journal of the Korean Society for Geospatial Information Science 18:119-129.

Jung JH, Kim SP, Hong SC, Kim KM, Kim ES, Im JH, Heo J. 2013b. Effects of national forest inventory plot location error on forest carbon stock estimation using k-nearest neighbor algorithm. ISPRS Journal of Photogrammetry and Remote Sensing 81:82-92.

Jung JH, Nguyen HC, Heo J, Kim KM, Im JH. 2014. Estimation of aboveground forest biomass carbon stock by satellite remote sensing -A comparison between *k*-nearest neighbor and regression tree analysis. Korean Journal of Remote Sensing 30:651-654.

KFRI (Korea Forest Research Institute). 2011. The 5th national forest inventory report.

KFRI (Korea Forest Research Institute). 2014. Development of forest carbon map using national forest inventory data and RS/GIS techniques.

KFS (Korea Forest Service). 2010. Development of producing and reporting systems for forest statistics based on national forest inventory data.

KFS (Korea Forest Service). 2012a. development of quantification and verification technique of forest-carbon change using remotely sensed data.

KFS (Korea Forest Service). 2012b. Growth response model for major tree species using tree ring information of national forest inventory.

KFS (Korea Forest Service). 2014a. Study of usage and analysis for using NFI data.

KFS (Korea Forest Service). 2014b. Study of needs of Korea forest statistics and development of appropriate statistical methods.

Kim DH, Nor DK, Jeong JH, Kim SH, Chung DJ. 2008. Forest resources of the Korea based on national forest inventory data. Journal of Forest Science 24:159-164.

Kim DH, Nor DK, Kim SH, Lee WK, Jung DJ. 2009a. Tree ring DB construction using tree ring information national forest inventory. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:429-431.

Kim DH. 2013a. Analysis of the difficulty for permanent sample plot in national forest inventory. Proceedings of the 2013 Meeting of the

Korean Forest Society 2013:27.

Kim DW. 2015a. Development of stand growth models for *Pinus densiflora* stand using the NFI data. Ph.M. dissertation, Jeonbuk National Univ., Jeonju, Korea. [in Korean]

Kim ES, Kim CM. 2015. Estimation of forest growing stocks in small-area level considering local forest characteristics. Journal of Korean Forest Society 104:117-126.

Kim ES, Kim KM, Lee JB, Lee SH, Kim CC. 2011b. Spatial upscaling of aboveground biomass estimation using national forest inventory data and forest type map. Journal of Korean Forest Society 100:455-465.

Kim ES, Kim KM, Lee JB, Lee SH. 2011a. Estimating spatial distribution of above ground biomass using national forest inventory data and forest type map. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:254-257.

Kim ES, Kim KM, Lee JB, Lee SH. 2012a. Uncertainty analysis for estimating spatial distribution of aboveground biomass carbon stock using national forest inventory data and forest type map. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:451-453.

Kim ES, Lee SH. 2013. Small area estimation considering regional variation in forest growing stock Proceedings of the 2013 Meeting of the Korean Forest Society 2013:341-344.

Kim ES. 2013b. Application of forest statistics from the extended region to produce tree stocks of subregion in South Korea. Journal of Korea Forest Management and Information 2013:67-70.

Kim JC, Yim JS, Jung IB, Kim SH. 2011c. Biodiversity assessment from the 5th national forest inventory on Jeju Island. Proceedings of International Workshop for Practice of Forest Ecosystem Management 2011(Poster presentation).

Kim KM, Lee JB, Jung JH. 2015. Comparison of forest carbon stocks estimation methods using forest type map and landsat TM satellite imagery. Korean Journal of Remote Sensing 31:449-459.

Kim KM, Roh, YH, Kim ES. 2014a. Comparison of three kinds of methods on estimation of forest carbon stocks distribution using national forest inventory DB and forest type map. Journal of the Korean Association of Geographic Information Studies 17:69-85.

Kim KM. 2012. Spatially explicit estimation and the uncertainty analysis of carbon stocks in pine forest using growth model and GIS. Ph.D. dissertation, Seoul National Univ., Seoul, Korea. [in Korean]

Kim MI, Lee WK, Choi SE, Kwon TS. 2013a. Estimation of forest carbon storage and change based on RCP scenario. Journal of Korea Forest Management and Information 2013:16-18.

