INTEGRATED APPROACH AND INVENTORY SYSTEM FOR THE EVALUATION OF SUSTAINABLE FOREST MANAGEMENT INDICATORS AT LOCAL SCALES IN WESTERN EUROPEAN REGIONS*

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ABSTRACT

In the past decade, sustainability of forests has been assessed through monitoring of widely-accepted criteria and indicators for sustainable forest management. Evaluation of sustainable forest management indicators has generally been conducted at national levels on the basis of forest inventory data and agreed lists of indicators from inter-governmental processes. In parallel, forest certification schemes and processes have been developed and are generally conducted at smaller scales such as regional or management unit levels. Increasingly, sustainable forest management indicators will need to be evaluated at those local scales to answer public questions and facilitate social dialogue on the basis of scientifically sound and pertinent information.

To undertake this type of evaluation within homogeneous bio-geographic zones and a socio-economic context, an integrated approach is proposed combining (i) use of reference pilot zones, (ii) elaboration of indicators and evaluation of their pertinence through scientific studies for priority domains (carbon sequestration, forest damage, soil disturbance, landscape patterns and biodiversity, global value of products and services), (iii) comparative test of common protocols, and (iv) organisation and sharing of forest information at regional levels with stakeholders and public. Preliminary

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testing has been carried out on key indicators corresponding to priority issues for planted forests of European Atlantic regions.

Keywords: criteria and indicators; sustainable forest management; regional scales; inventory system.

INTRODUCTION, CONTEXT, AND RATIONALE

In the decade since the Rio summit in 1992, held to find answers to the global problems of forest degradation and destruction internationally, there has been a world-wide development of governmental and non-governmental mechanisms to adopt ecological, economic, and socially acceptable forest management standards, to evaluate the conformity of practices to those standards, and to assess the sustainability of forests using mutually agreed principles and a set of criteria and indicators to monitor changes in valued forest system components. These criteria and indicator systems have been developed through nine main inter-governmental processes covering most world forests and 150 countries. Among them, the Pan European process and related criteria and indicator system has evolved through the successive Ministerial Conferences for the Protection of Forests in Europe since 1990; based on six well-known criteria (*see* Box 1), it currently includes a set of 35 quantitative indicators and 17 qualitative indicators (MCPFE 2003). Reporting and monitoring of criteria and indicators are conducted at national level and many indicator values are derived from national forest inventories (e.g., MAP 2000). Even though most principles and criteria are common to all processes, there are still large differences between countries in number, content, and evaluation method of sustainable forest management indicators, as well as burning questions about their pertinence and how they can apply or be improved in the particular context of plantation forests.

Box 1

In the Pan European process for sustainable forest management, indicators are organised in six chapters called criteria :

C1: Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles

C2: Maintenance of Forest Ecosystem Health and Vitality

C3: Maintenance and Encouragement of Productive Functions of Forests(Wood and Non-wood)

C4: Maintenance, Conservation, and Appropriate Enhancement of Biological Diversity in Forest Ecosystems

C5: Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably soil and water)

C6: Maintenance of other socio-economic functions and conditions

In parallel, "soft law" mechanisms (Hickey 2004) such as forest certification schemes have been developed in many countries to determine, through third party transparent evaluation, whether forest management satisfies pre-established standards. Though Forest

Certification Schemes work in different ways around the world given the variety of ecological, socio-economic, and political situations, they are generally implemented at operational scales such as regional or management unit level where forest owners or managers are collecting a lot of data and information for reporting and monitoring purposes that could be used by criteria and indicator systems. All Forest Certification Schemes endeavour to conform with international governmental forestry principles and criteria for sustainable forest management, recognise the need to address simultaneously the three pillars of sustainability, and include requirements in terms of forest operations and planning, public consultation as well as maintenance of forest status and biodiversity, protection of soils and water, and social and cultural values. The rate of certification has been very high since 1995 and total certified forest area was close to 200 million ha in 2005.

However, irrespective of the degree of implementation of intergovernmental processes, or of forest certification schemes, it increasingly appears that the enforcement of forest management standards and the assessment of sustainable forest management criteria and indicators at various levels (international, national, subnational) require efforts in research and development (FAO 2004) in order to assist foresters, land-use planners, and policy-makers to adjust their practices and decisions and to facilitate dialogue on sustainable forest management. In particular, as demonstrated in the Canadian Model Forest Network, subnational and local levels (or meso scales such as watersheds, landscapes, regional territories) are very appropriate for sustainability assessment because of the possibility of adapting forest management and improving forest operations through close interactions between socio-economic factors, local authorities, and end-users and links with forest certification schemes.

Rationale

Criteria and indicators are still in the developmental stage and there are many issues such as scientific pertinence, continued relevance, and effectiveness of indicators that need to be resolved to make them fully operational (FAO 2004).

