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Original article

Towards a common set of criteria and indicators to identify forest restoration priorities: An expert panel-based approach

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ABSTRACT

Ecological restoration of forest ecosystems is increasingly being implemented in many parts of the world, as a response to widespread forest loss and degradation. In common with other conservation management interventions, restoration efforts should be directed towards areas where the maximum benefits are likely to be achieved. Such prioritisation requires the development of appropriate criteria and indicators (C&I), an issue poorly addressed by previous research. In particular, there is need for C&I that are operational, suitable for spatial analysis and mapping and applicable to a broad range of contexts. This investigation aimed to verify whether this might be achieved through the elicitation of experts' opinion, when considering biodiversity conservation as the main objective of restoration. A Delphi process was performed, aimed at defining the key ecological criteria and a broad set of indicators. 389 criteria and 669 related indicators were provided in total and grouped into clusters relating to individual criteria. A total of 20 criteria referred to the need for restoration and 18 to its feasibility. In the second round of the Delphi process, 8 definitive criteria were identified along with some 90 related indicators. Finally, a face-to-face meeting was conducted to show how ready-to-use C&I can be obtained for application to a specific context starting from the Delphi's results. The study highlights the potential value of combining the Delphi process and face-to-face meetings for identifying practically applicable C&I for planning ecological restoration. However, the diversity of views identified within a single group of stakeholders suggests that the development of a generally applicable set of C&I for forest restoration will be difficult to achieve in practice.

1. Introduction

An urgent question in nature conservation is: where to act first? This is primarily related to concerns of an economic kind: financial resources are limited, hence conservation efforts should focus on areas where interventions will produce the greatest benefits. Conservationists have addressed the prioritisation issue in a variety of ways (Mittermeier et al., 1998; Roberts et al., 2002). According to Myers et al. (2000), areas with exceptional concentration of endemic species and with high rates of habitat loss may be defined as biodiversity hotspots, which constitute a priority for conserving the most species at the least cost. Alternatively, species richness, endemism, unusual ecological or evolutionary phenomena and habitat rarity have been used at a global scale to identify ecoregions that should be accorded priority for conservation (Olson and Dinerstein, 2002). Previous research into conservation priority-setting has primarily focused on the design of protected area networks, which may be informed by analysis of the relative vulnerability of different areas to environmental pressures or threats (Wilson et al., 2005). However, relatively little attention has been given to priority-setting in the context of ecological restoration activities.

Ecological restoration refers to the concept of re-establishing the main characteristics of an ecosystem that has been degraded, damaged or destroyed (Jordan et al., 1987), and is usually carried out to enhance the conservation value or productivity of a given area (Hobbs and Norton, 1996). Restoration actions are increasingly being implemented throughout the world (van Andel and Aronson, 2005; Rey Benayas et al., 2009), supported by global policy commitments such as the Convention on Biological Diversity (Article 8f), in response to growing concerns about widespread ecological degradation and habitat loss. Forest ecosystems have received particular attention in this respect (Lamb et al., 2005), reflecting both the widespread extent of the deforestation and the high importance of forests with respect to the maintenance of biodiversity and the provision of ecosystem services to human populations (FAO, 2006). The problem of prioritising forest areas to be restored is a critical one. The identification of priorities depends upon the objectives

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of the restoration process, which are often multiple and different in nature: enhancing biodiversity, providing local communities with financial and livelihoods benefits. (Lamb and Gilmour, 2003; Mansourian et al., 2005). Different objectives may result in identification of different priority sites, establishment of different tree species and selection of different restoration methods. Approaches are therefore required that are able to account for multiple objectives and enable their potential implications to be explored (Lamb et al., 2005).

Operationally, the objectives driving restoration prioritisation can be linked to a number of criteria that express the degree of achievement of restoration objectives (Kangas and Kangas, 2002). With respect to forests, criteria relating to management objectives might usefully be viewed in the context of Sustainable Forest Management (SFM), which has been the focus of an intensive international policy dialogue during the past two decades (Nussbaum and Simula, 2005). Specifically, this has led to the development of a wide variety of different criteria and indicators (C&I) designed to assess progress towards SFM. Criteria may be defined as the essential elements or major components that define SFM (e.g. 'structure and diversity of forest ecosystem resemble original forest'), whereas indicators are qualitative or quantitative parameters of a criterion, which provide a basis for assessing the status of, and trends in, forests and forest management (e.g. 'canopy opening is minimised') (Prabhu et al., 1996). The C&I have been developed under a series of international processes, including ITTO, the Pan-European (or 'Helsinki') Process, the Montreal Process, and the Tarapoto, Lepaterique, Near East, Dry Zone Asia and Dry Zone Africa processes, each of which have generated sets of C&I (Newton, 2007). Criteria and Indicators have found widespread application in the forest sector and they are considered as a useful tool for assessing progress towards SFM (Wijewardana, 2008), as indicated by a substantial literature (Stork et al., 1997; Mendoza and Prabhu, 2003; ITTO, 2005). Although the C&I processes share similar objectives and overall approach, and provide a valuable source of information on the indicators that are considered important for forests in different regions, most have focused on developing C&I for application at the regional or national level. Only four of the nine processes (ATO, ITTO, Lepaterique and Tarapoto) have produced sets of C&I for application at the local level, which is the level most likely to be of value in supporting practical forest management.

Although forest restoration can be viewed as one of the management options that might contribute to the broader goals of SFM, indicator sets specifically designed for the identification of forest restoration priorities are few. There have been some attempts at defining prioritisation criteria at global and regional levels (WCMC, 2000; Newton and Kapos, 2003). At a more local level, some studies coupling decision analysis and GIS have used small sets of case-specific criteria to identify priorities (Cipollini et al., 2005; Marjokorpi and Otsamo, 2006). Nevertheless, a ready-to-use list of criteria that restoration practitioners can directly apply in practice is lacking. On the one hand, regional-level criteria are too generic (e.g. 'potential of a given area to support forest cover') or vague (e.g. 'areas in close proximity to forests'), and few specifications are made regarding how they might be assessed in practice (WCMC, 2000; Newton and Kapos, 2003). On the other hand, local-level criteria are context-specific; their applicability to other contexts has rarely been examined (Cipollini et al., 2005).

