Pesquisa Florestal Brasileira PFB

Pesquisa Florestal Brasileira
Brazilian Journal of Forestry Research
http://pfb.cnpf.embrapa.br/pfb/
ISSN: 1983-2605 (online)

Special session - IV NFI Symposium

# The Spanish National Forest Inventory: history, development, challenges and perspectives

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**Index terms:**
Monitoring
Biodiversity
Forest assessment

**Termos para indexação:**
Monitoramento
Biodiversidade
Avaliação da floresta

Received in 26/08/2016
Accepted in 27/07/2017
Published in 29/09/2017

doi: 10.4336/2017.pfb.37.91.1337

**Abstract -** It is important to have a statistically robust forest information data base which can be updated and can provide long-term information. National Forest Inventories (NFI) provide one of the best large-scale sources of information, and therefore are a cornerstone of forest policies. The scopes of NFIs, which are the primary source of data for national and large-area assessments, has been broadened to include new variables to meet increasing information requirements. This paper describes the history, methodology and guidance of Spanish NFI and international requirements. The current objectives are determined by analysing future perspectives and possible direction of future assessments. These objectives include harmonization of NFI, open data source and to broaden the number of field variables monitored (multi-objective inventory) in order to effectively fulfil information requirements.

## O Inventário Florestal Nacional Espanhol: história, desenvolvimento, desafios e perspectivas

**Resumo -** É importante ter uma base de dados florestal estatisticamente robusta, que possa ser atualizada e possa fornecer informações em longo prazo. Os inventários florestais nacionais (IFN) fornecem uma das melhores fontes de informação de larga escala e, portanto, são a base para políticas florestais. O escopo dos IFNs, que são a principal fonte de dados para avaliações nacionais e de grandes áreas, foi ampliado para incluir novas variáveis, visando atender a crescentes requisitos de informação. Este artigo descreve a história, metodologia e as orientações do IFN espanhol e os requisitos internacionais. Os objetivos atuais são determinados através da análise das perspectivas futuras e possível orientação de avaliações futuras. Estes objetivos incluem a harmonização do IFN, fonte aberta de dados e ampliação do número de variáveis de campo monitoradas (inventário multiobjetivo), a fim de efetivamente cumprir aos requisitos de informação.

## Introduction

Spain, with a total area of 50,560,000 ha, is divided into 50 provinces and 17 autonomous communities. Non-cultivated countryside termed ‘montes’ in Spanish occupies an area of 26,280,281 ha (including forest, other wooded land, grasslands, wetlands, dunes and sandy areas) of which 18,541,971 ha correspond to forest. The average contribution of the forestry sector accounted for 1.0% of Spanish gross value added (1.76% including the furniture industry) in the period 2000/2008 (España, 2012). Furthermore, 35% of the economic value associated with Spanish forests comes from non-wood products and services such as cork, hunting, honey, pine nuts and chestnuts, resin, mushrooms and extensive livestock farming.

Forests in Spain are classified as public or private according to the ownership:

- Public forest (29.10% of the total forest) belong to the State, to autonomous communities, to local authorities or to other public entities (government-owned institutions or corporations or other public bodies).
- Private forests (70.89%) are those owned by individuals, societies, collectives and other private entities.

Coniferous and broadleaf forests account for similar amounts of forested area in Spain (6.4 and 8.6 million ha, respectively) while mixed forest covers 3.5 million ha. The broadleaf species which cover the greatest forest area are the holm oak (*Quercus ilex* L.), followed by Pyrenean oak and pubescent oak (*Q. pyrenaica* Willd. and *Q. humilis* Mill. respectively), eucalyptus (*Eucalyptus* spp.) and cork oak (*Q. suber* L.). The conifer species which have the greatest presence are the Aleppo pine (*Pinus halepensis*), followed by maritime pine (*P. pinaster* Mill.), Scots pine (*P. sylvestris* L.) and black pine (*P. nigra* Arnold).

Currently, maritime pine is the most productive species, with over 500,000 $m^3$ of stock, followed by Scots pine and stone pine (*P. pinea* L.) accounting for 300,000 $m^3$. As regards broadleaf species, eucalyptus, pedunculated oak and sessile oak (*Q. robur* L. and *Q. petraea* L) and beech produce over 400,000 $m^3$ per year in northern Spain.

The Spanish National Forest Inventory (SNFI) is a monitoring and evaluation project providing robust, reliable information regarding forest ecosystems and their trends. At national level the NFI is the most important forestry project due to its longevity (over 50 years) and extensive field data collection. The importance of this project for the state administration is reflected in the corresponding budget that has been allocated continuously since 1986.

