CONSERVING GOD'S OWN COUNTRY: BIODIVERSITY IN AGROFORESTRY LANDSCAPES OF KERALA, INDIA

by

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Abstract

The traditional homegardens of Kerala, India, may offer a sustainable balance between food production and ecosystem conservation. These complex agroforestry systems, situated within the Western Ghats biodiversity hotspot, may provide refuge for species threatened by habitat destruction while still supplying food, fuel, medicines and income to local families. Despite their potential value, these ancient and diverse gardens are quickly disappearing with the rapid expansion of housing development and monoculture plantations of non-edible cash crops, threatening both biodiversity and food security. This project explores the potential of homegardens to support wild biodiversity, and the perspectives of local home owners on homegardens and wildlife. I used a combination of sociological and biological field surveys, as well as remote sensing and GIS, to examine 1) the diversity of birds, amphibians, insects and trees in homegardens; 2) the biotic and abiotic landscape features which influence this diversity; and 3) the attitudes of home owners toward ongoing land-use change, local wildlife and larger conservation and environmental issues. I found substantial variation in the structure and composition of individual homegardens, as well as their landscape context, and significant correlations between these attributes and the richness and abundance of animal taxa residing within. I also found strong, positive attitudes among home owners toward agroforestry and the environment, but generally negative attitudes toward local wildlife. These results illustrate the importance of landscape and vegetation features when assessing wildlife habitat in human-dominated systems, as well as the need for interdisciplinary approaches to account for human management of ecologically valuable lands. This project highlights the value of maintaining traditional farming methods in rural landscapes, and aids our understanding of land-use decisions and their importance for conserving biodiversity.

Résumé

Les jardins familiaux traditionnels du Kerala, en Inde, ont la capacité d'offrir un équilibre durable entre production alimentaire et conservation des écosystèmes. Ces systèmes agroforestiers complexes, qui sont situés dans le point chaud de biodiversité Western Ghats, peuvent fournir un refuge pour les espèces menacées par la destruction de l'habitat, tout en fournissant de la nourriture et des médicaments aux familles locales. Bien qu'ils soient de grande valeur, ces divers et anciens jardins disparaissent rapidement du fait de l'expansion rapide de nouvelles maisons et plantations d'arbres en monoculture, menaçant la biodiversité et la sécurité alimentaire. Ce projet explore le potentiel des jardins pour maintenir la biodiversité, et les points de vue des propriétaires de maisons sur les jardins familiaux et la faune locale. J'ai combiné des enquêtes sociologiques avec des relevés biologiques à l'utilisation de la télédétection et des systèmes d'information géographique, afin d'examiner: 1) la diversité des oiseaux, des grenouilles, des insectes et des arbres dans les jardins familiaux; 2) les caractéristiques du paysage qui influent cette diversité; et 3) les attitudes des propriétaires de maisons envers les changements d'utilisation des terres, la faune locale et les questions de conservation et d'environnement. J'ai montré que la structure et la composition des jardins variait substantiellement, tout comme les caractéristiques du paysage. J'ai aussi montré des corrélations significatives entre ces caractéristiques d'habitat et la richesse et l'abondance des animaux. Mes résultats montrent aussides attitudes positives parmi les propriétaires de maisons envers les systèmes agroforestiers et l'environnement, mais des attitudes négatives envers la faune. Ces résultats soulignent l'importance des caractéristiques du paysage et de la végétation pour évaluer l'habitat de la faune dans les systèmes domainé par l'Homme, aussi bien que la nécessité d'approches interdisciplinaires pour tenir compte de la gestion humaine des terres de grande valeur écologique. Ce projet souligne aussi la valeur du maintien des methodes agricoles traditionnelles dans les paysages ruraux, et facilite notre compréhension des décisions concernant l'utilisation des terres et leur importance pour conserver la biodiversité.

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Chapter 1

Introduction and Research Objectives

1.1 The Importance of Biodiversity

Global biodiversity is disappearing at an unprecedented rate, launching us into Earth's sixth mass extinction and the epoch now known as the 'Anthropocene'. Largely attributed to broad-scale human activities including habitat destruction, over-exploitation, climate change and pollution, biodiversity loss is widespread (though not homogeneously) throughout the globe (IUCN 2013). The acknowledgement of this ongoing phenomenon has made biodiversity protection a top priority for conservationists, scientists and politicians, as exemplified by the United Nations Convention on Biological Diversity (1992), the World Summit on Sustainable Development (2002) and the Millennium Ecosystem Assessment (2005). While researchers and policy makers attempt to design and implement strategies to curb human activities which threaten species, many ecologists and biologists are still working to understand the basic mechanisms which regulate ecosystems and influence biodiversity.

Biodiversity, a term popularized in the late 1980s by renowned ecologist and conservation biologist Edward O. Wilson (Krebs 2001), is defined by the United Nations Convention on Biological Diversity as "the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part" (United Nations 1992). Typically measured as the proportional representation of distinct species, genetic phenotypes or ecosystems within a system of interest, biodiversity has become a primary focus for ecological researchers, appearing over 140 thousand times in published academic literature since 1987 (ISI Web of Knowledge search, October 2015). This research has encompassed a broad range of topics concerning biodiversity, from basic quantification of existing diversity to strategies for conservation and restoration.

Studies of the abiotic and biotic environmental factors which dictate species diversity date back at least as far as Connell's (1978) seminal work on the intermediate disturbance hypothesis, and yet the processes by which biodiversity is altered or sustained are not entirely understood. Broad patterns in biodiversity are well documented; globally, species richness is known to correlate with latitude, with the greatest numbers of species occurring near the tropics; regionally species richness tends to correlate negatively with elevation, and positively with humidity and temperature (Gaston 2000). Locally, however, areas of high diversity do not always coincide between different taxa; that is, where one group may be species rich, another may be species poor (Gaston 2000). Although high habitat heterogeneity generally begets high levels of biodiversity, different taxa do not always respond similarly to environmental inputs (Tews *et al.* 2004; Loreau *et al.* 2001). This may be of particular importance in human-dominated systems, where anthropogenic influences further complicate ecological interactions. For example, Bos *et al.* (2007) found that reductions in tree diversity in Indonesian agroforests negatively influenced species richness of ants but not beetles, and Bailey *et al.* (2010) found that predatory birds and spiders are more affected by habitat isolation than herbivorous beetles, true bugs and snails in Swiss orchards. Further, both local and landscape factors can affect species diversity. For example, local factors, such as tree size and density, as well as landscape factors, such as proximity to forest and roads, have all been shown to influence bird diversity (Clough *et al.* 2009; Maas *et al.* 2015; Naidoo 2004; Waltert 2005).

Despite the uncertainty in the mechanisms which drive biodiversity, there is widespread consensus among the scientific community on the importance of biodiversity to humankind (Hooper *et al.* 2005). High diversity maintains ecosystem functioning and biogeochemical cycles, as well as providing resilience to environmental change (Loreau *et al.* 2001). This in turn benefits humans through ecosystem services – the collection of benefits people derive from natural systems (Millenium Ecosystem Assessment 2005). Services provided by living species include provisioning services, such as food provided by fish, game and crops; regulating services, such as pest control provided by predators; and cultural services, such as the aesthetic value of plants and animals. Though not all species directly provide benefits to humans (and may, in fact, cause some harm) and many different species provide similar services, high diversity is necessary to ensure enough variability to maintain ecological stability and provide services to human populations across both space and time (Hooper *et al.* 2005; Loreau *et al.* 2001).