- Some indicators are based largely on empirical concepts, and therefore require an improved knowledge of forest ecosystem functioning (e.g., impact of regeneration status on biodiversity); however, comprehensive ecosystem assessments are generally complex, costly, and impractical for sustainable forest management monitoring purposes.
- Existing indicators by their definition or their implementation are often not pertinent, because they can change independently of the real status of the forest (e.g., number of staff members in charge of forest health monitoring, part of forestry in the National Product, defoliation).

- Availability and representativeness of data are often limited, specially at meso scales, regarding environmental and social issues such as non-wood products, biodiversity, water protection, social and cultural values, public access.

Until now, the elaboration and selection of indicators have been guided largely by convenience and availability of data, as well as scientific pertinence; for example, in some domain areas of pan-European criteria (C4 or C6 for example), it appears that the indicator-based approach and tools have been applied and used before being fully validated. Thus, better understanding of current sustainable forest management indicators and development of new ones are required, as well as development of methodologies to measure and monitor them in a cost-effective way over various spatial and temporal scales.

In this context, the paper focuses on the measuring at local level of a range of sustainable forest management indicators in the framework of the Ministerial Conferences for the Protection of Forests in Europe, using a multi-resource inventory system and an integrated approach combining:

(i) use of reference forest pilot zones within homogeneous bio-geographic zones and the socio-economic context of the European Atlantic Regions;

(ii) elaboration of indicators and evaluation of their pertinence through scientific studies for priority domains (carbon sequestration, forest damage, soil disturbances, landscape patterns and biodiversity, global value of products and services);

(iii) test and evaluation of sampling methods and harmonised protocols, and

(iv) organisation of forest information at regional levels and sharing with stakeholders and public.

The work has been conducted in the frame of a European Union funded project (FORSEE*) gathering expertise from a consortium of 24 scientific and technical partners from four European Union countries (France, Ireland, Portugal, Spain). In this paper, methods and preliminary results are presented for key indicators corresponding to priority issues for planted forests of the European Atlantic regions.

MATERIAL AND METHODS

The main components are summarised in Fig. 1, and the methods are described below for:

phase 1/ selection of pilot zones and indicators by expert panels
phase 2/ elaboration of harmonised protocols and data collection
phase 3/ analysis of data, assessment of costs and dissemination

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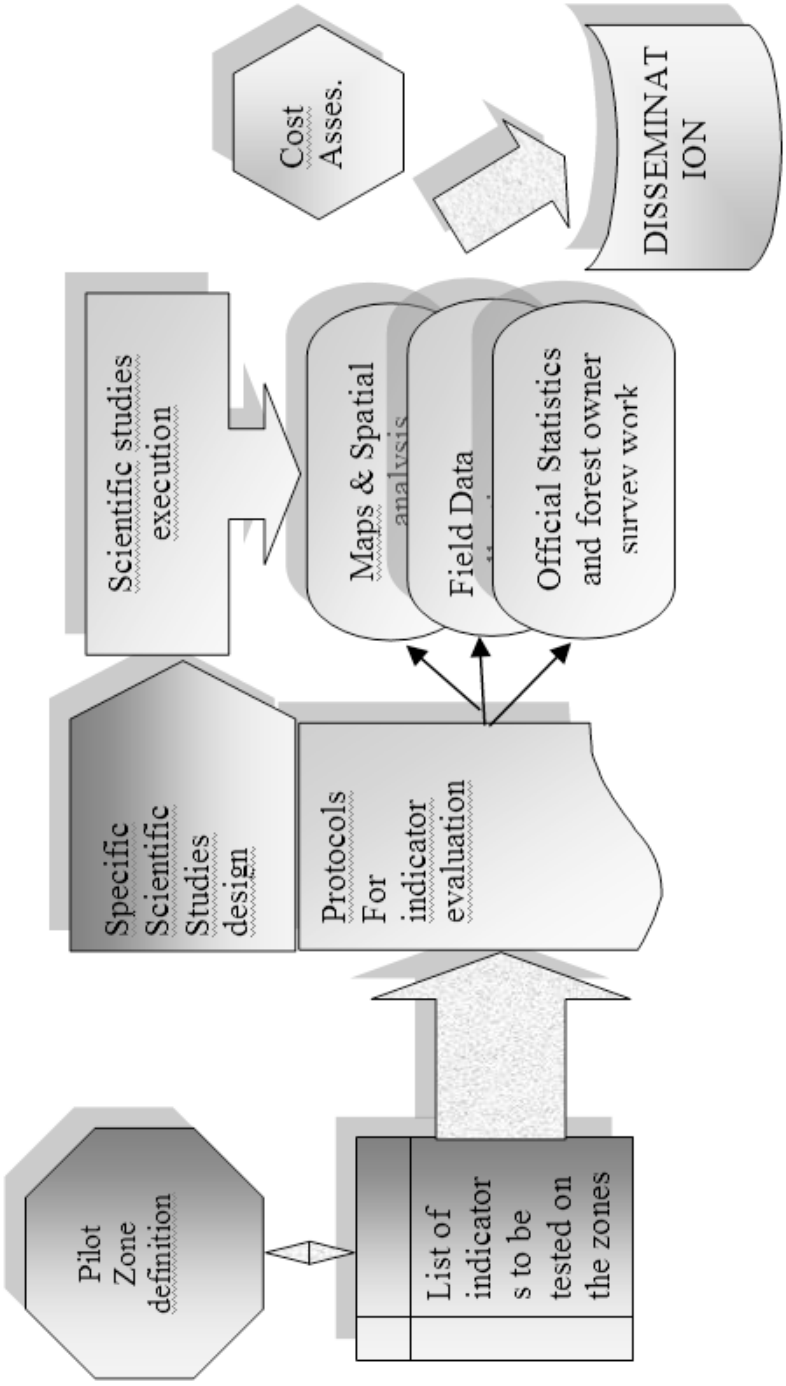


