Towards an Effective Integration of Forest Inventories and Natural Resources Surveys: The Italian Perspective

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Abstract.—International and regional efforts to define a suitable list of criteria and indicators for sustainable forest management show the new role of forestry within the environmental sector and the need for an effective integration of forest inventories in natural resources surveys. This paper examines the potential of forest inventories to support such needs, with specific reference to the Italian situation as a case study, in the enlarged framework of the European Union. In this country, where forest policy is mainly administrated at the local level, forest inventories have been on the increase since the late seventies. In spite of the many applications, a substantial sporadicalness in the adoption of inventory for forest planning and control, and a marked productive perspective can be stressed, although the high variability internal to the country in economic viability, ecological diversity, and assessment capabilities by different authorities has to be mentioned. The opportunity for simple monitoring and inventory systems focused on an overall assessment of forest attributes is devised. The field of landscape ecology can represent a common communication base to integrate the different matters in a holistic manner, solving problems in landscape planning and management. Geographic information system methodologies offer the means to operatively address this approach.

The Rio Declaration, the Forest Principles, the Helsinki-Lisbon process, and various elements of the environmentalist concept of forest quality are beginning to be used extensively in Italian forestry, in the framework of the new forest policy of the European Union (EU). The general objectives of these processes are well shared. Forest inventory and monitoring are recognized as a main focus of ecosystem management. However, their practical implementation is actually quite contradictory.

In Italy, most natural and seminatural environments are represented by forests, woodlands, and other wooded lands. On one hand, the increasing concern of people, researchers, and public administration for the values of such environments has increased the need for reliable and standardized information on forest attributes: statistics, georeferenced databases, thematic cartography, etc. On the other hand, inventories are rarely exploited for actual forest planning and control, and they are still fundamentally oriented to timber. Furthermore, to a large extent, comparable information at the national level is still missing; available data from different authorities and projects are often not homogeneous, either at national or local levels because they are developed using different measurement standards, sampling design, etc. (Corona and Ambrosini 1995, Tosi and Marchetti 1998).

Within this framework, carrying out sound forest inventory and monitoring initiatives may encourage the technical and organizational development of the whole forestry sector. Changes in land cover and in other ecosystem features have a direct impact on the social expectations about forests, especially their links with nature conservation, global climatic changes, and recreation activities. The interrelationship between forestry, nature conservation, and land planning is becoming increasingly tight in Italy, especially in the context of EU; new actions on this side have been implemented about funding, directives, and regulations.

OUTLINING THE STATE OF THE ART

Currently, the only forest information available for the whole of Europe comes from the aggregation of national data, estimated at different times and by different methods. These data are not comparable due to their typology and reliability (Köhl and Päivinen 1996). For more than 10 years, the emerging technology has been remote sensing (e.g., see the EU programs: FIRS - Forest Information from Remote Sensing, and FMERS - Forest Monitoring in Europe from Remote Sensing I&II), and the geographic information systems (GIS) integration of remote sensing (RS) techniques with existing databases. However, cartographic information for the whole of Europe is still limited to the basic classes: forests, other land (Kennedy and Folving 1997).

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A first step towards more effective coordination at the EU level has been made through the Coordinated Information on the European Environment (CORINE) program. The program has produced a Land Cover Map with three forest classes (conifers, broadleaves, mixed forests); such a map represents a common cartographic reference, suitable as an integration base for natural resource surveys. The Environmental European Agency (EEA) is now arranging the transformation of CORINE into a permanent information system.

Main EU actions are also devoted to standardizing inventory methods and proposing harmonized systems of definition and nomenclature: e.g., see the European Forest Information and Communication System (EFICS) program (EC 1997). Now near completion, a new system of nomenclature for habitat classification (EUNIS, European Information System on Nature) will integrate the older systems (CORINE Biotopes, Natura 2000, and Emerald networks, etc.), guaranteeing improved correspondence with CORINE Land Cover classification. The aim is to create a common European reference set of habitat units, with a common description and a common hierarchical classification. This will enable referencing and reporting of habitat data in a comparable manner for use in nature conservation, inventories, monitoring, and assessment; it will not replace existing national or sectoral systems except if member institutions want it to, but EEA will request that national data be based on this reference (Pinborg 1998). Indeed, the range of such initiatives clearly highlights the significant potential of EU in this perspective; the Union is becoming the main leader and reference for forest management planning processes, for inventory methods to be adopted and data to be measured at national and local levels.

