Dutch forest monitoring network, design and results

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Summary
The new Dutch forest monitoring network is a policy-guided, multiple-use, GIS-oriented forest monitoring network. It is designed to provide the Dutch government, on a cyclic 8-year basis, with actual information about Dutch forests. Variables that reflect the information needs of policy makers and interest groups were selected by means of interviews and workshops. High-ranking variables are: wood stock, ownership, stand age, management status, biodiversity, carbon stock, and recreational use. These and other variables are being measured on 3622 forest sites, selected according to an unaligned systematic sampling design. The data are stored in an ORACLE data base, made accessable by internet.
Results: total Dutch forest area approximates 360,000ha; 46% is owned by private owners and societies for nature conservation; coniferous forests dominate (60%); most forests were planted in 1940-1980; total above ground volume of living trunk wood amounts to 56.3 million m^3; most common treespecies are Quercus robur, Pinus sylvestris, and Betula pendula; most common shrubs are Sorbus aucuparia, Prunus serotina, and Rhamnus frangula; most common other species are Deschampsia flexuosa, Rubus fruticosus s.l., and Dryopteris dilatata.

Nomenclature follows Van der Meijden (1996).

Introduction

In The Netherlands, forests occupy 10% of the land area. They are used for many purposes: economic, recreational, environmental, and biodiversity. Multi functional use of forests is being stimulated by the Dutch government and other policy makers (LNV 2000). Moreover, the Dutch government has the responsability of formulating forest policies and an obligation to fill in current and foreseen international land use and forest enquiries (TBFRA, Forest Focus, LULUCF). For performing these tasks thoroughly a new multifunctional forest inventory was required.

Until 2001, in The Netherlands, forest inventories were carried out four times (Centraal Bureau voor de Statistiek 1985; Dirkse 1998). They were all funded by the government. The Fourth forest inventory was finished in 1985. The data of this last inventory became outdated and in 1998 the need for a new forest inventory was felt. However, by then, a forest inventory was supposed to deliver not just data on wood stock and harvest, but on land-use, environmental quality, and biodiversity as well. Mainly for reasons of efficiency, a forest inventory was expected to become a multifunctional resource inventory. Consequently, the collected data should equally meet the information needs of policy makers and other interest groups. Since some information is only needed temporarily, the forest inventories were to allow for replacing variables according to these change of interests. Other conditions to be met were: simplicity of design and GIS compatibility.

Basically, forest inventories estimate resources: areas and stocks. Usually a forest inventory includes a sampling design, variables to be measured, a field campaign, a design for a data base, and standard reporting. This paper introduces the new Dutch forest monitoring network and reports first results.

Sampling design

For area estimation, many sampling techniques exist. Stratified random and systematic sampling techniques are well known (De Vries 1986). Little known however is unaligned systematic sampling. This design was proposed by Quenouille (1949). It is a method of plane sampling which uses sampling points that are systematic in both directions, but unaligned. Its estimates should be less susceptible to linear patterns. Smartt and Grainger (1974) investigated its efficiency in estimating relative areas of patches on a vegetation map. Compared to strictly random or stratified designs, the unaligned systematic design proved to be most efficient.

In preparing the new Dutch forest monitoring network, three sampling designs were simulated, using a digital map of Duthch forests (Dirkse et al. 2001). Included were simple random sampling, random sampling per square, unaligned systematic sampling (Dirkse & Daamen 2000). Simple random sampling was taken as a base line design. A stratified random sampling scheme was left out because such a scheme does not optimally fit GIS and monitoring requirements. Four sampling densities were taken into account: 1 sampling point per 1km^2, 1 sampling point per 4km^2, 1 sampling point per 16km^2, 1 sampling point per 64km^2, 1 sampling point per 265km^2. Simulation revealed, that for all densities, the standard errors did not differ significantly among the designs. However, because the unaligned systematic design performs best in a GIS environment, this sampling design was favoured. In a density of one sampling point per km^2, it estimates Dutch forest areas with a standard error of less than 10%. The total number of forest sampling plots amounts to 3622. For practical reasons, the plots are grouped in three regional clusters of nearly equal number. Forest is primarily defined as a forested area in which crowns of trees cover more than 20%. The definition used approximates the FAO standards (UNECE FAO 2000).

