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Agricultural land-use change in Kerala, India: Perspectives from above and below the canopy

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ABSTRACT

Despite the availability of a wide range of tools, measuring and explaining changes in land cover and land use in tropical regions can be extremely challenging. Kerala, India, is a biodiversity hotspot with a high population density and a long history of complex agricultural land-use patterns. Some reports suggest that agriculture in Kerala, which historically is rice paddy-wetland and agroforestry-based, is on the decline. However, the evidence is often anecdotal, especially with regards to smallholding homegarden agriculture. In this study we employ mixed methods, including remote sensing, quantitative household surveys, and semi-structured interviews, to unravel the complex land-cover and land-use changes occurring in Kerala.

Results indicate that, from a land-cover change perspective, agroforests are in dynamic equilibrium with other land covers, being cleared for roads and new buildings, but offset by the expansion of younger, less diverse agroforests into paddy wetlands. Yet beneath the canopy, agroforests are undergoing rapid land-use change not discernible using remote sensing. These changes include a reported decrease in the cultivation of 80% of Kerala's primary crop species during 2003–2013, alongside a dramatic decline in chickens (from 12.5 to 2.6 per homestead on average) and cows (from 1.7 to 0.8). Over this period, no crop increased in cultivation. According to farmers, the primary drivers of this shift were declining profitability of agriculture in Kerala, labour shortages, unreliable weather, unfamiliar pests and diseases, and government policy.

Despite the undeniable move away from agricultural activity in homegardens, we conclude that these ecologically and culturally important systems are not disappearing, but rather evolving to meet the needs of a less agricultural Kerala. Our research highlights the value of using mixed methods for characterizing land-use and land-cover histories in tropical regions.

1. Introduction

Changes in land use and land cover are an important manifestation of human interactions with the environment, with manifold consequences for ecosystems and human livelihoods (DeFries et al., 2007; Foley et al., 2005). There has been a rapid rise in scholarship over the last two decades aiming to understand the ecosystem service tradeoffs related to land-use practices (DeFries et al., 2004; Nair et al., 2009; Tomscha et al., 2016). How best to manage landscapes to balance human needs and environmental conservation has become a key focus of research and policy debate (Benton, 2007; DeFries and Rosenzweig, 2010; Green et al., 2005).

Yet land use must be accurately measured before it can be effectively managed. Various quantitative and qualitative methods have been developed to identify and measure changes in land use and cover (Lambin et al., 2003; Luyssaert et al., 2011; Munsi et al., 2010; Veldkamp and Verburg, 2004). These include, but are not limited to, classification of remotely sensed imagery, physical field measurements, consulting government records, and interviewing land users or occupants.

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Measuring land-use/cover change (LUCC) is complicated by the dynamic nature of human-managed landscapes, which experience changes at multiple scales, and not necessarily at the same time. This is especially true of tropical landscapes in developing countries, in which agricultural land holdings tend to be both small and diverse in style of agriculture. Agricultural landscapes in these regions range from subsistence- to commercial-based and tend to exhibit high spatiotemporal variability in crop selection, which can be based on markets, available technologies, government incentives, pest prevalence, investment potential, and so on (Altieri, 2009; Wrigley, 1971).

Kerala, a tropical state in South India, is an example of a region with a dynamic history of land-use change that has not been particularly well-documented. Archaeological evidence suggests that Kerala participated in global agricultural markets for at least 2000 years, trading spices first with the Romans, and later with Portuguese, Dutch, and British merchants (Jeffrey, 2001). In addition to spices such as black pepper (*Piper nigrum*) and cardamom (*Elettaria cardamomum*), Kerala has been a major producer and exporter of rice (*Oryza sativa*) and coconut (*Cocos nucifera*) (Kumar, 2005). Traditionally, much of Kerala's agricultural activity has centered on homegardens. According to (Kumar and Nair, 2004), homegardens are "intimate, multi-story combinations of various trees and crops, sometimes in association with domestic animals, around homesteads." Homegardens, which are the result of generations of successive crop intensification, are renowned for their species richness, multifunctionality and sustainability (Kumar et al., 1994; Kumar and Nair, 2004). As such, it is important to differentiate between homegardens, which are the places − houses and farms − where people live, and agroforestry, which is a land cover category. Agricultural land in a homegarden is primarily agroforest, in which plantation crops such as coconut, banana, or rubber (*Hevea brasiliensis*) are either well integrated, or in which plantation-style cultivation constitutes a limited proportion of homegarden area. Agroforests, on the other hand, consist of not only homegardens but also mixed agroforests not associated with a homestead. The vast majority of Kerala's rural homesteads contain homegardens, yet these farms are quite small, and other forms of agriculture such as plantations and paddy land also exist.