FIG. 1–Overall project components and activities

Selection of Representative Forest Pilot Zones

Definition and setting up of reference pilot zones for sustainable forest management was conducted on the basis of a combined analysis by expert scientists for each sustainable forest management criterion and forest owners associations from all regions. The rationale for the choice and definition of the pilot zones was to be able to demonstrate sustainable forest management in the long term through improved sustainability assessment methods and pertinent quantitative indicators at levels intermediate between the forest management unit level and the regional or national level.

Main criteria used for definition and design of the pilot zones included:

- Size: large enough to be pertinent at landscape level (inclusion of watersheds and rural territories grouping several communes in counties) and to be informative at other levels (forest management unit or regional)
- Location: representative of regional bio-geographic conditions (climate, soils, elevation, hydrography)
- Forest types: representative of main tree species and cultivated forest ecosystems (IEFC 2000), and of forest ownership and management units
- Forest uses: each zone includes multiple use of forests including wood production (recreation, conservation, water protection)
- Data: availability of monitoring data and presence of long-term experimental sites within the zone
- Interfaces: possibility of information transfer and facilitating of dialogue between foresters, local authorities, and end-users.

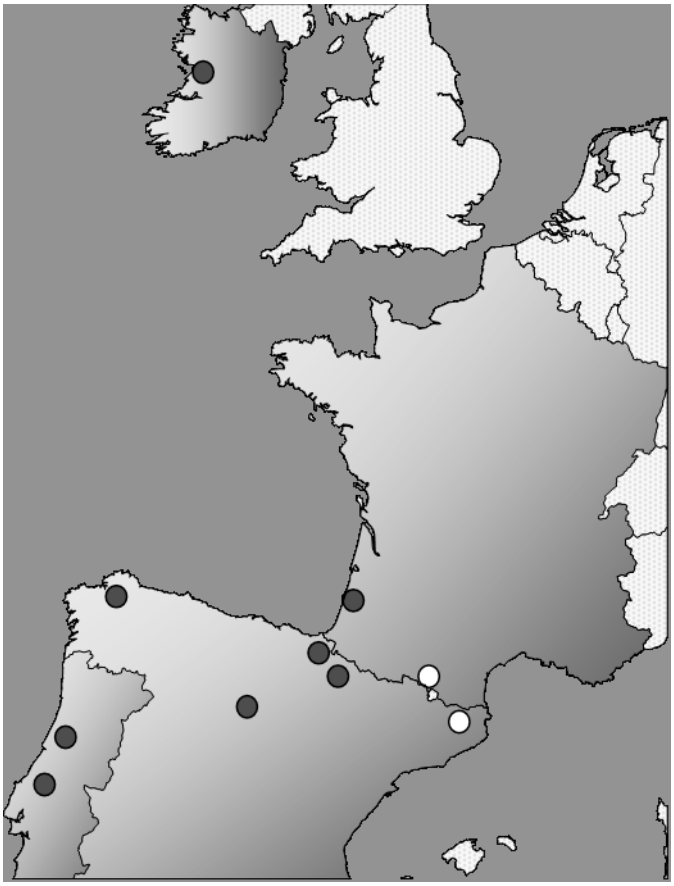
Most of the pilot zones follow administrative boundaries (several communes or counties) to facilitate access to socio-economic data, and include natural physiographic units (watersheds, natural landscapes). At this stage, it seems that flexibility on the pilot zone size and limits is required in order to adapt to the local context: some of the indicators will be estimated on the basis of a larger area, or on a smaller area depending on the domain of concept. The main characteristics and location of the forest pilot zones for European Atlantic regions are summarised in Table 1 and the attached map.

Selection of Indicators and Expert Panels

The choice of the indicators to test or improve was based primarily on the Pan European process and on the improved list of quantitative indicators from the "Fourth Ministerial Conference for the Protection of Forests in Europe" in Vienna (MCPFE 2003), but a large range of indicators from other sources has been also considered by the expert panels for the assessment of each criterion C1 to C6.

