THE USE OF THE FLUVIAL FUNCTIONING INDEX FOR RIVER MANAGEMENT

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Abstract: The ecological approach for understanding a river requires not just a holistic vision and an interdisciplinary background, but also specific tools, which can help in combining different perspectives and types of information.

The Fluvial Functioning Index (FFI), published by the Provincial Agency for Environmental Protection of Trento (Italy) in 2000, is a method that aims to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics, and biological features. Moreover the FFI is able to produce a synthetic but comprehensive evaluation of the ecological functionality of the river.

The results of the FFI application can be mapped using a GIS software and become a valuable support for an integrated river basin management. An example of the use of FFI for land planning in the Province of Trento (italy) is also described.

INTRODUCTION

This paper aims to give an overview of the Fluvial Functional Index as tool to “an integrated approach to river management”. “Integration” is a key word for the present and the future management of rivers as integrated management of land and water is an underlying principle of the EC Water Framework Directive (European Commission, 2003). Integration refers to all water bodies: internal, transitional, marine and ground water, but also to scientific disciplines related to water and land management. This means that the ecological study of rivers needs a progressive enlargement of the perspectives and the scale of observation. An

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integrated approach therefore must consider ecological processed occurring at different scales (i.e. microhabitat, riffle and pools sequence, river stretch, river basin), each characterised by their own forms and features (Naiman *et al.*, 1992)

THE FLUVIAL FUNCTIONING INDEX

The FFI was officially presented in 2000 (Siligardi *et al*., 2000) but the history of the method started at the beginning of the 90's with the Riparian Channel and Environmental Inventory (R.C.E.-I) published by Petersen (1992). The R.C.E-I was adapted for the Italian context by Maiolini and Siligardi (1993) and further developed by of a working group appointed by the Italian Agency for Environmental Protection. Now the FFI is widely applied in Italy and there is a national week long course specifically to train staff of the Regional and Provincial Italian Environmental Agencies.

THE PRINCIPLES OF THE METHOD

The objective of the FFI is to evaluate the whole river ecosystem with particular attention to its functionality in terms of retention and cycling capacity of the fine and coarse particulate organic matter (short FPOM and CPOM) (Elwood *et al*., 1983), of buffer potential of the riparian ecotones (Negri, 1997) as well as of morphological structure able to support and sustain well diversified and stable biological communities (Sansoni, 1987). Secondary objectives but not less important are the FFI results which can be used in order to plan, forecast and verify the policy and strategy applicable for the river and land management.

Through the description of morphological, hydraulic and biological parameters interpreted in the light of the principles of the river ecology, the associated functionality is evaluated. This integrated reading of the riverine environment is used, to define the river comprehensive functionality. This approach is different from other river assessment methodologies: normally river analysis draws attention to compounds of the ecosystem such as the macro-invertebrate community, chemical quality of the water or morphological features. These methods do not include an overall assessment of the watercourse and this differs from the FFI, which aims to assess the entire riverine environment. It must be underlined that the FFI does not wish to replace the existing river quality evaluation methods but is another tool which can be useful in order to support an integrated strategy fro river protection, management and restoration.

It must be also stressed that the concept of functionality is different from naturality. An almost pristine river with no significant pressure can be fragile and its functionality less than expected. A typical example is the Mediterranean rivers of South of Italy, where riparian vegetation can be naturally poor and the difference in discharge regime between the wet and the dry season can significantly stress biota.

THE FIELD ACTIVITY: THE FFI QUESTIONNAIRE

The FFI should be applied to the whole river starting from the mouth to the source. Before starting to apply the method in the field it is important to gather information regarding the major pressures in the catchment, data about the hydrological regime and biological and chemical analysis, and aerial pictures and maps in order to have a better understanding of the threats and strengths of the area under evaluation.

The river should then be divided in “homogeneous” stretches: this being stretches which have no variation in terms of functionality. The river is provisionally split into stretches based on the information described above and a field survey. This initial split is verified during the application of the full method which normally involves covering the whole length of the river on foot, where physically possible. The river stretches range between a few tens of meters to some kilometres. About 5 kilometres a day is the normal average length of river that can be covered when carrying out FFI..

