Chapter 14
China

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14.1 The Chinese National Forest Inventory

14.1.1 History and Objectives

Large-scale forest surveys began in China, from 1950 to 1962, when the forest census was undertaken. This survey aimed to assess the state of forests in the whole country after the new People's Republic of China was set up in 1949. In 1962, the former Agriculture and Forestry Ministry (AFM) mandated the provincial forestry departments to compile forest data from various inventories, such as reconnaissance inventories and forest management inventories conducted during 1950–1962. These provincial data were summed to provide national results. This was the first time that forest data were gathered, compiled and reported at national level. From this forest census, the general forest status in China was revealed, although the scope of inventory only involved the main forest regions and the state forest bureaus, representing about 3 million km^2 (Xiao 2005; Lei et al. 2009; Lin et al. 2013).

In 1973, the AFM conducted two pilot forest inventories in the Jiwen Forest Bureau of Daxinganling and the Huitong County of Hunan Province respectively. Using past experience and study results of the two pilot inventories, the first national forest inventory (NFI1) was conducted at a county-level during 1973–1976, which is usually referred to as the "4th Five-Year Plan Inventory" (Xiao 2005). Except for some regions where a sub-department survey method was used, the sampling survey method was applied in most regions, however not unified for the entire country. The primary emphasis of NFI1 was on the assessment of the current status of the forests.

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Thereafter, the importance of monitoring forest change resulted in the establishment of a permanent sampling grid in each province for continuous forest inventory (CFI) during the 2nd NFI 1977–1981. All subsequent NFIs were primarily based on the CFI system. The first re-measurement of the permanent plots was done in the 3rd NFI 1984–1988. From this inventory, not only the current state of forest resources was obtained, but also the development trends. Since the 4th NFI 1989–1993, four newly established regional forest monitoring centres were responsible for technical instructions, quality checks, statistical compilations, and output reporting at regional level. In the 5th NFI 1994–1998, the United Nations Development Programme (UNDP) and Crisis Prevention and Recovery (CPR) 91/151 project "Establishment of National Forest Monitoring System" was completed and an integrated pilot study on new technology applications was conducted in the Jiangxi Province using remote sensing (RS) data, geographic information systems (GIS), and advanced database and modelling techniques. The pilot laid a foundation for the application of new techniques such as RS and GIS in the NFI and for the optimisation and improvement of the CFI system.

In the 6th NFI 1999–2003, RS technology was widely applied. Several provinces in the western China, such as Tibet, Xinjiang, Gansu, Qinghai and Sichuan, conducted their first complete inventories. Nationally, a total of 415,000 ground plots were measured, and 2.84 million RS plots were interpreted. The sampling area covered the total land area of 31 provinces of the country except Taiwan, Hong Kong and Macao. It was the first complete inventory of the mainland China. In the 7th NFI 2004–2008, several new ecological variables on forest health, ecological functions and biodiversity were integrated in the inventory and a national evaluation of forest ecological services was implemented for the first time (State Forestry Administration 2004, 2009). The assessment of these ecological services was continued and tree biomass equations for main tree species were developed in the most recent 8th NFI 2009–2013 (State Forestry Administration 2014a; Zeng 2014). The NFI results are used for macro decision-making and by forestry administration, as well as for the provision of regional, national, and international forest statistics.

14.1.2 Sampling Methods and Periodicity

The NFI is the largest forest monitoring program in China and covers all land, including forest land and non-forest land. The inventory has a 5-year cycle, with about 20 % of the provinces implementing an inventory each year. The sampling schemes of the 31 provinces (not including Taiwan, Hong Kong and Macao) are adapted to the geographic characteristics and structure of the forest resources. Since China's NFI system has been implemented for more than 40 years, some of the provinces improved their sampling designs according to the national specifications for continuous forest inventory. At present, most of the provinces employ a systematic sampling design, and all the sample plots are permanent. A few of the provinces divide the territory into strata according to eco-geographic regions. Each

stratum is considered as an independent sub-population in which systematic sampling is applied (Xiao 2005; Lin et al. 2013).

The sample size in each province depends on the variability of the sample units, and the desired sampling precision and confidence level. Among the 31 provinces in China, the smallest sample size is less than 3 thousand plots, and the largest sample size is more than 10 thousand plots. The permanent plots are located systematically on two-dimensional grids, with the grid spacing varying considerably between provinces. The smallest spacing of plots is 1×2 km, the largest 8×8 km.