TABLE 1–Summary of main characteristics of forest pilot zones for sustainable forest management indicator evaluation in European Union Atlantic regions

Pilot zone (region and country)	Location	Tree species	Area (ha)	Forest (%)	Elevation (m)	Boundaries	Ownership
Western Ireland	Mayo	Sitka spruce Lodgepole pine	25 000	10	20–100	Administrative (county)	Farm forestry
Aquitaine (France)	Pontenx	Maritime pine	100 000	83	0–50	Watershed nested in administrative boundaries	90% private forests
Euskadi (Spain)	río Ibaizabal	*Pinus radiata*	50 000	65	100–600	Watershed	Private forestry
Navarre (Spain)	Roncesvalles	Beech Oak	18 000	73.5	600–1200	Municipalities	Public forest
Leon (Spain)	Rio Carrion	Poplar Corsican pine Scots pine	18 600	26	800–1000	Watershed nested in administrative boundaries	Private forests in agricultural landscape
Galicia (Spain)	Guitirriz	Maritime pine *Eucalyptus globulus* *Pinus radiata* Oak	45 000	75	400–700	Municipalities	Private and community forests
Northern Portugal	Sousa Valley	Maritime pine + *Eucalyptus*	77 000	38	100–600	Forest owner association in administrative boundaries	Small private forests
Central Portugal	Pinhal Interior Norte	*Eucalyptus globulus* Maritime pine	272 000	55	600–1200	Administrative zone (county)	Private forests in rural areas



Location map of forest pilot zones in France, Ireland, Portugal, and Spain

Expert panels included for each region representatives of public and private forest owners, national and territorial authorities, and scientific experts.

One of the most important factors in the choice of indicators was **relevance**, given regional environment and economic context: making sure that the indicator was in fact related to the perceived sustainability of forest management in the pilot zone, and that any changes in its estimated value accordingly reflected a change in the forest system. At this stage, it was considered that there was too much uncertainty in the estimation process to be able to benchmark indicators. Also, any indicator relevant only at national or management unit level, but not at pilot zone or regional level, was not considered.

The second factor taken into account for the choice of indicators was the **feasibility** constraint related to the project timeframe and resources. The experts were invited to select only indicators that had a chance of being evaluated within 3 years.

The third factor was the need to concentrate scientific efforts on indicators that require **improvement** or development of measurement and inventory methods; when existing tools are providing good and reliable data, there is no need to conduct in-depth investigations on this topic (for example, this is usually the case with wood volumes estimated through the national forest inventories in the European Atlantic Regions).

Elaboration of Harmonised Protocols for Indicator Evaluation

The second phase of this integrated approach involves a review of current indicator monitoring methods in the four countries involved, and the design of a common framework with harmonised protocols to be tested for indicator evaluation in all regions on the basis of the indicators selected in Phase 1. Protocols were developed by expert panels for each criterion and group of indicators, and harmonised through combined technical committee and inter-group meetings. The protocols involve three main task types currently carried out for each pilot zone:

(1) Mapping: A common list of basic maps and spatial analyses to apply to them have been defined.

(2) Field work: In each pilot zone about 100 plots are sampled according to the harmonised field protocol, collecting data for all the criteria for sustainable forest management.

(3) Surveys of forest owners and analyses of socio-economic statistics are conducted in each pilot zone or region taking into account local specificities but using a common framework.

Specific Scientific Studies for Evaluation of Pertinence and Development of Methodologies

In parallel with direct indicator evaluation through harmonised protocols, the approach includes specific in-depth studies for elaboration and improvement of indicators. It is well documented that scientific background is lacking in many sustainable forest management fields such as biodiversity (Marchetti 2004) for the selection, evaluation, and monitoring of sustainable forest management indicators. As part of the integrated approach, specific studies were conducted in some regions for each criterion that could be used, and then tested at a further stage in all pilot zones. The allocation of research study topics between regions was based on regional priorities and on research needs and existing research programmes (Table 2); all criteria were considered, except C3 (maintenance and encouragement of productive functions of forests) which is already well-documented.

The perspective of the development of forest plantations as carbon offsets or sinks and potential carbon markets under the Clean Development Mechanisms of the

TABLE 2–Specific scientific studies by region and by sustainable forest management criterion

Region	Related criterion
Western Ireland	C1 : Carbon storage
Aquitaine	C4 : Biodiversity
Euskadi	C5 : Soil protection
Navarra	C1 : Carbon storage
Castille y Leon	C2 : Forest health
Galicia	C1 : Carbon storage
Northern Portugal	C6 : Socio-economics
Central Portugal	C1 : Carbon storage

Kyoto Protocol (Carle *et al.* 2002) led the participants to conduct four co-ordinated in-depth studies to improve C1 indicators and supporting indicators for carbon, producing allometric functions, or volume/weight ratio required for understorey carbon assessment. The specific study for C2 was conducted on poplar plantations in Castille y Leon (Spain) to improve and validate forest health indicator protocols (Stanford *et al.* 2003). The specific on biodiversity indicators (C4) in Aquitaine (France) aimed at identifying the key parameters (at landscape and stand level) required to estimate global (all taxa) diversity of a forest system. Specific study in Basque country (Spain) on soils will mainly provide methods to assess forest soil sustainability in mountainous areas, and also provide accurate pedo transfer functions. The C6 specific research aimed at improving methods to assess total economic value of forests (Mendes 2005) incorporating new parameters such as biodiversity values or harmonised data on employment, and using results from other investigations (carbon stock estimation in C1). Detailed methods and results from these specific studies are not discussed in this paper.