Consequently, there is a need for C&I appropriate for prioritising forest restoration actions at local levels, that are readily applicable to different contexts. In order to be useful for the identification of priority sites, C&I should be able to capture spatial variability, given that forest management plans are spatially explicit and are typically developed and implemented using a Geographical Information System (GIS) (Kangas et al., 2000). The development of C&I sets is commonly based on past experience: existing sets are considered and a pool of experts is involved to review and/or develop them (Prabhu et al., 1999). The use of expert knowledge for natural resource management, though not the best choice in absolute terms, is the only way of taking decisions when knowledge based on objective observations is not available (Hannah et al., 1998; Burgman et al., 2001; Kangas and Leskinen, 2005; Geneletti, 2007).

Based on these considerations, this study aims to provide a contribution towards defining a generally applicable set of ecological criteria and indicators to identify forest restoration priorities that may contribute to the specific objective of biodiversity conservation. The method is based on surveys and interviews conducted with a panel of experts. In this paper, we use the term criterion to indicate the general concept (e.g. 'fragmentation of native forest'), while the term indicator is used to refer to an operational way to express or measure a criterion (e.g. 'edge density', 'patch density'). Both definitions are consistent with SFM C&I processes, such as the Montreal Process (1995). The study was designed to develop criteria and indicators that are applicable to a wide range of ecological contexts and appropriate for use at the landscape scale (i.e. tens to hundreds of square kilometres), being the scale at which forest restoration decisions are typically made in practice.

2. Methods

Previous studies on the selection of restoration priorities (WCMC, 2000; Newton and Kapos, 2003) simultaneously considered areas where restoration is needed (e.g. owing to the presence of endemic species or threats), and areas where restoration is likely to succeed (e.g. owing to soil conditions). This suggested that C&I should belong to two main groups: those that refer to the need for biodiversity restoration (B), and those that refer to the feasibility of the restoration interventions (F) (Orsi and Geneletti, 2010). The first group of C&I is then expected to define where restoration is more urgent for the conservation of biodiversity. The second group is intended to provide an information about the 'restorability' of land (Hobbs and Harris, 2001; Suding et al., 2004; Miller and Hobbs, 2007), which is the ecological cost of successfully achieving the restoration goals. Starting from this rationale, we used a distance survey with a panel of experts to develop a list of generally applicable C&I linked to B and F. Subsequently, we managed a face-to-face meeting to show how a compact set of C&I readily applicable to a specific context can be obtained starting from the overall list.

The Delphi survey technique was used for the distance elicitation. This technique, developed in the early 1950s by the RAND Corporation, is a method for structuring a group communication process in a way that allows individuals to deal with a complex problem (Linstone and Turoff, 1975). Delphi surveys aim to solicit the advice of a panel of experts, and whenever possible to forge a consensus (Richey et al., 1985; Oliver, 2002). The approach is based on structured and written questionnaires to which panellists are asked to answer anonymously. All responses are summarised and reported back to panellists who have the opportunity to revise their judgments. Turoff and Hiltz (1996) highlighted the opportunities offered by computer-based Delphi processes and today most Delphi surveys are carried out via the Internet. The Delphi technique has been extensively applied to conservation and natural resource management (Crance, 1987; Hess and King, 2002; Oliver, 2002; MacMillan and Marshall, 2006; Geneletti, 2008), but rarely to ecological restoration.

The Delphi survey, which was entirely managed via email, was based on questionnaires with both open and closed questions. In the first round participants were asked to specify their expertise and draw preliminary lists of C&I. Responses were rearranged by clustering similar criteria, and the reviewed lists were re-distributed to experts. In the second round experts were asked to choose from the lists a limited number of criteria for B and for F and to attach indicators to each of them. The information provided in round two was used to define the final lists of criteria for B and F and to reduce the number of indicators. Anonymity was preserved throughout the Delphi survey.

2.1. Identification of the panel of experts

The experts involved in the Delphi process were identified in three ways: personal knowledge, literature review and project databases. This study was carried out in the framework of an EC-funded research project (ReForLan) involving ten research institutions from Europe and Latin America (Newton, 2008). A group of forest restoration experts involved in ReForLan constituted the primary scientific panel that participated in the survey, which was extended to include their individual networks of contacts of other specialists in the field. A literature review on forest restoration, mostly carried out on international peer-reviewed journals, provided us with a further list of names. Finally, we browsed restoration projects databases, such as the Forest Restoration Information Service (FRIS) of UNEP-WCMC (2008) and that of the Society for Ecological Restoration International (2008), to obtain names of people who actively conducted forest restoration projects around the world. The definition of the sample was aimed at obtaining varied expertise both in terms of geographical area and habitat type. We contacted via email more than 120 people affiliated with universities, governmental agencies, corporations and private consultants in the five continents.

2.2. Delphi survey: round one

The first round included four tasks: (i) define the geographical expertise; (ii) define the ecological expertise; (iii) identify C&I that lead to the identification of areas that should be accorded priority for biodiversity restoration; and (iv) identify C&I that influence whether or not restoration is feasible on a particular site. Participants were asked to rank on a four-point Likert scale (with categories 'none', 'moderate', 'good', 'very good') their level of expertise in different geographical regions. Participants were then asked to specify their ecological experience by ranking on the same four-point scale their level of expertise in different habitat types. The classification of forest habitats proposed by the FRIS was employed for this purpose. Tasks 3 and 4 referred to factors B and F respectively and were similarly structured. Experts were asked to identify criteria, to specify why these were considered important, and to attach one or more indicators to each criterion. Experts were given the possibility to comment on each of the four tasks of the questionnaire.

