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Influence of Land-use Changes in River Basins on Diversity and Distribution of Amphibians

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INTRODUCTION

Land-use changes as an aftermath of ad-hoc decisions aimed at meeting the needs of human population is considered to be a paramount factor in the decline of biodiversity all over the world. They not only reduce biodiversity of a region, but over time and space, influence on natural resources, hydrology, nutrition cycle, natural habitat, etc. In an area of rapid land-use changes and in an era of mass extinctions, conservation and management of biodiversity is a Herculean task, especially in the species-rich tropical region, where the human dependencies on the natural resources are also more.

Similar situation prevails in the Western Ghats of India, one of the tropical biodiversity hotspots rich with fauna and flora. It forms about 6% of India's landmass, but harbours more than 30% of all vertebrate and plant species of India. It is a mountain belt having a spread of about 1600 km in length, 100 km in width and with altitudes ranging from 300 to 2700 m above msl along the west coast of India (8°N-21°N). The region has varied forest types from tropical evergreen to deciduous to high altitude *sholas*. It is also an important watershed for peninsular India with as many as 37 west flowing rivers, three major east flowing rivers and innumerable tributaries. The richness and endemism in flora and fauna of this region is well established with over 4000 species of flowering plants (38% endemics), 330 butterflies (11% endemics), 289 fishes (41% endemics), 135 amphibians (78% endemics), 157 reptiles (62% endemics), 508 birds (4% endemics) and 137 mammals (12% endemics). This mountain stretch has influenced regional tropical climate, hydrology and vegetation and endemic plant species.

To a certain extent bringing in biodiversity rich regions under the protected area network viz., national parks and sanctuaries have helped in conservation, but most often they are ad-hoc decisions and not based on systematic studies. In such situations, it becomes imperative that one needs to look for biological indicator species that surrogate for other species and habitat of the region, which ultimately helps in prioritising the conservation areas of a region. Amphibians, the vertebrates with dual life stages are regarded as one of the best biological indicators due to their sensitivity to slightest changes in the environment and they are used as surrogates in conservation and management practices. The objectives of this paper are to:

1. map the diversity and distribution of amphibian species of the region,
2. understand the relationship of amphibian diversity with landscape variables,
3. prioritise areas of conservation using this relationship.

MATERIALS AND METHODS

Study Area

Three river basins, namely Bedthi, Aghanashini and Sharavathi in the Central Western Ghats (between 12°-16°N) were considered for this study as depicted in Fig. 1. These rivers are west flowing rivers and form a part of Uttara Kannada, the district with highest forest cover (78%) in Karnataka.