PRELIMINARY RESULTS

Selected Indicators for Evaluation

Selected quantitative indicators currently evaluated are detailed in Tables 3 and 4 with regional priorities:

- Well-documented and reliable indicators are not considered further (e.g., wood volumes provided by national forest inventories, protection forest areas); nevertheless, some indicators such as forested areas or growing stock have been selected for comparison of definition, method, and benchmarking with international standards (IPCC 2000; FAO 2000).
- Indicators are included for which a more complete or accurate estimation needs to be provided than is currently given by the official statistics (for example forest employment or carbon stocks indicators).

TABLE 3–Selected indicators for all pilot zones with short description, origin, and work requested

Criteria	Short description	Origin			Type of work requested		
		Process	ID in process	Type	Map (T2,1)	Field (T2,2)	Enquiry (T2,3)
1	Forest area — Area of forest and other wooded land, classified by forest type and by availability for wood supply, and share of forest and other wooded land in total land area	MCPFE Vienna	1.1	Indicator	X		
1	Growing stock — growing stock on forest and other wooded land, classified by forest type and by availability for wood supply	MCPFE Vienna	1.2	Indicator	X		
1	Carbon stock (EXPANSION FACTORS)	MCPFE Vienna	1.4	Indicator	X		
1	Carbon stock in the woody biomass (above and below ground)	MCPFE Vienna	1.4.1	Indicator	X	X	X
1	Carbon stock in the soils	MCPFE Vienna	1.4.2	Indicator		X	
1	Carbon in the dead wood stock	IPCC	1.4.3	Indicator		X	
1	Carbon in the litter stock	IPCC	1.4.4	Indicator		X	
1	Carbon in the understorey	IPCC	1.4.5	Indicator	X	X	
2	Damages	MCPFE Vienna	2.4	Indicator		X	
2	Key factors for damages	Expert group		Verifiers		X	
3	Increment and fellings	MCPFE Vienna	3,1	Indicator	X		
3	Roundwood harvested (value and volume)	MCPFE Vienna	3,2	Indicator		X	X
3	Non-wood products	MCPFE Vienna	3,3	Indicator			X
3	Forest under management plans	MCPFE Vienna	3,5	Indicator	X		X
3	Accessibility	MCPFE Lisboa	3,6	Indicator	X		X
3	Harvestability	MCPFE Lisboa	3,6	Indicator	X		
4	Tree species composition	MCPFE Vienna	4.1	Indicator	X		
4	Vascular plant diversity	Expert group		Verifiers		S	
4	Carabid diversity	Expert group		Verifiers		S	
4	Bird diversity	Expert group		Verifiers		S	

TABLE 3–cont.

Criteria	Short description	Origin			Type of work requested		
		Process	ID in process	Type	Map (T2,1)	Field (T2,2)	Enquiry (T2,3)
4	Habitat parameters	Expert group		Verifiers		X	
4	Regeneration	MCPFE Vienna	4.2	Indicator	X		
4	Naturalness	MCPFE Vienna	4,3	Indicator	X		
4	Introduced tree species	MCPFE Vienna	4,4	Indicator	X		
4	Deadwood	MCPFE Vienna	4,5	Indicator		X	
4	Landscape pattern	MCPFE Vienna	4,7	Indicator	X		
5	Percentage and length of stream with appropriate riparian buffer	Expert group		Indicator	X		
5	Potential erosion risk	Expert group		Indicator	X		
5	Road/trail density in the riparian areas	Expert group		Indicator	X		
5	Soil carbon stock and water holding capacity	MCPFE Vienna	1.4.2r	Indicator		X	
5	Nutrient status / total depth - water table depth	MCPFE Vienna	2.2	Indicator		X	
5	Total nutrient stocks & nutrient balance	Expert group		Indicator		X	
5	Fast visual assessment of soil disturbance	Expert group		Indicator		X	
5	Soil disturbance related to standard forest management activities	Expert group		Indicator		S	
5	Physical characterisation of soil disturbance categories	Expert group		Verifiers		S	
6	Forest holdings	MCPFE Vienna	6,1	Indicator			X
6	Net revenue	MCPFE Vienna	6,3	Indicator			X
6	Expenditure for services	MCPFE Vienna	6,4	Indicator			X
6	Forest sector workforce	MCPFE Vienna	6,5	Indicator			X
6	Occupational safety and health	MCPFE Vienna	6,6	Indicator			X
6	Accessibility for recreation	MCPFE Vienna	6,10	Indicator			X
6	Total economic value of forest production	Expert group		Indicator			X

TABLE 4–Indicators with priority for evaluation in each region (1 high, 2 medium, 3 low)