While it is apparent that biodiversity is necessary to sustain human health and well-being, species continue to disappear at an alarming rate. Some estimates suggest that we are losing up to 10% of our species per millennium – up to one thousand times the long-term average extinction rate of the fossil record (Millenium Ecosystem Assessment 2005). Amphibians, of which 1910 of the 6312 known species are in danger of extinction, are the most threatened animal group, followed by mammals, of which 716 out of 5494 species are endangered or extinct (IUCN 2013). These losses come as a result of the irreparable impact humans have had on the planet, including the transformation of half of the global land surface, the addition of 1020 Gt of carbon dioxide to the atmosphere, and the diversion of half of all fresh water for human consumption (Millennium Ecosystem Assessment 2005). The decline of biodiversity has already begun to show serious consequences for humanity: declines in ocean diversity have led to the collapse of 29% of global marine fisheries (Worm *et al.* 2006); reductions in mammalian diversity have been linked to increased prevalence of Lyme disease and hantaviruses in North America (Keesing *et al.* 2010); and the loss of wild pollinators has forced farmers to rent hives or hire labourers to manually pollinate tree crops (Winfree *et al.* 2011; Partap and Ya 2012). Additionally, experimental evidence suggests that losses of plant diversity in agricultural systems can lead to reductions in crop yield and increased prevalence of pests and disease (Cardinale *et al.* 2012).

In response to these biological crises, global conservation efforts have exploded over the past fifteen years, costing approximately $21.5 billion US annually (Waldron *et al.* 2013). However, this amount falls short of the estimated cost of achieving the goals set out in the Convention on Biological Diversity (McCarthy *et al.* 2012) and resources are not currently distributed based on need (Brooks *et al.* 2006, Myers *et al.* 2000). In fact, conservation hotspots – the regions of greatest biological diversity which also face the greatest extinction risks – tend to occur in tropical developing countries (Myers *et al.* 2000). In these areas, threats to biodiversity may be exacerbated by human need, as poverty can lead to over-exploitation of natural resources

(Sunderlin *et al.* 2005). This has prompted many researchers to seek sustainable livelihood options for rural peoples in conservation hot-spots, and promote public education on the importance of biodiversity conservation.

1.2 The Potential of Agroforestry

The International Union for Conservation of Nature (IUCN) cites habitat degradation and loss as the number one threat to global biodiversity (IUCN 2010). Agriculture is the chief driver of habitat loss (IUCN 2010) with over 49 million km^2 of global land currently under agricultural use (more than 30% of the total global land area) and an additional 171,000 km^2 being added annually (FAO 2013). Yet an estimated 800 million people are still chronically undernourished, increasing the pressure to further expand and intensify agricultural systems (FAO 2015).

While the majority of agricultural land practices are detrimental to wild populations, agroforestry systems have been cited as potential oases for disappearing species (Galluzzi *et al.* 2010; Nair 2008). Agroforestry, a traditional practice common in tropical regions throughout the globe, may provide a balance between food production and ecosystem maintenance (Jose 2012). Defined as an integrated agricultural approach involving the combination of trees or woody plant species with other crops or livestock (Huxley 1983), these heterogeneous and structurally complex systems have been heralded as sustainable methods of food production that maintain the ecosystem services and habitat provided by natural forests (Foley *et al.* 2005; Steppler and Nair 1987). In addition to reducing pests and disease, sequestering carbon, and regulating water and air quality, agroforestry systems are believed to promote biodiversity by creating fully functioning ecosystems that resemble the natural forest environment (Schroth *et al.* 2004). While they are no substitute for natural forests, agroforestry systems may lessen the trade-offs between conservation and food security, and help prevent further destruction of forest lands, particularly in highly degraded areas (Noble and Dirzo 1997).

Put simply, an agroforest is any multi-species agricultural system which contains trees, and can include anything from coffee and cocoa plantations to slash-and-burn systems (Schroth *et al.* 2004). They can therefore range dramatically in size, structure and in the number of different cultivated species (Scroth 2004). Homegardening, a practice which has sustained families throughout the tropics for millennia, is a type of agroforestry that is situated immediately next to a homestead, typically less than two acres (Kumar and Nair 2004). Homegardens contain a diverse assemblage of tree, shrub and herbaceous species which provide nutritional value through diet variation, and resilience to changes in climatic and economic conditions by reducing the dependency on individual crop species (Gautam *et al.* 2009; Imbruce 2007; Siviero *et al.* 2011). They also contain a variety of medicinal and ornamental species which are integral in preserving traditional cultural practices (Finerman and Sackett 2003; Papp *et al.* 2013). Finally, homegardens may act as refugia for many threatened and endemic species, particularly in landscapes where natural ecosystems have been diminished (Schroth *et al.* 2004). In return, these species support the garden environment by improving soil quality, controlling pests and pollinating flowering plants, thereby reducing dependency on chemical fertilizers, pesticides and genetically modified crops (Drescher *et al.* 1999; Malézieux *et al.* 2009).

Figure 1.1. An example of a homegarden in Kerala (Source: Author).

Though homegardens typically contain more domesticated and exotic species, their floristic diversity can be comparable to that of nearby forests (Kumar and Nair 2004). The number of different crops housed can range wildly – from 5 to 141 species in some cases (Neulinger *et al.* 2013) – and is dependent on physical factors such as elevation (Kehlenbeck *et al.* 2007) and soil type (Fraser *et al.* 2011), or socioeconomic factors such as ethnicity, gender roles and financial status (Bernholt *et al.* 2009; Coomes and Ban 2004; Kehlenbeck and Maass 2005). Though their faunal diversity is typically lower than that of natural forests (Kudavidanage *et al.* 2012, Scales and Marsden 2008), homegardens have been shown to provide important habitat for wild animal species. For example, Raheem *et al.* (2008) demonstrated that homegardens in Sri Lanka provided habitat for several native species of land-snails threatened by deforestation, as well as corridors between fragmented patches of rainforest. Similarly, Goulart *et al.* (2011) found homegardens in Brazil to be effective foraging sites for frugivorous birds.

Despite the potential of homegardens to provide wildlife habitat, they remain relatively understudied (Guitart and Pickering 2012; Kumar and Nair 2004; Scales and Marsden 2008). Most researchers have focused on the diversity of cultivated species, and those who have examined wild fauna typically compare the diversity of a single taxon between natural forests, homegardens, and more intensive agricultural systems (*i.e.* Armbrecht *et al.* 2005; Cicuzza *et al.* 2011; Tylianakis *et al*. 2006; Waltert *et al.* 2004). In most cases, faunal diversity in agroforests falls somewhere between that of forests and conventional agriculture. This approach, however, ignores the incredible variability that exists between homegardens. While conceptually well defined, homegardens are in reality highly variable in size, age and composition, as well as degree of fragmentation and connectivity within the greater landscape (Kehlenbeck *et al.* 2007; Perfecto and Vandermeer 2008). Further, different animal taxa will respond to these variables in different ways, limiting the applicability of single-taxon studies.

