FLUVIAL FUNCTIONING INDEX (FFI): A CASE STUDY IN SURFACE WATER BODIES OF THE SAGARMATHA NATIONAL PARK AND BUFFER ZONE, EASTERN NEPAL

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***Abstract*— The aim of this research was to analysis status of high altitude surface water bodies (lakes, springs as well as rivers) of the Sagarmatha National Park, Khumbu region from different sampling points ranging from 1900m to 5300m altitude. To understand the entire riverine environment, it is one of the uniqe tools which do not replace the existing river quality evaluation methods. This tool helps to approach to present and future management of rivers. It is an integrated strategy for river protection, management and restoration. From the GIS software, directly displayed on the map to understand the functionality level. Many sapling sites like Likewise Gokyo spring between Gokyo 2nd lake and 1st lake, Tamang spring categorized to Fair to poor in condition. Namche spring categorized to poor to very poor condition, which indicated the very poor condition due to no vegetation in primary as well as secondary perifluzial zone, which indicated that proper attention, should be given for further degradation as well as sustainable development of water ecosystem.**

1. Introduction : Fluvial Functioning Index(IFF) especially for river, was published by the Provincial Agency for Environmental Protection of Italy [1] underlying principle of the EC water framework Directive[2] was used. In fact, It is a tool approach to present and future management of rivers. FFI method can be a useful tool to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics and biological features.It is also useful in order to support an appropriate river basin management. The output of the FFI is a river stretch map indicating the functionality level of the river because this method can be easily implemented into GIS system. For FFI, water bodies were classified into different types on the basis of their threats and disturbances.

2. MATERIALS AND METHODS

2.1 STUDY AREA

2.1.1 Topography: The Sagarmatha National Park (SNP) located in the southern slope of Sagarmatha (Mt. Everest), lies in the Solukhumbu district of the north eastern region of Nepal and covers 1148 sq km area. The buffer zone area declared around the Sagarmatha National Park covers 287.04 sq km (Fig. 1). This park lies about 140 km east of Kathmandu .It ranges between $27^0$06'45" and $27^0$30'19" N latitude to $86^0$30'53" to $86^0$99'08" E longitude. The park is characterized by rugged topography and altitude of park ranges from 2845 m at Jorsella to 8848 m at the top of the Mt. Everest (the world's highest mountain peak). It comprises three Villages Development Committees (VDCs) namely Namche, Khumjung and Chaurikharka. The mountains in Sagarmatha National Park are geologically young and broken up by deep gorges and glacial valleys.