Criteria	Short description	Priority for evaluation							
		Ireland	Aquitaine	Navarre	Euskadi	Castilla y Leon	Galicia	Portugal N	Portugal C
1	Forest area — Area of forest and other wooded land,classified by forest type and by availability for woodsupply, and share of forest and other wooded land in total land area	1	1	1	1	1	1	1	1
1	Growing stock — growing stock on forest and other wooded land, classified by forest type and by availability for wood supply	2	1	1	1	1	1	1	1
1	Carbon stock (EXPANSION FACTORS)	1	1	1	1	2	1	1	1
1	Carbon stock in the woody biomass (above and below ground)	1	1	1	1	1	1	1	1
1	Carbon stock in the soils	1	1	3	1	2	1	1	1
1	Carbon in the dead wood stock	2	1	3	1	2	2	1	1
1	Carbon in the litter stock	2	1	3	1	2	2	1	1
1	Carbon in the understorey	1	1	3	1	2	2	1	1
2	Damages	1	1	1	1	1	1	1	1
2	Key factors for damages	1	1	1	1	1	1	1	1
3	Increment and fellings	2	1	1	2	1	1	1	1
3	Roundwood harvested (value and volume)	2	1	2	2	1	1	1	1
3	Non-wood products	2	2	2	1	2	2	1	2
3	Forest under management plans	1	1	1	1	1	1	1	1
3	Accessibility	1	2	3	1	1	1	1	2
3	Harvestability	1	2	3	1	2	1	1	2
4	Tree species composition	1	1	1	1	1	1	1	1
4	Vascular plant diversity	3	1	3	1	2	2	2	2
4	Carabid diversity	3	1	3	3	2	3	3	1
4	Bird diversity	3	1	3	3	3	3	3	1

TABLE 4–cont.

Criteria	Short description	Priority for evaluation							
		Ireland	Aquitaine	Navarre	Euskadi	Castilla y Leon	Galicia	Portugal N	Portugal C
4	Habitat parameters	3	1	3	2	1	2	3	1
4	Regeneration	1	1	2	1	2	2	1	1
4	Naturalness	1	1	2	1	2	1	2	1
4	Introduced tree species	1	1	2	1	1	1	2	1
4	Deadwood	2	1	2	1	2	2	2	1
4	Landscape pattern	2	1	3	1	1	1	3	1
5	Percentage and length of stream with appropriate riparian buffer	1	1	1	1	1	1	3	1
5	Potential erosion risk	2	1	1	1	1	1	3	1
5	Road/trail density in the riparian areas			1					
5	Soil carbon stock and water holding capacity	1	1	1	1	1	1	1	1
5	Nutrient status / total depth- water table depth	3	1	2	1	1	1	1	1
5	Total nutrient stocks & nutrient balance			3					
5	Fast visual assessment of soil disturbance	3	2	1	1	2	1	3	1
5	Soil disturbance related to standard forest management activities	2	2	3	1	1	1	3	2
5	Physical characterisation of soil disturbance categories			3					
6	Forest holdings	1	1	1	1	1	1	1	1
6	Net revenue	1	2	2	2	2	2	1	1
6	Expenditure for services	1	2	3	2	2	2	1	1
6	Forest sector workforce	1	1	2	2	2	1	1	1
6	Occupational safety and health	2	2	2	2	2	2	1	1
6	Accessibility for recreation	2	2	2	1	1	2	1	1
6	Total economic value of forest production	2	2	3	2	2	2	1	1

- Selected indicators include those to be evaluated through alternative methods, in order to compare results and validate or invalidate the existing methods (for example, carbon stock estimated from global expansion factors is compared with estimation from individual tree parameters and incorporation of missing carbon pools).
- Some indicators are to be tested for pertinence through evaluation of verifiers based on intensive data collection and correlation studies between the estimated indicator and the real status of the system (for example, biodiversity indicators will be checked against multi taxa inventories).
- Finally, some indicators have been kept in the selection because there are no current reliable data for their evaluation and the objective is to generate a reference value (dead wood, damage, non-wood products) for future monitoring

Harmonised Field Protocols

The elaboration of harmonised field protocols was considered essential for the comparability of the results. The selected indicators list implies the collection of traditional forest inventory data, such as tree diameters and heights, as well as additional data not usually available from current forest inventories: damage, dead wood (snags and logs), soil carbon, shrub biomass, biodiversity. The harmonised field protocols include the following guidelines:

- Field measurements occur in plots systematically spread over the pilot zones — a grid of 1 km × 1 km is one of the most common sampling intensities, except for some areas where sampling intensity could be based on a pre-fixed sampling error from previous forest inventory.data
- On each sampling location, previously marked on photo-interpreted orto-photomaps, the following cluster of four plots, 50 m from each other and in a cross design, and two transects will be implemented (Fig. 2 and 3):
  (1) National Forest Inventory plot — following the protocol established by the National Forest Inventory of each country for tree and stand characterisation; soil and understorey carbon is also evaluated in this plot.
  (2) International Co-operative Programme* spirals — following the International Co-operative Programme European Forest protocol (ICP 2004) and sampling the 20 trees closest to plot centre.
  (3) Snag plot — in one of the International Co-operative Programme plots, all snags within a fixed radius (defined according to the National Forest Inventory plot) are sampled.