In forest inventories, some variables are standard, such as dominant tree species, stand age (year of germination), tree species composition, tree diameter at breast height (dbh), forest protection (disturbances), ownership, and species composition of tree, shrub and ground layers. Most of these variables are related to economic use of forests. However, since forests are no longer being used for wood production only, other variables needed to be incorporated. By means of a workshop and about twenty interviews, policy makers were asked for additional variables related to recreational use, ecological management, and environment. Policy makers were selected purposively, so as to represent most groups of interest. Interviews were structured by a protocol. The additional variables were ranked and those with the highest ranking were added to the standard variables. Tables 1 and 2 summarize the variables incorporated in the field program.

Table 1. Variables measured in three successive forest inventories in The Netherlands. Prior to 1982 forest inventories were carried out by mapping and inspecting all woodlands.

Variable	Remarks		1982	2000
Type of forest	Forest for timber production, natural forest, spontaneous forest, other wooded land			
Principal tree species	Tree species bominant by crown cover			
Ownership	Information provided by the land register			
Year of germination	Year of germination of principal tree species			
Mean height	Mean height of highest tree per are			
Area of forest development stage	Phase in forest development cycle: bare, young, dense scrub, poles, dense stand of trees, thin stand of trees			
Size of forest development stage	Divided in four classes of magnitude			
Method of establishment	Planted or natural regeneration			
Harvest	Clear felling, group felling, single tree felling, no felling			
Disturbances				
Waste	Recreational left behinds, heaps of agricultural or garden waste, rubbish dumps from management			
Opening to the public	Restricted or unrestricted opening to the public			
Accessibility	Signposted routes for biking, walking or riding			
Reachability	By bus, car, bike or on foot			
Noise	Caused by nature (wind, trees, wild animals), voices or dogs, tractors or chain saws, cars, aircraft			
Soil	Seven soil classes, read from an			

	auger core: poor sand, rich sand, calcareous sand, clay, calcareous clay, peat, loam			
Humus	Thickness of L, F, and H layers in upper 40 cm of sand or loam			
Species composition	Species list of vascular plants (including trees and shrubs) and mosses, with abundances.			

Table 2. Variables measured per tree in the sampling plots

Variable	Remarks		1982	2000
Tree species	according to species concepts used in Dutch forestry (species of some large genera, such as Salix, lumped into a single category).			
Diameter at Breast height (dbh)	Measured to the nearest mm with digital caliper. Only trees with dbh of 50 mm or more.			
State of tree	Alive or dead (standing or lying)			
Tree form	Length of stem			
Stem quality	Number of branches a.o.			

Field campaign

Field work was carried out by three groups of two persons. Each group consisted of a forest ecologist and a botanist. The groups worked in separate regions. For the location of sampling points, each group was provided with a 1:10000 field map, a measuring tape, a compass, and a GPS receiver. The locations to visit were stored in the digital caliper and indicated on the field maps. The circular sampling plots measure 300m^2.

Diameter breast high (dbh) was measured (bark included) to the nearest mm with a digital caliper. Trees with dbh less than 50 mm were excluded.

Field work is designed to be carried out during four years, starting in 2001. Each year a quarter of total forest sampling points will be inventoried. The years of recording (2001, 2002, 2003, 2004) were randomly assigned to the sampling points.

Data base

Data are stored in a relational data base (ORACLE). Access to the data base is by Standard Query Language (SQL). Main tables are: 'Plotopnamen, Boommetingen, and Vegetatiopnamen'. These tables contain uncoded and coded information. The latter is transcribed in ancillary tables. Key variable is 'Plotnumber'. A key variable allows for a join of tables in SQL queries. Input constraints on data help keeping the integrity of the data base and preventing from errors.

The entire data base may be downloaded in Access format by granted users. Summaries are available on WWW.natuurcompendium.nl and bosdata?

Results

The results presented are preliminary, because they are based on half (1811) of the number of sampling plots (Dirkse et al. 2003). Since this half represents a random selection, the basal data are representative of Dutch forests and likewise, the results are unbiased.

Area

Total Dutch forest area approximates 360,000ha (Table 2; Dirkse et al. 2001). Almost half of this area (47%) is concentrated in two provinces: Gelderland and Noord-Brabant.