While a wealth of literature exists on the sociological aspects of homegardens, few studies have attempted to make connections between the biological diversity of homegardens and the perspectives of their owners. Many studies have explored the nutritional, economic and cultural benefits of diversity of cultivated species in homegardens. For example, Aguilar-Stoen *et al.* (2009) found that crop diversity in the homegardens of Candelaria Loxicha, Mexico, provides homegardeners with resilience to changing climatic and market conditions, and also allows them to re-establish old or preferred crop varieties. Similarly, Akhter *et al.* (2010) found that homegardens in Bangladesh provide important opportunities for women to earn income and support the food security of their families. But no studies were found which explore the socio-economic benefits of wild animal species in homegardens, or the attitudes of homegarden owners toward biodiversity conservation. As homegarden owners are the key stakeholder in the management of these systems, and ultimately determine the fate of their own lands, it is important to understand their reasons for maintaining homegardens and the factors which may cause them to convert them for other purposes. It is also important to understand their attitudes toward the local fauna which inhabit their homegardens and the potential human-wildlife conflicts that may exist, as promoting homegardens as refugia for wild species may be largely unsuccessful in communities in which animals are seen as problematic.

1.3 The Kerala Landscape

Kerala, a tropical state in southern India, provides an ideal location to study biodiversity in agroforestry systems. Outside of the few major cities, the rolling green landscape is littered with small agroforestry lands, some purportedly dating back as many as 4000 years (Kumar and Nair 2004). Between the scattered houses, a maze of interconnected homegardens winds around paddy fields, rubber plantations and rivers. Rarely are the gardens separated by fences; a subtle change in elevation or crop types may be the only indication of a property line. Each garden contains an astounding mixture of up to forty different tree species, each providing food, medicine, timber, fuel or fodder to the local families. Below the canopy, herbs, vegetables and spices twist around tree trunks, making use of every bit of arable space. Meanwhile, a stunning collection of birds, insects, amphibians, reptiles and small mammals find food and shelter in between the branches and leaves.

Kerala is, by all accounts, a unique Indian state. With just under 35 million people spread over 39 thousand square kilometers, it has one of the lowest population densities in the country (859 /km^2) (India Planning Commission 2008). Situated between the Lakshadweep Sea and the Western Ghats mountain range, this narrow state features 600 km of sandy coastline to the west, followed by palm-lined brackish backwater channels, low rice-paddy wetlands, rolling green midlands, and thickly forested highlands to the east. With a warm maritime equatorial climate and two heavy monsoons bringing up to 3000 mm of annual rainfall, the Kerala landscape is bursting with plant and animal life. Situated within the Western Ghats biodiversity hotspot, a region of both high endemicity and high extinction risk (Myers *et al.* 2000), Kerala supports 9107 km^2 of forest reserve land – home to many charismatic and endangered species, such as the

Indian elephant (*Elephas maximus indicus*), Bengal tiger (*Panthera tigris tigris*), and Nilgiri tahr (*Nilgiritragus hylocrius*). Together, the five different forest types (low elevation tropical wet and semi- evergreen, mid elevation tropical moist and dry deciduous, and high elevation temperate/sub-tropical montane or *shola*) harbour an estimated 4000 flowering plant species, 1272 of which are endemic and 159 threatened, as well as 145 mammals (12 endemic), 486 birds (16 endemic), 164 reptiles (89 endemic), 196 freshwater fish (84 endemic), 85 amphibians and 4027 insects (Kerala Forests and Wildlife Department 2009).

Figure 1.2. Examples of Kerala wildlife (from top-left to bottom-right): Indian elephant (*Elephas maximus indicus*), Bonnet Macaque (*Macaca radiate*), Great Egret (*Casmerodius albus*), Oriental Garden Lizard (*Calotes versicolor*), Kani Bushfrog (*Pseudophilautus kani*), Blue Tiger (*Tirumala limniace*), Northern Spotted Grasshopper (*Aularches miliaris*), Greater Crimson Glider (*Urothemis signata*) (Source: Author).

While its climate and geography are unlike any other Indian state, it is Kerala's history and culture that make it truly unique. Traditionally a matrilineal agrarian society, Kerala (formerly the Malabar Coast) was established as a major port location for spice exports as early as 3000 BCE (Jeffrey 1992). Strong trade routes variously attracted Arabs, Greeks and Romans, and Jewish, Muslim and Christian communities were well established in the region by 400 BCE. During the fifteenth to eighteenth centuries CE, the ports were variously held by the Portuguese, Dutch and finally British in 1795. The modern state of Kerala was established in 1956, ten years after India declared independence. Keralites elected one of the first communist-led governments in the world during their first election. By the mid-1970s, Kerala began attracting the attention of international scholars, journalists and policy-makers, as birth rates and infant mortality had hit a record low while average life expectancy, female life expectancy, literacy rate, female literacy rate and sex ratio had quickly outpaced all other Indian states. Interestingly, these successes occurred despite the fact that per capita income remained relatively low. This gave rise to the 'Kerala model of development', leading many economists and social scientists to believe this type of vast improvement in quality of life and standards of living could be possible without a substantial industrial, agricultural or political revolution (Jeffrey 1992).

Today, Keralites still enjoy a Human Development Index that exceeds that of every other state, as well as many other developing countries (India Planning Commission 2008). Ambitious reforms to public health, education and land ownership have created a state where the average citizen has a secondary school education, 1 to 2 children and half an acre of land (India Planning Commission 2008). Malayalam, a language not spoken anywhere else in the world, is the primary language of 97% of the population, and religion in Kerala is split between Hinduism (55%), Islam (27%) and Christianity (18%) (Government of India 2010). Branded 'God's Own Country' by the state tourism department, the economy is primarily service based (60.66% of Net State Domestic Product in 2003-2004) with tourism related industries (trade, hotels and restaurants) contributing 23.33%. Agriculture is the second largest sector, contributing 13.15% (India Planning Commission 2008). Approximately 76.6% of the total land area is under agricultural use, with over half of that land being occupied by coconut, rubber and rice. Homegardens are the dominant agroforestry system in Kerala, with approximately 4.32 million homegardens covering an area of 14,000 km^2, approximately 36% of the total land area (Kumar 2006).

Despite the importance of agriculture to the region, evidence suggests that agricultural lands are in rapid decline. With improved education and increasing globalization, many young Keralites are leaving their family land to seek employment abroad, particularly in the Persian Gulf (Raman 2012). Currently, remittance income obtained from some 2.2 million Keralite expatriates contributes nearly one third of the state domestic product (500 billion INR; Raman 2012). Meanwhile, the real estate market is rapidly expanding, driving up land and housing prices. In response, many families are clearing their homegardens and dividing their land holdings for sale or housing construction (Fox 2015). In order to remain profitable, many remaining farmers are forced to move away from traditional agroforestry to more commercialized rubber and arecanut plantations (Depommier 2003; Guillerme *et al.* 2011). As this process of urbanization continues, Kerala's wildlife, and the services they provide, will be increasingly threatened.