* International Co-operative Programme on Assessment and monitoring of Air Pollution Effects on Forests www.icp-forests.org

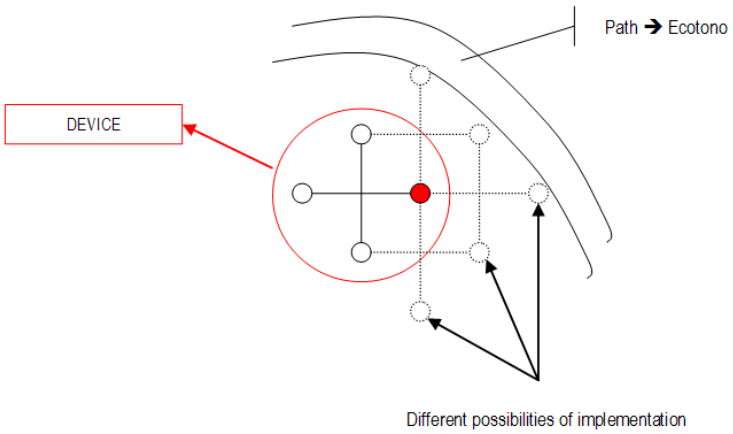


FIG. 2–Different possible locations for the inventory device taking as reference the location of the National Forest Inventory plot

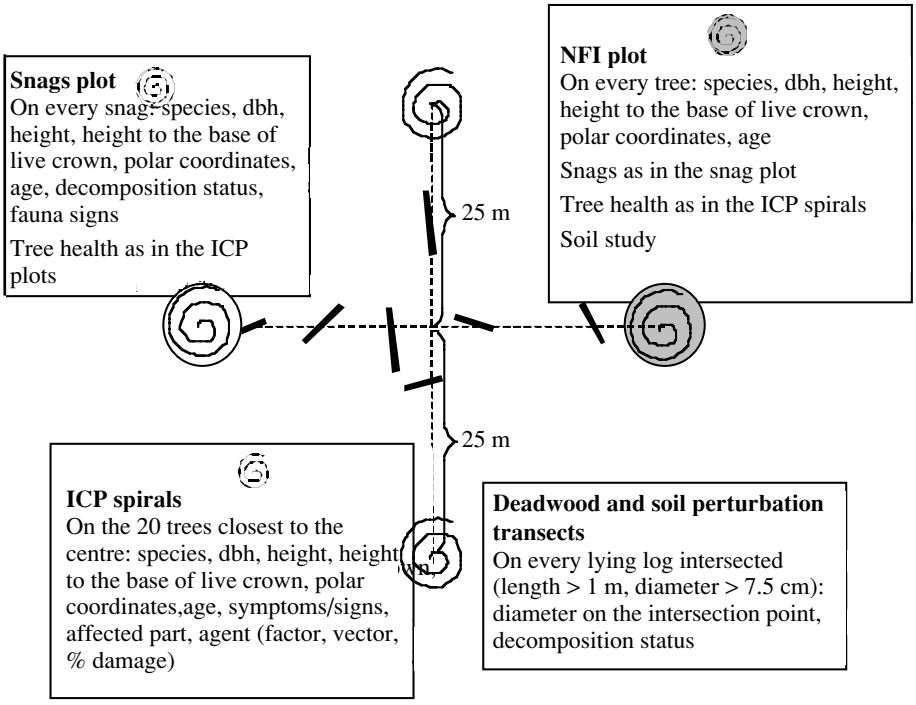


FIG. 3–Detail of the inventory device used for Sustainable Forest Management indicator evaluation.

(4) Deadwood and soil perturbation transects — linking the centres of the plots where dead wood in logs, and soil perturbations, will be sampled.

The sampling unit should be installed, wherever possible, inside the target strata defined by the National Forest Inventory plot, with the satellite plots falling inside the same strata in order to avoid samples that are partially outside the target strata; for that, the sampling device can be rotated around the National Forest Inventory plot (*see* Fig. 2); rotation may also be aimed at maximising its coincidence with ecotones or slopes.

Data collected in the National Forest Inventory plot include:

Characterisation of the site: GPS position; azimuth; slope; topography; recent forest management activities; piled wood; recent stumps; soil description; soil disturbances; fire scars; signs of erosion and compaction; signs of game or grazing; silvicultural system.

Tree variables: species; diameter at breast height; height; height to the base of live crown; age-class; polar co-ordinates relative to plot centre; age in even-aged stands.

Understorey survey: understorey use; number of species; vertical and horizontal structure; species in the shrub strata; phytovolume (area covered by shrubs × mean height of shrubs); regeneration.

Soil characterisation: litter floor sampling (fresh, partially decomposed, decomposed); soil samples for the 0–30 cm and 30–60 cm depths (Fig. 4).

Inventory of snags: as in the snag plot.