Kim MI, Lee WK, Gui GS, Yu HN, Choi SE, Kim CG, Kwon TS. 2014b. Estimating stand volume *Pinus densiflora* forest based on climate change scenario in Korea. Journal of Korean Forest Society 103:105-112.

Kim MI, Lee WK, Nam KJ, Yu H. 2013b. Estimating *Pinus densiflora*`s carbon storage and sequestration based on climate change scenario in Korea. Proceedings of the 2013 Meeting of the Korean Forest Society 2013:748-750.

Kim SH, Kim JC, Jeong JH, Sim WB, Yoo BO. 2009b. Development of national forest inventory program for monitoring and assessing forest resource and carbon pools in Korea. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:451-453.

Kim SW, Son YM, Kim ES, Park H. 2014c. Estimation of growing stock and carbon stock based on components of forest type map: The case of Kangwon province. Journal of Korean Forest Society 103:446-452.

Kim SY, Jang MN, Abino AC, Kim CH, Lee YJ. 2014d. Canopy fuel characteristics of major conifer species in South Korea. Proceedings of the 2014 Meeting of the Korean Forest Society 2014:194.

Kim SY, Jang MN, Lee BD, Lee YJ. 2013c. Assessment of canopy fuel characteristics for five major coniferous species in Korea. Journal of Korean Forest Society 102:247-254.

Kim SY, Jang MN, Seo YO, Lumbres RIC, Seo SH, Lee BD, Lee YJ. 2012b. Optimal stand density to prevent of crown fire spread in *Pinus densiflora* stands. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:1176-1178.

Kim TW, Choi HK, Ko SY, Yim JS, Shin MY. 2012c. Accuracy assessment of *k*NN-based thematic map by bootstrap technique. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:1179-1183.

Kim WS. 2015b. A study of forest soil carbon storage using the 5th Korea national forest inventory data. Ph.M. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Kitahara F, Mizoue N, Yoshida S. 2009. Evaluation of data quality in Japanese. Environmental Monitoring and Assessment 159:331-340.

Ko EJ, Choi KM, Jeong JH, Kim CH, Kim SH, Sung JH, Jung DJ. 2013a. Growth pattern of *Quercus acutissima* by ecoregion in South Korea. Journal of Korea Forest Management and Information 2013:41-53.

Ko EJ, Choi KM, Jeong JH, Kim CH, Sung JH, Cho HK, Jung DJ. 2013b. Growth pattern of *Zelkova serrata* and *Celtis sinensis* by using NFI data. Journal of Korea Forest Management and Information 2013:42-46.

Ko EJ, Choi Km, Yun BH, Kim CH, Sung JH, Kim SH, Jung DJ. 2014. Characteristics of growth for *Pinus densiflora* by ecoprovinces using national forest inventory data in Korea. Proceedings of the 2014 Meeting of the Korean Forest Society 2014:193.

Ko EJ, Kim JS, Kim JK, Jeong JH, Kim SH, Kim CH, Shin MY. 2012. Growth characteristics of *Quercus mongolica* based on national forest inventory data in Korea. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:352-355.

KOFPI (Korea Forestry Promotion Institute). 2013a. Assessment of the Korea's forest resources.

KOFPI (Korea Forestry Promotion Institute). 2013b. Development of assessment technique for the change of forest resources based on permanent sampling data of national forest inventory.

Lam TY, Czaplewski RLPD, Yim JS, Lee KH, Kim SH, Kim RH. 2013. Comparison of Kalman filters in combining panel data from the annual inventory system of the South Korea national forest inventory. Research Note RMRS-RN-52 1-15.

Lee HY. 2012. Prediction of spatial distribution and forest carbon storage on *Pinus densiflora* and *Quercus* spp. stands in Korea using 4th forest cover map and HyTAG model. Ph.M. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Lee JH, Choi JK, Lee WK, Lee YJ, Jung DJ, Kim SH. 2012. Analysis of growth characteristic for *Pinus densiflora* using information of national forest inventory. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:1203-1206.

Lee JH, Im JH, Kim KM, Heo J. 2015a. Change analysis of aboveground forest carbon stocks according to the land cover change using multi-temporal landsat TM images and machine learning algorithms. Journal of the Korean Association of Geographic Information Studies 18:81-89.

