Localization of Buffer Strips by using IFF field data and Landsat-TM satellite data

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Abstract

In recent years the need to restore impacted habitats has become a fundamental aspect of environmental management in order to match sustainable development requirements. This is particularly important for fluvial habitats because of their role in the landscapes as environmental corridors. For these reasons the correct management of the restoration ecology interventions is mandatory and the ecosystem characteristics, as well as the influence of its landscape, have to be taken into account. In order to correctly realize buffer strip intervention, one of the most used restoration techniques, we propose an approach which uses field measurements for fluvial functionality and satellite data integrated with hydrological models to obtain information on the landscape influence on the river system. The investigation involved the high valley of the Agri River located in the Basilicata region, Southern Italy.

The first step to the analysis involves the investigation of the fluvial ecosystem quality by using the Italian IFF Index (Fluvial Functionality Index), which differentiates various river segments in different levels of functionality. Meanwhile, by using a multispectral satellite image (LANDSAT TM 5) a land use map of the area of interest was performed. This land use map represented an important input for the hydrological simulation, which identified fluvial segments receiving the highest amount of landscape surface runoff, which is the most important cause of pollutant transporting from surrounding areas.

All the results have been recorded and integrated in a Geographical Information System to define the final prediction for the localization of the buffer strips. The results obtained underline that the identification of the intervention sites realized by using the IFF field measurements and satellite-based hydrological analyses are complementary since critical segments respectively identified are not completely overlapped. Therefore, an integrated approach is fundamental to better plan the management of restoration ecology interventions.

Keywords: fluvial habitat, satellite, IFF, Landsat-TM, hydrological model, GIS.
1 Introduction

The anthropic pressure over fluvial habitats has become, in the last years, more and more important. For this reason, the need of restoration ecology interventions, devoted to improve the ecological fluvial functionality, has increased. Among the several techniques, the construction of buffer strips has been recognised useful 1) to increase the river-landscape connectivity; 2) to limit the pollution impact of the surface runoff coming from river watershed; 3) to create new habitats in riparian ecotones (see, e.g., Vought et al. [1]; Mander et al. [2]). Such techniques are particularly efficient in removing pollutants from diffused (non punctual) sources; furthermore, they are economically convenient, as underlined by a widespread literature (see, e.g., Borin et al. [3] and references therein).

In this paper we propose a method to plan the right localization of such interventions, on the basis of the knowledge of the different levels of the local fluvial functionality and the behaviour of the watershed runoff. The methodology integrates field measurements and hydrological analyses based on remote sensing data.

The information about ecological fluvial functionality has been obtained by applying the Italian IFF Index (Index of Fluvial Functionality) (Siligardi et al. [4]). Fluvial segments receiving the highest amount of surface runoff have been identified by applying a distributed hydrological model that utilizes a land use map derived from satellite data.

2 Methods

The study area is the high valley of the Agri River (Southern Italy): the water level gauge of Tarangelo (watershed of about 507 km$^2$) represents the outlet of the sub-basin considered herein (Figure 1). It has a typical humid climate with frequent rains and consistent baseflow. Forests and semi-natural areas are the mainly present covers, whereas the remaining part consists of agricultural areas and small artificial surfaces. The basin has a heterogeneous geologic and lithological nature made up of calcareous mountains and plains of gravel, sand, clay and flysch.

Such an area actually shows attractive mountainous landscapes around an alluvial plane located at about 580 m above sea level. This particular configuration allows for the presence of a very rich faunal and vegetational biodiversity and also it is possible to find rare or threatened species. All these peculiarities have led to the institution of a National Park in the area, which is currently being established.

Moreover, it is important to underline that the interested territories also show a rich presence of valuable natural resources such as water and oil. In relation to the latter, there is an important oil-drilling activity, which represents a critical element for a sensitive area such as the one described above.

In this context, we evaluated the usefulness of a combined approach (Figure 2) for identifying the most threatened fluvial sectors, where the
localization of buffer strips can preserve the local quality of the fluvial ecosystem.

![Study area: the high sub-basin of the Agri River.](image)

**Figure 1: Study area: the high sub-basin of the Agri River.**

### 2.1 The IFF field data

The information about ecological fluvial functionality was obtained by applying the Italian Index of Fluvial Functionality (IFF, Siligardi *et al.* [4]). This index considers all the features of a fluvial or stream habitat: land use, vegetational riparian buffer, biological characteristics, hydrological and hydraulic characteristics and has been widely applied in Italy to all river typologies.

Such an index is carried out by walking along the entire river from the mouth to the source and observing the variations in the different characteristics of interest. The IFF is obtained assigning different functionality scores by answering to 14 questions regarding the various aspects of the fluvial habitat (see, e.g., Carone and Manfreda [5]; Balestrini *et al.* [6]).

The total score of the index provides a value, which corresponds to different levels of functionality ranging from the best (I class) to the worst (V class); also 4 interclasses are present (e.g., I-II, II-III, etc.).

Each class can be mapped along the two riverbanks by using the relative colours and symbols as specified by the protocol (Siligardi *et al.* [4]). For this reason the index is user-friendly in the interpretation also for non-experts and thus it is really useful for final decision-makers in fluvial resource management.