The questionnaire was accompanied by a one-page description of the project and its purposes. Particular attention was given to the definition of C&I and to the rationale of the method with reference to B and F. Regarding indicators, it was specified that an indicator must: (i) show a clear relationship between its levels and related consequences; (ii) be measurable over the bi-dimensional space; and (iii) show a direct relationship with the broad factor (B or F) it refers to.

The set of indicators related to a given criterion was expected to fully describe it, by providing a comprehensive description of its contribution to the broad factor (B or F) it refers to.

2.3. Delphi survey: round two

In the second round, participants were presented with the lists for B and F that resulted from round one. The lists were generated after processing the results of the first round. In particular, semantic clusters of criteria were obtained following a two-step process. Firstly, criteria defined by similar wording or synonyms were aggregated. Secondly, a further aggregation was carried out by bringing together criteria that, although defined by non-synonymic words, had the same meaning according to the comments provided by experts. Criteria or indicators not complying with the definitions provided were disregarded. Participants were asked now to identify a set of most relevant criteria by selecting up to eight criteria from both the B and F list. For each criterion, they were also asked to select up to three indicators. As in the first round, experts were given the opportunity to provide comments and remarks.

2.4. Face-to-face meeting

As an extension to the study, we conducted a face-to-face meeting to discuss the C&I resulting from the Delphi survey. This is to simulate what would happen in real-world situations when, given the broad list of C&I, it is necessary to define a manageable subset that might be meaningfully applied to a specific context. The meeting was arranged during one of the ReForLan Project's workshop (held in Salta, Argentina in May 2008), which was attended by an international group of forest restoration experts These were provided with the definitive lists of criteria that emerged from the second round of the Delphi. The selection of such criteria was based on a quantitative analysis of consensus: only criteria selected by a minimum rate of participants in round two of the Delphi were considered. For each criterion, all of the indicators selected at least once during round two were presented to experts. The preference rate accorded to each indicator during round two was also provided. Experts were now asked to define for each criterion the set of indicators necessary and sufficient to completely define that criterion. For this purpose, the indicator requirements provided in the questionnaires were considered as the fundamental guidelines. Experts were free to revise indicators if they did not entirely satisfy the above requirements. The resulting set was discussed and validated within the group to ensure that it was representative of the key factors.

3. Results

3.1. Delphi survey: round one

Round one was completed by 37 people (response rate: 30.8%). Table 1 reports the assessment of geographical and ecological expertise as structured in the questionnaire. Europe, North America and Latin America were the best known regions among experts. With respect to habitats, there were three types (Temperate continental, Temperate mountain, Tropical mountain) on which more than 50% of experts possessed some knowledge and 12 with a knowledge ranging from around 27% to 50%.

Experts listed 205 criteria for the B factor and 184 for the F factor. These were grouped into 20 and 18 clusters respectively, according to different criteria as shown in Tables 2 and 3, which summarise the responses to tasks 3 and 4. The list for the F factor is divided into ecological criteria (10) and socioeconomic criteria (8). 345 indicators were proposed for the B factor, and 324 for the F factor. Slightly fewer than 50% of them were discarded for not meeting the requirements that had been specified in the instructions attached to the questionnaire. The number of indicators per criterion varied from only one (e.g. 'historically forested area') to 18 (e.g. 'diversity at the species level').

3.2. Delphi survey: round two

Round two was completed by 30 people out of the initial 37 (response rate: 81.1%). Histograms for B and F were drawn to show

Table 1
Geographical and ecological expertise of the participants.

	Level of expertise [% of the total respondents]			
	None	Moderate	Good	Very good
Geographical region				
Europe	51.35	24.32	10.81	13.51
North America	43.24	27.03	10.81	18.92
Caribbean	86.49	8.11	5.41	0.00
Latin America	45.95	10.81	8.11	35.14
Africa	72.97	13.51	10.81	2.70
Asia	64.86	10.81	8.11	16.22
Middle East	91.89	8.11	0.00	0.00
Oceania	81.08	8.11	2.70	8.11
Forest habitat				
Boreal coniferous forest	67.57	8.11	5.41	18.92
Boreal mountain	72.97	5.41	13.51	8.11
Boreal tundra woodland	75.68	8.11	13.51	2.70
Temperate continental forest	16.22	32.43	24.32	27.03
Temperate mountain	37.84	21.62	10.81	29.73
Temperate oceanic forest	62.16	10.81	2.70	24.32
Temperate steppe/prairie	51.35	29.73	8.11	10.81
Subtropical desert	72.97	21.62	2.70	2.70
Subtropical dry forest	67.57	16.22	5.41	10.81
Subtropical humid forest	64.86	10.81	16.22	8.11
Subtropical mountain	67.57	10.81	18.92	2.70
Subtropical steppe	89.19	8.11	2.70	0.00
Tropical desert	83.78	13.51	2.70	0.00
Tropical dry forest	51.35	16.22	21.62	10.81
Tropical moist deciduous forest	59.46	10.81	16.22	13.51
Tropical mountain	48.65	13.51	16.22	21.62
Tropical rain forest	51.35	16.22	13.51	18.92
Tropical shrubland	70.27	18.92	8.11	2.70
Mangrove	78.38	13.51	5.41	2.70

Notes: Numbers represent the percentage of respondents who have a certain level of expertise in a particular geographical area or habitat. Total number of respondents was 37.

the rate of consensus of experts on each criterion (Fig. 1). The histogram for F was divided into two by distinguishing between ecological (Fe) and socioeconomic criteria (Fs). The histogram for B shows two criteria ('disturbance' and 'degree of threat') with very high accorded preference (more than 70%) and another four criteria ('diversity at the ecosystem/landscape level', 'diversity at the species level', 'ecosystem services', 'landscape degradation') with preference equal or above 60%. The histogram for Fe shows four criteria ('land-use conflicts', 'degradation', 'disturbance', 'natural regeneration potential') with a preference of 50% or more, with all others being largely below that percentage. Similar results were obtained with the histogram for Fs, where ('land ownership', 'political will', 'restoration costs' and 'willingness of locals') had a preference rate significantly higher than 50%.