Lee JY, Han SH, Kim SJ, Chang HN, Yi MJ, Park GS, Kim CS, Son YM, Kim RH, Son YH. 2015b. Estimating the changes in forest carbon dynamics of *Pinus densiflora* and *Quercus variabilis* forests in South Korea under the RCP 8.5 climate change scenario. Korean Journal of Agricultural and Forest Meteorology 17:35-44.

Lee SJ, Yim JS, Son YM, Kim RH. 2015c. Estimation of the carbon stock and greenhouse gas removals by tree species and forest types in Gangwon province. Journal of Climate Change Research 6:303-310.

Lee SW, Byun JK, Kim SH. 2010. Carbon storage in forest floors and mineral soils, Korea. Proceedings of the 2010 Meeting of the Korean Forest Society 2010:230-232.

Lee WA, Choi JK, Lee WK, Lee YJ, Kim SH, Jung DJ. 2009a. Comparison of growth characteristics for Korea red pine, Korea white pine, Japanese larch in Gang Won province. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:410-413.

Lee WA, Choi JK, Shin JW, Lee WK, Lee YJ, Jung DJ, Kim SH. 2011a. Analysis of growth characteristics for *Larix leptolepis* using information of national forest inventory. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1128-1128.

Lee WA, Park JT, Choi JK, Lee WK, Lee YJ, Kim SH, Jung DJ. 2009b. Analysis of diameter growth characteristics of major species by national forest resource inventory - In the Ganwon-do forest. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:515-518.

Lee YJ, Ko EJ, Choi KM, Jeong JH, Jung DJ, Kim CJ. 2013a. Estimation of growth models for *Ulmus davidiana* by national forest inventory data in Korea. Proceedings of the 2013 Meeting of the Korean Forest Society 2013:294-295.

Lee YJ, Ko EJ, Choi KM, Jeong JH, Kim CJ, Kim SH, Jung DJ. 2013b. Regional growth model of *Cornus controversa* by using NFI data. Journal of Korea Forest Management and Information 2013:37-41.

Lee YJ, Nor DK, Kim SH, Kim CH, Shin MY, Han SH, Ko EJ, Namgung YC, Jeong DJ. 2011b. Growth characteristics of *Prunus sargentii* Rehder on the use of national forest inventory data in Korea. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1113-1117.

Lund HG. 2009. National forest inventories and global resource assessments. Forests and Forest Plants 1:29.

Magnussen S, Smith B, Uribe AS. 2007. National forest inventories in North America for monitoring forest tree species diversity. Plant Biosystems 141:113-121.

May DM. 1998. The north central forest inventory and analysis timber products output database-a regional composite.

Nam KJ, Lee WK, Kwak DA, Kim MI, Kwak HB, Lee SJ. 2012. Estimation of forest volume and carbon storage using sustainable forest management. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:456-459.

Nam KJ, Lee WK, Kwak DA, Kim MI, Kwak HB. 2013. Estimation forest volume and forest cover according to climate change in forest practice area. Proceedings of the 2013 Meeting of the Korean Forest Society 2013:751-754.

Nam KJ. 2013. Forest cover and volume change by climate change in forest practice area. Ph.M. dissertation, Korea Univ., Seoul, Korea. [in Korean]

Namgung YC, Jeong JH. 2012. Estimating dead wood using national forest inventory data. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:1184-1186.

Namgung YC, Yun BH, Yang YJ, Kim CH, Jung DJ. 2014. Interspecific competition and growth characteristics of *Pinus densiflora* forest by sixth-tree sampling -national forest inventory data in Korea-. Proceedings of the 2014 Meeting of the Korean Forest Society 2014:181.

Natural Resources Canada, 1999. A plot-based national forest inventory design for Canada. Canadian Forest Service, Pacific Forestry Centre, Victoria. BC. pp. 70.

Nor DK, Kim SH, Kim CH, Shin MY, Han SH, Lee YJ, Ko EJ, Namgung YC, Jung DJ. 2011. Growth characteristics of *Carpinus laxiflora* on the use of 5th national forest inventory data in Korea. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1118-1122.

Paille G. 2013. History of forestry in Canada.

Park HJ, Shin HS, Nor YH, Kim KM, Park KH. 2012a. Estimating forest carbon stocks in Danyang using kriging methods for aboveground biomass. Journal of the Korean Association of Geographic Information Studies 15:16-33.