The need for homogenous, objective forest statistics for decision making at national level provided the impetus for undertaking the first SNFI1 between 1965 and 1974. This first NFI, based on the interpretation of aerial photography, provided the basis for successive NFI cycles. Although the initial objective was to follow a 10-year cycle, the second SNFI2 did not commence until 1986 due to circumstances related to the national infrastructure (Villanueva, 1997). Since SNFI2, a continuous inventory has been conducted with permanent plots with a cycle of approximately 10-years. SNFI2 incorporated certain improvements thanks to the availability of new technology. However, the SNFI3, which commenced in 1997, included further assessments. Based on recent forest information requirements (both national and international), new measurements were taken in the field (Vallejo & Sandoval, 2013). Furthermore, under the auspices of Cost Action E43 in 2010, the need to harmonize forest indicators and definitions worldwide led not only to comparable estimates but also to the implementation of new field assessments, which were integrated into SNFI3 methodology. SNFI3 field work ended in 2007, and the SNFI4 started in 2008 and is currently ongoing, with field data collection and data processing work progressing simultaneously (Table 1, based on Alberdi et al., 2014).

**Table 1.** Spanish National Forest Inventories (SNFI) summary.

| Inventory | Year | Stratification | Sampling method and field plots | Number of plots |
|---|---|---|---|---|
| SNFI 1 | 1965–1974 | Grid over photographs | Optimal allocation of plots; temporary plots | 65.000 |
| SNFI 2 | 1986–1995 | Grid over maps | Systematic 1-km x 1-km grid; permanent plots | 84.203 |
| SNFI 3 | 1997–2007 | Grid over digital maps (1:50,000) | Same systematic grid as NFI2; permanent plots | 95.327 |
| SNFI 4 | 2008–2018 | Grid over digital maps (1:25,000) | Same systematic grid as NFI3; permanent plots | Not available |

Source: Alberdi et al. (2014).

Although the primary objectives of the NFIs have changed over the years, the current aim of the Spanish NFI is to provide information at national and regional levels about the state and evolution of forests through the analysis of growing stock, carbon pools, development of forest resources, forest health, risks and forest biodiversity.

**Sampling design**

From SNFI3 onwards, the forest area estimation and stratification area described prior to the SNFI itself using the Spanish National Forest Map (SNFM) (E:1:50,000) (SNFM50). The main purpose of the SNFM is to provide the base mapping layer for the SNFI. Like SNFI, SNFM operates on a ten-year cycle. Currently, the area of each SNFI4 forest stratum is estimated using the SNFM25 (E:1:25,000), adding the tessera (i.e. basic unit, having a specific land use with homogeneous forest structure and forest type) belonging to each stratum (Table 1). The photointerpretation and digitization is performed on digital orthophotos provided by the National Geographic Institute as part of the National Plan for Aerial Orthophotography (PNOA). The methodology for producing SNFM comprises three phases: manual digitalization on screen by photo-interpretation, field monitoring and quality control. The main stratification factors are: the main species, crown cover, stand age categories and sometimes ownership type. Geographical aspects such as islands are also considered. In the digitalization, process, ancillary information is used such us previous SNFM, plots data from previous SNFI, National Topographic Map (1: 25,000), thematic cartography, SPOT 05 satellite image and regional maps. Field visits are programmed with two aims: a) to classify the tessera and its variables showing some problems in the digitalization phase; b) for quality control. Approximately 10% of the tessera of the SNFM are visited.

This map differs from the SNFM50 in the scale used, the size of the minimum tessera (2.5 ha in forest), in the identification of national forest types, fuel models and in the identification of shrub type formations in other areas of wooded land and shrub. The minimum spatial unit in the SNFM25 depends on the land class type: forest land (1 ha); floodplain forest (0.5 ha); agricultural land (2 ha); beaches, dunes and sandy areas (0.5 ha); wetlands (0.5 ha); inland water (1 ha); and urban land (1 ha) (Robla González & Vallejo Bombin, 2010).

The permanent sampling plots are established systematically at the intersections of the 1-km x 1-km grid in the forest areas identified by the SNFM. The sampling design unit is the province. In the case of any inconsistencies of SNFM and SNFI, discrepancies are analyzed and modifications are made if needed. However, due to budget constrains not all plots of the grid are measured and therefore differences in the plot number since SNFI2 can be noted (Table 1) apart from those caused because of forest area changes.