1.4 Research Objectives

In this thesis, I use quantitative and qualitative techniques to better understand the role of homegardens in maintaining wild animal populations in Kerala. The goal of my research is to identify environmental factors which promote wildlife in homegardens, and to explore the relationship between homegarden owners and the local wildlife. This information could be used to help guide efforts to conserve local wildlife by identifying homegardens to prioritize or strategies to increase useable habitat, and by anticipating the public response to conservation measures. This thesis first quantitatively examines patterns of faunal diversity of six major taxa (birds, frogs, butterflies, dragonflies, other insects and soil invertebrates) in sixty homegardens across Kerala to assess the role of both local and landscape structural variables in influencing biodiversity. In Chapter 2, I use biological field surveys and remotely sensed imagery to address the following:

1. How much variability in animal species richness and abundance exists between homegardens?
2. How much variability in tree and animal community composition exists between homegardens?
3. Which factors, local (canopy or understory structure, tree size and diversity, property size) or landscape (landscape context, distance to nearest wetland, road or forest), best explain this variability?
4. Do any of these factors strongly affect multiple taxa?

This thesis then explores the attitudes of homegarden owners toward local wildlife, ongoing landscape change, and biodiversity conservation in general. In Chapter 3, I use qualitative methods, including surveys and semi-structured interviews, to ask the following:

1. What are the attitudes of homegarden owners in Kerala to ongoing changes to the landscape?
2. What incentives do they have to maintain their homegardens and what do they feel drives the conversion of agricultural lands to other land uses in the area?
3. What are their attitudes toward wildlife, and have they observed changes in the abundance of wild animals over the past decade?
4. Which, if any, environmental issues concern them, and do these concerns impact the way they manage their land?

The thesis concludes with a final discussion linking the results of the two chapters and considering the implications of the results for the management of agroforestry landscapes for biodiversity.

Chapter 2

Wild Species Diversity in Kerala Homegardens

2.1 Introduction

Biodiversity, which is necessary for the maintenance of ecosystem functioning and services such as pollination, nutrient cycling and pest control (Hooper *et al.* 2005), is declining globally at an alarming rate (Chapin *et al.* 2000). Conservation of biodiversity is therefore of immense concern, particularly in tropical developing nations where biodiversity is high, human development is low, and deforestation is rampant (Myers *et al.* 2000). Often overlooked as potential harbours for biodiversity, agricultural systems are of increasing interest to conservationists aiming to preserve ecosystem functioning in highly modified landscapes (Tscharntke *et al.* 2005). Recent empirical evidence has shown that many tropical farming systems provide habitat and foraging ground to wild species otherwise displaced by human activities, and that the biodiversity supported depends on the intensity of agricultural management (Benton *et al.* 2003; Scales and Marsden 2008).

Agroforestry, an ancient and traditional land-use system employed throughout the tropics, may provide a sustainable method for both food production and biodiversity conservation in vulnerable landscapes (Schroth *et al.* 2004). Broadly defined as an integrated agricultural approach involving the combination of trees with other crops or livestock (Huxley 1983), agroforestry systems assist in preserving ecosystem services and functioning by maintaining complex canopy and understory structure (Bardhan *et al.* 2012; Deheuvels *et al.* 2012). While no substitute for primary forests (De Beenhouwer *et al.* 2013), agroforestry systems can help alleviate pressure on wild populations by providing corridors between forest fragments or buffers between forests and more intensively modified lands (Schroth *et al.* 2004). Agroforestry may also supplement habitat for wild species in landscapes where little to no forest remains (Schroth *et al.* 2004).

Our understanding of the contribution of agroforestry to biodiversity conservation, and of the factors which determine the suitability of these systems as wildlife habitat, however, is limited (Scales and Marsden 2008). Most relevant studies have focused on comparing the richness and abundance of a single taxon between agroforests, natural forests, and other land-use systems (e.g., Goodale *et al.* 2014; Korasaki *et al.* 2013; Palacios *et al.* 2013; Valencia *et al.* 2014). Few studies account for the incredible variability that exists in both the local structure and landscape context of agroforestry systems (but see Clough *et al.* 2009; Jha and Vandermeer 2010; Stenchly *et al.* 2012), which are known to influence species diversity of mammals (Michel *et al.* 2007), birds (Cleary *et al.* 2005; Galitsky and Lawler 2015), reptiles (Brown *et al.* 2011), amphibians (Murrieta-Galindo *et al.* 2013) and insects (Stoner and Joern 2004). Additionally, these studies do not consider the variability in how different taxa might respond to these environmental factors (Scales and Marsden 2008). In order to improve our understanding of the potential conservation value of agroforestry systems, and therefore our ability to effectively manage agricultural landscapes for biodiversity, we must move beyond categorical comparisons of differing land-use systems and explore options for improving suitability of agroforestry habitat while still offering sustainable livelihoods to local peoples.

This study aims to identify the most important drivers of biodiversity across multiple taxa within agroforestry systems in Kerala, India. Kerala, one of the southernmost Indian states, is a lush tropical landscape comprised of a diverse array of traditional homegardens – small scale agroforestry systems that are situated around a primary residence (Fernandes and Nair 1986) – intermixed with rice paddy wetlands and plantations. Few natural forest patches remain, except at high elevations. Situated along the Western Ghats, a global hotspot for endemic biodiversity and an area of high conservation concern (Myers *et al.* 2000), these homegardens support rich canopy and understory communities of birds, reptiles, amphibians, invertebrates, plants and fungi (Gopal and Kurien 2013; Kunte *et al.* 1999; Rahman *et al.* 2012). There is, however, a substantial range in both the size and composition of the gardens, from large, cash-crop dominated plantations to small, minimally managed land holdings. Additionally, homegardens throughout Kerala are disappearing at a rapid rate, due to increasing human population density, fragmentation of land holdings and conversion to commercial monocultures (Depommier 2003; Guillerme *et al.* 2011; Fox 2015). This landscape thus provides an ideal location for exploring drivers of biodiversity in highly populated and highly threatened areas. To better understand the factors which drive biodiversity in agroforestry systems, my study addresses the following questions:

1. How much variability in animal species richness and abundance exists between homegardens?
2. How much variability in tree and animal community composition exists between homegardens?
3. Which factors, local (canopy or understory structure, tree size and diversity, property size) or landscape (landscape context, distance to nearest wetland, road or forest), best explain this variability?
4. Do any of these factors strongly affect multiple taxa?

2.2 Methods

2.2.1 Study Area and Site Selection

Kerala, India, is a mid-sized state on the south-western tip of the Indian subcontinent (Figure 2.1). It is a narrow state – 39,863 km^2 in area with 190 km of coastline. The tropical state experiences two seasonal monsoons (June to August and September to December) delivering an average of 2923 mm of rainfall annually, and average temperatures ranging from 22 to 34 °C. The Western Ghats mountain range runs along the eastern border of the state, creating a rolling topography that peaks at 1800 MASL. Toward the west, the landscape flattens into lowlands scattered with rivers, backwaters and lagoons (India Planning Commission 2008). The mid and lowland areas are dominated by iron oxide rich laterite soils, while the highlands contain a mixture of laterite and loamy hill soils (Kerala Department of Soil Survey and Soil Conservation 2014). Kerala houses an estimated 5725 endemic species, including 1272 flowering plant species, 56 mammals and 86 amphibians. The state contains 11309 km^2 of forest (28% of the total land area), 80% (9107 km^2) of which is within forest reserves (Kerala Forests and Wildlife Department 2009).