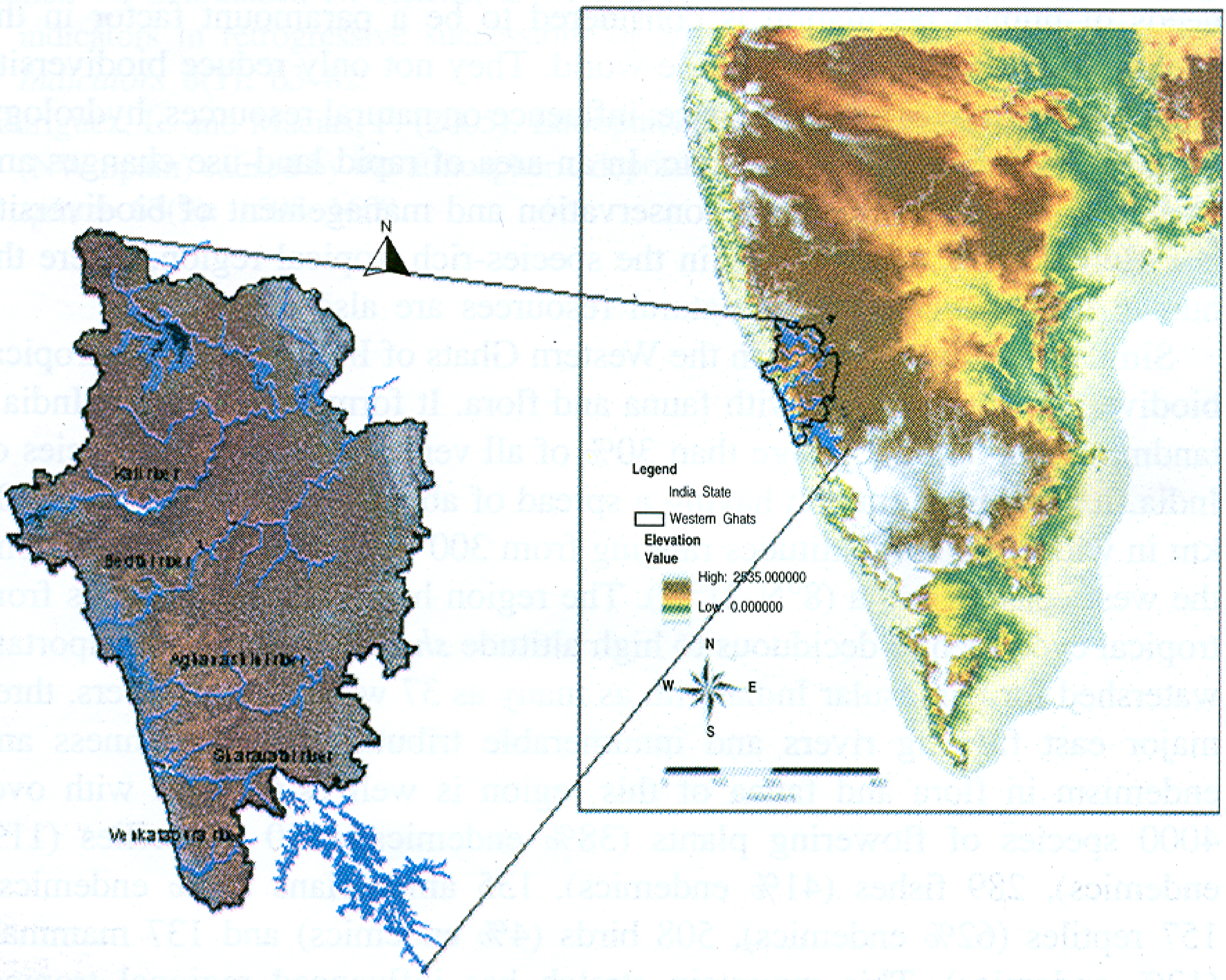

Fig. 1 False colour composite image of Uttara Kannada district - study area in the Western Ghats.

River Bedthi originates at Dharwad District as Shalmala and confluences at Kalghatgi with another stream from Hubli flowing westward for about 161 km to merge with Arabian Sea. It has a catchment of about 3878 sq. km. Similarly, river Sharavathi originates near Ambuthirtha of Shimoga district, traverses for about 132 km and confluences at Honnavar to the Arabian Sea. The magnificent waterfall, Jog, is situated in the course of this river. The catchment area of this river is about 3005 sq.km. These two rivers originate in neighbouring districts, but more than 60% of their drainage networks are within Uttara Kannada district. River Aghanashini having a catchment of about 1390.52 sq.km traverses westward for about 121 km from the origin at Manjguni of Uttara Kannada itself and confluences with Arabian Sea at Tadri. Though the catchment of all these river basins have the influence of land-use change, it is more evident in the catchments of River Sharavathi, where four hydel projects have come up since 1930s. Similar situations are expected in Aghanashini as a thermal power plant is expected at Tadri and in Bedthi, with numerous expansions of road networks, transmission lines, etc. To study the influence of land-use changes, upper catchment area of 1991.43 sq.km of Sharavathi River basin is considered (Fig. 2).