Italy is one of the last European countries with only one cycle of National Forest Inventory (NFI). The Italian NFI was carried out in 1985 by systematic sampling on a 3- x 3-km grid (MAF/ ISAFA 1988). The NFI has not been repeated yet. There are some specific initiatives in the domain of land use and land cover statistics and concerning biodiversity assessment that could be connected to NFI, given their objectives and/or framework (table 1). Examples are the new "Censimento Generale dell'Agricoltura" (National Agricultural Survey), the "Carta della Natura" (Nature Map, at two scales: 1:250000/1:50000), and the "Completamento delle Conoscenze Naturalistiche di base" (Completion of the Basic Naturalistic Information, mapped at scale 1:250000). Although these initiatives are carried out by RS-based mapping (integration of Landsat TM images and digital orthophotos) and not by statistical sampling, the examined issues overlap to a large extent with the wished for repetition of NFI. Their integration would be highly fruitful, and they can be potentially devised to evolve into a global environmental inventory system. They will also benefit from an effective and prompt integration with regional forest inventory efforts.

Table 1.—*Italian forest area according to various information sources. Surfaces are expressed in square kilometers*

	NFI[1]	Censimento Generale Agricoltura[2]	Annuario statistiche forestali[3]	CORINE Land Cover[4]	TBFRA[5]
Broadleaved forests	48,090	37,283	50,174	49,021	
Conifer forests	13,320	11,055	14,362	13,096	62,810
Mixed forests	n.a.	6,768	3,558	9,746	
Other wooded land	21,609	n.a.	n.a.	25,356	30,360
TOTAL	83,019	55,106	68,094	97,219	93,170

[1] Processed NFI data. Reference year: 1985. Forest area definition: minimum crown cover equal to 20 percent, minimum area equal to 0.2 ha, minimum width equal to 20 m.

[2] Data provided by ISTAT (Italian Agency for Statistics). Reference year: 1990. Forest area definition: minimum crown cover equal to 50 percent and minimum area equal to 0.5 ha; only the forests with known owners are considered by this census.

[3] Data provided by ISTAT (Italian Agency for Statistics). Reference year: 1994. Forest area definition: minimum crown cover equal to 50 percent and minimum area equal to 0.5 ha.

[4] Coordinated Information on the European Environment, Land Cover Map. Data provided by Ministero dell'Ambiente & Centro Interregionale. Reference year: 1989 for Sicilia, Calabria, Puglia, Basilicata, Abruzzo, Molise; 1995-96 for the other Regions. Forest area and other wooded land are defined on the basis of the minimum mapping unit (= 25 ha) at the third hierarchical level of the CORINE Land Cover system of nomenclature (see: http://www.eea.dk/document/Entrecrep/Corine).

[5] Temperate and Boreal Forest Resources Assessment (EUROSTAT). Reference year: 1995. Forest area definition is that of FRA2000 classification (see: UN-ECE/FAO paper GE.97-2223I, July 1997).

n.a.: not available

Within Italy, regional forest inventories have been mostly developed and optimized with respect for local needs and uses, lacking a common approach. Relevant differences in sampling design, mapping, definitions, measurement standards, filing and elaboration of the data, etc., can be highlighted. The objectives spread from timber production assessment (e.g., poplar inventories in Po valley) to forest ecosystem monitoring (e.g., inventories of the Regions Umbria and Liguria). Only a few common attributes are assessed by all the regional and the national surveys; among these, attributes directly related to wood growth and yield are still the dominant ones (table 2).

FOREST ATTRIBUTES AND INVENTORY ISSUES

Contrasting with the wood-production-oriented character of current forest inventory and monitoring procedures, an information-needs assessment carried out in the EFICS study has highlighted that, in Italy, the most expected information concerns forest health and biodiversity; data on wood production rank only third in order of importance (Tosi and Marchetti 1997).