At present, the sample plots are fixed-area plots in all 31 provinces. Only one province (Guangxi) used to apply variable-area plot, i.e. point sampling or angle count sampling (also known as Bitterlich or variable radius plot sampling), which was converted into fixed-area plot in 2005 (Cen et al. 2007). The plot sizes vary between 0.06 and 0.10 ha, but most of them have a size of 0.0667 ha (1 Chinese mu). Plot shape includes three types: square, rectangular, and circular. The square plot is usually used, and rectangular plot is used in only a few provinces. In Tibet, a circular plot is used. The sampling design of NFI for 31 provinces in China is detailed in Table 14.1.

14.1.3 Data Collection

Besides the basic data such as the allocation of sample plot (administrative region, geographical coordinates), the list of field staff and inspection team, the dates of surveying and checking, the NFI collects data on three categories: stand-level variables, tree-level variables and auxiliary information.

Stand-level variables describe the plot attributes and include the following variables:

- Landform
- Elevation above sea level
- Slope direction
- Slope position
- Slope gradient
- Surface configuration
- Dune height
- Coated sand thickness
- Erosion gully area ratio
- Bedrock bareness
- Soil group
- Soil texture
- Soil gravel content
- Soil layer thickness
- Humus layer thickness

Table 14.1 Sampling design of the NFI for the 31 provinces in China (State Forestry Administration 2010)

Province	Sub-population	Land area (1000 ha)	Plot number	Grid	Plot shape	Plot size	Year of last inventory
Beijing	/	1641	4074	2 × 2	Square	0.0667	2011
Tianjin	/	1131	2818	2 × 2	Square	0.0667	2012
Hebei	/	18,769	11,709	4 × 4	Square	0.06	2011
Shanxi	/	15,662	9915	4 × 4	Square	0.0667	2010
Inner Mongolia	/	118,300	17,951	8 × 8	Rectangular	0.06 (10 × 60)	2013
Liaoning	/	14,574	4613	4 × 8	Square	0.08	2010
Jilin	/	18,919	8865	4 × 16/3	Square	0.06	2009
Heilongjiang	I	10,054	1571	8 × 8	Square	0.06	2010
	II	6479	1013	8 × 8	Rectangular	0.06 (10 × 60)	2010
	III	28,928	9083	4 × 8	Square	0.06	2010
Shanghai	/	634	3365	2 × 1	Square	0.0667	2009
Jiangsu	/	10,260	8536	4 × 3	Square	0.0667	2010
Zhejiang	/	10,180	4249	4 × 6	Square	0.08	2009
Fujian	/	12,150	5051	4 × 6	Square	0.0667	2013
Jiangxi	/	16,695	2608	8 × 8	Square	0.0667	2011
Shandong	/	15,222	9646	4 × 4	Square	0.0667	2012
Henan	/	16,700	10,358	4 × 4	Square	0.08	2013
Hubei	/	18,590	5820	4 × 8	Square	0.0667	2009
Hunan	/	21,184	6615	4 × 8	Square	0.0667	2009
Guangdong	/	17,677	3685	6 × 8	Square	0.0667	2012
Guangxi	/	23,760	4948	6 × 8	Square	0.0667	2010
Hainan	/	3391	2829	4 × 3	Square	0.0667	2013
Chongqing	/	8234	5133	4 × 4	Square	0.0667	2012
Sichuan	/	48,374	10,007	6 × 8	Square	0.0667	2012

(continued)

Table 14.1 (continued)

Province	Sub-population	Land area (1000 ha)	Plot number	Grid	Plot shape	Plot size	Year of last inventory
Guizhou	/	17,617	5500	4 × 8	Square	0.0667	2010
Yunnan	/	38,264	7891	6 × 8	Square	0.0667	2012
Tibet	/	122,844	5855	6 × 8	Circular	0.0667	2011
Shaanxi	/	20,598	6440	4 × 8	Square	0.08	2009
Gansu	I	44,973	2817	2 × 3	Square	0.08	2011
	II		4038	3 × 3	Square	0.08	2011
	III		10,846	4 × 8	Square	0.08	2011
Qinghai	I	72,151	76,616	2 × 2	Square	0.08	2013
	II		51,620	4 × 2	Square	0.08	2013
Ningxia	/	5195	12,936	2 × 2	Square	0.06	2010
Xinjiang	I	16,470	16,474	3 × 4	Square	0.08	2011
	II		59,917	6 × 4	Square	0.08	2011