In 1982 the forest area was found to be 334,026ha (Centraal Bureau voor de Statistiek 1985). So, in nearly two decades it has increased by 25,819ha, implying an average net increase of 1,434ha per year.

Ownership

Nearly half of the forests (46%) is owned by private owners and societies for nature conservation (Table 3). The other part (48%) is owned by state departments and local authorities. Privately owned forests equal those owned by the state.

Table 3. Estimated area per owner group

Owner group	Area (ha)
State	115,643
Local authorities	58,020
Nature Conservcancy	53,848
Private owners	114,252
Unknown	18,082
Total	359,845

Dominant trees

Dutch standing forests are dominated by conifers. Coniferous forests occur on 159,722ha (60%). Forests of Scots pine (Pinus sylvestris) are most abundant, these occupy 95,974ha (36%). Deciduous forests occupy 100,345ha (40%). Among these, forests of Pedunculate Oak (Quercus robur) are most abundant, these occupy 45,304ha (17%). Clear-cut areas hardly occur.

Since 1982, the area of coniferous forest has declined by 7585ha. In the same time, deciduous forests increased by 33,067ha. The increase of deciduous forests is mainly caused by a strong increase (newly planted or spontaneous) of Pedunculate Oak (Quercus robur).

Table 4. Estimated area of standing forests

Forest type	Area (ha)
Coniferous	159,758
Deciduous	100,345
Clearant area	199
Non standing forest	99,543
Total	359,845

Age

In The Netherlands, nearly all forests originate from planting. Standing forests planted before 1900 are very few (4%). They consist only of Scots Pine, Pedunculate Oak, and Beech. Most standing forests (51%) were planted between 1940 and 1980. These forests consist of a variety of tree species. Standing forests planted after 1980 mainly consists of Oak and Poplar.

In 2001-2002, trees in standing forests had an average age of 53.3 year. In 1980 this average was 43.3. So, in two decades, the average age of trees in standing forests has increased by 10 years. This is mainly due to changes in forest management: less clear cut and more thinning.

Volume
Total above ground volume of living trunk wood is estimated to be 56.3 miljon m^3 (Table 5). To this volume, Scots pine contributes 27% and Pedunculate Oak 19%. These contributions outweigh by far those of all other species. Douglas Fir is third with a volume portion of 8%. The estimated average standing volume amounts to $194m^3$ per ha. This includes both dead and living stems.
In 1984-1985, standing volume was $158m^3$, which implies an increase by $36m^3$. This increase reflects the ageing of Dutch forests.

Table 5. Estimated above ground volume of living stems ($1000m^3$)

Tree (group)	Volume
Scots Pine	15536.6
Douglas Fir	4804.3
Japanese Larch	3596.7
Other conifers	5947,4
Pedunculate Oak	10500.1
Beech	2916.0
Other deciduous trees	13003.0
Total	56304.1

Recreation
Most forests (73%) are open to the public. Some forests are closed for several reasons: military, hunting, or nature protection. Accessability is rather high, 37% may be reached by car, indicating that many forests are accessable by a network of local roads. As a consequence, in most Dutch forests (66%) the noise of traffic (by road or air) is heard (Table 6). The noise of road traffic predominates (54%). A minority of the forests (21%) may be called quiet. In these tranquil forests only voices of wild animals, birds or just wind are heard.

Table 6. Source of dominant sound in Dutch forests as heard by two persons on working days. Mean observation time was about 1 hour.

Dominant source of sound	frequency %
Nature (birds, wind)	21
Humans, dogs	2
Engines (tractor, chain saw)	11
Traffic (car, bus)	54
Aircraft	12
Total	100

Flora
According to the plot recordings, Pedunculate Oak (Quercus robur), Scots Pine (Pinus sylvestris), and Silver Birch (Betula pendula) are by far the most common tree-species (Table

6). They occur in the tree layer of more than 30% of the forests. Less frequent, but still present as a tree in 10-15% of the forests, are Red Oak (Quercus rubra), Douglas Fir (Pseudotsuga mensiesii), Beech (Fagus sylvatica), Japanese Larch (Larix kaempferi), and Downy Birch (Betula pubescens).
In the shrub layer, Rowan (Sorbus aucuparia) is most common. It occurs in 33% of the forests. Silver Birch (Betula pendula) and Pedunculate Oak (Quercus robur) are the most common rejuvenating tree species. Their offspring reached into the shrub layer of 21% of the forests.
In the herb layer, Rowan (Sorbus aucuparia), Pedunculate Oak (Quercus robur), Wavy Hair-grass (Deschampsia flexuosa), and brambles (Rubus fruticosus s.l.) are the most common plant species. They occur in more than 50% of the forests.