Knowledge of forest ecosystems and the relationship with human impact is currently undergoing strong development. The quali-quantitative characterization of forests

Table 2.—*Examples of attributes currently recorded in sample plots by Italian national and regional forest inventories: NFI = National Forest Inventory; pRFI = percent of the Regional Forest Inventories that take into account the attribute. Original data are drawn from Tosi and Marchetti (1998).*

Attribute	NFI	pRFI	Attribute	NFI	pRFI
Land tenure	Yes	100	***Regeneration***		
Site characteristics			Abundance	Yes	45
Aspect	Yes	100	Distribution	Yes	36
Elevation	Yes	100	Gamic/agamic origin	Yes	9
Humus type	-	9	Health	Yes	36
Litter	-	9	Prevailing species	Yes	45
Physiographic position	Yes	82	***Forest health***		
Slope	Yes	100	Damaged stems	Yes	18
Soil depth	Yes	36	Defoliation	-	9
Soil structure	-	9	Foliage decoloration	-	9
Soil texture	Yes	27	Site damages	Yes	9
Stoniness	Yes	64	***Tree attributes***		
Ecosystem characteristics			Bark thickness	-	27
Animal tracks	-	9	BH increment	Yes	45
Clearings width	-	9	Cork (quality, thickness, size)	Yes	9
Ecotones (type, shape, length)	-	9	Crown size and shape	-	45
Dead wood	-	9	DBH	Yes	100
Shrub abundance and distribution	-	9	Social position	-	45
Vegetation (phytosociologic survey)	-	9	Species	Yes	100
Stand structure			Stem quality	Yes	55
Coverage percent	Yes	82	Stump diameter	Yes	27
Dominant trees age	-	9	Total height	Yes	100
Height and spatial tree distribution	-	45	Upper-stem diameters	-	45
Plantation spacing	Yes	9	***Harvesting potential***		
Stand age	Yes	100	Accessibility	Yes	82
Silvicultural characteristics			Distance from the nearest road	Yes	18
Forest type	Yes	100	Road density	-	55
Silvicultural system	Yes	82	Rocky outcrops	-	27
Tending practices	Yes	18	Roughness	Yes	36
			Under-cover density	-	27

has been theoretically extended, focusing on their values as complex and multifunctional systems in an integrated way: wildlife habitat, soil erosion control, nature conservation, aesthetic values, recreation, etc. The opportunity for simple monitoring and inventory systems focused on an overall assessment of forest attributes has been devised (Corona and Ambrosini 1995; see also table 3).

However, the current level of actual knowledge is still unsatisfactory for several reasons and for several aspects. Even the total area of forests actively managed is still not well recognized in Italy. Comparing the data from Censimento Generale dell'Agricoltura with CORINE Land Cover leaves at least 1.2 million ha of forests with unknown owner (table 1). The impact of such a problem cannot be actually quantified; nonetheless, it cannot be neglected from an environmental and socioeconomic point of view (Bianchi *et al.* 1998).

Forest fires represent another main aspect for which data are still not available on a permanent statistical inventory basis. Specific research initiatives on such a topic are in progress at the EU level; see Reg. 2158/92/EU and followings, DOBRIS 3+, and other research programs on fire risk assessment, management, and monitoring of burnt-over areas using RS techniques (e.g., Megafires, Fuego, Skymed).

Table 3.—*Selected miscellaneous examples of indicators to be monitored at management unit/landscape levels within a multiple-use forestry context*

Age structure within stands
Amount of big trees
Amount of strictly protected forest area
Amount of old-growth forest areas
Amount of undisturbed forest areas
Amount of other forest areas with special ecological values (e.g., wet biotopes)
Dynamic series of vegetation
Forest fragmentation (e.g., fractal dimension, contagion, and interspersion of forest cover: see also table 6)
Implementation level of forest management planning
Local community participation in forest management planning
Net increase in forest area
Non-wood goods
Number of shrub species
Number of tree species
Standing dead wood

A high impact on Italian forest accounting will be exerted by the new forest area definitions introduced by FAO Global Forest Resources Assessment (FRA2000) implying that future surveys will be routinely extended to cover woodland with forest crown cover of more than 10 percent and the so-called "other wooded land" (forest crown cover between 5 and 10 percent). It is essential that forest inventory domain extends outside woodlands; in Italy, this class includes many natural and seminatural environments, neighboring, and often dynamically connected to, the forests, with a fundamental ecological value (e.g., abandoned agricultural land, the areas above the timberline, etc.). The only current examples of inventories concerning "other wooded land" are the "abandoned agricultural land" surveys to assess reforestation suitability, e.g., see the forest inventories of Umbria Region, of the Park of the Simbruini Mountains, and of the Comunità Montana Alto Lazio.