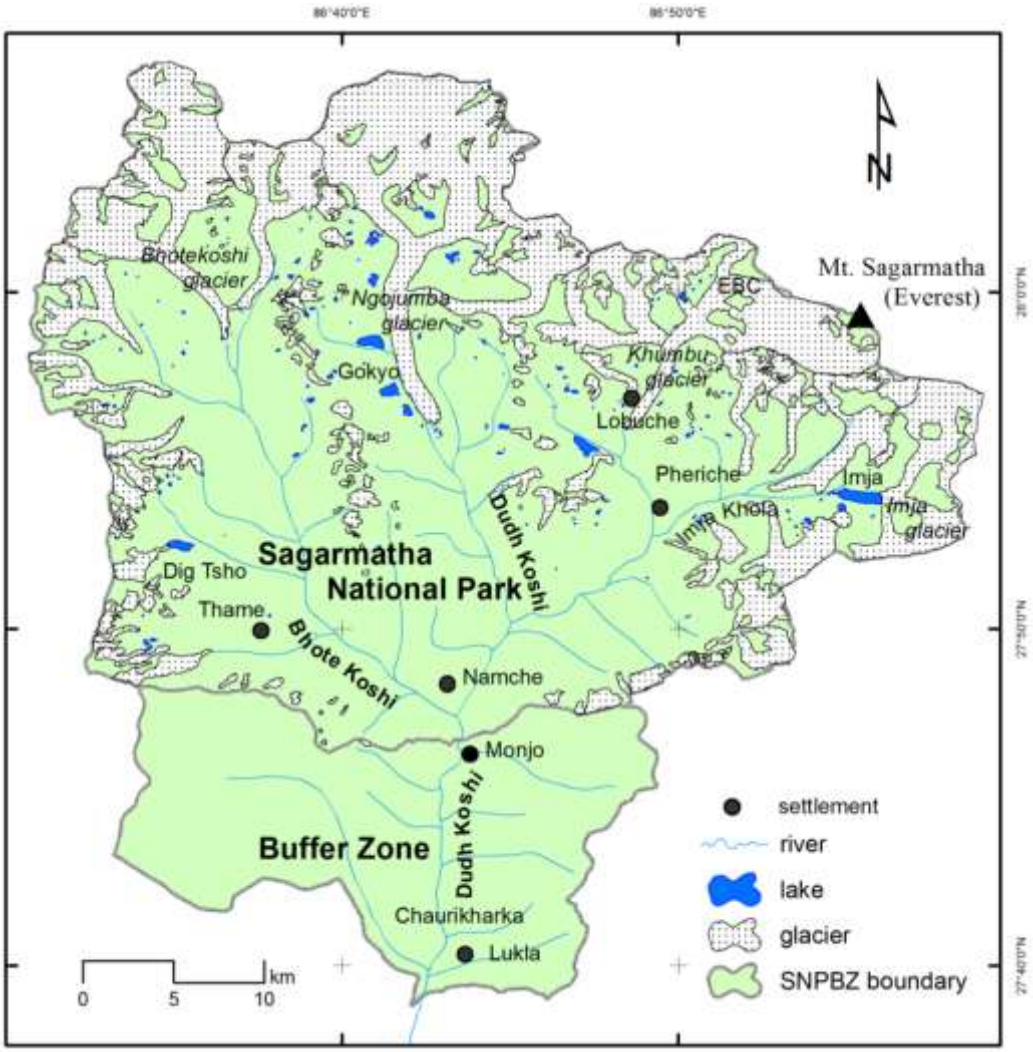

Figure. 1 Major sites of water bodies in Sagarmatha National Park and Buffer Zone.

2.1.2 Land use

Most of the park (65.6%) comprises barren land above 5,000 m, glacier (16.24%), grassland (6.88%), shrubs or bush (5.9%), Ponds (0.59%), settlement and agriculture (0.79 %) , nearly 3.31% is forested and water bodies (rivers) 0.01% [3] .

2.1.2 Population

Total population of Solukhumbu district is 105886 (51200 male and 54686 female) with total household 23785. A total of 1999 household with 7161 people live in three VDCs *viz.* Chaurikharka, Namche and Khumjung where SNP and BZ lie. Main religions in this area followed are: Hindu, Buddism, Islam, Kirat, Khristian, Prakriti etc [4] . Among the total household (23758) in Solukhumbu, 5842 household doesn't have toilets and 12 564 households have ordinary toilet (simple pit). Similarly, using the source of drinking water is river by 415 household s, uncovered Kuwa (well) by 682 households[4] .

2.1.3 Weather

About 80% of the precipitation falls in the monsoon season from June to September. Lukla and Namche Bazaar receive 950mm and 860mm precipitation per year and decrease with elevation. An average minimum temperature is in January whereas maximum during August (-7.7 to 16.2^0c). Tourism is major source of economy of Khumbu region and many local residents still depend upon agro-pastoral activities. The area is inhabited mainly by Sherpa, followed by Tamang, Rai ethnic groups.

2.1.4 Hydrology:

The sagarmatha region is drained north to south by three major rivers namely DudhKosi, the BhoteKosi and ImjaKhola. Imja khola originates in Khumbu glacier and Dudhkosi in Ngozumpa glacier. Bhotekosi originates in Tibet and it meets Dudhkosi at Larchadobhan below the Namche Bazar. Several tributaries feed these major river systems. The major lakes in the SNP are Imja and Gokyo.

