A New Improvement of the Naturalistic Indicator of Forest Quality

An Italian Case Study

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***Abstract*— This paper describes a new improvement of the previous defined Forest Quality Indicator (FSQ) for biodiversity assessment and conservation purposes. The two novelties of the work in progress include the following aspects: the embedding of a shape feature of the forest patches, and the consideration of the plantation for ecological restoration in the computation of the indicator. The results are shown on a case study of a municipality of the West Po Plain (North Italy). The improved indicator seems to be very promising in describing the realistic situation of the forest quality in the territory. This suggests that it can be used efficiently to guide policy makers and planners to choose the best forest types/patches for restoration and connectivity.**

Keywords - biodiversity; environmental indicator; forest status quality; patch shape; plantations.

I. INTRODUCTION

This work in progress represents a new improvement of the Naturalistic Indicator of the Forest Quality (Forest Quality Indicator, FSQ) described in [1]. Such indicator was performed considering the stratification, the percentage of alien species and the percentage of protected species (often corresponding to true forest species, such as *Anemone nemorosa*, *Campanula trachelium*, *Carex elongata*, *Convallaria majalis*, *Listera ovata*, *Neottia nidus-avis*, and *Primula vulgaris*) characterizing the different forest patches of the analyzed area (the Province of Pavia, Lombardy Region, North Italy). Furthermore, the proposed indicator took into account also the size of the forest patches, and only patches greater than 10.000 square meters were considered. In fact, patches smaller than 1 ha generally show low species richness [2] and a scarce floristic quality due to the edge effect which can increase the abundance of weedy and alien species [3]-[5]. The richness and floristic quality (due to true forest species) of the forest patches can be influenced not only by their size, but also by their shape. However, a correlation between the shape and the species richness of forest patches can be found when the patch size is sufficiently high. In fact, Dzwonko and Loster [6][7] found a negative correlation between the shape index of Patton [8] and the number of shrubs and forest species. In that case they worked with a restricted dataset of only 27 forests varying from 0.03 to 1.6 ha. With such small patch sizes it is possible that the entire patch was subject to the edge effects [9]. Honnay et al. [9] analyzed 234 forest patches varying in size between 0.5 and 5216 ha and found a correlation between the Patton shape index and the number of species in edges and clearings, the number of woody species and lianas and, as a consequence, with the total number of forest plant species. For these reasons, in the new improvement of the FSQ indicator, also the shape of forest patches was taken into account. Patches with linear shapes were not considered, applying an *ad hoc* erosion operator on the image data provided by Geographic Information Systems (GIS) of the project (as explained in Section II.) Such linear patches, together with those smaller than 10.000 square meters, that can be considered as punctual patches, do not represent core areas hosting complexes forest ecosystems (as the wide patches of compact shape where the edge effect is reduced) important for woody and herbaceous true forest species. However, they can represent critical elements to connect core areas and support the structure of a local/regional ecological network, and the evaluation of their quality should be better considered from the connectivity perspective. Here, in the new improvement of the FSQ indicator, only forest patches with similar geometric characteristics (wide size and compact shape) were considered, with the aim to evaluate more homogenous elements and have a more realistic picture of the forest quality useful for conservation purposes.

Besides embedding the geometric characteristics in the computation of the FSQ indicator, a second aspect has been considered in this work in progress: the evaluation of the importance of forest plantations. In fact, in the previous elaboration of the FSQ indicator, only natural forests were considered, while plantations were excluded from the evaluation. However, the Lombardy Region, in 2002 started and financed an important project aimed to create 10 new plain forests, each of them with a size of about 40 ha and planted with native trees and shrubs [10][11]. Actually, such forests have not still developed a typical structure of mature wood and a typical nemoral herb layer, which will require at least 20-30 years. Anyway, because of their importance for the restoration of the Lombardy plain and conservation purposes, such new forests were considered in the present work in progress. The objective of the research is to analyze and quantify the impact of considering also the forest plantations (for restoration purposes) on the values of the FSQ. The case of the Municipality of Travacò Siccomario (Province of Pavia) was preliminary considered, to test this