Note (1) The permanent plots in Jilin province were established through intensifying the 4 × 8 km grid by 50 %, that is, there are 3 plots for each 64 km^2; (2) The 5855 plots in Tibet only includes ground plots in the 1st sub-population (30 forestry counties); (3) The plot numbers of Gansu, Qinghai, Ningxia and Xinjiang include some RS-interpretation plots

- Litter layer thickness
- Vegetation type
- Shrub cover
- Shrub height
- Herb cover
- Herb height
- Vegetation cover
- Land type
- Land ownership
- Forest ownership
- Forest classes (ecological/commercial)
- Governance level of ecological forest
- Protection class of ecological forest
- Management class of commercial forest
- Tending measures
- Forest category
- Forest origin
- Dominant tree species
- Mean age (boring or visual estimation)
- Age class
- Production stage of economic forest
- Mean diameter
- Mean height
- Crown cover
- Forest community structure
- Stand storey structure
- Species composition
- Naturalness
- Accessibility
- Forest disaster type
- Forest disaster class
- Forest health class
- Number of 4-side trees (e.g. isolated trees beside croplands, roads, rivers, and villages or residential areas)
- Number of bamboos
- Natural regeneration class
- Size class of land type
- Reason of land type conversion
- Deliberate interference (Y/N).

Tree-level variables describe the sample tree attributes. They include the following variables:

- Tree type (trees in forests; scattered trees in other forest land; isolated trees beside croplands, roads, rivers, and villages or residential areas)

- Species
- Diameter at breast height (the dbh threshold is 5.0 cm measured over bark)
- Tree height (only 3–5 trees per plot with average dbh for calculating the mean height)
- Stand storey
- Azimuth
- Distance.

Auxiliary information includes forest damages, vegetation status, natural regeneration, artificial afforestation, and changes of plot attributes such as land type, forest category, origin, dominant species, age class, and vegetation type.

Detailed information about the data collected by the China's NFI and the variables assessed are available from the technical specifications on national continuous forest inventory (State Forestry Administration 2014a).

14.1.4 Data Processing, Reporting, and Use of Results

Field assessments and measurements constitute the input variables for the estimation algorithms applied by the China's NFI. Basically, area-related estimates and volume-related estimates can be distinguished.

The estimation of area has two components, the land and forest category related data collected on sample plots and the area of the province. The area represented by one sample plot is calculated by dividing the total land area by the total number of sample plots located in the respective category. The area of each province, municipality, or autonomous region is obtained from the official statistics and is assumed to be error-free. The area estimate of a given category is equal to the sum of plots located in the category multiplied by the area represented by the plot.

The estimation of the volume of standing stock, increment, and drain is of particular interest for forest land. The estimation procedure includes several steps. After field data collection, the data undergo quality control procedures. Volume is then calculated for each sample tree. Different equations are applied depending on the species of the sample tree. For each plot the represented volume per hectare is calculated as the sum of per hectare values represented by individual trees. These per hectare estimates are aggregated to a mean volume per hectare for forest and multiplied by the area of forest to obtain the total volume of standing stock and growing stock. Mean volumes per hectare and total volumes are also estimated for different categories, such as the ownership, the origin, forest types, and age classes (State Forestry Administration 2011).

Change estimates are obtained from the assessments of two consecutive NFIs. The volume increment of sample trees is calculated as the difference between the volume at the second and the first occasion. Sample trees that have exceeded the dbh-threshold of 5.0 cm between the two NFIs are included in the increment estimation. The drain is assessed by recording the sample trees that have been

harvested or that have disappeared naturally since the previous field assessment. The drain is defined as the volume at the moment of the first assessment (State Forestry Administration 2011).

China's NFI provides estimates at two regional scales, the national level, and the 31 provinces. The estimates include total forest area, forest cover or percentage, growing stock, increment and harvest. The NFI is used as basis for decision-making in forestry and environmental policy, forest management, forest products industries, and for evaluating the consequences of the decisions taken. It also provides country reports for international organisations such as the United Nations Food and Agriculture Organization (FAO) Forest Resources Assessment process, and sustainable forest management report for Montréal process. Therefore, users of the NFI data include forestry and environmental policy makers, forest managers, forest industry decision makers, research scientists, and international organisations (Tomppo et al. 2010).