2.1.5 Tourism

Tourism in Nepal has been a great source of foreign exchange. Sagarmatha National Park attracts a large number of international tourists due to panoramic view of snow cap, clean environment, live glacier, glacier lakes, unique flora and fauna, scenic beauty of Himalayan peak, wonderful Sherpa culture, festivals , religion, etc. There are two major seasons of tourist inflow in the park : spring and autumn seasons, as a result the park is overcrowded during these seasons and creating a pressure on resource as resources.

Since the opening of Khumbu region to tourists and the first ascent of Everest in 1953, around half a million tourists (national and international) visited the SNP. In 1964, the number of tourists visited the Khumbu was 20 which rose to peak number 26788 in 1999 (Fig.2). Number of tourists in the Khumbu region slided down after 1999 because of insurgency in Nepal, however an accelerated trend was seen from 2007 (as a result of peace in the country) and reached to 25,818 in 2007, 30599 in 2008 and 32123 in 2009. In addition to the international tourists, a large number of people as porter and guide accompany tourists and national researchers.

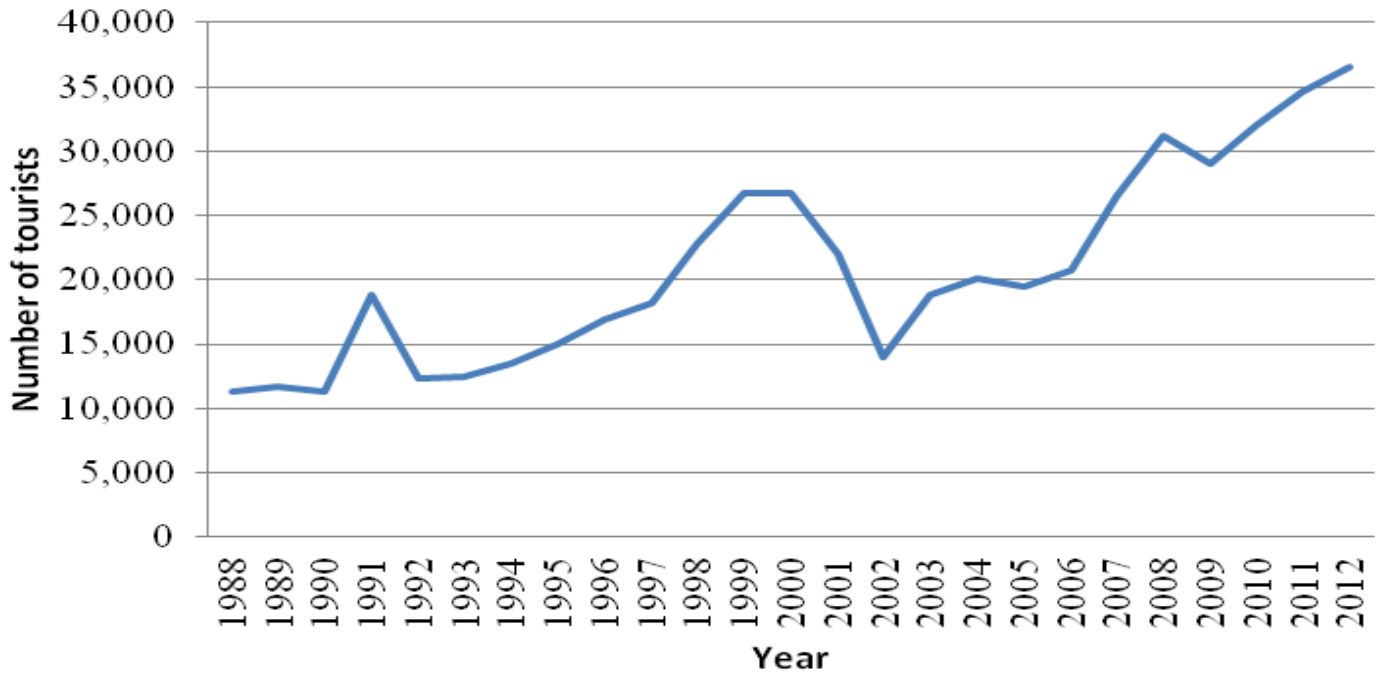

Fig. 2: Number of tourists visited in Sagarmatha National Park in 1988 to 2012.