**Sample plots**

Field data collection is performed by a government affiliated agency which is under the management of the Forest Inventory Service belonging to the Ministry of Agriculture (Ministerio de Agricultura, Alimentación y Medio Ambiente). Field crews, each consisting of a forest technician and two workers, continuously collect field data throughout the year with varying efficiency (from 1.5 to 2.5 plots per day) depending on the terrain and whether or not they measure the new biodiversity and related variables. The field crews are supervised by a forest engineer and formed buy five forest technicians. Field data equipment includes GPS (Global Positioning System), metal detector, vertex and a PDA (personal digital assistant) among other.

All plots are permanently marked by burying a metal tube at the plot center. Field plots consist of four circular concentric fixed area plots of 5, 10, 15 and 25 m radius. In the concentric circle of 25-m radius, trees with diameter at breast height (dbh) are measured when dbh $\geq$ 42.5 cm; in the 15-m circle, when dbh $\geq$ 22.5 cm; in the 10-m circle, when dbh $\geq$ 12.5 cm; and in the 5-m circle, all trees with a dbh $\geq$ 7.5 cm are measured and trees with 2.5 $\leq$ dbh $\leq$ 7.5 cm are counted (Figure 1). Azimuth and distance of each measured tree from plot center are also recorded. Additional field data observed and measured in the concentric sampling plots include plot identification, forest type, tree mensuration (dbh and height of all measured trees), erosion factors, anthropogenic activity, tree damage, shrub species and cover in the 10 m subplot.

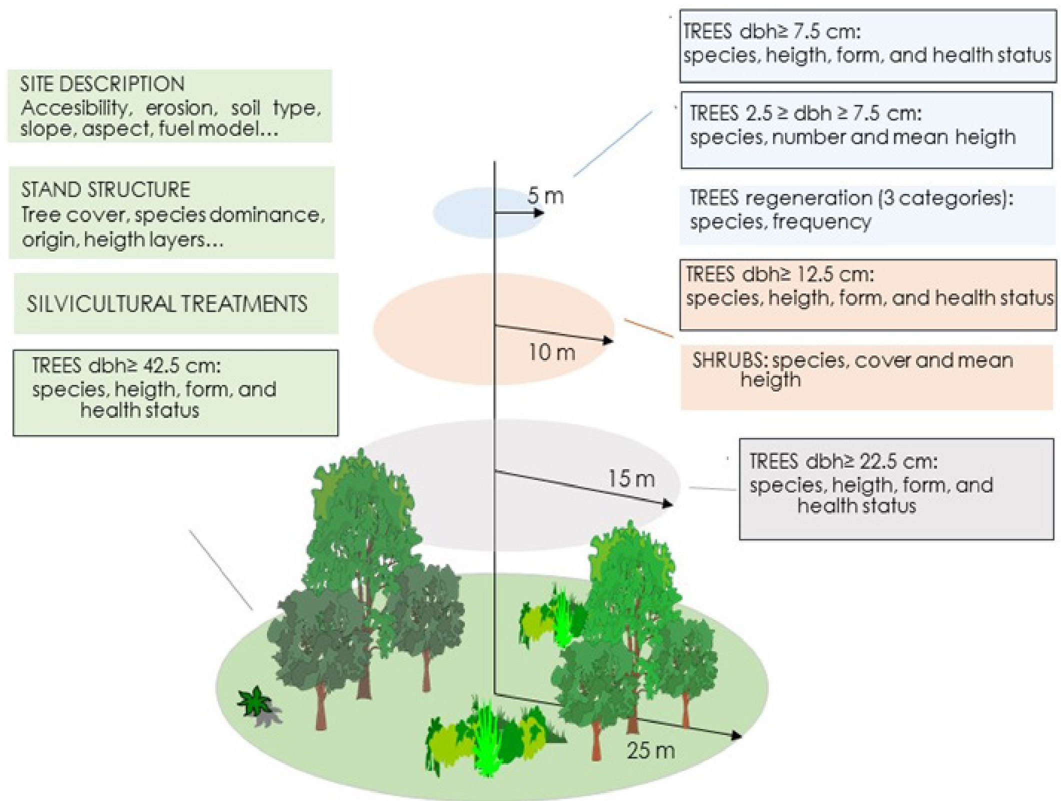


**Figure 1**. Spanish National Forest Inventory plot configuration.

**Multifunctional inventory**

To fulfil the new information and management requirements, a number of biodiversity and related indicators are assessed using data provided by SNFI. As more detailed and specific information was required, a decision was taken to design an appropriate methodology for estimating biodiversity within the framework of the SNFI, in addition to the existing inventory field data. This methodology was developed taking into consideration the national forest characteristics along with the international requirements and new initiatives (Alberdi, 2015; Vidal et al., 2016) and has been implemented since 2004 (SNFI3). The biodiversity and related assessment data are (Figure 2):