Histograms of Fig. 1 were then analyzed to see whether some criteria had received an outstanding preference. While this was possible in the case of Fe and Fs, from both of which 4 highly preferred criteria could be extracted easily by applying thresholds of 56.7% and 60% respectively, it was not so for B. In the latter case only a 50% threshold seemed to provide an acceptable distinction, which resulted in 8 criteria selected. Comments provided by experts encouraged the decision of moving some criteria from a list to another. In particular, 'ecosystem services', 'land use conflict' and 'recreation' were moved to Fs, 'remnants' was joined to 'natural regeneration potential' in Fe, 'degree of threat' to 'disturbance'. As our analysis is focused on ecological issues, we did not consider socioeconomic criteria in the subsequent parts of the paper.

Tables 4 and 5 show, for the most preferred criteria (see left-hand columns), the related indicators with indication of the intra-criterion citation rate, namely the percentage of respondents who selected that specific indicator among the respondents selecting the related criterion. As an average, each criterion was linked to 11 indicators. 'Connectivity-corridors' and 'degradation (B)' presented the lowest number of indicators (6), while 'diversity (species level)' presented the highest (17). The citation rate was highly variable within each criterion. Only four indicators were selected by at least 70% of experts: 'land use change', 'linkages between habitat units', 'landscape structural diversity', and 'amount of remnant vegetation'. Most indicators had citation rates between 10% and 40%.

3.3. Face-to-face meeting

The meeting lasted approximately four hours and involved six individuals, who share similar background and expertise. Experts discussed on each of the criteria included in Tables 4 and 5 and remodelled or simply selected the related indicators in order to provide the sets that are likely to fully assess the contribution of each criterion to B or F. The discussion produced a shortlist of 22 indicators: 14 for B and 8 for F (Table 6). Each criterion is associated with no more than three and no less than 2 indicators. Some indicators are exactly the same as in Tables 4 and 5 (e.g. 'road density'), some are slightly different (e.g. 'distance from nearest forest patch' instead of 'distance from protected sites') and some are completely different (e.g. 'predicted deforestation risk').

4. Discussion

The aim of this study was to explore the use of an expert panel-based approach to design a set of C&I that could potentially be used to prioritise areas for forest restoration, whose indicators had characteristics of measurability and non-redundancy. The results illustrate the difficulty in achieving such a goal. At one level, the research did succeed in developing a provisional set of generally applicable C&I that could potentially be used to prioritise areas for forest restoration. These have been designed for implementation at the level of individual landscapes, which is the level at which forest management decisions are typically made. The C&I could be of

Table 2
Criteria and indicators for the B factor, which refers to the need for biodiversity conservation.

Criteria	Indicators
Climatic conditions	Humidity; precipitation; temperature
Connectivity-corridors	Amount of interior habitat within a unit; corridor length; corridor width; distance from protected sites; linkages between habitat units; presence or absence of wild areas connected to the restoration area; types of linkages
Degree of threat	Area with threatened species; number of red list species; presence or absence of red list species; % of endangered forest; % of remained forest
Disturbance	Amount of area logged (ha); area of vegetation type after disturbance/area of vegetation type before disturbance; area/perimeter; density of steam crossings; distance from roads; disturbance classification; number of people depending upon the ecosystem; number of people living within the ecosystem; Natural Disturbance Type (NDT) classification; road density; % of agricultural area; % of area logged by slope class; % of invasive species; % of populated area
Diversity (ecosystem and landscape level)	Altitudinal variation; amount of dead wood; amount of deciduous trees; azimuthal variation; canopy cover; diversity of soil; landscape functional diversity; landscape structural diversity; presence or absence of diverse ecosystems at the landscape scale; presence or absence of water; quality of dead water
Diversity (species level)	Abundance; age; Beta diversity; evenness; Fisher's Alpha; forest density; number of birds; number of endemic species; number of interactions among species; number of keystone species; number of keystone species lost; number of major vegetation types; number of native species/number of exotic species; number of TER species; presence or absence of non-game species; Shannon diversity; species richness; % live/dead (mortality)
Diversity (genetic level)	Adaptive traits; canopy cover; genetic diversity among population; isozymes; number of stems per hectare by size class; neutral markers; nuclear inheritance; species-specific microsatellites
Ecosystem services	Carbon sequestration/productivity; distance from water; elevation; slope; soil retention (mass/ha); water provision (yield)
Fragmentation	Area of the fragments; core area; forest patch density; isolation; number of fragments; proximity; representativeness of the ecosystem in the world
Habitat availability	% ecosystem type by habitat type by watershed (500–5000 ha) (fine filter); % ecosystem type by habitat type by region (medium filter); % habitat type by region (coarse filter)
Historically forested area	Areas that were historically forested
Landscape degradation	Deforestation rate; fire frequency; frequency of landslides; land use change (%); pollution indices; road density; soil erosion; volume of sediment-debris
Protected areas	Distance from protected areas; presence or absence of protected areas
Rarity	Presence or absence of rare species; representation of biotype in the broader landscape; uniqueness index
Recreation	Amenity value; number of people visiting the area; visual impact assessment
Remnants	Amount of primary and secondary forest at varying distances; distance form edge of forest; distance from forest of certain size; distance from remnant vegetation; distance from seed sources; presence or absence of adjacent areas with land use types suitable for restoration; presence or absence of remnant vegetation; presence or absence of seed dispersers; tree and shrub density
Size	Area; area needed for restoring a vegetation type
Soil conditions	Nitrogen soil content; Organic matter content of upper soil horizon; Phosphorous soil content; soil macrofauna abundance; soil respiration; soil texture
Vegetation structure	Height distribution; horizontal structure: coarse woody debris-amount, size, level of decay; plant – strata diversity; structural stage; tree diameters; vertical structure: plant species composition, snags/wildlife trees-level of decay, cavity trees
Water ecosystem	Alkalinity; bank height; channel depth; channel width; dissolved O_2; distance from large rivers; hardness; length of water courses in the restoration areas; peak flow; pH; water clarity; wetness index; width of active floodplain