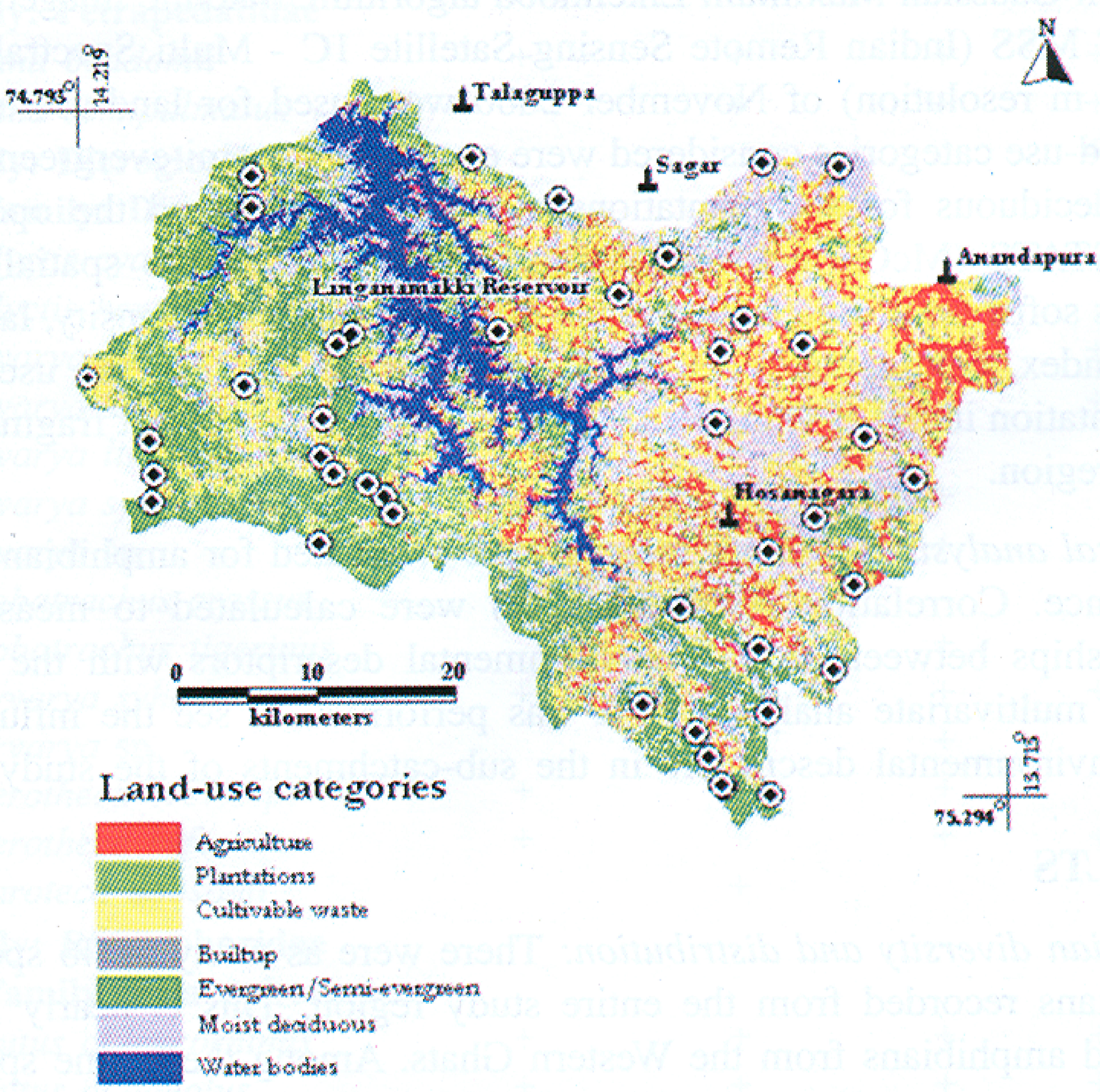

Fig. 2 Classified image of Sharavathi upper catchment. Dark circles indicate sampling localities.

Sampling Methods

Amphibian diversity and distribution: Systematic surveys of amphibians are being carried out in the entire district in all seasons, since 2003. Visual encounters, calls, tadpoles, foam nests and spawn are used to record the amphibians in the field. Two man-hours of searching is made using torch lights between 19:00-20:00 hr, by walking across the streams, forest floors, gleaning leaf litters, prodding bushes, wood logs, rock crevices, etc. All the species encountered are identified up to species level (if not up to genus level) using the keys of Bossuyt and Dubois (2001) and Daniels (2005). Opportunistic encounters are also recorded to enlist the species of the region.