14.2 Land Use and Forest Resorces

14.2.1 Classification of Land and Forests

14.2.1.1 General Land Classification

The land classification system used in China's NFI follows a hierarchical system of land types (Table 14.2). At the highest level the land area is divided into forest land and non-forest land. To qualify as forest, a piece of land requires a minimum area of 667 m^2, a minimum width of 10 m, and a minimum crown cover of tree species of 20 %. Forest land contains the classes of arboreal forest, bamboo forest, open forest land, shrub land, and other forest land. Non-forest land is distinguished into cropland, grazing land, inland water, built-up land and other land as described in Table 14.2. The details of the land classification system applied by China's NFI are described in the Technical Specifications on National Continuous Forest Inventory (State Forestry Administration 2004, 2014a).

The areas of forest and non-forest land classes according to the China's NFI are given in Table 14.2. The forest definition in China's NFI includes special shrubs, which overlaps with the Other Wooded Land (OWL) definition of FAO (2004). The forest definition in China contains also some areas of land that are considered as Other Land with Tree Cover (OLwTC) by FAO (2004). This is as a result of the smaller minimum area and smaller minimum width, and higher minimum crown cover in the national definition compared to the FAO definition. The non-forest categories correspond to OLwTC depending on the crown cover.

Table 14.2 Land use classes according to the national definition with area estimates (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Class name		Description	Area (1000 ha)	Corresponding to FRA classes (FAO 2004)
Forest land	Arboreal forest	Forest land with a minimum area of 667 m^2, a minimum width of 10 m, and a minimum crown cover of tree species of 20 %	177,470	Forest, intersection with OLwTC
	Bamboo forest	Forest land composed of bamboos with a minimum dbh of 2 cm	6006	Forest
	Open forest land	Forest land with a crown cover of tree species of 10–19 %	4007	Forest
	Shrub land	Forest land with a minimum crown cover of shrub species of 30 %, including two sub-classes: special shrubs[a] and general shrubs	65,729	Intersection with OWL
	Other forest land	Unclosed afforestation land, nursery land, clear-cut land, burned forest land, and planned forest land	59,378	Forest, intersection with OL
Non-forest land	Cropland		169,707	OL
	Grazing land		245,988	OL
	Inland water	Lakes, rivers, and other water bodies	33,126	Inland water bodies
	Built-up land	Industry and commerce, mining, traffic and transport, tourist facilities, dwellings and parking sites, gardens and parks	31,441	OL
	Other land	Unused and unproductive non-forest land	167,148	OL
Total land area			960,000	

Note The total forest area 2,128,000 ha in Taiwan, Hong Kong and Macao is included in "arboreal forest", and the other land area is included in "other land"

[a]Special shrubs are defined as shrub lands which provide mainly non-wood forest products and fruits, or lands above the timber line, or in areas with less than 400 mm precipitation or in karst and dry-hot valley areas

14.2.1.2 Forest Classifications by Use

According to the definition in China's NFI, forests include three forest types: arboreal forests, bamboo forests, and special shrubs. Forests are further classified according to the Forest Law into five categories: protective forest, special-use forest, timber forest, fuelwood forest, and economic forest as described in Table 14.3. The first two categories are called ecological forests, and the latter three categories are called commercial forests. The area of protective and economic forests includes also special shrubs.

Table 14.3 Classes within forest and their areas (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Forest classes	Description	Area (1,000,000 ha)
Protective	Provides protective functions and benefits	99.67
Special-use	Serves species conservation, environmental protection, defence, recreation, experiment, etc.	16.31
Timber	Serves timber production and wood supply	67.24
Fuelwood	Serves fuelwood supply	1.77
Economic	Provides non-wood forest products and fruits	20.56
Total forest area (not including the forest area in Taiwan, Hong Kong and Macao)		205.55

Table 14.4 Forest area according to the national forest definition by ownership categories (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Ownership category	Area (1,000,000 ha)	Area (%)
State forests	73.77	38.59
Collective forests	117.40	61.41
Total forest area	191.17	100

Note The forest area does not include special shrubs except economic shrubs

14.2.1.3 Classification by Ownership Categories

The China's NFI distinguishes two main categories of forest ownership: state forests, and collective forests. Over half (61 %) of the forest area belongs to category of collective community forests (Table 14.4).

