ECOLOGICAL AND ANTHROPOGENIC IMPLICATIONS OF TWO DECADES OF LAND COVER CHANGES IN THE UPPER NILGIRIS IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

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Abstract: Large scale changes in land cover can impact a range of ecosystem services, particularly in the context of global climate change induced extreme rain events coupled with longer dry seasons. A recent Landsat image was classified using over 400 ground control points and Maximum Likelihood Classification to obtain a map of the present extent of six classes of land cover. Changes in the area under these classes were then calculated based on a similar map published in 1996. There has been a significant reduction in forest plantations with a smaller reduction in natural forest, natural grassland with shrubs, forest plantation and water bodies. These areas have been replaced by tea plantations and vegetable cultivation. This is likely to increase risks of shallow landslides in this region. Reduced water quality due to increased erosion and transport of agrochemicals downstream coupled with an overall reduction of stream flow in dry season in the headwaters are some of the other likely outcomes of the land cover changes.

Keywords: *climate change, land cover change, remote sensing*

INTRODUCTION

Long term changes in land cover have an impact on a range of ecosystem services. These impacts are often amplified when coupled with global climate change induced phenomenon such as extreme rainfall events and longer dry seasons. The objectives of this study were to determine the extent of land cover changes in the Upper Nilgiris, more specifically the Nilgiri South range forest (NSRF). We discuss the possible impacts of these changes on major ecosystem services, vulnerabilities and biodiversity based on relevant scientific literature and reports from the study area. Changes under six major land cover classes were measured between 1996 and 2015 for the NSRF.

The study area covers 595 km^2 and falls in the Nilgiris district in the Indian state of Tamil Nadu. NSRF forms part of the headwaters of a major river system - the Cauvery. It also falls in the Western Ghats global biodiversity hotspot (Das et al., 2006; Mittermeier et al., 2011) and is part of the Nilgiri Biosphere Reserve. This region is also significant as an important vegetable growing region, tourist destination and for contributing to over 40% of the hydro-power for Tamil Nadu (Sikka et al., 2003). The Nilgiris is ranked amongst the most landslide prone districts in south India with many of the landslides attributed to high rainfall and clearance of forest cover.

We used a maximum-likelihood classification approach on cloud free terrain corrected (L1TC) Landsat8 images acquired in March 2015. Over four hundred ground control points were collected using hand-held GPS units and high resolution GoogleEarth images. The final product had an overall accuracy exceeding 73%.

METHODS

The Geographical Resource Analysis Support System version 7 (GRASS Development Team 2015) and the Quantum GIS package (QGIS Development Team 2015) were used to prepare a land cover map of the region. A maximum likelihood classifier algorithm was used for the classification of a level one terrain corrected (L1TC) Landsat 8 images acquired in March 2015. Six land cover classes were used to simplify and re-classify both the recent and the base map which was published in 1996 (Prabhakar & Pascal, 1996) (Table 1). These classes were: native montane Shola forests and grasslands, water bodies, tea plantations, vegetable gardens and forest plantations of exotic tree species. The latter class comprised largely of exotic trees such as wattle (*Acacia mearnsii*), blue gum (*Eucalyptus globulus*) and pine (*Pinus patula*). A total of 433 ground control points (GCP) were collected using hand-held GPS units and high resolution GoogleEarth imagery. Two thirds of these were used for training the image while a third was used as an input for the accuracy assessment. Finally, differences in areas and percent of changes were calculated between the two periods for each of the land cover classes.

Table 1: Reclassification of land cover map into six classes

New Vegetation Class	Composite classes in base map (1996)	Composite classes in 2015
Natural Forests	Dense evergreen forest, Dense forest Discontinuous thicket to low scattered shrub, Mixed arboriculture, Shola forest, Woodland to savanna – woodland	All forest areas and Shola
Water Bodies	Water bodies	Water bodies
Commercial Plantations	Tea, coffee	Tea, coffee
Agricultural land	Dryland agriculture	Dryland agriculture, harvested land
Grasslands	Clump savanna, grassland, tree to shrub savannah	All types of grassland
Forest plantations	Plantations, scrub woodland, swamp (all swamp were within forest plantations), scrub woodland	Wattle, pine, teak plantations, *Eucalyptus*

RESULTS AND DISCUSSION

We recorded a major decrease in areas under the natural forests and the forest plantations as well as natural grasslands, and to a smaller extent in water bodies. There was a commensurate increase in area under commercial plantations, largely tea and agriculture, largely vegetable gardens (Figure 1, Table 2). These changes have been driven by rapid development of agriculture in the region over the past decades.

Table 2: Change in land cover between 1996 and 2015

Land use class	Area (Sq. km)		Difference	
	1996	2015	%	Sq.km
Natural Forest	153.13	97.43	-36.37	-55.7
Water Bodies	21.31	14.95	-29.85	-6.36
Commercial Plantations	56.84	168.89	197.15	112.05
Agriculture Land	40.92	65.01	58.86	24.08
Natural Grassland with Shrub	122.70	81.21	-33.82	-41.49
Forest Plantations	185.28	152.72	-17.58	-32.56

Results of the accuracy assessment showed in Table 3, Kappa coefficient of 0.66 and overall accuracy of 73.74%. Accuracies of both the grassland and tea plantations were reduced due to spectral mixing. In grasslands, large tracts have been invaded by Scotch broom (*Cytisus scoparius*) and common gorse (*Ulex europaeus*), which are evergreen deep-rooted species. Regeneration in cleared wattle (*Acacia mearnsii*) plantations would also result in poor spectral signatures. Similarly, tea plantations tend to have associated shade trees of silver oak (*Grevillea robusta*) and fringes of forest plantations which adversely affect the spectral signature.