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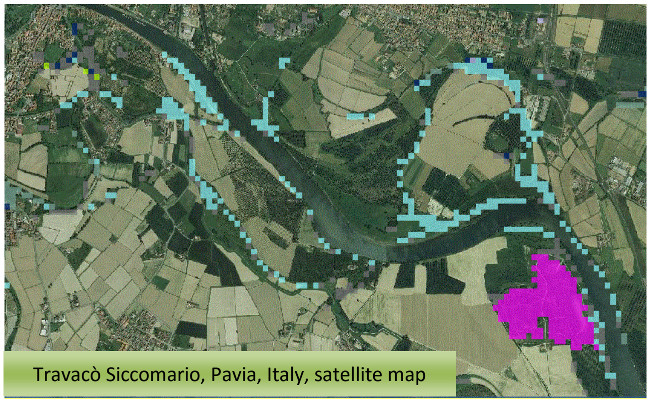

Figure 1. The territory under investigation (Municipality of Travacò Siccomario): the blocked colored areas superimposed on the geographic map show the presence of the natural forests (light greeen and light blue) and the plantation (pink).

elaboration because it hosts one of the ten new plain forests projected and realized with the support of Lombardy Region.

The aim of this paper is describing the data set and the methods used to extend the previous contribution in literature in the new work in progress. Moreover, to help readability, a brief summary on FSQ indicator is provided (for a detailed description, see [12].) The experimental results refer to the case study of the Municipality of Travacò Siccomario and they suggest an interesting starting point for future work.

II. DATA SET AND METHODS

As in the previous contribution [1][12], we have used a GIS database, free available from the Region Lombardy [13], in order to derive the useful description about the distribution of the forest in the territory. In Figure 1, the visual map for a portion of the Municipality of the case study under investigation is shown. Different colors refer to different types of forests. Particularly, the compact pink area refers to the forest plantation. The other colors refer to natural forests. These data are the input for both the two basic operations: the computation of the FSQ indicator (see Section II.A) and the processing by the Erosion operator (see Section II.B).

A. The Forest Status Quality Indicator

The FSQ expresses the forest quality status as the value of its ecological components, with particularly reference to the biodiversity conservation. In its first application [1][12] it was computed for each municipality of the provinces of Pavia and Lodi, considering only natural forests occurring on areas greater than 10.000 square meters [1]. A set of sub-regions occupied by natural forest F_i (i = 1, 2, n) was defined. Each of F_i may have one or more occurrences, denoted by the index k, in the territory (k = 1, 2, max(i)). The number of occurrences may vary from a minimum of 1 to a maximum, which depends on the forest type (max(i)). Each k-th occurrence is characterized by: (a) an area A^k_i, expressed in square meters, for i = 1, 2,…n and k = 1, 2, … max(i), and (b) a type of T_i, derived from the GIS ERSAF Database "Map of the Forest Types of Lombardy" [13]. For each forest T_i, we found the correspondence with one or more phytosociological tables [14]. For each forest type T_i, we defined a set of the following indicator components (s_i, a_i, p_i): the stratification (number of layers) of a forest type $_i$ (s_i), the percentage frequency of alien species (a_i) in the corresponding phytosociological table/s, and the percentage frequency of protected species (p_i) (according to the Lombardy regional law, L.R. 10/2008) in the corresponding phytosociological table/s. The three components can assume only discrete values, from 0 to 3, according to an if – then – else algorithm described in [1][12]. After determining the values of the set of components for stratification, alien and protected species, for each forest T_i, it is possible to compute the FSQ Indicator of a municipality of area S as

$$FSQ = \Sigma_i \ \Sigma_k (s_i + a_i + p_i)*A^k_i/S \qquad (1)$$

The FSQ definition is the weighted values of the components, where the weights are the ratios between the areas of the forests and the area of the territory under investigation. By using the primitives of the open source QGIS software [15], the values of A^k_i in the territory under investigation have been computed, in order to estimate the value of the FSQ indicator, according to (1).