An increasing impact on forest inventory and monitoring is also expected by the EU Habitat Directive (Dir. 43/92/EU) aimed at creating an European network of nature conservation sites. The directive requires the description of forests and other natural and seminatural habitats following a common system of nomenclature (the EUNIS system in the near future). After the designation of a site to be protected, the directive also imposes management planning and monitoring, posing the problem of assessing habitat and ecosystem changes with respect to biodiversity conservation. There are many procedures to measure diversity in a scientific sense, but it is doubtful if these procedures are suited to assess the specific features of forest biodiversity (Corona and Pignatti 1996). Quantitative and qualitative data on different factors are recognized as indicators, but because what they mean for biodiversity in forest landscapes is not truly understood, their monitoring could be ineffective. Even the question of how to assess the effects of forest management on biodiversity is complicated by the complexity of forest ecosystem relationships with human impact; there is little actual evidence of the effectiveness of improved forest management in preserving biodiversity even in relatively simple temperate systems (Mooney *et al.* 1996). Studies on forest biodiversity indicators are currently being carried out at the EU level; see concerted actions like Forest Biodiversity Evaluation (BEAR) and proposed shared-cost programs like Biodiversity Evaluation Tools for National Forest Inventories (NFIBET).

THE POSSIBLE CONNECTING ROLE OF LANDSCAPE ECOLOGY

One of the most fundamental considerations for the development of inventory and monitoring methods is the

need to consider forest ecosystem as a whole. From an operational point of view, such an approach implies wise use of RS and GIS techniques enabling a global view of the forest in the landscape, including borders, clearings, open woodland, etc. From a methodological point of view, the landscape ecology approach can provide a suitable basis for a common communication framework to integrate all different facets in a holistic perspective.

The forest landscape can be seen as a mosaic of individual parcels/patches of different land cover types. Landscape structure is largely determined by the origin, number, and size of the patches. Bailey *et al.* (1978) state that "the relationship between components of landscape and physical and biological processes is almost always through spatial pattern rather than through composition alone " Therefore, a natural way to describe and compare landscape structure is by measuring the shape and configuration of patches within a landscape, or other spatial attributes, using RS and GIS techniques.

Landscape ecology perspective is strongly appreciated in Europe. For instance, the EUNIS habitat classification system is based on general vegetation science with landscape elements to identify habitats. A synthetic comparison between land system and phytosociologic approaches is outlined in table 4. A comparison of the hierarchic levels among some widespread "typification-classification" approaches used in landscape ecology surveys is shown in table 5.

Table 4.—*Comparing land system and phytosociologic approaches, according to Blasi* et al. *(1998)*

Land system approach	Phytosociologic approach
Hierarchic system for for typification	Hierarchic system classification
Holistic	Synthetic
Always mapped	Independent of the presence of maps

In the light of the suggested perspective, landscape ecology could be a sound way to integrate forest in land analysis, and forest inventories can take the broader meaning and value of integrated systems of territorial analysis, at least concerning the main component of natural renewable resources. For instance, spatial/texture features can be used to quantify the degree of homogeneity/heterogeneity of the landscape (Corona and Ferrara 1998, Marchetti 1996). Fragmentation of the forest area can be characterized using some simple metrics of landscape, such as area of the biotopes, their density, size, and variability. In addition, edges, shape of the biotopes, core areas, and nearest neighbors can also be used as indicators of landscape diversity. There is also a group of diversity indices traditionally used in assessing species diversity that can be used to determine landscape homogeneity/heterogeneity (table 6).

