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Spatiotemporal analysis of the effects of forest covers on stream water quality in Western Ghats of peninsular India

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SUMMARY

The hydrological research has largely concentrated on two extremes – undisturbed forest cover versus cleared forest land, whereas most tropical forest areas are now a mix of secondary vegetation, and old forest interspersed with patches cleared for agriculture or other non-forest use (Bruijnzeel, 2004; Giambelluca, 2002). For this reason, research on spatiotemporal variations in the effects of a mix of primary forest, mature secondary forests and disturbed forests on stream water quality was conducted in four watersheds in the Western Ghats of peninsular India. The study indicated that every one percent decrease in the forest cover (all lands with tree cover of canopy density of 10% and above when projected vertically on the horizontal ground with minimum areal extent of one ha) increases turbidity, total suspended solids (TSS) and *Escherichia coli* by 8.41%, 4.17% and 3.91%, respectively as also decreases calcium hardness by 0.49%. However, when the forest cover was segregated into old forests (primary forest, mature secondary forest and undisturbed mature plantations) and, open and disturbed forests the old forests were observed to significantly improve ($p < 0.05$) most water quality parameters. In contrast the open and disturbed forests were observed to deteriorate the observed water quality parameters except for turbidity and TSS. The magnitudes of regression coefficients indicated that the old forests were 2.2 and 2.74 times more effective than the disturbed forests in reducing turbidity and TSS, respectively. Tradeoffs between the provisioning services and water quality improvement services of the forest were apparent.

1. Introduction

It is well accepted that in comparison to watersheds with other land uses, watersheds with natural forests almost always provide higher quality water with less sediment and fewer pollutants (Calder et al., 2004, 2007; Dudley and Stolton, 2003; Welsch, 1991). However, forests today are no longer a undisturbed patch of woodland but a mix of disturbed forests, secondary vegetation and old forest interspersed with patches cleared for agriculture or other non-forest use, particularly in the tropics (Bruijnzeel, 2004; Giambelluca, 2002). But the impact of changes in density and age or other such parameters of the forest cover on the stream water quality has not really been evaluated. Neither do we have studies that quantify the changes in water quality as a result of increase or decrease in the forests (Elias, 2010) making it difficult to incorporate the role of forests in decision making processes like cost-benefit analysis. There is still an ongoing debate regarding whether the land use of the entire catchment or that of the riparian zone is more important in influencing the water quality, all other factors remaining constant (Delong and Brusven, 1991; Johnson et al., 1997; Osborne and Wiley, 1988). Each catchment has a unique combination of characteristics that influence water quality therefore it is difficult to translate such research findings between countries and regions, between different catchment scales, between different forest types and species, and between different forest management regimes (IUFRO, 2007). Therefore the study aimed at finding answers to the questions – what is the influence of deforestation on the stream water quality in the Western Ghats of peninsular India? Is there any variation in the impact of the old and mature forests vis-a-vis the open and disturbed forests on the stream water quality?

The water quality parameters – turbidity, total dissolved solids (TDS), total suspended solids (TSS), pH, total hardness, calcium hardness, total chloride, Ca, Fe and Mg, total coliforms and *Escherichia coli* – were selected for the study. Time series secondary data

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over 13 years (1998–2010) of four watersheds of the Western Ghats, GIS and multivariate analysis tools were used to determine the correlation between water quality and forest cover. The study area is described in Section 2. Section 3 specifies the model, data collection and its processing. Section 4 gives the results followed by discussions and conclusions in Sections 5 and 6, respectively.

2. Description of the study area

This study focused on a cluster of four watersheds of the Western Ghat mountain ranges – Pise, Tansa, Lower Vaitarna and Manda – located between longitudes 73.127°E and 73.65°E and latitude 19.28°N and 19.70°N. Within the Pise watershed water samples were also collected at the sites Bhatsa and Sapgaon thereby adding sub-watersheds Bhatsa and Sapgaon (that are nested within Pise watershed) to the studied watersheds (Fig. 1). The watersheds lie on the Western Ghats mountain range. The main geological formation is the basaltic Deccan trap. This rugged tract is a network of deep cut ravines, numerous cross spurs and isolated hills. Most hills have plateaus with grassy lands and less tree cover as compared to the dense cover on slopes. The salient features of the watersheds are given in Table 1. The distinct seasons in a year are winter (December–February), summer (March–June), southwest monsoon season (June–September), and post-monsoon season (October–November), which is hot. The southwest monsoon season, June to September, provides about 94% of the annual rainfall. July is the wettest month with a rainfall of about 40% of the annual total. The average weighted rainfall is 2635 ± 346 mm per year.