Environmental descriptors: Rainfall data are collected from the nearest rain gauge station for the past twenty years. Mean annual rainfall for this period is considered for the analysis. For canopy coverage, densio-meters are used. Stream flow is graded on the basis of water persistence in the entire year. Vegetation sampling were carried out to calculate percentage tree endemics and evergreenness of the sub-catchments.

Land-use and fragmentation metrics: Land-use classification was carried out using remote sensing data through supervised classification technique based on Gaussian Maximum Likelihood algorithm. Satellite imageries from IRS 1C MSS (Indian Remote Sensing Satellite 1C - Multi Spectral Sensor of 23.5 m resolution) of November 2000 were used for land-use analyses. The land-use categories considered were evergreen to semi-evergreen forests, moist deciduous forests, plantations, agricultural land and the open land. FRAGSTATS (McGarigal and Marks, 1995), a landscape spatial pattern analysis software is used to determine the total edge, edge density, landscape shape index, contiguous forest patch and Shannon's index. We used forest fragmentation index of Hurd et al. (2002) to measure the forest fragmentation in the region.

Statistical analysis: Diversity indices were calculated for amphibian species abundance. Correlation coefficients (r) were calculated to measure the relationships between various environmental descriptors with the species data. A multivariate analysis, PCA was performed to see the influence of these environmental descriptors in the sub-catchments of the study area.

RESULTS

Amphibian diversity and distribution: There were as many as 46 species of amphibians recorded from the entire study region. This is nearly 34% of observed amphibians from the Western Ghats. Among these, one species is new to science and 59% are endemic to the Western Ghats. Table 1 lists species belonging to nine families that were recorded from the study area. Family Dicroglossidae and Rhacophoridae were represented by 14 and nine respectively, followed by Ranidae (five species). Species richness is high in

Sharavathi river basin, with 36 species, followed by Bedthi 33 and Aghanashini 27.

Table 1 Species diversity in the three river basins of Uttara Kannada district

	Aghanashini	*Sharavathi*	*Bedthi*	*Endemic*	*GAA*
Family: Bufonidae					
Bufo melanostictus	+	+	+		LC
Bufo scaber	+	+	+		LC
Bufo sp.	+				
Pedostibes tuberculosus	+	+	+	+	EN
Family: Microhylidae					
Ramanella montana		+		+	NT
Sub-family: Microhylinae					
Kaloula pulchra		+			LC
Microhyla ornata	+		+		LC
Microhyla rubra	+		+		LC
Family: Micrixalidae					
Micrixalus fuscus		+		+	NT
Micrixalus gadgili		+		+	EN
Micrixalus saxicola		+	+	+	VU
Family: Petrapedatidae					
Indirana beddomii	+	+	+	+	LC
Indirana semipalmatus	+	+	+	+	LC
Family: Dicroglossidae					
Sub-family: Dicroglossinae					
Euphlyctis cyanophlyctis	+	+	+		LC
Euphlyctis hexadactylus		+			LC
Fejervarya brevipalmatus	+		+	+	DD
Fejervarya keralensis	+	+	+	+	LC
Fejervarya limnocharis	+	+	+		LC
Fejervarya syhadrensis	+	+	+		LC
Fejervarya sp.			+		
Hoplobatrachus crassus	+				LC
Hoplobatrachus tigerinus		+	+		LC
Minervarya syhadris	+		+	+	EN
Minervarya sp.			+		
Sphaerotheca breviceps	+	+	+		LC
Sphaerotheca rufescens	+	+	+	+	LC
Sphearoteca dobsonii		+			LC
Family: Rhacophoridae					
Sub-family: Rhacophorinae					
Philautus cf.leucorhinus	+	+	+	+	EX
Philautus cf.luteolus	+	+	+	+	VU
Philautus cf.nasutus	+	+	.	+	EX
Philautus cf.ponmudi	+	+		+	VU
Philautus tuberohumerus	+	+	+	+	VU
Polypedates leucomystax		+			LC