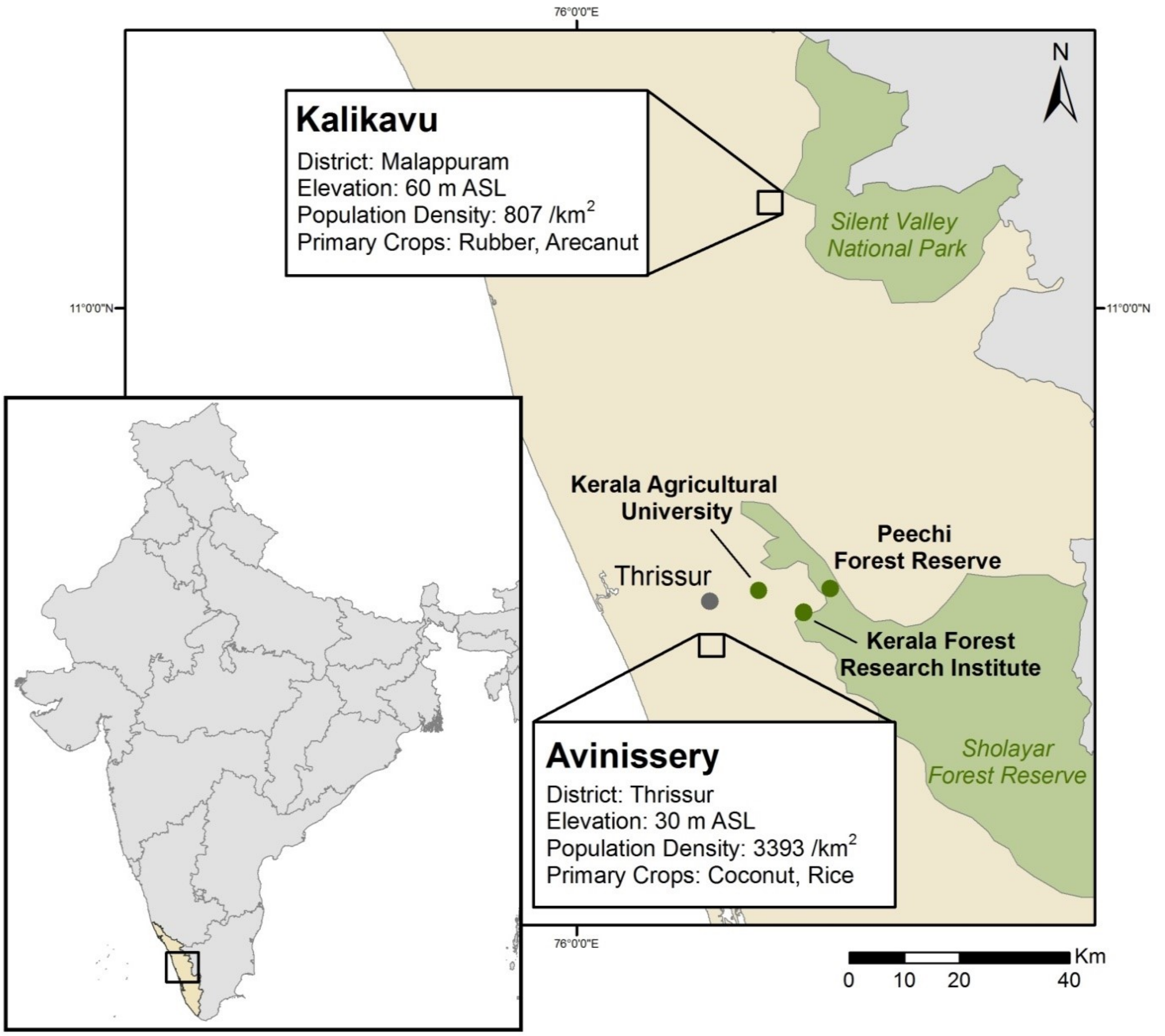

Figure 2.1. Map of Kerala including the two study regions (Avinissery and Kalikavu) and locations of forest and plantation sampling sites (Source: Author).

Homegardens are the dominant agroforestry system in Kerala, with approximately 4.32 million covering an area of 14,000 km^2 (Kumar 2006). Two study regions in Kerala were chosen based on homegarden abundance, available satellite imagery and variability in landscape composition. The first region, Avinissery, is a densely populated (3393 persons/km^2), lowland area (30 MASL) close to a major city centre and dominated by coconut and rice paddy wetland. The second region, Kalikavu, is a relatively sparsely populated (807 persons/km^2), midland area (60 MASL) close to a forest reserve and dominated by rubber, coconut and arecanut (Kerala Department of Economics and Statistics 2011).

Sampling occurred during the monsoon season (July – September) of 2014. Within each region of the two regions, I sampled a 900 m^2 (30 x 30 m) area in each of 30 gardens (for a total of 60 gardens). Potential homegardens were located by exploring each region for sites that met four criteria: 1) the garden area had to be at least 900 m^2 to provide a consistent sampling area 2) it had to include a minimum of two different tree species and one additional crop to differentiate it from a plantation, 3) the owners had to reside on the same property so it could meet the definition of a homegarden, and 4) it had to be a minimum of 200 m from all other samples to reduce the probability of double counting individual animals. Sites were sampled only if the property owner was available to provide access and consent.

Five natural forest areas and two plantations were sampled in addition to the sixty homegardens. Due to legal and logistical constraints, these sites were determined by local forest authorities and were located only within the district of Thrissur (Figure 2.1). Sampling areas were established so as to avoid trails and roads. Three of the five forest samples were taken from forests on university lands at Kerala Agricultural University (10°32’56” N, 76°17’09” E) and the Kerala Forest Research Institute (10°31’35”N, 76°21’03”E) and two were taken from the Peechi Forest Reserve (10°31”54”N, 76°22”25”E). One coconut and one rubber plantation were sampled at Kerala Agricultural University.

2.2.2 Dependent Variables: Animal Surveys

Within each garden, a global positioning system (GPS) was used to mark the boundaries of the property. Three 30 x 10 m sampling areas were arranged and demarcated so as to fit within the garden while avoiding property edges and structures such as driveways, wells and buildings. In very large properties, the sampling area was kept within 70 meters of the house. Within each sampling area, trained field assistants with extensive knowledge of local fauna collected richness and abundance data on six major taxa: birds (class *Aves*), frogs (order *Anura*), butterflies (suborder *Rhopalocera*), dragonflies and damselflies (order *Odonata*; hereafter “dragonflies”), all other insects and spiders (classes *Insecta* and *Arachnida*; hereafter "insects") and soil macrofauna (includes individuals of phylum *Annelida*, *Arthropoda* and *Pulmonata* greater than 2 mm).

Invertebrates were sampled during daylight hours (10 am – 4 pm). Butterfly and dragonfly richness and abundance were measured using 30 minute timed surveys, which have been shown to be more effective for detecting rare species (Kadlec *et al.* 2012). Observers moved slowly and continuously throughout the sampling area to assist sightings by disrupting stationary individuals. Due to their great abundance and diversity, all other insects were measured using a transect-sampling technique: five 30 m transects were evenly spaced within the sampling area in each garden, and one observer recorded all individuals encountered while walking each 30 m transect. Care was taken not to disturb the area prior to insect sampling, and observers spent no more than 30 minutes on each transect to regulate sampling effort (see Anderson *et al.* 1979 for further details on transect sampling). Soil macrofauna were sampled by digging five 25 x 25 x 25 cm holes and sieving the soil through a 2 mm mesh to isolate macro invertebrates. This depth is adequate as soil invertebrates have been shown to be most concentrated in the first 5-10 cm of the surface (Petersen and Luxton 1982). Digging sites were assigned by randomly selecting numbers along each transect line, but reassigned if necessary to avoid damaging crops. Leaf litter and aboveground biomass were removed prior to sampling. As tropical invertebrates are relatively poorly described, soil macrofauna and insects were identified only to order.