For each stretch a FFI form, which is divided into 14 questions, is filled in (Fig. 1 and Fig 2). There are 4 possible responses to each question and for each answer there is a fixed score. There is a progression apparent in the sequence of the questions. The first four concern bank vegetation, the extent of the riparian area and the land use pressure. The next two questions refer to the physical and morphological structure of the banks, due to the importance of the role that these have for the conservation of the river shape. Questions 7 to 11 are about the structure of the river bed, identifying the features related to the capacity of the river for self-purification (being self-sustaining). These five questions facilitate the comprehension of:

- characteristics that influence the biological composition of a particular habitat
- elements that characterize the static and dynamic morphology of the ecosystem (e.g. the succession of meanders, riffles, pools; presence of back waters, point bars, islands)
- the nature and size of non-living particles; (granulometry of different origin and size);
- the deposition and erosion processes.

The last three questions evaluate some key biological characteristics of the river ecosystem: periphyton, macrophytes and macrobenthos, and the state of the coarse particulate organic matter. This, normally called CPOM, is considered to be the energy input contributing to the trophic web of the ecosystem (Vannotte *et al*., 1980). The fact that there only three questions reserved for biotic aspects should not be taken as an underestimate of its importance, but rather as the balancing of the information contributing towards the assessment of the quality of the whole aquatic ecosystem and its surroundings.

F.F.I. FORM

Basin……Stream name……..……..

Location……

Stretch (metres)…….. high flow river width (metres)…… altitude…….

date ……record no…… photo no…… code……..

side	Left		Right
1) Land use pattern of the surrounding area			
Undisturbed forests, woods and/or natural wetlands	**25**		**25**
Meadows, pasture, woods, a few areas of arable and uncultivated land	**20**		**20**
Mainly seasonal cultivation and/or mixed arable and/or permanent cultivation	**5**		**5**
Urbanised area	**1**		**1**
2) Vegetation of primary perifluvial zone (fluvial zone around watercourse)			
Arboreal riparian formations	**30**		**30**
Shrub riparian formations (shrubby willow thicket) and/or reeds	**25**		**25**
Non-riparian arboreal formations	**10**		**10**
Non-riparian bushes or grass or no vegetation	**1**		**1**
2b) Vegetation of secondary perifluvial zone			
Arboreal riparian formations	**20**		**20**
Shrub riparian formations (shrubby willow thicket) and/or reeds	**15**		**15**
Non-riparian arboreal formations	**5**		**5**
Non-riparian bushes or grass or no vegetation	**1**		**1**
3) Extention of the perifluvial vegetation zone			
Perifluvial vegetation zone >30 m	**20**		**20**
Perifluvial vegetation zone 5-30 m	**15**		**15**
Perifluvial vegetation zone1-5 m	**5**		**5**
Perifluvial vegetation zone absent	**1**		**1**
4) Continuity of the perifluvial vegetation zone			
Perifluvial vegetation zone without interruption into vegetation	**20**		**20**
Perifluvial vegetation zone with interruption in vegetation	**10**		**10**
Frequent interruption or only continuous and consolidated herbaceous growth	**5**		**5**
Soil without or with thin herbaceous vegetation	**1**		**1**
5) Water conditions of the river bed			
Width of the annual peak flow bed less than three of the wet river bed		**20**	
With of the annual peak flow bed more than three times that the wet river bed with discharge fluctuations with seasonal return		**15**	
With of the annual peak flow bed more than three times that of the wet river bed with discharge fluctuations with frequent return		**5**	
Wet river bed non-existent or almost non-existent or presence of impermeabilisation of the river bed		**1**	
6**) Stream bank structure**			
Bank with arboreal vegetation and/or stones	**25**		**25**
Bank with grass and bushes	**15**		**15**
Bank with a fine grass layer	**5**		**5**
Bare banks	**1**		**1**
7) Retention structures of trophic matter			
River bed with large boulders and/or old trunks firmly embanked or presence of reeds or hydrophytes		**25**	
Boulders, cobbles and/or branches present with depositing of sediment or scarce and not extensive reeds or hydrophytes		**15**	
Retention structures free and mobile during flood events or absence of reeds or hydrophytes		**5**	
River bed with sandy sediment without hydrophytes or smooth artificial profile with uniform current		**1**	