Park SM. 2011. A study on the growth and biomass for *Quercus variabilis*. Ph.M. dissertation, Gongju National Univ., Yesan, Korea. [in Korean]

Park TJ, Lee WK, Kim MI, Cui GS. 2011. Application proposal of remotely sensed data for scale expansion and transformation of forest volume from national forest inventory. Symposium of the Korean Society for Geospatial Information Science 2011:197-200.

Park TJ, Lee WK, Lee JY, Byun WH, Kwak DA, Cui G. Kim MI, Jung RS, Pujiono E, Oh SH, Byun JY, Nam KJ, Cho HK, Lee JS, Chung DJ, Kim SH. 2012b. Forest plot volume estimation using national forest inventory, forest type map and airborne LiDAR data. Forest Science and Technology 8:89-98.

Powell DS, Faulkner JL, Darr DR, ZhiLiang Z, MacCleery DW. 1993. Forest resources of the United States, 1992. General technical report-rocky mountain forest and range experiment station, USDA Forest Service, (RM-234).

Power K, Gills MD 2006. Canada's forest inventory 2001. (Natural Resources Canada. Canadian Forest Service, Pacific Forestry

center. Information Report. Victoria). BC- X-408.

Pyo JK. 2013. A study on methods of uncertainty assessment for carbon accounting for *Pinus densiflora* in the Republic of Korea. Ph.D. dissertation. Kongju National Univ., Yesan, Korea. [in Korean]

Rudis VA. 1991. Wildlife habitat, range, recreation, hydrology, and related research using forest inventory and analysis surveys: A 12-year compendium.

Schadauer K, Gschwanter T, Gabler k. 2005. Austrian national forest inventory: Caught in the past and heading toward the future.

Seo HS, Park JM, Kim ES, Lee JS. 2015a. Estimation of forest volumes in the ecosystem region using spatial statistical techniques. Journal of the Korean Association of Geographic Information Studies 18:149-160.

Seo YO, Lee YJ, Jeong JH, Kim SH, Nor DK. 2009a. A study of the tree ring growth analysis by using NFI for major species in central Korea. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:349-352.

Seo YO, Lee YJ, Nor DK, Kim SH, Choi JK, Lee WK. 2011. Height-DBH growth models of major tree species in Chungcheong province. Journal of Korean Forest Society 100:62-69.

Seo YO, Lee YJ, Park SM, Kim SH, Choi JK, Lee WK, Jung DJ, Nor DK. 2010. Height-diameter models for major tree species in Chungcheong province. Proceedings of the 2010 Meeting of the Korean Forest Society 2010: 432-436.

Seo YO, Lee YJ, Park SM, Pyo JK, Jeong JH, Kim SH, Choi JK, Lee WK, Chung DJ, Moon HS. 2009b. Annual tree ring growth characteristics for major species in Chungbuk province. Journal of Agriculture and Life Science 43:1-6.

Seo YO, Roscinto ICL, Jung SC, Won HK, Lee YJ. 2015b. Application on national forest inventory data to estimate forest management ratios for private forests in Chungnam province. Journal of Agriculture and Life Science 49:31-37.

Seo YO. 2013a. Estimation and spatial distribution of carbon storage in *Pinus rigida* stands: The case of Muju area in Jeonbuk. Ph.D. dissertation. Kongju National Univ., Yesan, Korea. [in Korean]

Seo YO. 2013b. Estimation of biomass factors and its uncertainty for pitch pine (*Pinus rigida*). Ph.M. dissertation, Gongju National Univ., Yesan, Korea. [in Korean]

Shin JH. 2012a. Estimation of forest biomass and carbon dioxide absorption using geographic information system (GIS) and remote sensing. Ph.M. dissertation, Seoul National Univ., Seoul, Korea. [in Korean]

Shin JW, Choi JK, Lee WK, Lee YJ, Jung DJ, Kim SH. 2011. Diameter growth model for major tree species using tree ring information of national forest inventory. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1072-1072.

Shin JY, Won MS, Kim KH, Shin MY. 2013. Predicting the effect of climate change on forest biomass by different ecoprovinces and forest types in Korea. Korean Journal of Agricultural and Forest Meteorology 15:119-129.

Shin JY. 2012b. Predicting the effect of climate change on forest biomass in different ecoprovinces and forest types of Korea. Ph.M. dissertation, Kookmin Univ., Seoul, Korea. [in Korean]

Shin MY, Jeong JH, Kim SH, Han WS, Jeon EJ, Hwang JH. 2008a. A producing method for regional forest statistics based on national forest inventory data. Proceedings of the 2008 Meeting of the Korean Forest Society 2008:394-397.