B. The Erosion Operator

The first aspect of the work in progress here described is the introduction of the factor "shape" of the forest patches in the computation of the FSQ. By analyzing (1), in the original [1][12] FSQ definition, only the areas of forest patches are considered and weighted by the naturalistic components (s_i, a_i, p_i). The only limitation introduced on the geographic data is still a quantitative one (the 10.000 square meters as the minimum accepted size of the forest patch to be evaluated). However, we decided to take into consideration a characteristic that refers to the shape of a patch, i.e., to reduce the edge effect, which, in turn, reduces the floristic quality. This can be done by applying the standard mathematical morphology operator of Erosion [16], with a structural element of a circle of radius of 50 meters. In fact, Erosion is a typical image processing operator that allows to "erode" a connected area, starting from its perimeter and proceeding inside, of an extent that corresponds to a given shape of the structural element. In our case, the structural element is a circle of a given radius, in order to reduce the areas of the forests to their real inner shape, by excluding the areas near the boundary. If we use a circle as structural element, the shape of the forest will be remodeled in a symmetric way, all along the boundaries. The diameter of the structural element determines the minimum distance that a forest patch must have from its center to all the points of its boundaries, in order to be considered in the FSQ computation. As a result of the Erosion, the forest patches with a linear shape (a thin stripe less than 100 meters of amplitude) disappear from the map, as it can be seen in the experimental results reported in Section III. All the other patches are reduced by the erosion, to minimize the "edge" effect. With the introduction of the Erosion operator, we applied to each area A^k_i the Erosion operator E[], thus leading to a new expression of FSQ, denoted by FSQ_e:

$$FSQ_e = \Sigma_i \ \Sigma_k \ (s_i + a_i + p_i)*E[A^k_i]/S \qquad (2)$$

The new operator FSQ_e takes into consideration both the quantitative (areas) and the qualitative (shapes) aspects of the forest patches.

C. The Study Area

The study area includes the Municipality of Travacò Siccomario (geographical coordinates: 45° 8' 60,00" N 9° 9' 38,52" E). It is located in the Lombardy plain at an average altitude above sea level of 66 meters, and is mainly characterized by agricultural fields and urban areas. Natural forest areas are localized along watercourses and channels, often as linear elements dominated by mixed woody species as *Salix alba*, *Populus alba*, *Quercus robur*, *Ulmus minor* and, very frequently, the invasive *Robinia pseudacacia*. Wide forest patches are limited and dominated by the woody species above mentioned. As we consider only forest types that have at least one occurrence in the territory of area greater than 1 ha, only three types of natural forests survive these requirements: the *Salix alba* communities, the *Populus alba* communities, and *Robinia pseudoacacia* communities.

Moreover, in this study we want to include also plantations in the FSQ computation. In 2003-2004, one of the great plain forests of the Lombardy Region was realized in this municipality. Particularly meso-xerophilous and meso-igrophilous forest patches were realized on a surface of about 41 ha, planting native trees (such *Populus nigra, Ulmus minor, Acer campestre, Malus sylvestris, Carpinus betulus, Quercus robur, Salix alba, Alnus glutinosa, Populus alba, Prunus padus*) and native shrubs (such *Crataegus monogyna*, *Corylus avellana*, *Prunus spinosa, Sambucus nigra, Cornus sanguinea, Frangula alnus, Viburnum opulus, Salix cinerea*). Considering the woody floristic composition, the new forest can be considered as the forest type Oak-Elm wood (also including the Black Alder variant) [17]. The value set of components for stratification, alien and protected species is 3,2,2 for this plantation. In Table I all the forest types, of area greater than 1 ha, for the case study of Travacò Siccomario are shown.

III. Experimental Results

In the experiments of data analysis, for the case study here reported, we applied the erosion operator to compute the FSQ_e, according to (2) and compare the effect of the Erosion on each forest types of Table I. The computed value FSQ_e for the Municipality of Travacò Siccomario is 0.2004, vs. a value of FSQ of 0.2276, including all the forest types of Table I (both natural forest and plantation). The relative loss of the indicator is of 11.9%.

TABLE I. FOREST TYPES FOR THE CASE STUDY.

Naturalistic components (s_i, a_i, p_i).	**Description of forest types T_i and relative reference *syntaxa***
(1,1,0)	T_1: Willow wood of bank
(3,1,0)	T_2: White Poplar formation
(2,1,0)	T_3: Pure *Robinia pseudoacacia* wood
(3,2,2)	T_4: Plantation (Oak-Elm wood, also including the Black Alder variant)

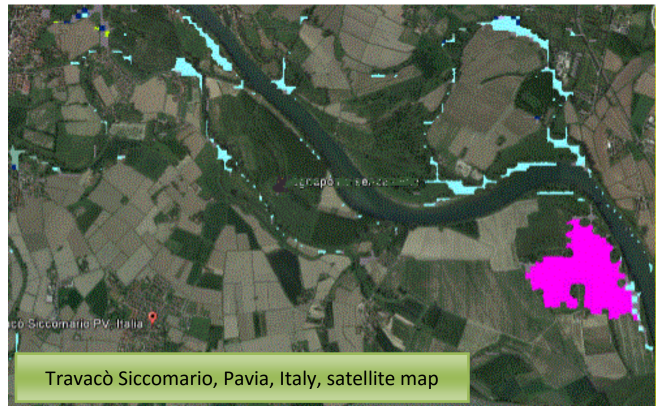

Figure 2. The territory under investigation after the Erosion operator applied to all the forest patches.