All watersheds were well served with all weather and fair weather roads. They had limited industries or urban settlements. Agriculture was the main economic activity and engaged most of the inhabitants either as cultivators, share croppers or as agricultural labourers. Owing to the inadequate irrigation facilities, most of the crops depend on the monsoon. Paddy (wet rice) was the principal crop while some millets and lentils were also grown in this season. Slash-and-burn agriculture and shifting cultivation was still practiced on a large scale causing rampant fires in the forests and the grasslands during the summer season. Economic compulsions has lead to extensive tracts of steep hill slopes being put under cultivation accelerating soil erosion and deforestation. The time gap for leaving land fallow under shifting cultivation had also reduced considerably (from 10–15 years to 2–3 years). At places plots of shifting cultivation were under permanent cultivation. But because of this practice of burning biomass on agricultural fields there was not much use of fertilizer and pesticides till the last decade (Singh, 2013).

The natural forests in catchments are Southern Tropical Moist Deciduous type (Champion and Seth, 1968). Local people have

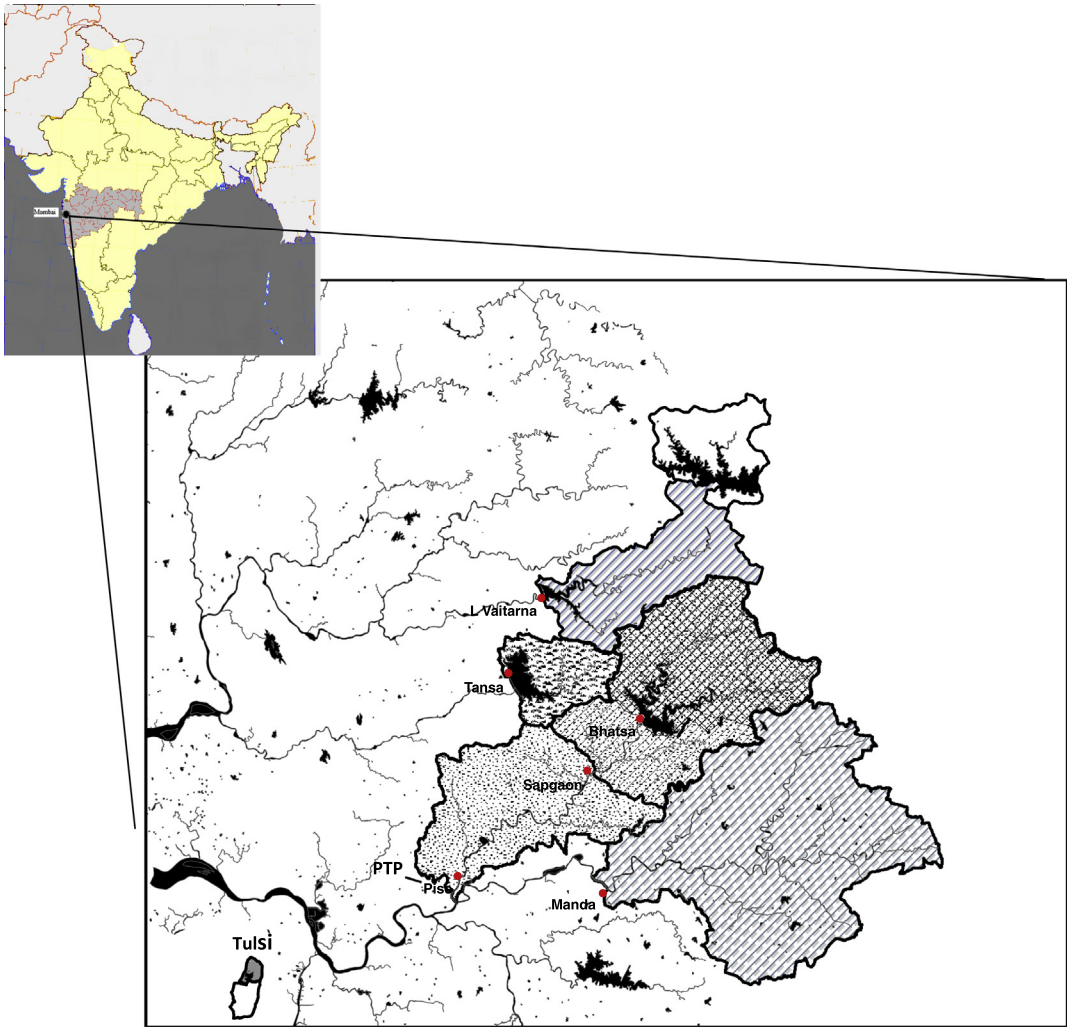

Fig. 1. Location of the study area, selected watersheds and sampling sites for water quality analysis.