(*contd.*)

(**Table 1** *Contd.*)

	Aghanashini	*Sharavathi*	*Bedthi*	*Endemic*	*GAA*
Polypedates maculatus		+	+		LC
Polypedates pseudocruciger		+	+	+	LC
Rhacophorus malabaricus		+	+	+	LC
Family: Nyctibatrachidae					
Nyctibatrachus cf. aliciae	+	+	+	+	EN
Nyctibatrachus major	+	+	+	+	VU
Nyctibatrachus cf. petraeus		+	+	+	EN
Family: Ranidae					
Clinotarsus curtipes	+	+	+		NT
Hydrophylax malabaricus		+	+		LC
Sylvirana aurantiaca		+	+	+	VU
Sylvirana sp.	+				
Slyvirana temporalis	+	+	+		NT
Family: Ichthyophiidae					
Ichthyophis beddomi		+		+	LC
Ichthyophis malabaricus			+	+	LC
Species richness	**27**	**36**	**33**	**24**	

Note: E—Endemic; NE—Non-endemic; GAA—Global Amphibian Assessment; EX—Extinct from type locality; EN—Endangered; Vu—Vulnerable; NT—Near threatened; LC—Least concerned, DD—Data deficient

Number of endemic species varied among the river basins, highest being in Sharavathi with 21 species, followed by Bedthi with 24 and Aghanashini with 14 species. Overall two species are extinct from the type locality, five species are endangered and six are vulnerable. Sharavathi and Aghanashini harbour both extinct species, while Bedthi harbours only one. Four endangered and all six vulnerable species are found in Sharavathi, whereas, in Aghanashini and Bedthi, this amounts to 3, 4 and 4, 5 respectively.

Environmental descriptors and amphibian diversity: Table 2 details the correlation coefficient (*r*) at statistically significant level ($P < 0.05$) for endemic species richness and abundance with environmental descriptors, land-use, fragmentation and landscape metrics. Endemic species richness is positively influenced by tree endemism; tree evergreenness; stream flow; canopy and rainfall. Similar among the land-use categories, evergreen-semi-evergreen has exhibited positive correlation with endemic species richness and abundance. The landscape metrics also have influenced species richness. Among the negatively influencing factors, agriculture, open lands and moist-deciduous categories reduce both endemic richness as well as abundance. Similarly, patch forest negatively influences the richness and abundance.

Table 2 Correlation coefficient (*r*) at significance level ($P<0.05$) between endemic species richness and abundance with environmental descriptors, land-use, fragmentation and landscape metrics

	Endemic species richness	*Endemic abundance*
Environmental descriptors		
Tree endemism (%)	0.513	
Evergreenness (%)	0.544	
Stream flow (%)	0.817	0.607
Canopy (%)	0.643	0.580
Rainfall (mm)	0.892	0.700
Land-use (%)		
Evergreen–semievergreen (%)	0.853	0.617
Moist deciduous (%)	–0.737	–0.735
Agriculture (%)	–0.734	–0.585
Open land (%)	–0.783	–0.659
Forest fragmentation index		
Interior (%)	0.635	
Patch (%)	–0.709	–0.577
Landscape pattern metrics		
Shape index	0.791	
Contiguous patch (m^2)	–0.809	
Shannon's index	0.842	0.618
Total edge (m)	0.832	0.551
Edge density (#/area)	0.715	

RELATIONSHIPS AMONG THE ENVIRONMENTAL DESCRIPTORS

Table 3 details the correlation coefficient at statistically significant level between various environmental descriptors. It is clear from the table that the variables that influence endemic species and abundance also influence each other. In order to project the influence of all these variables in reduced space, Principal Component Analysis, a multivariate analysis is run using MVSP3.2. Figure 3 depicts the plot of Principal Axes 1 and 2, with the variables and sub-catchments. Principal Axis 1 explains for 86.13% of the variability and Axis 2 for 7.59%. Table 4 gives the Principal Component loading on Axes 1 and 2.