Figure 1. The F.F.I form; question from 1 to 7

8).Erosion			
Little evident and not important	**20**		**20**
Only at bends and/or narrow passages	**15**		**15**
Frequent with cutting of the banks and of roots	**5**		**5**
Very evident with undercutting of banks and landslips or presence of artificial intervention	**1**		**1**
9).Cross-section			
Natural		**15**	
Natural with some artificial intervention		**10**	
Artificial with some natural elements		**5**	
Artificial		**1**	
10) River bed structure			
Diversified and stable		**25**	
Movable in stretches		**15**	
Easily moveable		**5**	
Cemented		**1**	
11) Riffles, pools or meanders			
Clearly distinguished and recurrent		**25**	
Present at different distances and at irregular intervals		**20**	
Long pools which separate short riffles or vice versa, few meanders		**5**	
Meanders, riffles and pools absent, straightened path		**1**	
12) Vegetation in the wet river bed			
Periphyton: only noticeable on touching and/or low covering of macrophytes		**15**	
Periphyton: visible and/or limited covering of macrophytes		**10**	
Periphytion: fair, presence of filamentous algae and/ or high coverage of macrophytes		**5**	
Periphyton thick and/or or very high coverage of macrophytes		**1**	
13) Detritus			
Presence of leaves and woods, vegetable fragments recognisable and fibrous		**15**	
Leaves and woods scarce, vegetable fragments fibrous and pulpy		**10**	
Pulpy fragments		**5**	
Anaerobic detritus		**1**	
14) Macrobenthonic community			
Well structured and diversified, appropriate to the fluvial type		**20**	
Sufficiently diversified but with altered structure as compared to what expected		**10**	
Poorly balanced and diversified with a prevalence of taxa tolerant of pollution		**5**	
Absence of a structured community, presence of few taxa, all tolerant of pollution		**1**	
Total Score			
Fluvial Functioning Level			

Figure 2. The F.F.I form; question from 8 to 14

THE CALCULATION OF THE FUNCTIONALITY LEVELS

The sum of the score of the single answers gives the final evaluation of the functionality of the right and left side of the river stretch, as the structure and the riparian formation type may change in the two watercourse banks. This total score represents the FFI value which can vary from 18 (the minimum) to 300 (the maximum value), each represented in map form by a and specific colour. These categories are summarised in the following table (Tab 1):

Table 1. Functionality levels divided in different categories:

FFI Value	Functionality level	Functionality evaluation	Colour
261 – 300	I	High	Blu
251 – 260	I-II	high – good	Blu-green strips
201 – 250	II	Good	Green
181 – 200	II-III	Good – moderate	Green – yellow
121 – 180	III	Moderate	Yellow
101 - 120	III – IV	Moderate – scarce	Yellow – orange
61 – 100	IV	Scarce	Orange
51 – 60	IV – V	Scarce – bad	Orange – red
14 – 50	V	Bad	Red

It must be underlined that these 5 categories are as recommended in the Water Framework Directive 2000/60 CE. The FFI method, proposed by National Environmental Protection Agency of Italy, is indicated as best practice by WFD Common Implementation Strategy- Working Group 2.7. It appears in Annex III (Summary of factsheets on current monitoring) of the final draft of Guidance on Monitoring for the Water Framework Directive (European Commission, 2002).

THE GIS MAPPING

The results of the FFI method can be directly displayed on maps using a GIS software. For each river stretch, two lines are drawn corresponding the left and the right bank and representing the functionality levels according to table 1. In this way the river is mapped completely as shown in Fig. 3. The maps are produced with a scale which is normally either 1:10,000 or 1:25,000 for a detailed perspective, and a 1:100,000 scale for an overall representation.

Of course along with the FFI information, there are other maps that can be shown illustrating other aspects such other monitoring results or major pressures. These are normally in a report which accompanies the maps. The report explains and describes the functionality of the river underlining which are the ecological compounds that should be improved or preserved.