Forest health and vitality: as in the International Co-operative Programme plots

Data collected in the snags sample plot include identification and characterisation of all snags inside the plot (tree variables, decomposition status, fauna signs). In the

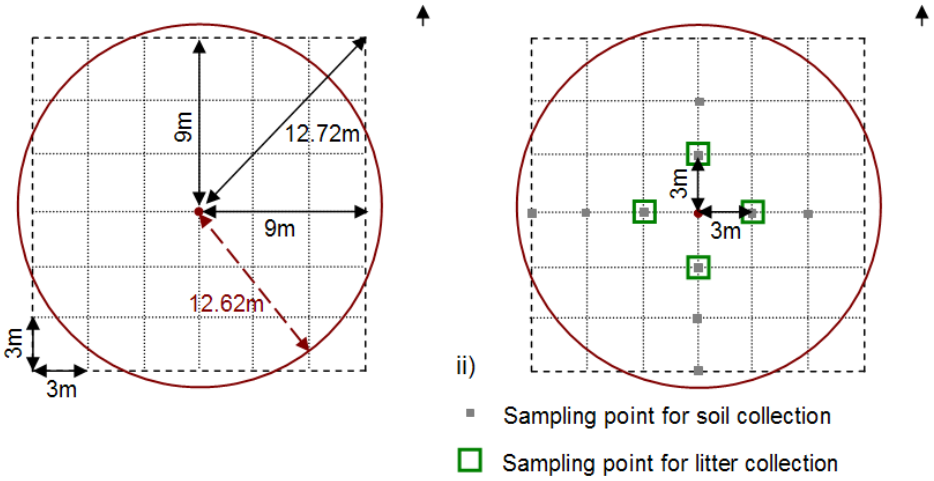


FIG. 4–Schema for the soil and litter floor sampling.

International Co-operative Programme plots, the 20 trees closest to the plot centre (search done on a spiral) will be analysed for symptoms/signs, affected part, agents, tree variables. In the deadwood transects all fallen logs (length >1 m, diameter > 7.5 cm) intersecting the transect will be identified, diameter on the intersection point will be measured, and decomposition status registered. The soil samples collected in the National Forest Inventory plot will be mixed, by soil depth, in a composite sample for the determination of the main physical and chemical characteristics.

Harmonised Socio-economic Strategy

Detailed inventory of data for socio-economic indicators related to the pilot zones has confirmed the heterogeneity of data coming from the official statistics and the lack of data for evaluation of some socio-economic quantitative indicators from Criteria 3 and 6.There are also large differences between regions and countries in defining the forest-based cluster and the boundaries of the system. The next steps of the project include:

- A SWOT analysis of the regional data available, currently performed to improve the accuracy and comparability of the data, and the sharing of experience from all regions involved.
- When data are missing (e.g., about services or non-wood goods), a first reference value will be provided through a harmonised survey currently being conducted with the forest owners.

Costs of Indicator Evaluation

The assessment of the cost of the evaluation of each indicator will be provided during the final phase after data collection. The issue of indicator measurement cost is important for the implementation of future monitoring at local to regional levels. Preliminary costs have been established for Criterion 1 indicators, including supporting indicators for carbon evaluation. Indicative values (including salary, travel expenses, consumables, specific tools, data cost-base 2004) ranging between 70 and 10,000 euros / indicator / region have been obtained.

CONCLUDING REMARKS

Scientific pertinence and feasibility of sustainable forest management indicators are important issues to address to promote continuous improvement of plantation forest management and adaptation to environmental and market changes.

Intermediate levels (landscape ecosystems, rural territories, and regions) are pertinent scales for sustainability impact assessment of forest management and for the evaluation of ecosystem services such as maintenance of biodiversity, purification

of air and water, regulation of water flow, soil conservation, carbon sequestration, and socio-economic functions of forest plantations.

It also appears that intermediate levels are the most appropriate for fostering communication, facilitating dialogue between foresters and society, and for linking local operational implementation of sustainable forest management and certification schemes with intergovernmental processes at national levels.

Within large and coherent bio-geographic and socio-economic zones, integrated approaches combined with regional prioritisation can provide an appropriate framework to develop and improve criteria and indicators. The establishment of a network of forest pilot zones where field-based measurements and socio-economic surveys are harmonised and combined with long-term monitoring and National Forest Inventory, is a promising approach

- for conducting co-ordinated scientific programmes for improving indicators and
- for transferring this knowledge to forest managers and other stakeholders.

Parallel development of indicators for all criteria at regional scales and comparison of evaluation methods between regions of different European Union countries show the lack of data for biodiversity and socio-economic related criteria, the heterogeneity of methods and of data quality, and the difficulty of harmonisation; preliminary results also indicate the limits and costs of some existing indicators.

As demonstrated through the development of this integrated approach, networking facilities and co-operation can be developed at those intermediate levels to check robustness of extended inventory tools, and to contribute to the harmonisation of indicator evaluation methods and comparability of results between regions and countries within the Ministerial Conferences for the Protection of Forests in Europe process. Further work is required to broaden the approach to other criteria and indicator processes, and issues that surround indicator development, understanding, and measurement.

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