Due to their diurnal activity patterns, frog and bird sampling occurred during early morning hours (5 am – 9 am). Frog richness and abundance was measured by systematically walking the sampling area for a 30 minute period and recording all individuals encountered visually (see Heyer *et al.* 1994 for details on frog sampling procedures). Bird richness and abundance was measured using sightings at a single point within the garden area for a period of 30 minutes. Time of day and current weather were noted at each sampling event, as these factors are known to influence animal activity, and thereby observation ability (Bibby *et al.* 1998). To avoid bias towards vocal species, birds were required to be seen within the garden area, no more than 30 m from the observer to be recorded. Flocks of birds flying overhead but not entering the garden area were not counted. Because canopy structure is typically more complex in forest systems, and because visual detection is more likely in agricultural systems than in forests (Karr 1981), the total number of birds recorded in forest sites is likely an underrepresentation of the total abundance and richness present. Birds were also sampled repetitively on three additional occasions over the course of a year to gain a more complete picture of the total number of species utilizing the plots, but these data are not analyzed here.

2.2.3 Independent Variables: Local and Landscape Factors

2.2.3.1 Local Vegetation Structure

Within each sampling area, I measured tree abundance, richness and size, as well as canopy and understory structure to quantify the vegetation structure. All trees, which include any woody plant species with a diameter at breast height (DBH) greater than 5 cm, within the sampling area were counted, identified and measured. Canopy was taken as any live vegetation greater than 160 cm from the ground. Canopy height was measured using a clinometer and canopy cover was measured using a spherical densitometer. Canopy height and cover were both measured at 5 randomly selected locations along each of the five 30 m transect lines within the sampling area, for a total of 25 measurements at each site. Similarly, understory (which includes any live vegetation less than 160 cm from the ground) height and cover were measured at 5 randomly selected locations along the same five transects. Understory cover was measured using a 50 x 50 cm quadrat to visually estimate the percentage of the total two-dimensional area occupied by foliage. Understory height was measured as the distance from the ground to the highest point of foliage within the quadrat. The mean and standard variation of each of these metrics (canopy height, canopy cover, understory height and understory cover) was calculated for use in the statistical models. Slope and aspect was also recorded for all sampling areas.

2.2.3.2 Landscape Context

Multispectral, 2.0 m resolution satellite imagery for the study regions was obtained from Geo-Eye-1™ (Figure 2.2). The image for Avinissery covers 43 km^2, and was taken on December 10, 2012. The image for Kalikavu has covers 35 km^2, and was taken on January 13, 2012. Pixel-based supervised classification using a maximum-likelihood algorithm was performed in ENVI™ (version 5.1, Exelis 2013) using 100 manually-selected training points for each of 5 classes: tree cover, open (non-treed) agriculture, roads (paved and unpaved) and other areas of exposed soil (such as mines and new construction sites), buildings and water. Using Geographic Information Systems (GIS) software and the GPS data collected from field sites, I mapped the locations of all sampling sites and overlaid them on the classified land cover maps. ArcMap (version 10.2.2, ESRI 2014) was used to measure the Euclidean distance from the centre of each garden to the nearest major road, rice paddy wetland (in Avinissery only) and forest reserve (in Kalikavu only). Fragstats 4.2 (Kevin Mcgarigal & Eduard Ene 2013) was used to quantify the percent cover of trees and human structures (including buildings, roads and other areas of exposed soil) within a 250, 500, 750 and 1000 m radius of the centre of each garden.

Figure 2.2. Samples of satellite imagery of Avinissery (above) and Kalikavu (below). Avinissery is a densely populated, lowland region composed of small coconut-dominated homegardens, interspersed around rice paddy wetlands. The small, brightly coloured white, red and blue spots are rooftops. Dark orange patches are areas of exposed soil, including roads and construction areas. Dark green textured areas are treed homegardens while the medium green and brown smooth patches are rice paddy fields. Kalikavu is a sparsely populated midland region featuring large rubber and arecanut dominated homegardens which are periodically cleared and replanted. Rooftops, roads and some other areas of exposed soil appear bright white in this image. Larger, tan patches are recently cleared plantations. Dense green patches are homegardens and plantations. The hilly, irregularly treed area in the upper right corner of the image is part of the Silent Valley Forest Reserve. There is no paddy wetland in Kalikavu (Source: GeoEye™).

2.2.4 Statistical Analyses

2.2.4.1 Variability among Taxa

Richness and abundance at each site were calculated for each taxon as the number of distinct species or orders and the total number of individuals, respectively. Bird, frog, butterfly, dragonfly and tree richness were calculated as the number of individual species, while insect and soil macrofauna richness were calculated as the number of orders. ANOVA was used to compare the mean richness and abundance of each group between Kalikavu and Avinissery. The mean richness and abundance for each taxon at the five forest sites was calculated but not statistically compared to the mean richness and abundance in homegardens, as the very low sample size may produce misleading results.

2.2.4.2 Community Composition

Non-Metric Multidimensional Scaling (NMDS) is an ideal ordination technique for ecological data, as it allows for non-linear relationships and excessive zeros in community datasets (McCune and Grace 2002). NMDS was performed separately for each taxon using the Bray-Curtis distance on community matrices using the package picante in RStudio™ (version 0.97.551, RStudio 2012). Ordination of birds, frogs, butterflies, dragonflies and trees were performed on species abundances, while ordination of insects and soil macrofauna were performed on order abundances. Sampling sites were also ordinated by vegetation structure using NMDS; mean and standard deviation of canopy cover, canopy height, understory cover and understory height, and mean tree DBH were included in the matrix. Mantel tests were performed between the first axis and dissimilarity matrix to determine the R^2 value for each axis. NMDS axis weightings were extracted from plots to be used as numerical response variables for community composition in the following analyses.

2.2.4.3 Environmental Relationships

Uni-variate linear regression was used to select the most appropriate explanatory variables to be included in environmental models. Ordinary least squares (OLS) linear regression was performed between each response variable (richness, abundance, diversity and NMDS axis scores of each of birds, frogs, butterflies, dragonflies, insects and soil macrofauna) and each explanatory variable

(Table 2.1) to determine the variables most likely to significantly influence each taxon in each region (Appendix A). Non-linear relationships were allowed for tree abundance and distance metrics by including the log of each of these variables. Due to excessive zeros in dragonfly data, resulting from a high proportion of sites having no dragonflies present, dragonfly abundance data were converted to binary (presence-absence) data and logistic regression models were used. Model significance was adjusted to $p<0.002$ using the Bonferonni correction, and residuals were examined to assess model assumptions.

From these univariate regressions, I chose two local and two landscape variables based on the greatest model R^2 values for each taxon/region combination to be used in Generalized Linear Models (GLMs; Table 2.2). For all models excluding dragonflies, GLMs with normal probability distribution were used (ordinary least-squares regression). Binomial GLMs were used for binary dragonfly data. For each GLM, parameters were successively excluded and the Akaike's Information Criterion for small sample sizes (AIC_c) was used to determine the best model (Burnham and Anderson 2002).