2.2 SAMPLE SITE SELECTION: The sampled water body sites were mostly selected along the trekking routes from Lukla to Everest base camp, Gokyo, Imja Lake and Thame. Water bodies (river and spring as well as out and inlet of lake) were classified into different types under the basis of their threats and disturbance. From the conversion table from the FFI ,excellent, good, poor and very poor status of the water bodies of different sampling points were calculated ,which useful tool to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics and biological features.

2.3 FIELD ACTIVITIES: For the field, a format was having 14 parameters or questions or indicators. But before going to field it was important to gather information regarding the major pressure in the catchment, data about the hydrological regime, aerial picture and maps for threats of the area. Questions 1-4 were related to: Bank vegetation, land uses pressure, extent of riperian area, 5-6: physical and morphological structure of bank, 7-11: about the structure of river bed (especially for capacity of the river for self purification), and 12-14: key biological characters like periphyton, macrophytes, macro benthos, etc. The samples form of FFI is given here. For analysis, from the conversion table from the FFI form, excellent, good, poor and very poor status of the water bodies of different sampling points were calculated (Table 1). The output of the FFI is a river stretch map indicating the functionality level of the river because this method can be easily implemented into GIS system.

Table 1: Conversion table from FFI value

S.N	*LEVEL*	*SCORE*	*JUDGEMENT*
1	1	261-300	Excellent
2	1-2	251-260	Excellent-Good
3	2	201-250	Good
4	2-3	181-200	Good –Fair
5	3	121-182	Fair
6	3-4	101-120	Fair-Poor
7	4	61-100	Poor
8	4-5	51-60	Poor-very Poor
9	5	14-50	Very Poor

3. RESULT AND DISCUSSION

Fluvial Function Level of water bodies was recorded and water bodies were categorized as excellent, good, poor and very poor. Water bodies (rivers and springs as well as out and inlet of lakes) were classified into different types on the basis of their threats

and disturbance. From the conversion table from the FFI ,excellent, good, poor and very poor status of the water bodies of different sampling points were calculated ,which useful tool to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics and biological features.