Table 3 Correlation coefficient (*r*) at significance level ($P<0.05$) among the environmental descriptors. 1. Tree endemism; 2. Evergreenness; 3. Stream flow; 4. Canopy; 5. Rainfall; 6. Evergreen–semievergreen; 7. Moist deciduous; 8. Agriculture; 9. Open land; 10. Interior; 11. Perforated; 12. Patch; 13. Shape index; 14. Contiguous patch; 15. Shannon's index; 16. Total edge; 17. Edge density

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
2	0.985															
3	0.812	0.855														
4	0.675	0.704	0.628													
5	0.791	0.824	0.973	0.749												
6	0.858	0.878	0.965	0.771	0.992											
7	–0.600	–0.703	–0.800	–0.811	–0.825	–0.797										
8	–0.667	–0.701	–0.920		–0.888	–0.860	0.689									
9	–0.697	–0.726	–0.866	–0.783	–0.931	–0.922	0.755	0.845								
10	0.701	0.695	0.806	0.596	0.841	0.847	–0.543	–0.865	–0.942							
11	0.736	0.706	0.799	0.526	0.828	0.849		–0.800	–0.885	0.962						
12	–0.674	–0.694	–0.862	–0.644	–0.895	–0.884	0.652	0.891	0.976	–0.979	–0.928					
13	0.873	0.900	0.907	0.762	0.925	0.952	–0.757	–0.697	–0.817	0.711	0.765	–0.753				
14	–0.870	–0.894	–0.906	–0.759	–0.918	–0.941	0.782	0.690	0.761	–0.633	–0.682	0.687	–0.978			
15	0.831	0.864	0.923	0.754	0.934	0.944	–0.818	–0.719	–0.773	0.630	0.665	–0.701	0.965	–0.994		
16	0.812	0.858	0.896	0.722	0.907	0.921	–0.802	–0.683	–0.752	0.614	0.661	–0.671	0.977	–0.973	0.969	
17	0.935	0.943	0.906	0.770	0.917	0.956	–0.714	–0.721	–0.837	0.770	0.814	–0.794	0.978	–0.960	0.941	0.921