- Ground cover: measurement of sampling units percentage corresponding to different types of ground cover (bare soil, litter, rocks, etc.). Many indicators can be estimated from field cover such as average cover; number of plots with more than 75% of one specific component or the Shannon-Weaver index (Shannon & Weaver, 1948) among others.
- Presence of invasive species: a list of invasive species likely to be found in forested areas of each monitored province is drawn up. The invasive tree, shrub and herbaceous species considered are then recorded in the 10 m, 5 m and 1 m radius subplots respectively. In addition, the presence of these species in the 25 m radius NFI plot is registered.
- Vegetation cover life forms: the total cover of herbaceous plants, ferns and three different shrub layers are recorded to define the vertical structure of the understory.
- Complementary stand structure measurements: as not all trees are measured due to the concentric circle plot design (depending on the tree diameters and distance to the plot center), additional tree location measurements and species identification for at least 20 trees are recorded. With this additional information, many horizontal, vertical

and combined indicators can be estimated together with neighboring indices.

- Dead wood: eight dead wood categories are recorded: dead standing trees (including snags, dbh > 7.5 cm, height > 1.3 m); dead downed trees (dbh > 7.5 cm); dead standing and downed saplings (2.5 < dbh < 7.5 cm); downed coarse wood pieces/downed branches (diameter at the small end > 7.5 cm, length > 30 cm); stumps/snags (diameter at mid height > 7.5 cm, total height < 1.3 m); coppice stumps (representative diameter at mid height > 7.5 cm, total height < 1.3 m); and accumulation (diameter > 7.5 cm of a representative branch at half length). The five decay classes proposed by Hunter (1990) and Guby & Dobbertin (1996) are considered, although two additional classes are defined: hollow dead wood (to avoid overestimation of volume) and recently cut (so that the probable amount of deadwood removed can be deduced). Dead wood volume and biomass can be derived from this information.
- Micro-sites: elements indicating naturalness, such as nests, and others showing human activity, such as the presence of cattle, are identified and recorded in each plot.
- Impact of browsing: browsing impact data are recorded in the 10 m radius subplot for trees, saplings and shrub species and in the 5 m radius for tree regeneration. For each species, the percent crown cover to the nearest 1% is visually estimated as a proxy for browse availability. Average browsing degree, indicating browse utilization is also recorded by species according to a 6-rank classification method proposed by Fernández-Olalla et al. (2006).
- Stand age: in each plot, tree age and diameter growth increment of the measured dominant tree are determined by means of core extraction at a height of 0.5 m above ground level. Diameter-age models of dominant tree species can be derived using this information and old growth trees can be identified (Alberdi et al., 2013).