Notes: Criterion names represent the clusters of synonymic criteria as provided by experts, while indicators include all those related to a given criterion that was consistent with the instructions provided.

direct value in supporting the implementation of policy initiatives focusing on the restoration of forest landscapes (Mansourian et al., 2005), by enabling resources to be targeted on those areas where positive outcomes are most likely to be achieved. This development of C&I also directly addresses one of the policy-relevant ecological issues recently identified as a priority by a consortium of scientists and decision-makers in the UK (Sutherland et al., 2006), namely how to decide which areas should be prioritised for restoration.

However, one of the key findings of this research was the difficulty of achieving consensus among members of the expert panel. The experts initially provided a large number of criteria, which needed to be grouped into cognate areas in order to make them manageable for the purpose of the study. This diversity in responses partly arises from the ambiguity associated with many of the terms and concepts used in restoration ecology, which has been recognised as a general problem in ecological science (Peters, 1991; Starzomski et al., 2004). The decision of extracting from the whole set of criteria a shortlist is questionable as all criteria are potentially relevant and might have a role for prioritising restoration sites. Despite a filtering based on just the frequency of selection is simplistic, we assumed that the most cited criteria are somehow fundamental. This is supported by the fact that, as experts provided their answers in an anonymous way, reciprocal influences were eliminated. In addition, many of the concepts conveyed by the least cited criteria are partly embedded in the most cited ones. For example, 'fragmentation' is partly described by 'connectivity-corridors', 'historically forested area' is included in 'degradation', 'forest characteristics' are stressed by both 'degradation' and 'natural regeneration potential' and 'soil' refers to issues partly taken

Table 3
Criteria and indicators for the F factor, which refers to the feasibility of restoration interventions.

Criteria	Indicators
Ecological	
Accessibility	Distance from centres of appropriate capacities; distance from transport infrastructures; distance from cities; geomorphology; number of available vehicles; type of roads; type of vegetation
Climate	Climate change parameters; rainfall; relative humidity; wind
Degradation levels	Amount of old-growth trees; amount of remnant vegetation; amount of seed dispersers; compaction; erosion of topsoil; number of pioneer species; number of remnant tree species; nutrient depletion; soil fertility; species richness
Disturbance	Amount of herbivores; fire frequency; land use; livestock data; number of invasive species; people per km^2; presence or absence of invasive species; presence or absence of noxious weeds; presence or absence of pests and diseases in the region; regeneration ability of invasive species; road density; type of livestock
Forest characteristics	Calliper – diameter; diversity; historical forest composition and structure; Landscape Biological Survey of Vegetetion (LaBiSV); number of exotic species; number of forest patches; number of stems per hectare by size class; patch distribution; presence or absence of desired plant species; presence or absence of mycorrhizae; presence or absence of old growth forest; presence or absence of secondary forest; species richness; tree height; uneven-aged/even aged forest; % live/dead; % threatened plants; % tree – plant species composition as a deviation from a baseline such as site series or late-seral plant community
Land use conflicts	Differential land cover use transformation rates; land use; landscape development plans; presence or absence of abandoned lands; presence or absence of private properties; presence or absence of utilities (power lines, etc.); suitability of land for alternative land uses; transformation matrix for each land cover type
Natural regeneration potential	Distance from natural forest; distance from protected areas; distance to seed sources; growth potential; number of birds; number of seed trees and shrubs; pests and diseases adaptability; presence or absence of minimal biotic structures; presence or absence of biological corridors; presence or absence of unique genetic variants at populations using neutral markers, such as isozymes, microsatellites or DNA sequences; rhizomes and root material; seedling density; survival capacity; syndromes classification of the landscape unit; wind direction; % of species with different dispersal modes
Size of habitat	Area; number of fragments
Soil	Acidification of the substrate; altitude; aspect; bedrock type; bulk density; cation exchange capacity; compaction; concentrations of heavy metals; concentrations of pesticides; daily and annual temperature fluctuation; depth; erosion; fertility; microbial communities; organic matter (%); pH; plant-available phosphorous; precipitation; presence or absence of toxic chemicals; presence or absence of toxins; slope; slope below 35%; soil type; structure; total nitrogen
Water availability	Annual precipitation; aridity and humidity index; distance from rivers; elevation above the average groundwater level; field capacity of the soil; infiltration rate; precipitation distribution; soil depth
Socioeconomic	
Economic sustainability	Amount of food provided; amount of wood provided; number of economically important species; price of products
Forest governance	Inspections; laws and regulations
Land ownership	Area of ownership; pattern of land ownership and tenure; public or private owner
Monitoring	Amount of funds; partnerships
Political will	Amount of incentives; amount of resources invested; number of institutions involved; presence or absence of incentives; subsidies or fines to stimulate or discourage restoration activities
Restoration costs	Area to be restored; cost of fences; economic value of land; labour cost; monetary cost; perimeter; seedling production cost
Technical knowledge	Presence or absence of technical information
Willingness of locals	Amount of community investment; degree of interest; number of NGOs working in the area; number of people interested; number of programs of environmental education

Notes: Criterion names represent the clusters of synonymic criteria as provided by experts, while indicators include all those related to a given criterion that was consistent with the instructions provided.

into account by ‘degradation’. With respect to indicators, the fact that only ten of the 88 analysed (i.e. 11%) were cited by more than 50% of respondents reflects the different values held by the experts consulted.