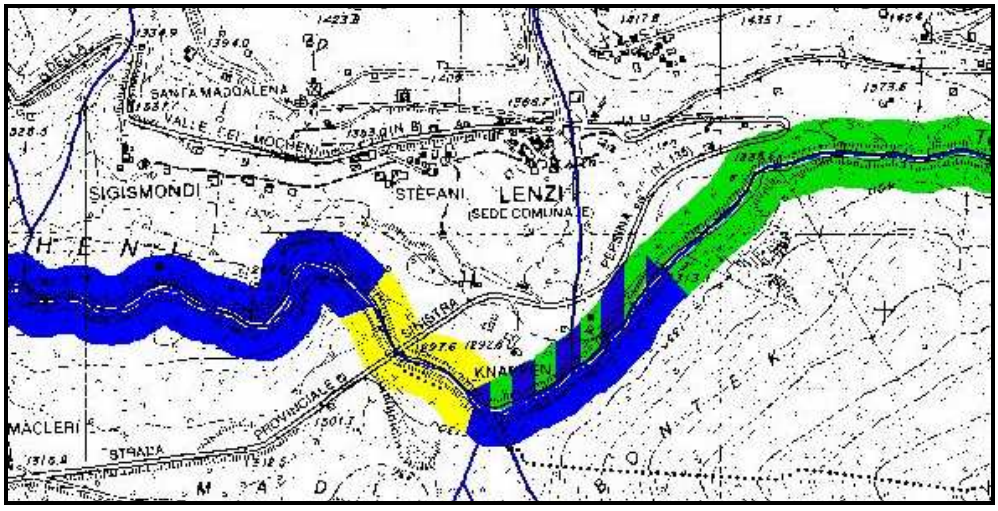

Figure 3. An example of map with the F.F.I functionality level expressed with different coloured stretches

THE USE OF THE FFI FOR IRBM AND LAND PLANNING

There are examples of the use of FFI used as support for river management The Province of Trento set up a working team of the Environment Agency in order to investigate and assess its main rivers.

The gathered information was used and implemented in the new Provincial Plan for Water Resources Utilisation, which is approved in 2004. This plan will effect the water management of the entire province for the next years and will play a the role of a general river basin management plan. This is an example of how the ecological and morphological assessment of a river can support water course and water resources protection planning

Through the FFI different functional zones along the main provincial rivers have been identified. This zoning process was based on field data and led from a simple ecological assessment to integrated water course planning. The result was a final document that includes a map that identifies three different river area types with different restoration potential and management possibilities:

1. “adequate ecological quality”: zones with high ecological and functionality value which don’t need restoration and must be preserved. Any major human intervention are banned.

2. “ecologically altered strips”: 30 meter wide strips along the river with restoration potential. In these areas further new urban and agricultural development schemes will not be allowed. The strips guarantee an adequate space for restoring the river and floodplain. This is also very

important for flood protection in order to maintain an area where rivers can expand freely in high flows.

3. "highly urbanised strips": these are severely compromised and almost impossible to restore. In these strips restoration opportunities are greatly reduced. Normally the only possible intervention to improve the functionality of the river is to increase the diversity of the river bed.

CONCLUSION

Following the experience gained in Italy as well as the participation European research project (Siligardi, 2003) it has been demonstrated that the FFI method can be a useful tool in order to support an appropriate river basin management. As the output of the FFI is a river stretch map indicating the functionality level of the river, this method can be easily implemented into a GIS system. In addition the FFI can:

- indicate the fragility of the river ecosystem and therefore underline which river features (i.e. vegetation, bed, sinuosity…) may cause a decrease of the functionality
- be used to verify which water course areas are most suitable for river restoration schemes (Negri *et al*., 2004)
- foresee the possible effects of river works, i.e. new flood protection or river diversion aiding environmental impact assessment.

The FFI has also the advantage of being a rapid and low cost method. The estimated cost for 1 km of FFI is about 250 euros. At the moment the complete manual of the method is downloadable in Italian for free at: http://www.provincia.tn.it/appa/Pubblica/FrPubbl.htm but an English version will be published during 2005.

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