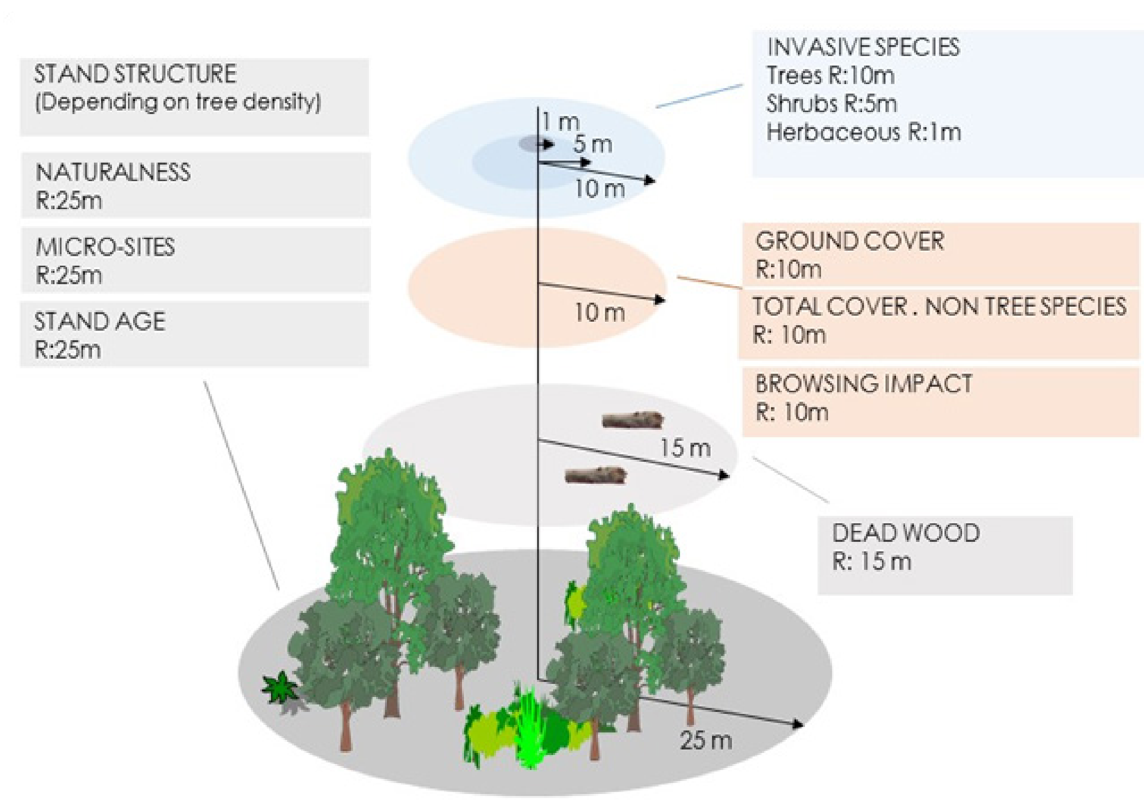


**Figure 2**. Spanish National Forest Inventory monitoring plots of biodiversity and related measurements.

## Data processing and reporting

SNFI data are used nationally and regionally (autonomous communities and provinces) to formulate forest and environmental policy and for international reporting (Global Forest Resources Assessments, Forest Europe, State of Europe's Forests criteria, indicators and reporting related to greenhouse gas monitoring).

The volume of single trees is estimated as the volume of the bole over bark, above stump (considered 20 cm height) and to a stem top diameter of 7.5 cm. The volume of growing stock of trees includes the stem volumes of all living trees of all species with dbh ≥ 7.5 cm. The general models used to calculate volume over and under bark are:

$$V_{ob} = a_1 + b_1 d_i^2 h_i \quad (1)$$

$$V_{ub} = a_2 + b_2 V_{ob} + c V_{ob}^2 \quad (2)$$

Where $V_{ob}$ and $V_{ub}$ are the volume ($dm^3$) over bark and under bark respectively, and $a_1$, $a_2$, $b_1$, $b_2$, c the model parameters, d (mm) is the dbh and h the total height of the tree.

For each tree species and taper form (six categories), an equation is defined. The volume of large branches (diameter at the small end > 7.5 cm) is also calculated using specific models per tree species depending on the dbh (Alberdi et al., 2010; Instituto Nacional para la Conservación de la Naturaleza, 1990).

The estimated value per plot and hectare is calculated by expanding the tree values using a scale factor ($f_i$) which varies according to the plot radius (depending on the diameter threshold) (equation 3). The scale factor is defined as the relation between the plot area and the reference area (1 ha) (Bravo et al., 2002).

$$f_i = \frac{10.000}{\pi * R_i^2} \quad (3)$$

Where $R_i$ is the plot radius.

Finally, stratum values are estimated by determining the area and number of plots of each stratum (defined by the SNFM). The estimated error (at 95% level) for estimates of the growing stock volume generally varies between 5% and 10%. The error is calculated using a stratified estimator based on systematic sampling and from a systematic stratified (a posteriori stratification) sampling. Change assessments are obtained using permanent plots through comparisons of two consecutive inventories.

Other usual estimates estimated by SNFI include number of stems, regeneration, tree damage (cause, importance and location), shrub species, shrub cover and height (from which biomass can be derived) and dead wood. These can be classified by forest type, altitude or forest ownership (España, 2008).

Biodiversity and related indicators are also provided by forest type including degree of naturalness; tree and shrub species diversity; area covered by one, two, three and more than tree species; several stand structure indicators (such as dbh and height deviation); browsing impact and dead wood volume estimation (Alberdi, 2015).

Additionally a forest evaluation is assessed. Based on the information generated by the SNFI along with exogenous information, mainly from national forest statistics, an assessment of the services generated by the forest is obtained (Vallejo & Sandoval, 2013).