Clearly, the erosion has reduced the areas of the forest patch, and consequently the indicator is lower. However, the loss of the areas is not equal for all the four forest types. In fact, the loss is determined by the shapes of the patches, which are quite different in the territory under examination. The loss percentages are the following: 3.6% for the plantation, 35.2% for the *Salix alba* communities, 51.3% for the *Populus alba* communities, and 61.2% for the *Robinia pseudoacacia* communities. It is interesting to note that the plantation is the forest type with the lowest loss; this indicates that the project has considered a good shape, which is very close to an ideal core area. Moreover, the *Robinia pseudoacacia* communities have the highest loss, and it is a positive aspect, because of the very low floristic quality, due to the dominance of alien species in linear and fragmented patches. In Figure 2, the map of the territory after the erosion is shown. The reduction of the colored areas of the forests types is evident, by comparing Figure 2 to Figure 1. In Figure 3, the areas before and after the erosion are plot, for each forest type of Table I.

IV. Conclusion and Future Work

The new improvement of the FSQ here presented and the obtained experimental results put in evidence that our methodological approach is realistic in evaluating the forest quality and may give useful information for the choice of which forest patches should be enhanced for conservation purposes (in our case study, *Salix alba* and *Populus alba* communities) or not (*Robinia pseudoacacia* communities). The promising results suggest to extend the FSQ_e computation for all the municipalities considered in [12].

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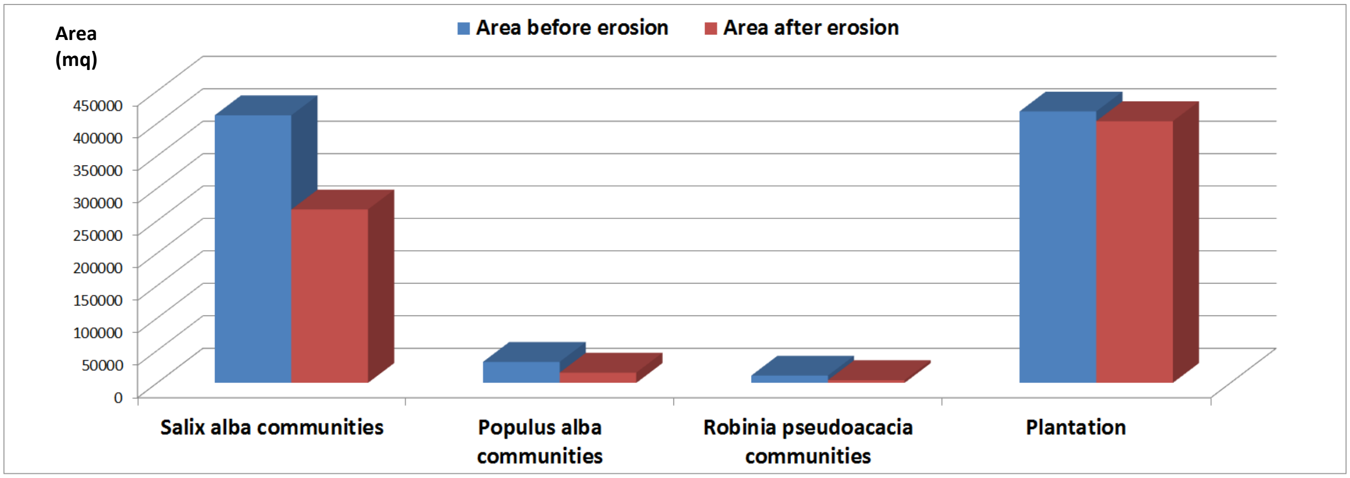

Figure 3. The areas (in sqare meters, on Y-axis) for each the forest types (on the X-axis), before and after the Erosion.

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