Shin MY, Kim SH, Jeong JH, Kim CC, Jeon EJ. 2008b. Development of volume growth rate model for major *Quercus* species in Korea. Journal of Korean Forest Society 97:627-633.

Shin MY, Kong JS, Kim SH, Han WS, Jeon EJ, Hwang JH. 2007. Estimation of growth rates by age class for main oak species in Korea. Proceedings of the 2007 Meeting of the Korean Forest Society 2007:42-46.

Shin MY, Kong JS, Kim SH, Han WS, Jeon EJ. 2008c. Estimation of volume growth rates by age class for main coniferous species in Korea. Proceedings of the 2008 Meeting of the Korean Forest Society 2008:362-365.

Smith WB, Vissage J, Sheffield R, Darr DR. 2001. Forest Statistics of the United States, 1997.

Smith WB. 1991. Assessing removals for north central forest inventories.

Smith WB. 2002. Forest inventory and analysis: a national inventory and monitoring program. Environment Pollution 116:233-242.

Son YM, Lee SJ, Kim SW, Hwang JS, Kim RH, Park H. 2014. Mapping and assessment of forest biomass resources in Korea. Journal of Korean Forest Society 103:431-438.

Song YH, Nor DK, Jeong JH, Kim SH, Jung DJ. 2009. Phytosociological study of the forest vegetation by national forestry inventory in Korea. Proceedings of the 2009 Meeting of the Korean Forest Society 2009:425-428.

Song YH, Nor DK, Kim Sh, Kim CH, Jung DJ. 2011. Forest vegetation type by 5th national forest inventory data in Korea. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:624-627.

Tomppo E, Heikkinen J. 1999. National forest inventory of Finland- past, present and future. statistics, registries, and science-experiences from Finland 89-108.

USDA Forest Service, 1958. Timber resource for America's future (Forest Resource Report No. 14). pp. 713. US Department of Agriculture, Forest Service, Washington, DC.

USDA Forest Service, 1965. Timber trends in the United States (Forest Resource Report No. 17). US Department of Agriculture, Forest Service, Washington DC.

USDA Forest Service, 1973. The outlook for timber in the United States (Forest Resource Report No. 20). pp. 367. US Department of Agriculture, Forest Service, Washington, DC.

USDA Forest Service, 1981. Tree biomass- a state-of-the-art compilation (Gen. Tech. Rep. WO-33). pp. 34. US Department of Agriculture, Forest Service, Washington, DC.

USDA Forest Service, 1982. An analysis of the timber situation in the United States 1952 - 2030 (Forest Resource Report No. 23). pp. 499. US Department of Agriculture, Forest Service, Washington, DC.

Van Hooser DD, Cost ND, Lund HG. 1992. The history of the forest survey program in the United States.

Waddell KL, Oswald DD, Powell DS. 1989. Forest Statistics of the United States, 1987.

Xie X, Wang Q, Dai L, Su D, Wang X, Qi G, Ye Y. 2011. Application of China's national forest continuous inventory database. Environmental Management 48:1095-1106.

Yim JS, Cho HK, Kim SH, Jeong JH, Shin MY. 2009a. Sample size consideration in *k*-NN estimator using annual national forest inventory data in Korea. Proceedings Extending Forest Inventory and Monitoring 2009:145.

Yim JS, Cho HK, Lee JS, Shin MY. 2011a. Development of remote sensing techniques to estimate forest carbon sequestration. Green Technology Forum 2011.

Yim JS, Chung SY, Jung IB, Cho HK, Shin MY. 2010a. Improving of *k*NN-based forest growing stock volume estimates using satellite image variables. Proceedings of the 2010 Meeting of the Korean Forest Society 2010:413-416.

Yim JS, Han WS, Hwang JH, Chung SY, Cho HK, Shin MY. 2009b. Estimation of forest biomass based upon satellite data and national forest inventory data. Korean Journal of Remote Sensing 25:311-320.

Yim JS, Han WS, Jung IB, Kim SH, Shin MY. 2010b. Application of synthetic estimator for estimating forest growing stock volumes at the small-area level. Journal of Korean Forest Society 99:285-291.