This illustrates the complexity of the problem: a relatively large number of indicators could reasonably be taken into account when prioritising areas for restoration. However, as noted by Tacconi (2000), any conservation research or management action is influenced by the values held by those involved, and the values held by a researcher will influence an individual conception of a problem and its interpretation. Restoration actions can therefore be considered to be similar to other forms of natural resource management, where no single perspective is necessarily complete, and no single solution is likely to be optimal (Lal et al., 2001). This uncertainty limits the feasibility of obtaining compact lists of measurable and readily applicable C&I through distance elicitation methods, if geographical and/or habitat contexts are not specified. The face-to-face meeting showed that there is greater scope for developing such a list if experts are asked to revise an existing set of C&I, to ensure that they comply with given requirements and are suitable to specific contexts.

The diversity of views and values highlighted here even within a single group of stakeholders, namely the ecological research community, arguably militates against the development of a generally applicable set of C&I for forest restoration. Proposals for developing generally applicable (or ‘core’) sets of indicators have been made for SFM (Castañeda, 2000) and for biodiversity indicators more generally (Newton and Kapos, 2002). A recent review of progress in C&I for SFM (Wijewardana, 2008) highlighted the value of rationalising indicator sets, to improve their applicability and usefulness. The face-to-face meeting contributed to an initial filtering of C&I by selecting the supposedly most relevant issues and disregarding or re-shaping the indicators that did not meet some basic requirements. Further improvements can only be achieved through application of C&I in real-world case studies, which would also

Table 4
Indicators for the B factor as selected by experts.

Criteria	Indicators	Citation (%)
Connectivity-corridors	Linkages between habitat units	70.59
	Presence or absence of wild areas connected to the restoration area	52.94
	Amount of interior habitat within a unit	47.06
	Distance from protected sites	29.41
	Corridor length	23.53
	Corridor width	23.53
Degradation	Land use change	89.47
	Deforestation rate	47.37
	Fire frequency	36.84
	Soil erosion	36.84
	Road density	21.05
	Pollution indices	5.26
Disturbance	Disturbance classification	65.22
	N. of people depending upon the ecosystem	47.83
	Area of vegetation type after disturbance/area of vegetation type before disturbance	43.48
	Amount of area logged	21.74
	% of invasive species	21.74
	N. of people living within the ecosystem	13.04
	Natural Disturbance Type (NDT) classification	13.04
	% of agricultural area	13.04
	% of populated area	13.04
	Area/perimeter	8.70
	Distance from roads	8.70
	Road density	8.70
	% of area logged by slope class	4.35
Diversity (ecosystem/landscape level)	Landscape structural diversity	70.00
	Landscape functional diversity	60.00
	Canopy cover	40.00
	Presence or absence of diverse ecosystem at the landscape scale	30.00
	Diversity of soils	20.00
	Presence or absence of water	20.00
	Altitudinal variation	15.00
	Amount of deciduous trees	10.00
	Amount of dead wood	5.00
	Azimuthal variation	5.00
	Quality of dead wood	5.00
Diversity (species level)	N. of endemic species	57.89
	Beta diversity	52.63
	N. of keystone species lost	47.37
	Species richness	47.37
	N. of keystone species	42.11
	N. of major vegetation types	26.32
	Abundance	10.53
	Age	10.53
	Forest density	10.53
	N. of native species/N. of exotic species	10.53
	Evenness	5.26
	Fisher's Alpha	5.26
	N. of birds	5.26
	N. of interactions among species	5.26
	N. of TER species	5.26
	Shannon diversity	5.26
	% live/dead	5.26

Notes: The citation rate is the percentage of respondents who selected a given indicator out of those who selected the related criterion.

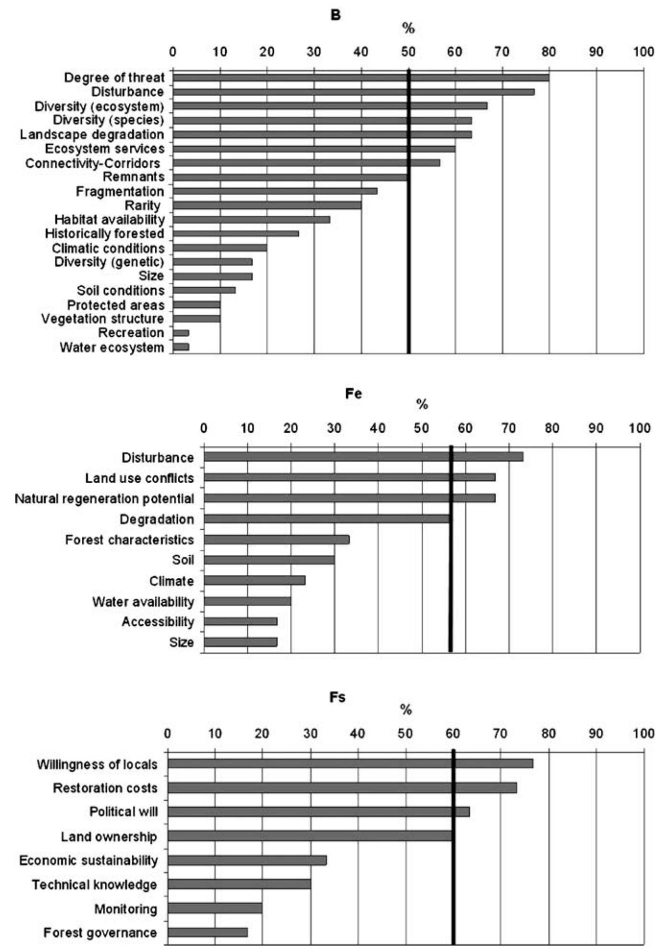

Fig. 1. Histograms showing the preference accorded to criteria for B (need for restoration) and F (feasibility of restoration) during the Delphi survey. The histogram for F is divided in two: ecological criteria (Fe) and socioeconomic criteria (Fs). Thick lines show the consensus thresholds adopted for selecting the supposedly most relevant criteria. Thresholds are 50%, 56.7% and 60% for B, Fe and Fs, respectively.

enable the results presented here to be further validated. For example, the evaluation of potential redundancies could be assessed by measuring indicators at several locations and subsequently applying multivariate statistics (e.g. principal component analysis) (Danz et al., 2004).