14.2.1.4 Forest Management and Cutting Systems

The forests in China are managed in ecological and commercial management systems. For ecological forests, the management target is to strengthen protection function and ecological benefits; and for commercial forests, the target is to increase timber production, fuelwood supply, and non-wood forest products. Also, the forests in China are managed in natural and planted management systems. Since the Natural Forest Protection Program was implemented in major forest regions in 1998, good results have achieved in protecting natural forests in China. The results of recent NFIs have showed that the proportion of natural forests with harvesting operations has decreased while harvest levels in plantations has increased. At present, a new policy is taken into consideration under which all natural forests in China will be protected and commercial cutting in natural forests will be prohibited in the near future.

The forest cutting quota system in China is an important part of cutting management. Provincial forest cutting quotas are made by the State Forestry Administration and approved by the State Council for execution every 5 years. According to the forest cutting quota during the period of "12th five-year plan" (2011–2015), the maximum annual cut volume of the whole country was 271 million m^3. The cut volume could be distinguished by the type of harvesting. About 52 % of cut volume was for final cutting. Tending cutting accounted for about 26 % of cut volume. Regeneration cutting accounted for about 6 %, and other cutting contributed about 16 % of the total harvest. Also the cut volume was classified by forest category and origin. About 80 % of the cutting quota was in commercial forests, and about 70 % was in plantations (State Forestry Administration 2011).

14.2.1.5 Legal and Other Restrictions for Wood Use

The decision to harvest trees is made by the forest owner but all operations must comply with the related regulations, such as Regulations on National Ecological Forests (2013) and Regulations on Forest Harvesting and Regeneration (1987). In 1st grade national ecological forest stands that are located in world natural heritage site, international important wetland, national nature reserve, national forest park, and other areas with special ecological importance or protective function, management activities are generally not allowed and cuts are forbidden. In 2nd grade national ecological forest stands, only selection cuts are allowed in regeneration cutting, and cutting intensity can't exceed a certain level, for example, the cut volume percentage should be less than 15 %, and the canopy cover of remaining trees should be more than 60 %. In pre-mature forest stands clear-cuts are prohibited and also tending activities are not allowed to exceed a certain intensity level. Clear-cuts must not exceed a certain area (5 ha) and a new stand has to be established either by natural regeneration with artificial measures or planting before the end of the next year.

An important point with regard to the availability of wood resources is the accessibility, particularly in mountainous regions. According to the results of 8th NFI, about 13 % of the stocking volume of pre-mature, mature, and post-mature timber forests is inaccessible. Long logging distances and steep slopes increase the hauling costs for wood. Cable crane logging is necessary in forest areas that cannot be accessed by machinery like harvesters, forwarders or tractors because of steep slopes. These logging technologies are more expensive than conventional harvesters or forest tractors and may not be economically feasible in every case.

14.2.1.6 Further Classification of Forests

In addition to the previously described classifications of the forest area further stratifications are used in national statistics and reporting. Commonly used stratification variables are origin, age group, and tree species. The stratifications of the forest area are based on the field assessment of the forest plot. Forests are classified

by origin into two types: natural forests and plantations. Natural forests account for 64 % of the total forest area (Table 14.5).

The arboreal forests are classified into five groups by age: young, middle-aged, pre-mature, mature, and post-mature forests. The arboreal forest area and percentages by age groups are given in Table 14.6.

In China there are more than two thousand tree species. According to the dominant tree species or species groups, the top 10 are *Quercus* spp., *Betula* spp., *Cunninghamia lanceolata, Larix* spp., *Pinus massoniana, Populus* spp., *Pinus yunnanensis, Eucalyptus* spp., *Picea* spp., and *Cupressus* spp. The top 10 species or groups account for more than half of the arboreal forest area (Table 14.7).

Table 14.5 Forest area according to the national forest definition by origin categories (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Origin category	Area (1,000,000 ha)	Area (%)
Natural forests	121.84	63.73
Plantations	69.33	36.27
Total forests	191.17	100

Note The forest area does not include special shrubs except economic shrubs

Table 14.6 Arboreal forest area according to the national definition by age group (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Age group	Area (1,000,000 ha)	Area (%)
Young	53.32	32.39
Middle-aged	53.11	32.27
Pre-mature	25.83	15.69
Mature	21.76	13.22
Post-mature	10.58	6.43
Total arboreal forests	164.60	100