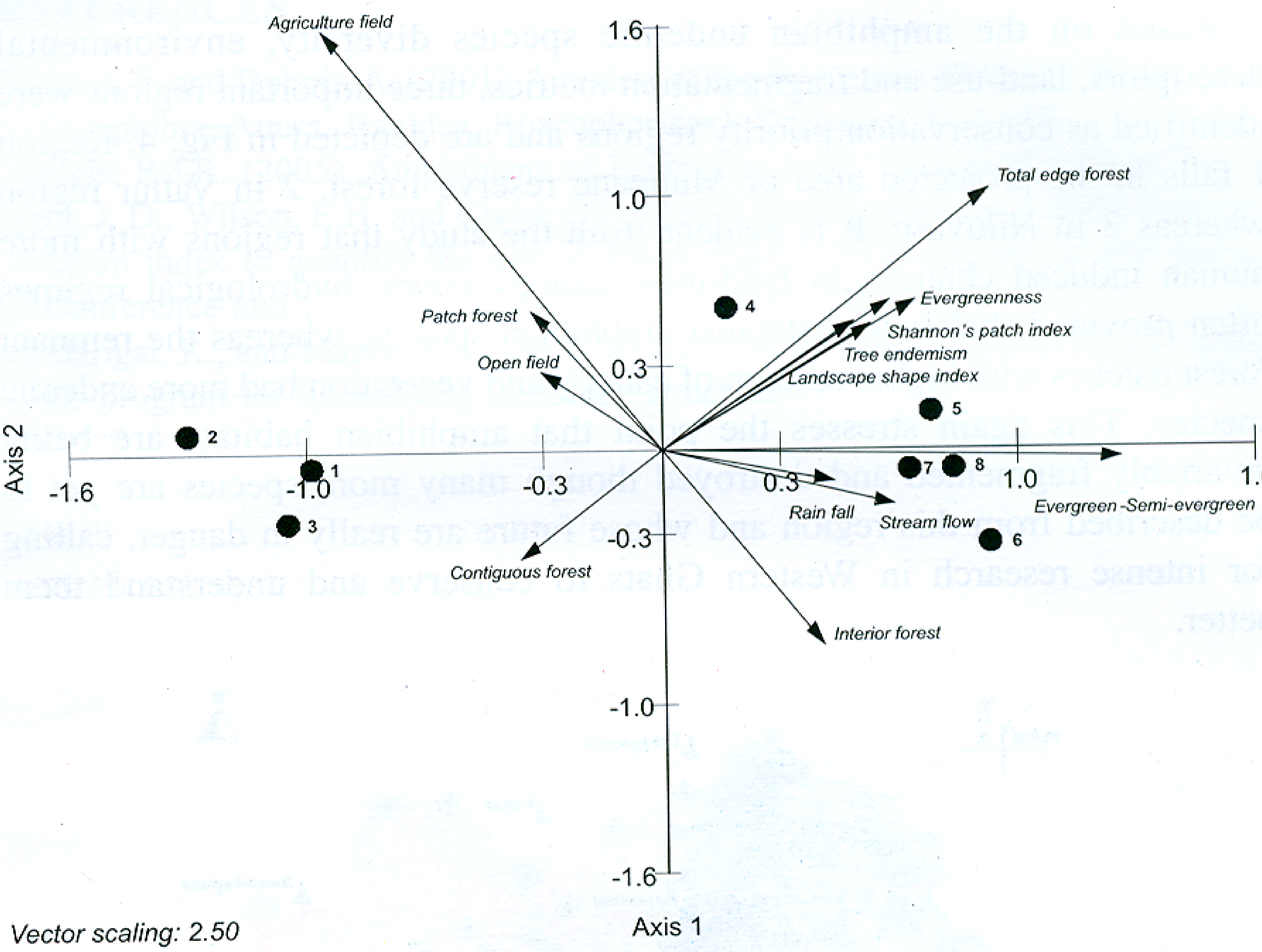

Fig. 3 Biplot of Principal Component Analysis performed for environmental descriptors. 1. Nandiholé, 2. Haridravathi, 3. Mavinholé, 4. Sharavathi, 5. Hilkunji, 6. Hurli, 7. Nagodi and 8. Yenneholé.

Table 4 Variable loadings of Principal Component Analysis performed for environmental descriptors

Variable loadings	*PC1*	*PC2*
Tree endemism (%)	0.233	0.194
Tree evergreenness (%)	0.282	0.231
Stream flow (%)	0.257	–0.087
Canopy (%)	0.086	0.101
Rainfall (mm)	0.191	–0.049
Evergreen-Semi-evergreen (%)	0.509	–0.015
Moist deciduous (%)	–0.101	–0.038
Agriculture (%)	–0.373	0.657
Open land (%)	–0.133	0.124
Interior forest (%)	0.178	–0.304
Perforated forest (%)	0.101	–0.122
Patch forest (%)	–0.143	0.218
Shape index	0.214	0.2
Contiguous forest (m^2)	–0.157	–0.169
Shannon's index	0.254	0.232
Total edge (m)	0.364	0.404

Based on the amphibian endemic species diversity, environmental descriptors, land-use and fragmentation metrics, three important regions were identified as conservation priority regions and are depicted in Fig. 4. Region 1 falls in the protected area of Muppane reserve forest, 2 in Vallur region whereas 3 in Niluvase. It is evident from the study that regions with more human induced changes in land-uses, canopy cover, hydrological regimes often provided shelter to generalist amphibian species, whereas the remnant forest patches with higher amount of canopy and vegetation had more endemic species. This again stresses the point that amphibian habitats are being invariably fragmented and destroyed though many more species are yet to be described from this region and whose future are really in danger, calling for intense research in Western Ghats to conserve and understand them better.