Table 7. Frequency (%) of ten most common vascular plant species in Dutch forests. Herb layer contains all vascular plant specimens <2m. Shrub layer contains woody specimens between 2-6m. Tree layer contains trees and shrubs >6m.

Vascular plant species	Herb layer	Shrub layer	Tree layer
Quercus robur	64	21	46
Sorbus aucuparia	57	33	-
Deschampsia flexuosa	53	-	-
Rubus fruticosus s.l.	50	-	-
Betula pendula	22	21	32
Pinus sylvestris	21	-	41
Prunus serotina	37	20	-
Dryopteris dilatata	41	-	-
Rhamnus frangula	33	20	-
Dryopteris carthusiana	38	-	-

Discussion

In The Netherlands, forests are used by many people in a variety of ways. Recreational use has become very important. Forest inventories are funded by the national government. For both social and financial reasons, a forest inventorie was bound to be a multi purpose resource inventory. Which means that as many interest groups as possible should be able to use the data. In preparing the forest inventory, four aspects were important: choice of variables, sampling design, data base, and accessabillity of data. The new Dutch forest monitoring network is a policy-guided, multiple-use, GIS-oriented forest monitoring network. Obviously, even in a multi purpose forest inventory, many variables reflect a forestry tradition, because silviculture remains one of the reasons for having a forest inventory. Traditional inventory variables are dominant tree species and diameter breast high. Variables related to other interest groups are chosen according to preferences among interest groups. These preferences were obtained by means of interviews and workshops. The final number of variables was set by the amount of money available for the inventory.

Forest inventories are supposed to quantitatively estimate areas or quantities, so, a sound sampling design should be chosen (De Vries 1986; Brus & De Gruijter 1997; Kenkel et al. 1998; De Gruijter 2000). Sampling designs may be grouped in two: design-based designs and model-based designs (systematic). This dichotomy roughly separates the classical random designs from systematic designs. Random designs allow for estimating the optimal number of sampling points, given a prescribed level of confidence. Systematic designs formally lack this possibility. But, given the same number of sampling points, systematic sampling is usually found to be more accurate than strictly random sampling or even stratified random sampling (Smartt & Grainger 1974; De Vries 1986). However, we found both strictly random and systematic designs equally efficient, the unaligned systematic design having (in simulation) an almost negligable advantage of a less variable variance. As a consequence, other than statistical reasons for choosing a sampling design became more important, such as GIS compatibility and monitoring. Systematic designs are better suited to a GIS data environment, because the observation points are distributed regularly making interpolation and mapping more easy. Therefore, an unaligned systematic sampling design was chosen for selecting sample localities in Dutch forests.

Nowadays, data are stored in relational data bases, digitized files from which cross-referenced information can be retreived. Data bases should guarantee data accessabillity for a period as long as possible. The Dutch data are stored in an ORACLE database. This type of data base was chosen because an other application of it has been used since 1984 and proved to be stable and reliable for about twenty years. Other data bases probably will do as well, provided they are relational and rigid.

The inventory results are succesfully reported each year in updated reports (Dirkse et al. 2003). These reports are available for free. At the end of the inventory, the raw data will be made freely accessible for internet users. The reason behind this is, that people who pay for forest inventories have the right of being informed about the results. So, if governments fund forest inventories, the data should become available for all civilians.

Conclusions

If forests are serving several purposes, forest inventories should become multiple use resource inventories. Consequently, variables to be measured should reflect the information needs of several groups of interest (stake holders) and include recreation, nature and environment as well as forestry. Some systematic sampling design may be chosen because this suits a GIS data environment and monitoring better than a stratified random design. Data should be stored in a relational data base, made freely accessible by internet. Reporting by reports or papers should be maintained.

Litterature

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