Note The arboreal forest area does not include economic forests 10.73 million ha

Table 14.7 Arboreal forest area according to the national definition by species (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Tree species (groups)	Area (1,000,000 ha)	Area (%)
Quercus spp.	16.72	10.15
Betula spp.	11.26	6.84
Cunninghamia lanceolata	10.96	6.66
Larix spp.	10.69	6.50
Pinus massoniana	10.01	6.08
Populus spp.	9.97	6.06
Pinus yunnanensis	4.55	2.76
Eucalyptus spp.	4.46	2.71
Picea spp.	4.21	2.56
Cupressus spp.	3.66	2.22
Total of top 10	86.49	52.54

14.2.2 Wood Resources and Their Use

14.2.2.1 Standing Stock, Increment and Drain

Estimates of standing stock, increment and drain are based on the sample tree measurements at the plots on arboreal forest land. They are calculated as volume of stem wood over bark. Stem wood according to the China's NFI includes the whole trunk from the ground or collar of root to the top. The minimum dbh is 5.0 cm measured over bark. Trees below this threshold are not included in regular NFI estimates. The volume of standing stock only includes the volume of growing stock, not including volume of standing dead wood. Increment and drain are calculated as mean annual estimates for the period between two consecutive NFIs, which are based on the permanent sample plots (State Forestry Administration 2011). The national definitions for standing stock, increment and drain are compiled in Table 14.8.

According to the 8th NFI, the arboreal forest has a standing volume of 14,479 million m^3 of stem wood over bark (not including Taiwan, Hong Kong, and Macao). Between the inventories 2004/2008 and 2009/2013, about 680 million m^3 of volume increment have been produced each year and almost 441 million m^3 drained annually (333 million m^3 harvested, and 108 million m^3 dead). Thus, the drain between 2004/2008 and 2009/2013 is about 65 % of the increment in the same time period. The top 10 tree species or species groups in growing stock are *Quercus* spp., *Abies* spp., *Larix* spp., *Picea* spp., *Betula* spp., *C. lanceolata, Populus* spp., *P. massoniana, P. yunnanensis,* and *P. densata*. The top 10 species or groups account for about 55 % of the standing stock of arboreal forests. For the increment and drain this order of tree species is different: *Populus* spp. and *C. lanceolata* contribute the highest shares of increment, followed by *P. massoniana* and *Quercus* spp.; while *C. lanceolata* contribute the highest shares of drain, followed by *P. massoniana* and *Populus* spp. Table 14.9 gives the estimates of standing stock, increment and drain by top 10 tree species or groups. Increment and drain are average annual values for the period 2004/2008–2009/2013.

Table 14.8 Definitions for volume of standing stock, increment and drain

Quantity	Definition
Standing stock	Volume of trees with dbh ≥ 5.0 cm over bark, including the bole (wood and bark), and stem top, and the above-ground part of the stump, not including volume of standing dead trees
Increment	Volume increment of surviving trees with dbh ≥ 5.0 cm over bark plus the volume of ingrown trees and half of the estimated growth of harvested or dead trees between two consecutive NFIs
Drain	Volume of trees with dbh ≥ 5.0 cm over bark at the first measurement that were found to be harvested or dead in the subsequent NFI plus half of estimated growth between measurements, including two categories: cut volume and dead or mortality volume

Table 14.9 The volume of standing stock, increment, and drain on arboreal forest land (8th NFI, 2009–2013) (State Forestry Administration 2014b)

Tree species (groups)	Standing stock (1,000,000 m^3)	Annual increment (1,000,000 m^3/year)	Annual drain (1,000,000 m^3/year)
Quercus spp.	1294	46	25
Abies spp.	1166	11	13
Larix spp.	1001	35	20
Picea spp.	999	13	8
Betula spp.	918	28	13
Cunninghamia lanceolata	726	74	67
Populus spp.	624	76	42
Pinus massoniana	591	56	46
P. yunnanensis	502	18	11
P. densata	350	4	2
Total of top 10	8171	361	247

14.2.2.2 Tree Species and Their Commercial Use

Cunninghamia lanceolata and *P. massoniana* are the most economically important tree species in China, especially in the southern region. In northern China, *Populus* spp. is the most economically important tree species. According to the "Report 2012 of Forestry Development in China" (State Forestry Administration 2012a), 91 % of the timber products in China's forests is round wood, and 9 % is fuelwood. Certain broadleaved species are used for special purposes if they feature high wood quality or unique properties. In the recent years the use of pulpwood for paper production has increased considerably. The stock of *Eucalyptus* spp. plantations was about 19 million m^3 in NFI6, 46 million m^3 in NFI7, and 160 million m^3 in NFI8.