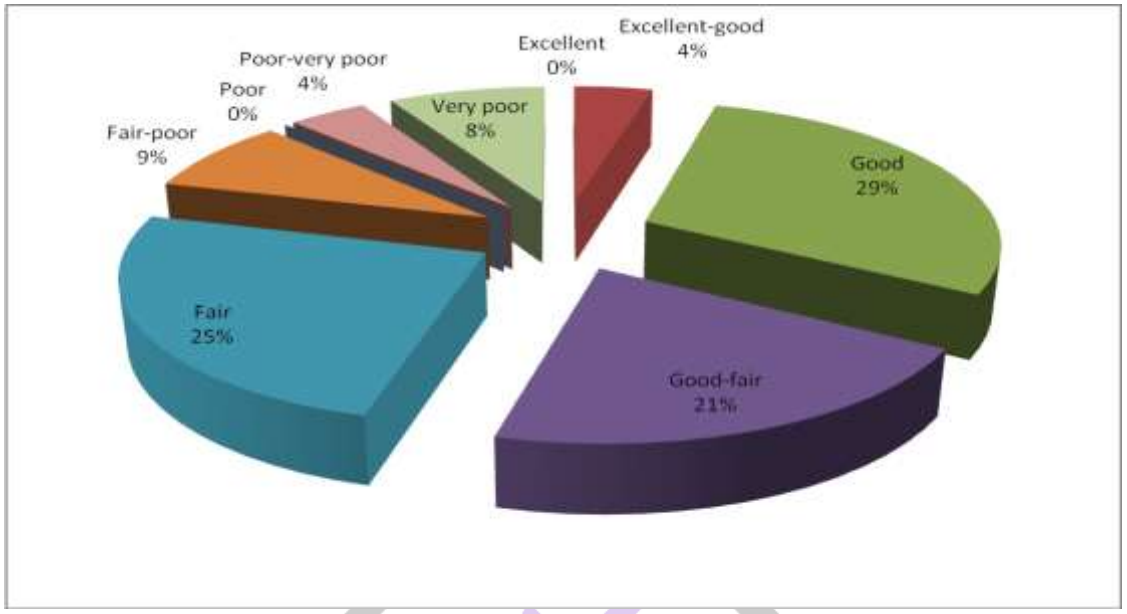

Figure 3 : FFI Index category in percentage

More sites of springs and rivers showed good flavial fuctional level (29%). Which is followed by fair (25 %) and Good- fair (21%), very poor (8%), poor to very poor (4%) (Fig. 3). Muse khola was categorized into good to excellent in condition (Fig. 4). Very dense vegetation in left and right of the river, good extension of primary as well as secondary perifluval zone, well developed riperian vegetation which all combined factors affect for the good hydrological ecosystem as well as sustainable developed model ecosystem than the other streams system.

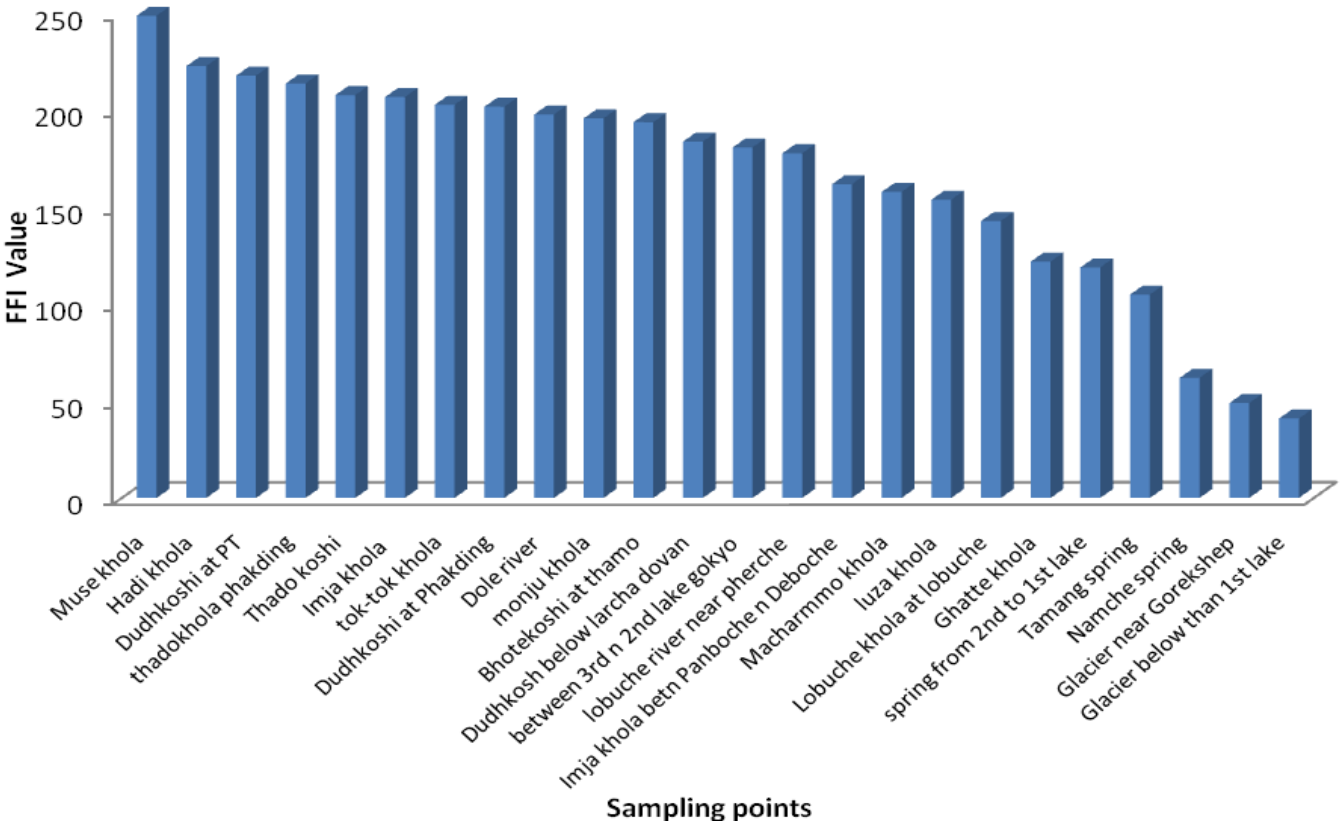

Figure 4 : FFI value of different sampling stations of water bodies in SNPBZ**.**