Rapid agricultural land-use changes have occurred in Kerala since the 1970s. In particular, local land-use scholars have noted a shift towards monoculture and conventional cash-crop agroforestry, at the expense of traditional, species-rich homegardens (Kumar, 2005; Peyre et al., 2006). While a shift towards monoculture-style agriculture would be consistent with shifts observed in other developing regions, it would be at odds with the fundamental cultural importance of tropical agroforestry to rural Keralites (Kumar and Nair, 2004). Furthermore, observations of this transition have been mostly anecdotal, as land-cover data collected by the state fail to account for the complexity of Kerala's agricultural landscapes (Kumar, 2005). In addition to the alleged shift from traditional to monoculture-style agriculture, another important land-use change has been the recent conversion of paddy land into simple agroforests and other agricultural crops (Guillerme et al., 2011). It is important to note that new agroforests are often fundamentally different than traditional homegarden agroforests, as the latter are, by definition, intensively managed, more complex, and much older.

Understanding LUCC in complex landscapes requires a multi-faceted approach (Lambin et al., 2003; Veldkamp and Verburg, 2004). Using Kerala as a case study, we explored the use of a mixed-methods approach to gain a more complete understanding of LUCC at multiple scales. First, using high-resolution satellite imagery, we estimated broad-scale land-cover changes in three of Kerala's environmental and agricultural zones. We then zoomed in to the scale of the homegarden to conduct quantitative household surveys and semi-structured interviews with farmers. While the remote sensing analysis aimed to identify changes in the areal extent of land cover, the farm-scale component of the study aimed to identify the individual land-use changes that were occurring, as well as the drivers of these changes. Finally, we synthesized the disparate data sources to develop a coherent explanation of agricultural LUCC changes in Kerala over the last decade.

2. Methods

2.1. Study area

Despite its small size (38 863 km^2), Kerala is topographically and ecologically diverse, consisting of a mix of coastland, wetlands, and plains to the west, and rolling hills and the Western Ghats mountain range to the east. Crop choice depends primarily on topography and elevation, but also on crop profitability, soil type, availability of irrigation, and public policy (Guillerme et al., 2011; Kannan and Pushpangadan, 1990; Narayanan, 2006). The most common crops grown in Kerala are rice in the lowlands; tea (*Citrus sinensis*), coffee (mostly *Coffea arabica* and *C. canephora*), and spices in the uplands; and banana (various species), coconut and arecanut palms (*Areca catechu*) nearly everywhere (Kumar, 2005). Common homegarden food crops include jackfruit (*Artocarpus heterophyllus*), mango (*Mangifera indica*), curry tree (*Murraya koenigii*), and banana, among many others. Yet Kerala's crop composition has experienced considerable shifts since the 1950s, characterized by declines in rice and increases in coconut and rubber (Kumar, 2005).

In addition to being biophysically, ecologically, and agriculturally diverse, Kerala is socially, culturally, and economically diverse, and is distinct from the rest of India. Kerala has the highest Human Development Index (0.825 in 2015;(United Nations Development Program, 2015) and highest literacy rate (93.91%; (Government of India, 2011) of any state in India. Kerala's universal social services have resulted in a healthy, highly educated population that often travels abroad to find gainful employment (Prakash, 1998). It is estimated that one person works overseas for every five people employed in Kerala, with foreign remittances accounting for roughly 25% of the state's economy (Zachariah and Rajan, 2012). This mass exodus of skilled and unskilled workers has come hand-in-hand with labour shortages since the 1970s, which are generally assumed to have contributed to the decline in paddy cultivation and a rise in agroforestry in the 1980s and 90s (Kannan, 1998).

We conducted land-cover analyses in three panchayats (the smallest political administrative unit in Kerala): Avinissery, Kalikavu, and Poothrikka (Fig. 1). Panchayat choice was based on the availability of high-quality archival satellite imagery as well as to best represent Kerala's diverse natural environments and varied population density. Avinissery is a densely populated, low-elevation panchayat consisting primarily of homegardens and paddy rice. Kalikavu is close to the Western Ghats, has low population density, larger farm size, and produces large amounts of tree crops such as rubber, coconut and arecanut. Poothrikka, which produces rice, rubber, and homegarden crops (e.g. mango, jackfruit, and bananas), is between Avinissery and Kalikavu with regards to elevation and population density. We selected five additional panchayats for landholder surveys and interviews, using the same environmental and demographic criteria as described for the first three (Fig. 1).

2.2. Remote sensing & land-cover change

For each of Avinissery, Poothrikka, and Kalikavu, we acquired an IKONOS-2 image from early 2000 and a GeoEye-1 image from 2012 (Table 1). We selected the imagery using the following criteria: 1) high-quality images with low cloud cover (< 5%); 2) sufficient spatial overlap between paired images to encompass the entire panchayat; 3) paired images as close as possible to 10 years apart; 4) image pairs for each panchayat comprised a temporally coincident 10-year period; and 5) minimal seasonal variation between images in a pair. We collected