### 2.2 The satellite data

Remote sensing data were used to obtain a land use map of the studied area. This map has represented the basis for the calculation of surface runoff by using a hydrological distributed model.
A summer image from Landsat 5 TM (Thematic Mapper) sensor (spatial resolution of 30 m) was used to perform a hybrid classification approach that we experienced as very useful for high heterogeneous territories (Simoniello et al. [7]).

A preliminary unsupervised classification was performed by using the ISODATA algorithm (Tou and Gonzalez [8]) to obtain a set of unsupervised training sites. Other training areas were identified on the basis of field territory knowledge obtaining thus the complete set of training signatures. By using the Maximum Likelihood supervised procedure (Richards [9]), we performed the final classification.

2.2.1 The hydrological analyses
The analysis of surface runoff is particularly important since the transport of solid-suspended substances and dissolved elements may strongly degrade the river water quality.
In order to obtain information about the surface/subsurface runoff for the study area, the hydrological characterization of the river basin has been carried out by means of a distributed hydrological model that has been successfully tested over a broad number of basins in Southern Italy (see, e.g., Manfreda et al. [10]; Sole et al. [11]). The model uses a grid-based approach and requires a land use map integrated with data concerning vegetation status, morphology (Digital Elevation Models) and soil pedological characteristics. Runoff generation is estimated from the rain intensity and soil moisture status, and is calculated using a default runoff coefficient, which depends upon slope, land use and soil type (De Smedt et al. [12]).

Model runs, driven by recorded rainfall have been used to quantify the susceptibility level to diffused surface runoff along the main river channel. By applying such a methodology we defined all the portions of the river in which there is a critical contribution of runoff and we localized fluvial segments receiving the higher runoff load.

3 Results and discussion

The functionality levels mapped on the basis of the field IFF measurements are shown in Figure 3. In such a map it is possible to see that the river has a first segment (Photo 1 in Figure 3) in the best class (I), which has all the characteristics of the primary natural structure of a fluvial ecosystem. The functionality strongly decreases along the segments with concrete banks (Photo 2) and increases again in the upper part of the river (Photo 3).

Results from the classification procedure show a land cover structure with relevant differences between the bottom of the valley and highest areas (Figure 4). The vegetation of the valley is characterized mainly by cultivated areas mixed with natural herbaceous stands. Some scattered residual patches of ancient forests are also present. Besides the agricultural areas, the anthropogenic activities are represented by an industrial area mainly related to oil-well activities and a number of quarries. Small-urbanized areas are scattered over the territory. The mountainous areas are characterized by precious natural stands such as beech forests.

The fluvial segments receiving the higher amount of runoff load are plotted in Figure 5. The map shows that the upper part of the river is the most critical for the runoff load; moreover, these segments are characterized by the higher presence of numerous intensively cultivated areas in the neighbouring (see Figure 4).

By comparing Figure 3 and 5 it is possible to note that along the riverbanks some segments are critical from both the point of views (fluvial functionality and critical runoff load), whereas other segments are characterized by the presence of a single critical parameter.

In the medium part of the sub-basin a segment receiving critical amounts of surface runoff coincides, along the left bank of the river, with a part of the IFF segments showing the lowest measured functionality (class III-IV).
Figure 3: Functionality Levels of the Agri River; I class = very good, II-III = good/mediocre, III = mediocre, III/IV = mediocre/poor (the IFF class colours are not the same suggested by the protocol to make the b/w figure more readable).

Figure 4: Land use map obtained from Landsat-TM data classification.
Towards the upper part of the river it is possible to see that along both the riverbanks, critical segments for runoff are in correspondence with a medium IFF class (III) and furthermore they threaten a little part of the river which still maintain an almost good functionality (class II-III).

Rather one of segments receiving critical amounts of surface runoff is located (along the right bank of the river) in correspondence to the fluvial segment with the highest functionality (class I).

Figure 5: Map of fluvial segments receiving critical amounts of surface runoff.

4 Conclusions

In this paper we proposed a combined approach based on field measurements (IFF) and satellite data (Landsat-TM) for localizing the most efficient sites for buffer strip interventions in fluvial habitats. The analysis evaluates two parameters critical from both an ecological and hydrological point of view (fluvial functionality and surface runoff load). The first is related to the intrinsic fluvial habitat characteristics, whereas the second estimates the influence on the river of the whole watershed. These two parameters can enhance critical conditions since the IFF evaluates the river efficiency in recycling the organic matter and a high surface runoff is on of the principal carrier of the organic matter and pollutant into the fluvial environment. To solve such problems, buffer
strip interventions are considered one of the most efficient and cost-effective restoration techniques. The typology and dimensioning of the buffer strips have to be related to the information on critical sources and levels that can be derived by applying this methodology. In particular, where the critical segments are strictly overlapped the fluvial ecosystem is more vulnerable and significant restoration ecology interventions have to be planned.

The proposed methodology provides complete information on the fluvial health status for technicians and decision makers involved in planning and management of restoration ecology interventions such buffer strips.

References