14.3 Assessment of Wood Resources

14.3.1 Forest Available for Wood Supply

14.3.1.1 Assessment of Restrictions

The field assessments of the China's NFI include all sample plots in the sampling grid, with the exception of plots in inaccessible terrain which are assessed using satellite imagery. The existence of legal restrictions is not assessed in the field.

With regard to other restrictions and in particular to harvesting possibilities, China's NFI assesses several relevant variables. The slope is decisive for the use of harvesting and logging technologies. In driveable terrain, technologies like harvester, forwarder, and tractor can be employed, whereas in steep areas cable cranes and cable harvesters have to be used. Another crucial variable is the accessibility for pre-mature, mature, and post-mature timber forests. Three classes are divided according to the conditions of harvesting, skidding, and transporting. The information can be used for assessment of forest resources available for wood supply. From the results of 8th NFI, the majority (87 %) of growing stock in pre-mature, mature, and post-mature timber forests is available for wood supply.

14.3.1.2 Estimation

In the study on the forest resources timber supply capacity analysis in China (Zhang and Gao 2014) the legal restrictions due to nature conservation and ecological protection were taken into account by limiting harvests according to the related regulations on forest harvesting, forest tending, and ecological forest conservation. The study results showed that the reasonable harvest volume was between 274 and 317 million m^3 per year, and the area of pre-mature, mature and post-mature timber forests was 19.2 million ha, which occupied about one-third of total timber forest area and was available for wood supply.

The utilisation of wood resources also depends on the harvesting costs. In locations with difficult accessibility the harvesting costs may render harvesting uneconomic as the costs are not covered by the revenue obtained from the harvested product. To estimate the available wood resources under given economic conditions the harvesting costs (including machine costs and labour costs) are calculated and compared to the revenue achievable under the current wood price situation.

14.3.2 Wood Quality

14.3.2.1 Stem Quality and Assortments

The basic quality classes for round wood are veneer logs, sawn timber and industrial round wood like pulpwood. Apart from these categories other assortments may be specified for particular purposes, such as mine timber and instrument or resonance wood. Veneer logs are of very good quality and require a minimum length of 2 m and a minimum diameter of 30–40 cm depending on the veneering technology. The quality classes of sawn timber contain different grades specified with butt rot, minimum diameter and minimum lengths of the log. The specifications of the quality grades are different for logs from coniferous and broadleaved trees.

Table 14.10 Stem quality classes as assessed by the China's NFI

Stem quality class	Description
1-Timber tree	Timber length is more than 40 % of total length of the tree
2-Semi-timber tree	Timber length is more than 2 m for coniferous tree or 1 m for broadleaved tree, but less than 40 % of total length of the tree
3-Fuelwood tree	Timber length is less than 2 m for coniferous tree or 1 m for broadleaved tree

14.3.2.2 Assessment and Measurement

Diameter classes are related to the stem quality. During field data collection, all sample trees in pre-mature, mature, and post-mature forests are classified by dbh into 4 classes: 5.0–12.9 cm, 13.0–24.9 cm, 25.0–36.9 cm, and ≥37.0 cm. Before the 7th NFI, three classes of stem quality are distinguished in the field. The three stem quality classes are described in Table 14.10. However, in the 7th and 8th NFI, the assessment of stem quality classes was discontinued.

In addition, several other variables are assessed on individual sample trees that are relevant with regard to stem quality. These include the tree status dead or alive, information whether a tree is forked or not, and some other stand- and site-specific variables like the type of forest and the elevation above sea level.

14.3.3 Assessment of Change

14.3.3.1 Assessment and Measurement

The estimation of increment and drain in the China's NFI is based on the field measurements on permanent plots at two consecutive points in time. Sample trees can be distinguished into trees present only at the first occasion, trees present at the first and second occasion, and trees present only at the second occasion. Sample trees that have been present at the first occasion and that are no longer present on the plots at the second occasion are recorded in the field assessments and the type of drain (cut or mortality) is determined. Sample trees present at the first and second occasion on the plots are recorded to determine the growth of survivour trees. Sample trees present only at the second occasion are used to estimate the ingrowth part of the increment.