Some of the results, however, are contrary to expected patterns in land use. For example, clear felling of forests in India was banned in 1996 by a Supreme Court order, barring specific areas earmarked by the forest department (Rosencranz and Lélé 2008). While it is possible that the baseline dataset over or under represents area under some of the classes, recent reports of large scale encroachments in the region do support our findings (Palaniappan and Soundariya Preetha, 2015; Ananth, 2015).

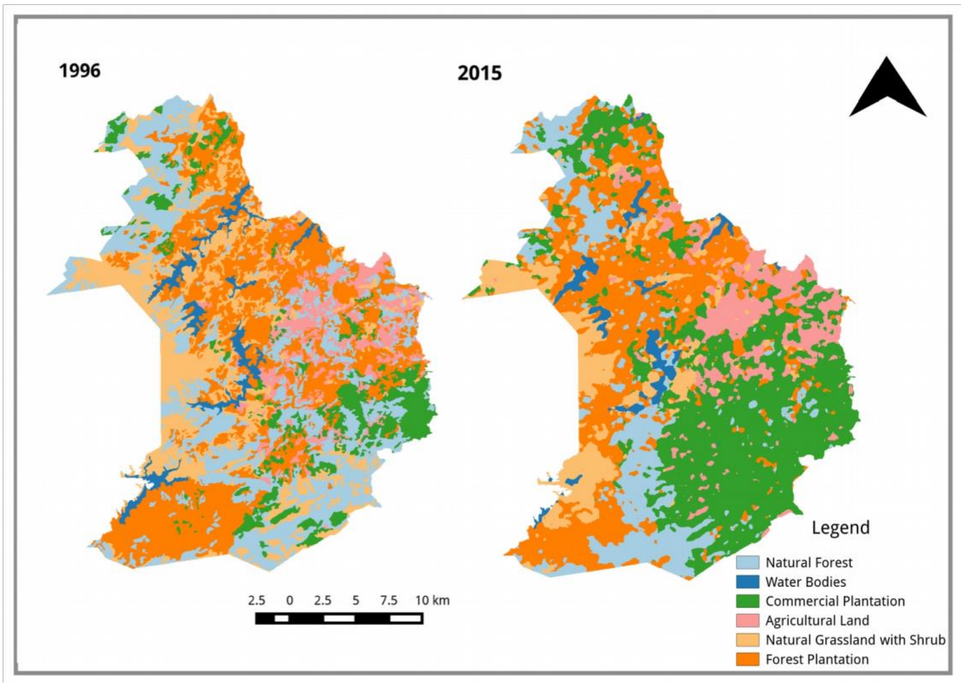

Figure 1: Land cover comparisons between a published datasets of 1996 (Prabhakar & Pascal, 1996) and a recent map based on Landsat8 imagery

Table 3: Accuracy matrix for the classified map. The accuracy values for the grassland class were lowered due to spectral mixing by evergreen exotic shrubs such as Scotch Broom and Gorse. Accuracy values of tea plantations were reduced on account of spectral mixing with forest plantations

Class	% Commission	% Omission	Estimated Kappa
Natural Forest	20.3	14.4	0.70
Water Bodies	0	3.3	1
Commercial Plantations	52.1	39.7	0.39
Agriculture Land	13.6	28.0	0.85
Natural Grassland with Shrub	67.1	41.8	0.31
Forest Plantations	31.8	50.2	0.58

CONCLUSION

Over the past two decades, the area under forest plantations had reduced by 17.58% and that under natural forests and grasslands by 36.37 and 33.82% respectively. Tea plantations and vegetable gardens have taken their place and increased by 197.15% and 58.86% respectively. This constituted a conversion of 136.13 (Sq.km) from tree cover to tea or vegetables. The observed land cover changes reflect ongoing agricultural expansions which are driven by both government initiatives and market driven increases in areas under tea gardens. There has also been a government led clearance of forest plantations to encourage re-establishment of native grassland species. However, this has a number of implications in the context of increased climate change induced extreme rainfall events in this region (Goswami et al., 2006; Goswami and Ramesh 2008). Shallow landslides are a serious hazard in this region and removal of forests from sloping areas can greatly increase the probability of shallow landslides, particularly in the context of extreme rainfall events (Bhagavanulu, 2008; Ganapathy et al., 2010). Old stands of forest plantation species harbour an undergrowth of native Shola forest species, providing a superior habitat to fauna than the tea monoculture or vegetable cultivation which has replaced them. Removal of these stands of forests will result in the obvious loss of this biodiversity (Lockwood, 2015). What is less obvious is the likely increase in evapotranspiration as new growth, across species, has higher evapotranspiration demands than old stands (Dunn & Connor, 1993; Ryan et al., 2000).

Rapidly transpiring species, such as eucalyptus and wattle, can significantly reduce dry season stream-flow, with negative repercussions for both anthropogenic and ecological water requirements (Samra et al., 2001; Dye, 2004). These are magnified in the context of global climate change which predicts longer drier periods and higher temperatures during the dry seasons. The increase in vegetable gardens in the region also has serious environmental implications. There is high use of fertilizers and pesticides in these gardens. Furthermore, many of them are located on steep gradients with little or no terracing. Coupled with extreme rainfall, this leads to high rates of erosion and discharge of pollutants into the streams which are the major source of water supply to settlements downstream. Unfortunately there are no local records of the impact these changes in land cover have had on water quality. The upper Nilgiris form the headwaters of the Cauvery River, among the largest east-flowing rivers in Peninsular India. Land cover changes in this region have important implications for both provisioning and regulatory hydrologic services and dry-season stream flow. Dry season stream flow is crucial both for anthropogenic requirements and to sustain its rich biodiversity. These consequences need to be weighed against any perceived benefits from land cover change, be they economic as in the increase in agricultural production or even ecological such as the restoration of grasslands.

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