## Challenges and future perspectives

The SNFI provides robust and reliable forest information for forest management and policies; therefore the continuation of this project is crucial for the forestry and environmental sectors. However, given the new and increasing information requirements along with the potential provided by the SNFI, new variables could be recorded which will not only increase our knowledge but also create information synergies with existing measurements from the different forest types. The main variables that could add to the current forest information and are under analysis at this time are the following:

*Species volume models*. In Spain, volume models were developed during SNFI1. Nevertheless, as a result of certain factors associated with stand evolution (density and climate change among others) it has now been confirmed that the diameter-height relationship has changed and therefore the volume models need to be revised.

*Spanish National Forest Inventory of productive stands*. Productive stands in Spain, mainly located in the North West (around 7% of the forested area) supply approximately 75% of the wood consumed. However, the rotation period is shorter than the 10-year SNFI cycle. Hence, it was decided that the cycle in this area should be reduced to 5 years in order to obtain more accurate and comprehensive information.

*Monitoring Soil*. Yet, no effective, economical way of monitoring soil data has been defined and only pH and texture have been recorded. The incorporation of soil variables such as depth or quality index would be particularly useful to further our understanding of the overall functioning of the forest ecosystem.

*Shrubs types in non-forest areas*. SNFI focuses on wooded areas, and the SNFM25 only provides general structural characteristics regarding other wooded land and areas of shrub. However, these landscapes comprise a large area and play an important social and ecological role. The establishment of permanent plots in these areas would provide important information although the sampling intensity should be lower initially.

*European harmonization process*. The supranational administration of the European Commission requires the NFIs to be comparable because European information is obtained through aggregation (Tomppo et al., 2010). Although certain aspects such as the assessment of forest area (Vidal et al., 2008) or above ground biomass (Vidal et al., 2016) have already been addressed as part of the harmonization process, further studies are needed.

*Collaboration with non-European countries and international Organisms*. Although no plans exist to extend the harmonization process beyond Europe, collaboration and cooperation with other countries (especially Central and South American countries) is considered important given the international information requirements (FAO and REDD +).

*New technology*. New technological developments such as LIDAR (Laser Imaging Detection and Ranging), the Sentinel satellite constellation belonging to European Union (EU) (2014) or even drones could play an important role in capturing forest information and reduce the current costs of NFIs. However, despite the potential utility of this new technology, fieldwork will still be required (McRoberts & Tomppo, 2007), especially regarding parameters such as regeneration, deadwood, shrubs, etc. (McRoberts et al., 2010).

*Sampling optimization*. One of the first analyses that should be performed is an error analysis of the different parameters. In Spain, the number of plots needed to have acceptable volume errors for main species is smaller that the monitored ones according to the sampling design. So, today, the number of plots has been reduced due to the economic crisis rather than expanding the inventory cycle. In the future, the adverse effects of this reduction in sampling are likely to be mitigated by using information provided by new technologies and forest stand modeling.

*Increased accuracy of estimates*. The use of sub-meter GPS is needed to improve location accuracy and make it possible in future to combine location information with information provided by remote sensing.

*Multi-functionality*. Due to changing policy needs and therefore the increasing forest information requirements, more variables must be recorded. NFIs provide one of the best forest information systems and therefore have been converted into multifunctional inventories. New variables such as those related to non-wood forest products are currently being analyzed with a view to estimating production of such products through information provided by NFIs.

However, it is important to be able to adequately transmit this extensive forest information to society through accessible databases, comprehensive reports and publications aimed at the different people involved (stakeholders, managers, policy makers…). It is also important to create synergies between the different forest information networks such as Forest Habitats of Natura 2000 or the Level I Forest Condition Monitoring established under the auspices of the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (Fischer & Lorenz, 2011).

## Conclusions

SNFI is the most important forestry project at national level due to its long period of validity (over 50 years) and extensive field data collection. Additionally, it provides robust information for forest management and policies. SNFI current aim in its four cycle (SNFI4) is to provide information at national and regional level about the state and evolution of forests through the analysis of growing stock and carbon pools, development of forest resources, forest health, risks and forest biodiversity.

To fulfil the new information and management requirements, a number of biodiversity and related indicators are assessed using data provided by SNFI. These indicators include information related with ground cover, invasive species, vegetation cover life forms, stand structure, dead wood, micro-sites, browsing impact and stand age.

The main topics currently being analyzed and which could be add to future SNFIs are: improved species volume equations, additional soil and non-wood forest products data and the establishment of permanent plots in other wooded land. Additionally, case studies considering the incorporation of information from new technologies and the participation in the European harmonization process are being carried out nowadays.

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