14.3.3.2 Estimation of Increment

The increment estimated by China's NFI is defined as the volume increment of survivour trees between two field assessment periods plus the volume of ingrown

trees that exceed the dbh threshold of 5.0 cm between the two points in time (State Forestry Administration 2011). The volume of the sample trees is calculated by applying the one-variable volume equations V = f (dbh), where dbh is the diameter at breast height. The volume functions contain all stem parts above ground level or root collar and include the tree elements bole plus stump, bark and the stem top.

Estimates of change include the increment of trees that die between cycles, are felled or fall over naturally as well as for trees that grow into the sample. Also the increment or volume of trees on land areas converted to forest or changing from forest to other land uses are considered in the increment and drain estimates. The NFI increment estimates are average annual increments for the time period between two field assessments. To obtain increment per hectare and total increment, the increment data of individual sample trees are converted into annual and per hectare values for each sample plot. The plot-level estimates are averaged to obtain the mean increment per year and per hectare and are furthermore multiplied by the forest area to calculate the total increment. National estimates are gross increment and they are calculated by forest and ownership categories, age classes and tree species.

14.3.3.3 Estimation of Drain

The NFI drain estimated by the China's NFI is defined as the volume of trees that were found to be harvested or dead between two field assessment periods. The volume of the sample trees that have disappeared between measurement occasions is calculated using the tree measurements at the first occasion and adding half of estimated growth between measurements. Individual tree volumes are estimated using the previously mentioned volume equations, and species-specific growth is estimated using the observed growth of trees measured at both measurement occasions. The volume of felled trees on land areas converted to other land-uses is included in the drain estimates.

The drain estimates of NFI are average annual volumes of drain for the time period between two measurement periods. Drain per hectare and total drain are obtained by referring to the situation and the number of trees represented by the sample trees at the time of the first assessment. National estimates are calculated by forest and ownership categories, age classes and tree species.

Besides the periodic drain estimates of NFI, annual statistics on the amount of wood harvested in China's forests are compiled in the "Forestry Statistics in China", which is published by the State Forestry Administration (State Forestry Administration 2012b). The statistics given by the "Forestry Statistics in China" are lower compared to the NFI estimates. The differences are mainly due to the fact that the "Forestry Statistics in China" reports only commercial wood volume whereas China's NFI reports all harvested volume, including wood used by the forest owners themselves.

14.3.4 Other Wooded Land and Trees Outside Forests

14.3.4.1 Assessments and Measurements

The sampling grid in China's NFI covers all land-use classes and ownership categories of the mainland of China. It is broadly similar to the FAO's Other Wooded Land definition (FAO 2004). All trees that exceed the dbh-threshold of 5.0 cm are measured, including trees growing on non-forest land. The land-use and ownership categories were also determined for plots located outside the forest. Thus, growing stock, increment, and drain of trees outside forests are also available.

14.3.4.2 Estimations

Besides the growing stock, increment and drain of arboreal forests are given in the China's NFI (see Table 14.9), those of trees outside forests are also estimated. For example, from the latest 8th NFI, the growing stock volumes of open forest, scattered trees in other forest land, and isolated trees beside villages (residential areas), roads, rivers, and croplands (so called "4-side trees") are 106, 789, and 401 million m^3 respectively. The total growing stock volume in China is 16,433 million m^3, including forest stock volume of 358 million m^3 in Taiwan, Hong Kong and Macao.

14.4 Conclusion

The availability of wood and biomass resources has become an increasingly important issue in the recent years at both national and regional scales. Therefore reliable data and information about the amount of wood and biomass available on a sustainable level are essential to develop strategies that take into account the multiple forest functions including: economic use, nature conservation and protection, and recreation. China's NFI, as the largest national forest monitoring program, has continuously broadened its thematic scope since its establishment in the 1970s. Through the integration of additional data from various sources like China Forest Ecosystem Research Network, China's NFI has estimated forest biomass carbon storage and assessed the forest ecological services in recent years (Li and Lei 2010; Project Group for Assessment of Forest Ecological Services in China 2010; Zeng 2014). Since the 7th NFI, some variables on forest health and ecological function have been added in monitoring items, and the main objective has started to convert from timber monitoring to ecological monitoring (Yang et al. 2015). Also, some ideas for improving the NFI system in China were presented in recent years (Yan et al. 2011; Zeng 2013). With regard to the estimation of

available wood and biomass resources, the consideration of new reporting requirements will provide further methodological developments to satisfy the information needs of decision makers.

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