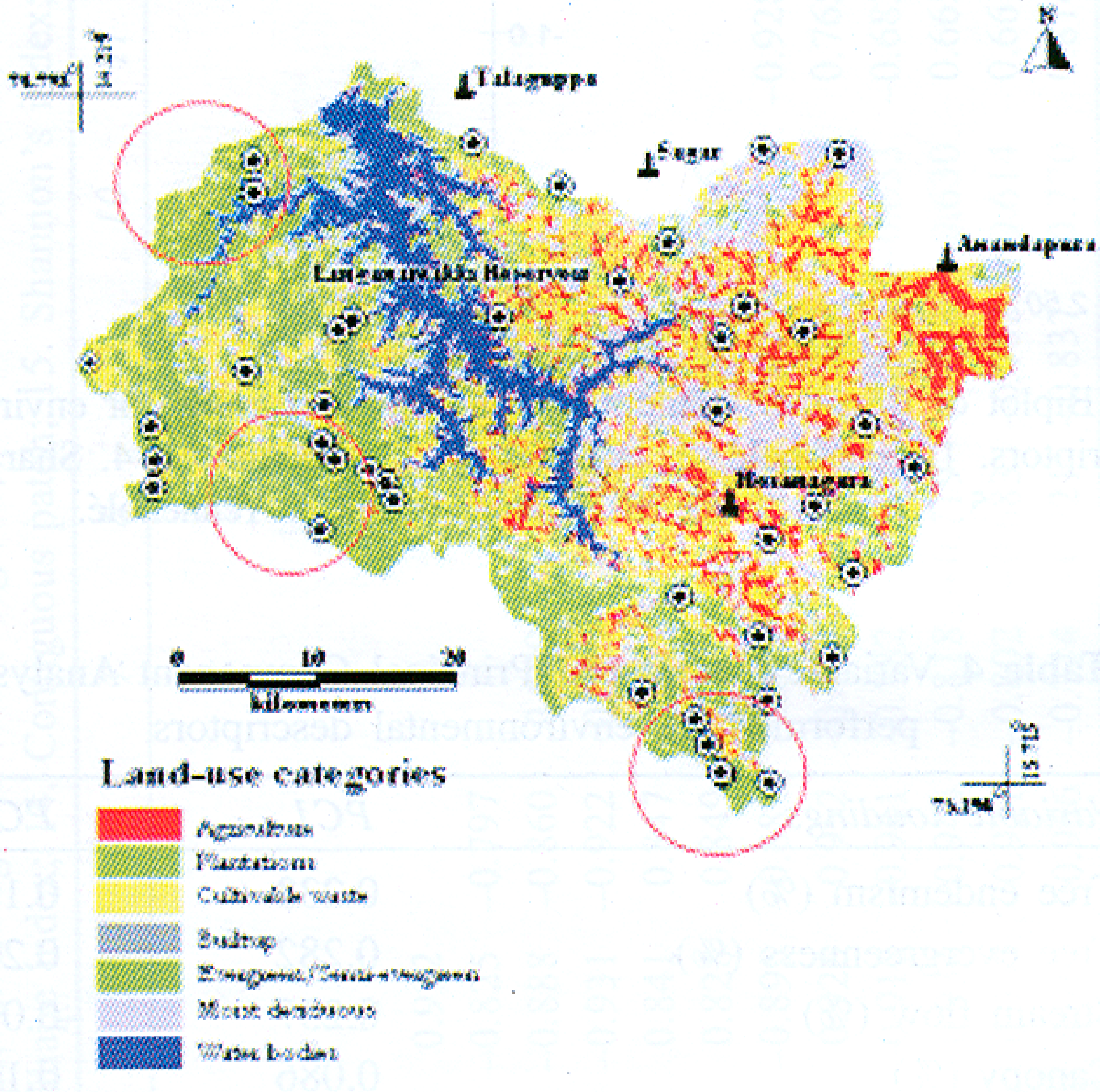

Fig. 4 Conservation priority zones in Sharavathi river basin. 1. Muppane, 2. Vallur and 3. Niluvase.

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