Yim JS, Han WS, Kim SH, Shin MY. 2009c. Estimation of annual forest statistics using the national forest inventory data in Korea. Proceedings of International Symposium on National Forest Inventory 2009:61.

Yim JS, Jung IB, Cho HK, Kim JC, Kim SH. 2013a. Chronological analysis of timber resources by using NFI data. Journal of Korea Forest Management and Information 2013:11-15.

Yim JS, Jung IB, Cho HK, Kim SH. 2013b. Quality management system for the national forest inventory in Korea. International symposium- Sustainable forest ecosystem management in rapidly changing World 2013.

Yim JS, Jung IB, Cho HK, Shin MY. 2010c. Evaluation of applicability of medium-resolution satellite data by combining with field data for

forest carbon stocks estimation in Korea. Proceedings the 21st IUFRO Conference 2010:331.

Yim JS, Jung IB, Kim JC, Kim SH, Ryu JH, Shin MY. 2012a. Estimation of forest growing stock by combining annual forest inventory data. Journal of Korean Forest Society 101:213-219.

Yim JS, Jung IB, Kim JC, Kim SH, Shin MY. 2011b. Assessment of forest carbon sequestration on Jeju Island based on national forest inventory. Proceedings of Forest Technologies for Mitigating Climate Change 2011(Poster presentation).

Yim JS, Jung IB, Kim JC, Kim SH, Shin MY. 2011c. Study of forest carbon storage across soil horizons by using NFI data in Kangwon province. Symposium of Climate Change Research 2011:36.

Yim JS, Jung IB, Kim JC, Kim SH, Shin MY. 2011d. Study of quality control and management method to improve NFI data collection. Proceedings of the 2011 Proceedings of the 2011 Meeting of the Korean Forest Society 2011:166-171.

Yim JS, Jung IB, Kim JC, Kim SH, Shin MY. 2012b. A comparison of recalculation techniques for estimating previous forest growing stock at a provincial level. Proceedings of Forest Technologies for Mitigating Climate Change 2012:37-39.

Yim JS, Jung IB, Kim YJ, Cho HK, Shin MY. 2011e. Comparison of *k*NN-based forest growing stock estimates by image fusion. Proceedings of International Symposium on Remote Sensing 2011:1-4.

Yim JS, Jung IB, Kim YJ, Cho HK, Shin MY. 2011f. Mapping and evaluation of forest carbon stock derived from the NFI data and Landsat imagery. International Forest Fire Symposium 2011:323-326.

Yim JS, Jung IB, Yu BO, Kim JC, Kim SH. 2012c. Re-assessment of forest growing stock volume in Korea by annual forest inventory system. Proceedings of the 2012 Meeting of the Korean Forest Society 2012:1158-1162.

Yim JS, Kim ES, Kim CM, Son YM. 2015a. Assessment on forest resources change using permanent plot data in national forest inventory. Journal of Korean Forest Society 104:239-247.

Yim JS, Kim RH, Lee SJ, Son YM. 2015b. Land-use change assessment by permanent sample plots in national forest inventory. Journal of Climate Change Research 6:33-40.

Yim JS, Kim TU, Kim YJ, Jung IB, Cho HK, Shin MY. 2011g. Comparison of *k*NN-based forest growing stock volume estimates for multi-seasonal satellite images. Proceedings of the 2011 Meeting of the Korean Forest Society 2011:1142-1145.

Yim JS, Kim YH, Kim SH, Jeong JH, Shin MY. 2011h. Comparison of the *k*-nearest neighbor technique with geographical calibration for estimating forest growing stock volume. Canadian Journal of Forest research 41:73-82.

Yim JS, Yoo BO, Shin MY. 2012d. Comparison of forest growing stock estimates by distance-weighting and stratification in *k*-nearest neighbor technique. Journal of Korean Forest Society 101:374-380.

You JS. 2015. Analysis of annual land-use and Land-use change based on National Forest Inventory in Gyeonggi-do. Ph.M. dissertation, Chungbuk National Univ., Cheongju, Korea. [in Korean]

Zeng W, Tomppo E, Healey SP, Gawdon KV. 2015. The national forest inventory in China: history - results - international context. Forest Ecosystems 2:1-16.

Zhu Z, Evans DL. 1994. US forest types and predicted percent forest cover from AVHRR data. Photogrammetric Engineering and Remote Sensing 60:525-531.