FFI method can be a useful tool to assess the most important ecological aspects of the whole course of a river such as riparian areas, morphological characteristics and biological features.It is also useful in order to support an appropriate river basin management. The out put of the FFI is a river stretch map indicating the functionality level of the river because this method can be easily implemented into GIS system.

Many points like Thadokoshi phakding, Dudhkoshi at phakding, Dudhkoshi at phunki tenga, Imja khola have the good flavial function level due to good perifluzion vegetation as well as large stable boulders at the river bottom. Similarly Dudhkoshi below Larcha dovan, Monju khola, Dole khola, Bhotekoshi below Thamo showed fair to poor FFI condition.

Lobuche spring at lobuche settlement, Ghatte khola, Macharmmo khola, spring between 2nd and 3 rd lake, Luza khola, Lobuche spring near pheriche , these all sites showed between ranged 121-182 which indicated fair in condition and need to conserve the aquatic ecosystem (Table 1).

Likewise Gokyo spring between Gokyo 2nd lake and 1st lake, Tamang spring categorized to Fair to poor in condition. Namche spring categorized to poor to very poor condition. Glacier below 1st lake and Glacier near Gorekshep recorded the very least FFI value which indicated the very poor condition due to no vegetation in primary as well as secondary perifluzial zone, which indicated that proper attention should be given for further degradation as well as sustainable development of water ecosystem.

4. Acknowledgement

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[3] WWF. 2003. *Sagarmatha Community Agroforestry Project. A Retrospectrive (1996-2002)*. World Wide Fund/ Nepal, Kathmandu.

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APPENDIX.I Format of FFI

FFI FORM

Basin……Stream name……..

Location……

Stretch (metres)…….. width (metres)…… altitude……

date ……..record no…… photo no……

code……..

Tab 1a: The FFI form, question 1 to 6

Bank	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
Made up of non-riparian or herbaceous or absent shrub species	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
Made up of non-riparian or herbaceous or absent shrub species	1		1
3) .Extention of the perifluvial vegetation zone			
Perifluvial vegetation zone >30 m	20		20
Perifluvial vegetation zone 5-30 m	10		10
Perifluvial vegetation zone1-5 m	5		5
Perifluvial vegetation zone absent	1		1
4) Continuity of the perifluvial vegetation zone			
Continuous perifluvial vegetation without gap	20		20
Perifluvial vegetation zone with gap in vegetation	10		10
Frequent gaps or only continuous and consolidated herbaceous vegetation	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 times than the wet river bed		20	
Annual peak flow bed more than three times than the wet river bed with discharge fluctuations with seasonal variation		15	
Annual peak flow bed more than three times that of the wet river bed with discharge fluctuations with frequent variation		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 shrubs	15		15
Bank with a fine grassy layer	5		5
Bare banks	1		1

Tab 1b: The FFI form, question 7 to 14

7) Retention structures of trophic matter			
River bed with large boulders and/or old trunks firmly embanked or presence of reeds or hydrophyte strips	25		25
Boulders, cobbles and/or branches present with depositing of sediment or scarce and not extensive reeds or hydrophyte	15		15
Retention structures free and mobile during flooding or absence of reeds	5		5
River bed with sandy sediment without algae or smooth artificial profile with uniform current	1		1
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) Stream bottom			
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 small covering of macrophytes		10	
Periphytion fair, presence of filamentous algae and/or monotonous macrophytes		5	
Periphyton thick and/or macrophytes relatively unvaried		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 that expected		10	
Poorly balance and diversified with a prevalence of taxa tolerant of pollution		5	
Absence of a structured community, presence of a few taxa all relatively tolerant of pollution		1	
Total Score			
Fluvial Functioning Level			