To ensure the robustness of the results, the analysis was repeated a second time, aggregating data from the two regions for each taxa, and a third time using axis loadings from two NMDS plots, one including all local variables and one including all landscape variables, in place of explanatory variables. Aggregation of the data from the two regions produced similar overall results. The GLMs of taxon response variables against local and landscape NMDS axes produced models with greater AIC_c scores, and which are more difficult to interpret. The results of these additional analyses are thus not reported in detail in this chapter.

Table 2.1. Explanatory variables used in generalized linear models. Correlation coefficients between all explanatory variables are <0.8. Note that for landscape percent cover variables (percent cover trees, development) only one distance radius (250 m, 500 m, or 1 km) was used at a time to avoid strong correlations between variables. Information on tree species origins (native vs. exotic) was obtained from Nayar et al. (2006).

Variable	**Category**	**Avinissery**			**Kalikavu**		
		Min.	Mean	Max.	Min.	Mean	Max.
Mean Canopy Cover (%)	Local	17.0	87.9	99.3	82.4	95.2	100.0
S.D. of Canopy Cover (%)	Local	0.9	9.6	31.7	0.1	5.5	23.3
Mean Canopy Height (m)	Local	6.5	10.2	20.4	6.3	12.1	25.1
S.D. of Canopy Height (m)	Local	1.8	6.5	35.0	1.8	5.8	38.5
Mean Understory Cover (%)	Local	1.8	46.1	96.7	6.0	43.8	87.9
S.D. of Understory Cover (%)	Local	2.2	27.8	43.0	3.9	28.0	41.7
Mean Understory Height (m)	Local	0.1	0.3	0.7	0.1	0.3	0.5
S.D. of Understory Height (m)	Local	0.1	0.3	0.5	0.1	0.2	0.3
Tree Abundance (# individuals)	Local	4	44.7	113	28	63.8	166
Tree Species Richness (# species)	Local	1	9.3	18	2	5.7	17
Tree Diversity (Shannon Index)	Local	0	1.5	2.4	0.2	1.0	2.3
Mean Tree DBH (cm)	Local	14.2	19.7	30.4	9.4	16.2	24.5
Proportion of Exotic Trees	Local	0	0.3	0.8	0.2	0.8	1
Property Size (m^2)	Local	1033	3814	9603	1119	10190	186000
Distance to Road (m)	Landscape	25.4	253.1	665.9	22.5	164.4	557.6
Distance to Paddy (m; Avinissery Only)	Landscape	25.5	211.5	730.2	NA	NA	NA
Distance to Forest (m; Kalikavu Only)	Landscape	NA	NA	NA	179.1	1230.0	2846.2
Percent Cover of Human Structures (250 m radius)	Landscape	4.1	17.5	32.6	0.3	3.2	10.3
Percent Cover of Human Structures (500 m radius)	Landscape	5.4	18.9	26.7	0.7	3.6	13.4
Percent Cover of Human Structures (1 km radius)	Landscape	8.0	18.3	27.1	1.1	3.2	7.6
Percent Cover of Open (non-treed) Agricultural Land (250 m radius)	Landscape	46.2	65.4	82.2	28.6	57.6	80.9
Percent Cover of Open (non-treed) Agricultural Land (500 m radius)	Landscape	30.7	61.9	75.8	32.1	54.8	71.4
Percent Cover of Open (non-treed) Agricultural Land (1 km radius)	Landscape	36.2	60.6	71.9	37.8	54.1	64.3

Table 2.2. Explanatory variables chosen for GLMs based on results of univariate linear regressions.

Taxon	Avinissery	Kalikavu
Birds	SD Canopy Cover Property Size Human Structure Area (250 m) Distance to Road (log)	Tree Abundance (log) Tree Mean DBH Distance to Road Human Structure Area (1 km)
Frogs	Mean Understory Height SD Understory Height Distance to Paddy (log) Open Agricultural Area (log)	Mean Canopy Height SD Understory Height Human Structure Area (250 m) Distance to Road
Butterflies	Property Size SD Canopy Cover Open Agricultural Area (1 km) Human Structure Area (1 km)	Tree Diversity Mean Understory Cover Open Agricultural Area (500 m) Human Structure Area (500 m)
Dragonflies	Mean Understory Cover SD Canopy Cover Open Agricultural Area (500 m) Human Structure Area (500 m)	Mean Canopy Height Mean Canopy Cover Open Agricultural Area (500 m) Human Structure Area (500 m)
Insects	Mean Understory Cover Mean Understory Height Distance to Road Human Structure Area (500 m)	SD Canopy Height Mean Understory Cover Distance to Road Human Structure Area (250 m)
Soil Macrofauna	SD Understory Height Mean Understory Cover Distance to Paddy Open Agricultural Area	SD Canopy Height Tree Diversity Open Agricultural Area (500 m) Distance to Road

2.2.4.4 Spatial Autocorrelation

Spatial autocorrelation occurs when values obtained from sample sites are more or less similar than expected by chance based on their geographic proximity, and this can lead to bias and misinterpretation of results if not accounted for in ecological datasets (Legendre 1993). To determine if spatial autocorrelation was present in these data, spatial correlograms of Moran's I were constructed using the package `ncf` in RStudio™ to compare correlations of model residuals based on distance between sampling sites. Additionally, spatial variograms were constructed from model residuals using the package `geoR`. No spatial autocorrelation was detected in any of these models.

2.3 Results

2.3.1 Variability among Taxa

In total, 83 bird species from 38 families, 63 butterfly species from 5 families, 23 dragonfly species from 5 families and 15 frog species from 5 families were identified in this study, as well as 117 tree species from 40 families (Appendix B). No rare or endangered species were encountered; all species identified are listed as "common" by the IUCN Red List of Threatened Species. Additionally, I recorded insects from 22 orders and soil macrofauna from 11 orders. Across the entire region, the total number of species encountered in all taxa except frogs was greater in Avinissery than in Kalikavu, and, with the exception of frogs and butterflies, a greater number of species were unique to Avinissery (Table 2.3). Despite including only five sites, forests overall housed a greater total number of bird species, as well as number of unique bird species, but for all other taxa the homegardens were comparable. Plantations had considerably fewer species overall than all other regions, but this is heavily influenced by the small sample size (n=2).

Table 2.3. Number of species identified in each taxa and region.

	Avinissery Homegardens	Kalikavu Homegardens	Forests	Plantations
Total number of sites	30	30	5	2
Total number of species				
Birds	44	31	57	24
Butterflies	61	57	42	7
Dragonflies	23	21	7	5
Frogs	8	12	9	3
Trees	76	39	46	3
Number of unique species				
Birds	11	5	22	5
Butterflies	12	15	5	0
Dragonflies	7	6	0	0
Frogs	0	4	3	0
Trees	43	11	29	3
Total number of orders				
Insects	22	20	14	11
Soil Macrofauna	12	10	6	3
Number of unique orders				
Insects	3	1	0	0
Soil Macrofauna	3	1	0	0

The mean richness and abundance of all animal taxa in homegarden sites was greater in Avinissery than in Kalikavu (Figure 2.3). Tree abundance was significantly greater in Kalikavu homegardens ($F_{1, 58}$=8.134, p=0.006), but richness was greater in Avinissery ($F_{1, 58}$=11.200, p=0.001; Appendix C). Bird richness and abundance, and soil macrofauna abundance, were much greater in forest sites than in homegardens, while all other taxa were comparable. Insect abundance showed the greatest range in values between sites - from 743 to 12994 individuals in Avinissery and 343 to 4805 individuals in Kalikavu (Figure 2.3). Variation in species richness was greatest for butterflies (0 – 29 species) and least for frogs (0 – 6 species).