The emphasis in this research was on identifying indicators that can be measured. This reflects the problem that has characterised the development of ecological C&I relating to forests, namely the difficulty of ensuring that they can be operationalised (Newton and Kapos, 2002; Newton, 2007). Many indicators that have been proposed previously are difficult or even impossible to measure meaningfully, limiting their practical value. An example is provided by the concept of 'authenticity', which has featured in the discourse relating to forest landscape restoration as a way of describing the 'quality' of forest habitat (IUCN/WWF, 1999; Mansourian et al., 2005). As noted by Newton (2007), the concept of authenticity is very difficult to operationalise because it incorporates vaguely defined terms such as 'a balanced ecology' and 'a full range of species' within its definition, which themselves are difficult to measure.

Considering the indicators resulting from the face-to-face meeting, most meet the criterion of relatively easy measurability suggested by Dale and Beyeler (2001), although some (e.g. 'land cover heterogeneity') are open to different interpretations regarding practical measurement techniques. Some indicators also predict changes that can be averted by management actions (e.g.

Table 5
Indicators for the F factor as selected by experts.

Criteria	Indicators	Citation (%)
Degradation	Amount of remnant vegetation	76.47
	Erosion of topsoil	47.06
	Amount of old-growth trees	41.18
	Compaction	35.29
	N. of remnant tree species	35.29
	Species richness	29.41
	Amount of seed dispersers	17.65
	N. of pioneer species	17.65
	Soil fertility	17.65
	Nutrient depletion	11.76
Disturbance	Land use	59.09
	Fire frequency	45.45
	Amount of herbivory	40.91
	People/km^2	36.36
	Livestock data	22.73
	Presence or absence of invasive species	22.73
	Regeneration ability of invasive species	22.73
	Road density	22.73
	N. of invasive species	9.09
	Presence or absence of pests and diseases in the region	9.09
	Presence or absence of noxious weeds	4.55
	Type of livestock	4.55
Natural regeneration potential	Survival capacity	45.00
	Distance from natural forest	40.00
	Growth potential	30.00
	Presence or absence of biological corridors	25.00
	Distance to seed sources	20.00
	Presence or absence of minimal biotic structures	20.00
	Seedling density	20.00
	N. of seed trees and shrubs	15.00
	Presence or absence of unique genetic variants	15.00
	Rhizomes and root material	15.00
	Distance from protected areas	10.00
	N. of birds	10.00
	Syndromes classification of the landscape unit	5.00

Notes: The citation rate is the percentage of respondents who selected a given indicator out of those who selected the related criterion.

Table 6
The result of the face-to-face discussion.

Factor	Criteria	Indicators
B	B.1 Connectivity-corridors	B.1.1 Corridor length connected with the interior habitat
		B.1.2 Distance from nearest forest patch
		B.1.3 Edge density
	B.2 Degradation	B.2.1 Patch area
		B.2.2 Previously forested area
		B.2.3 Successional stages
	B.3 Disturbance	B.3.1 Distance to towns
		B.3.2 Population density
		B.3.3 Road density (distance to roads)
	B.4 Diversity (ecosystem/landscape level)	B.4.1 Aspect heterogeneity
		B.4.2 Elevation heterogeneity
		B.4.3 Land cover heterogeneity
	B.5 Diversity (species level)	B.5.1 Presence of threatened tree species
		B.5.2 Tree species richness
F	F.1 Degradation	F.1.1 Erosion risk
		F.1.2 Tree density
	F.2 Disturbance	F.2.1 Invasive species
		F.2.2 Livestock grazing pressure
		F.2.3 Predicted deforestation risk
	F.3 Natural regeneration potential	F.3.1 Climate
		F.3.2 Distance from remnants
		F.3.3 Vegetation types

Notes: Criteria are the same as reported in Tables 4 and 5, while indicators are those refined by experts during the face-to-face meeting.

'distance to towns', 'road density'), while some have a known response to disturbances, anthropogenic stresses and changes over time (e.g. 'edge density'). Those indicators referring to 'diversity', although synthetic when compared to the possible ways of describing the concept (Feest, 2006), are integrative, in that the full suite provides an assessment of the system at different scales of concern (Dale and Beyeler, 2001). Moreover, the double-level (ecosystem and species) description of biodiversity accounts for coarse and fine-filter conservation strategies, thus allowing a mesofilter approach to be potentially implemented (Hunter, 2005). One of the main advantages of the proposed indicators is their spatial character: all are expected to show variability over space, enabling them to be used in support of landscape planning activities. With access to appropriate data, the indicators could be mapped using basic GIS operations (e.g. distance calculation), facilitating their calculation and enhancing their practical value (Aspinall and Pearson, 2000; Newton and Kapos, 2002). However, some indicators (e.g. 'climate') are still quite vague and, at present, represent nothing more than relevant issues to be accounted for in restoration practice.