In Italy, some national databases organized on GIS's, like the digital terrain model and the land cover data of CORINE, could be properly integrated with data collected through forest inventories, from a landscape ecology perspective. At the regional level, the forest inventory of Liguria Region may represent a prototype for the integration in the Forest GIS of different analyses and modules; its main themes have concerned the status of forest ecosystems (evolution processes, decline symptoms, and fires), their spatial distribution in the landscape, and the multiple functions supported at local and regional levels (Marchetti *et al.* 1998).

FURTHER TOPICS

Final remarks towards an effective integration of forest inventories and natural resources surveys have to take into account the benefits from emerging technologies and the role of inventory systems connected to forest management planning and certification systems.

1. Given the increasing capability and potential of RS techniques (Corona and Ferrara 1998), it is even more essential to define nomenclature systems and statistical approaches that allow effective integration of RS mapping and ground sampling surveys; direct and derived forest and land-use attributes could be

Table 5.—*Hierarchic levels in some typification-classification approaches used in landscape ecology surveys (for details and bibliographic references, see Blasi* et al. *1998)*

CSIRO	ITC – Wageningen	Dent & Young	Phytosociologic approach
	Ecotope or site	Land element	Tessera
Land units	Land facet	Land unit/land facet	Catena
Land systems	Land system	Land system	Catena
	Main landscape	Main landscape	

Table 6.—*Examples of available indicators for assessing biodiversity by remote sensing (modified from Marchetti 1996). The features derived from the co-occurance matrix or geometrical structure of the group of segments could serve as the basis for a method to quantify and monitor the biodiversity of a landscape, and to compare the biodiversity of different landscapes. In addition to RS material, available ground truth data and other auxiliary data can be used.*

Indicators measurable from RS images or auxiliary data	Indicators of biodiversity when ground truth data are available
Image features - Haralick's texture - Fragmentation indexes * Area * Biotope density, size and variability * Biotope richness * Biotope richness density * Contagion and interspersion * Core area * Edge * Modified Simpson's diversity index * Modified Simpsons's evenness index * Nearest neighbor * Relative biotope richness * Shannon's diversity index * Shape Shannon's evenness index * Simpson's diversity index * Simpsons's evenness index - ..... *Territorial auxiliary data* - Minor biotopes (e.g., springs, streams network) - Topography (DEM) -	- Amount of forest of natural origin (e.g., as defined by EU DOBRIS+3) - Amount of old-growth forests (e.g., as defined by EEA, World Wildlife Fund, etc.) - Designated conservation/recreation areas - Forest reserves (e.g., see EU COST E4, 1997) - Key biotopes (e.g., EU Natura 2000 sites) (types, number, size, interspersion, rarity, etc.) - Habitat description (e.g., as defined by EU EUNIS physiognomic classification) - .....

assessed in the near future using high resolution imagery even at a local scale.

2. To effectively insert sustainable forestry issues into land planning, it is necessary to define inventory categories suitable to join cartographic and ground sampling efficiency with planning requirements and constraints. An interesting proper way out, useful also from a silvicultural point of view, may be found by structurally linking inventory categories (and strata) to forest typologies now being developed by many Italian Regions (e.g., Veneto, Liguria, Toscana, Piemonte, Lazio and Valle d'Aosta).

3. Most international political initiatives and their followups are making forest inventory and monitoring more and more crucial from a legally binding point of view. Forest inventories have to translate the meaning and the purposes of issues such as biodiversity conservation, forest management sustainability, etc., to actual figures and facts. A relevant example is the Kyoto legally binding protocol that explicitly refers to forest inventory data for assessing greenhouse gases emission/uptake balance at global and national levels.

4. A similar issue concerns forest ecocertification, which is being developed all over the world. As stressed by Lund (1998), "forest inventory designers and managers must familiarize themselves with the requirements for certification and work with the landowners and managers to ensure that the inventories and monitoring systems employed will yield the desired information at the least cost." For the EU countries, the Helsinki-Lisbon process (1994, 1998), which is refining criteria and indicators for sustainable forestry, represents a steady reference point (Parviainen and Paivinen 1998). The list of the most important forest attributes that have been collected during the EFICS study fits well with the criteria and indicators developed in that process. Twenty-seven significant indicators have been identified to assess

the sustainability of forest management at national level. In Italy, only a few of these can be currently obtained from the available inventory data. Adequate priorities then have to be set.

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