The next step, involving the combination of several indicators into one single multimetric index, is a complex one (Stoddard et al., 2008). As all indicators are (or should be) spatially-explicit, tools provided by spatial multicriteria decision analysis might be of value in this context (Malczewski, 1999). Maps could be generated for each of the adopted indicators and subsequently summed up to obtain a final 'prioritisation' map. Great attention should be paid to the assessment of value functions that normalize all indicators to a common scale of 'desirability' (Beinat, 1997), as well as to the combination methods and weighting schemes. The uncertainty involved in all of these operations calls for appropriate techniques to be applied to ensure that the results are robust. When considering the proposed C&I, two main prioritisation maps might be generated, one for B and one for F, from which priority sites could be extracted by means of thresholds or the application of selection algorithms (e.g. optimization). It should be emphasized that the ecological C&I identified by this study would constitute only an element of a true integrated approach to resource management and planning. Prioritisation of areas for restoration should also include socioeconomic criteria and incorporate the range of perspectives held by different stakeholders (Mansourian et al., 2005).

One of the key contributions of the current study relates to the methods used. Although other studies have proposed criteria that might be used to prioritise areas for forest restoration (Newton and Kapos, 2003; Marjokorpi and Otsamo, 2006), as far as we are aware, this is the first to employ the Delphi technique. The value of the Delphi in supporting natural resource management is widely recognised (Gokhale, 2001; Eakin et al., 2007) and its integration with face-to-face discussions can be of particular value in clarifying complex issues (Katzenbach and Smith, 1993; Gokhale, 2001). Our approach was a two-stage one. The Delphi process was used to elaborate a broad list of C&I and to identify a shortlist of criteria that are expected to have significant relevance. To this extent, the size of the sample (37 experts) and the wide spectrum of expertise in terms of geographical region, habitat type and restoration approaches should help ensure that the final results are sufficiently robust. The face-to-face meeting was instead aimed at making the general set of C&I applicable to a specific context. The fact that experts were provided with an initial list of C&I to start from allowed results to be obtained relatively quickly.

As the purpose of the survey was not simply to select C&I from a list, but rather to produce them from scratch, open-ended questions had to be used initially. This is common in classical Delphi approaches, which leave participants free to identify issues through unstructured questionnaires (Martino, 1983). However, it calls for complex qualitative analyses and sometimes arbitrary choices in order to summarise the sample of responses. While unstructured questionnaires give experts a considerable freedom in listing issues, such freedom becomes a significant drawback if not correctly managed. There is a substantial literature on qualitative analysis methods (Malterud, 2001; Patton, 2002), but little guidance is available on how such methods might be applied to Delphi studies. Some authors (Miller, 2001) have addressed this issue by introducing pre-determined indicators on which experts were invited to comment. This simplified approach, which is supposed not to reduce the value of comments received (Miller, 2001), has the fundamental drawback of preventing experts from designing ad hoc C&I.

Our approach to group criteria was essentially based on synonyms and comments provided by experts. The task was not straightforward and it necessarily led to loss of information. It was found that the group names selected could not always fully describe all possible nuances that constituting criteria had provided. This may have reduced criterion diversity for the subsequent rounds. Furthermore, a significant problem was encountered because of a lack of understanding among participants regarding the information requested. This highlights the difficulty of communicating the research objectives and scope, and may account for some of the variation in responses received. Indeed, it was necessary to exclude from further stages a number of responses that did not meet the requirements stated in the questionnaires. In particular criteria were omitted that were too generic (e.g. 'mosaic of surrounding land uses'), too specific (e.g. 'flagship species') or that failed to provide supporting information regarding their relevance. Similarly, indicators were omitted that were not operational (e.g. 'assessment of forest global status'), that just proposed specific tools (e.g. 'GIS mapping') or procedures (e.g. 'measure disturbance from historical records'). When a criterion was excluded, its indicators were excluded as well.

A further problem of the expert panel approach adopted here is that regardless of how experts are selected, and how representative their views are of current scientific opinion, their ecological understanding may be limited or flawed. The scientific understanding of the processes influencing biodiversity, and the relationship with ecosystem function, is developing rapidly (Jones, 2010). Consequently, the views expressed by experts may not adequately represent current ecological thinking. An example is provided by functional aspects of biodiversity, which may logically be an objective of ecological restoration efforts (Rey Benayas et al., 2009). Progress has recently been made in developing tractable measures of functional aspects of biodiversity (Petchey and Gaston, 2002; Petchey et al., 2004; Hooper et al., 2005). However, such functional approaches to biodiversity measurement did not emerge through the expert consultation process described here.

Finally, the decision of evaluating criteria and indicators as individual entities, that is without considering collections of them, was essentially suggested by time constraints. Such a grouped analysis would have called for an additional Delphi round, which most probably would have resulted in a significant loss of participants. Although this decision is expected to have affected our capacity to deal with redundancies in the lists of C&I, we believe that face-to-face discussions and real-world applications should help reducing such redundancies. Future validation of the results is clearly desirable. For a given case study, the C&I proposed during a specific face-to-face meeting should be tested in the field and subsequently their reliability examined by the same meeting's participants.

5. Conclusions

In natural resource management, expert knowledge can provide an invaluable contribution towards the solution of problems when empirical information is scarce or lacking. This study showed that the identification of criteria and indicators for forest restoration planning can be informed by Delphi surveys. Moreover, post-Delphi face-to-face meetings were shown to have potential in helping obtain C&I that are operational, moderately redundant and suitable for spatial analysis and mapping. The research produced a provisional shortlist of criteria and related indicators that could be used to support the prioritisation of sites for forest restoration, in conjunction with socioeconomic indicators and the values of different stakeholders. However, the expert panel approach adopted here identified a wide diversity of views and values even within a single group of stakeholders. This suggests that the development of a generally applicable set of C&I for forest restoration will be difficult to achieve in practice. Although the C&I identified here are directly applicable to support forest restoration planning through the use of GIS-based techniques, their validity should be further tested by their practical application in different contexts.

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