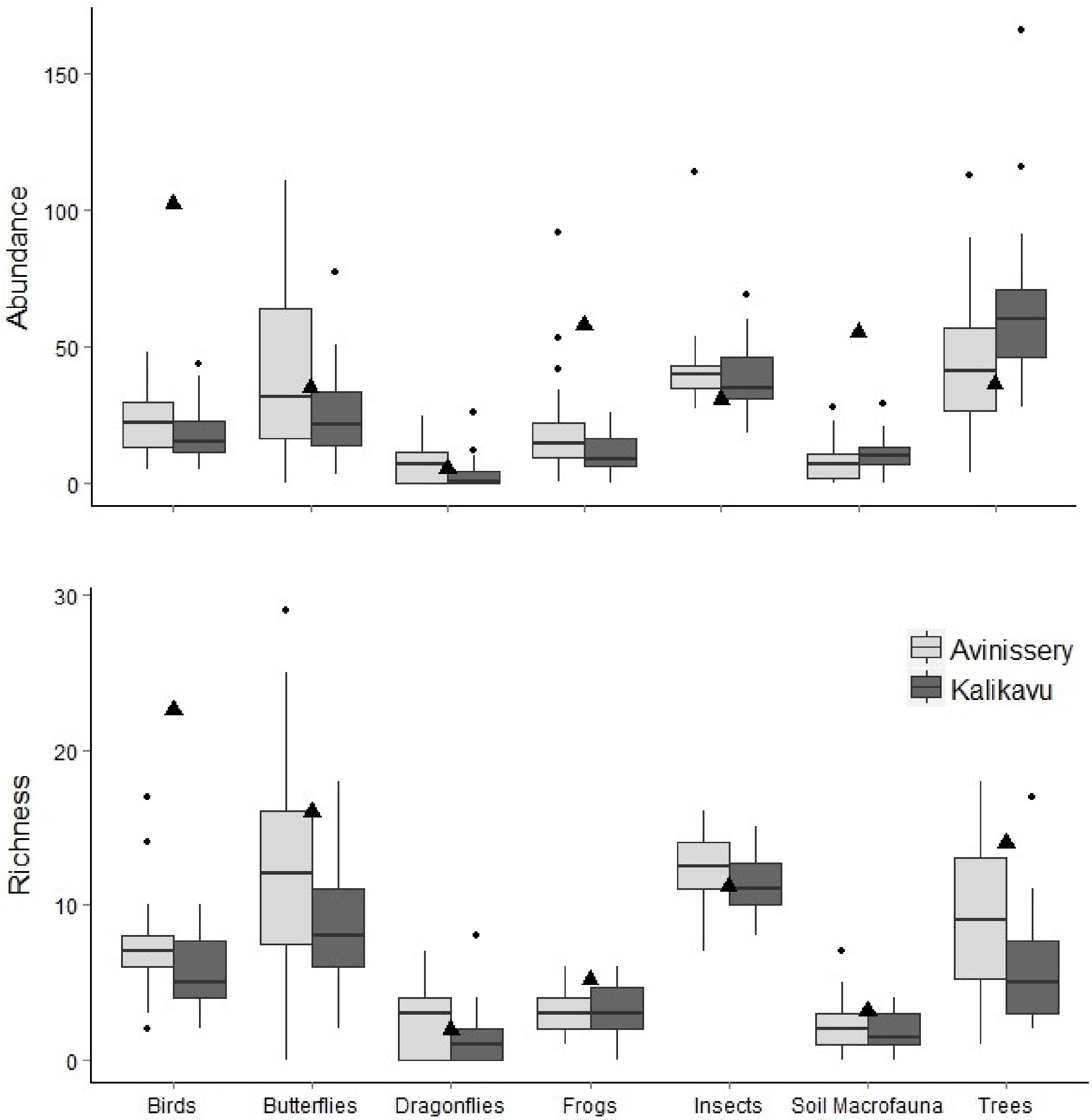

Figure 2.3. Mean abundance (above) and richness (below) of taxa in homegardens of Avinissery and Kalikavu. Insect and soil invertebrate richness indicate number of orders, while all others indicate number of species. Insect abundance has been square-rooted for presentation purposes. Closed circles indicate outliers, while black triangles indicate average values for five forest sites. Richness of birds, butterflies and trees is significantly greater in Avinissery ($F_{1,58}$=4.469, 9.529 and 11.200, p=0.039, 0.003 and 0.001, respectively). Abundance of butterflies, dragonflies and frogs is significantly greater in Avinissery ($F_{1,58}$=5.626, 7.251 and 5.902, p=0.021, 0.009 and 0.018, respectively). Abundance of trees is significantly greater in Kalikavu ($F_{1,58}$=8.134, p=0.006) (Source: Author).

2.3.2 Community Composition

Results of the NMDS suggest distinct tree community composition between Avinissery and Kalikavu (Figure 2.4a), but substantial overlap in vegetation structure (Figure 2.4b) and community composition for all animal taxa (Figure 2.4c-h). The ordination of tree community composition (2-axis solution, final stress=0.197, R^2=0.961) reveals separate clusters of sites in Avinissery and Kalikavu, as well as separation from forest sites (Figure 2.4a). The first axis is strongly correlated with tree richness (OLS, F=103.53, R^2=0.608, p=4.45e^{-15}), diversity (F=49.34, R^2=0.423, p=1.57e^{-9}), and mean DBH (F=48.03, R^2=0.416, p=2.31e^{-9}), while the second axis is strongly correlated with the proportion of exotic species (F=27.59, R^2=0.287, p=1.78e^{-6}). The ordination of vegetation structure (2-axis solution, final stress=0.184, R^2=96.6%), however, reveals no separation of sampling sites by region (Avinissery and Kalikavu), as well as no separation of forest sites from homegarden sites (Figure 2.4b).

Ordination of animal taxa suggests little difference in community composition between the two regions. Plots for birds (3-axis solution, final stress=0.184, R^2=0.966), frogs (2-axis solution, final stress=0.170, R^2=0.971) and butterflies (3-axis solution, final stress=0.198, R^2=0.961), show highly overlapped clusters for Avinissery and Kalikavu with most forest sites grouped separately (Figure 2.4c-e). No vegetation factors correlated significantly with bird NMDS axes, while several vegetation factors, including tree abundance and proportion of exotic species, correlated with frogs and butterflies. The ordination plot for dragonflies shows no clear clustering, and twenty-two sites were removed due to absence of dragonflies (Figure 2.4f; 2-axis solution, final stress=0.126, R^2=0.984). Ordination plots for insects (3-axis solution, final stress=0.171, R^2=0.971) and soil macrofauna (2-axis solution, final stress=0.183, R^2=0.966) show no clustering of homegarden or forest sites (Figure 2.4g-h). These stress values are within the 0.10-0.20 range that is considered acceptable for ecological datasets (McCune and Grace 2002).

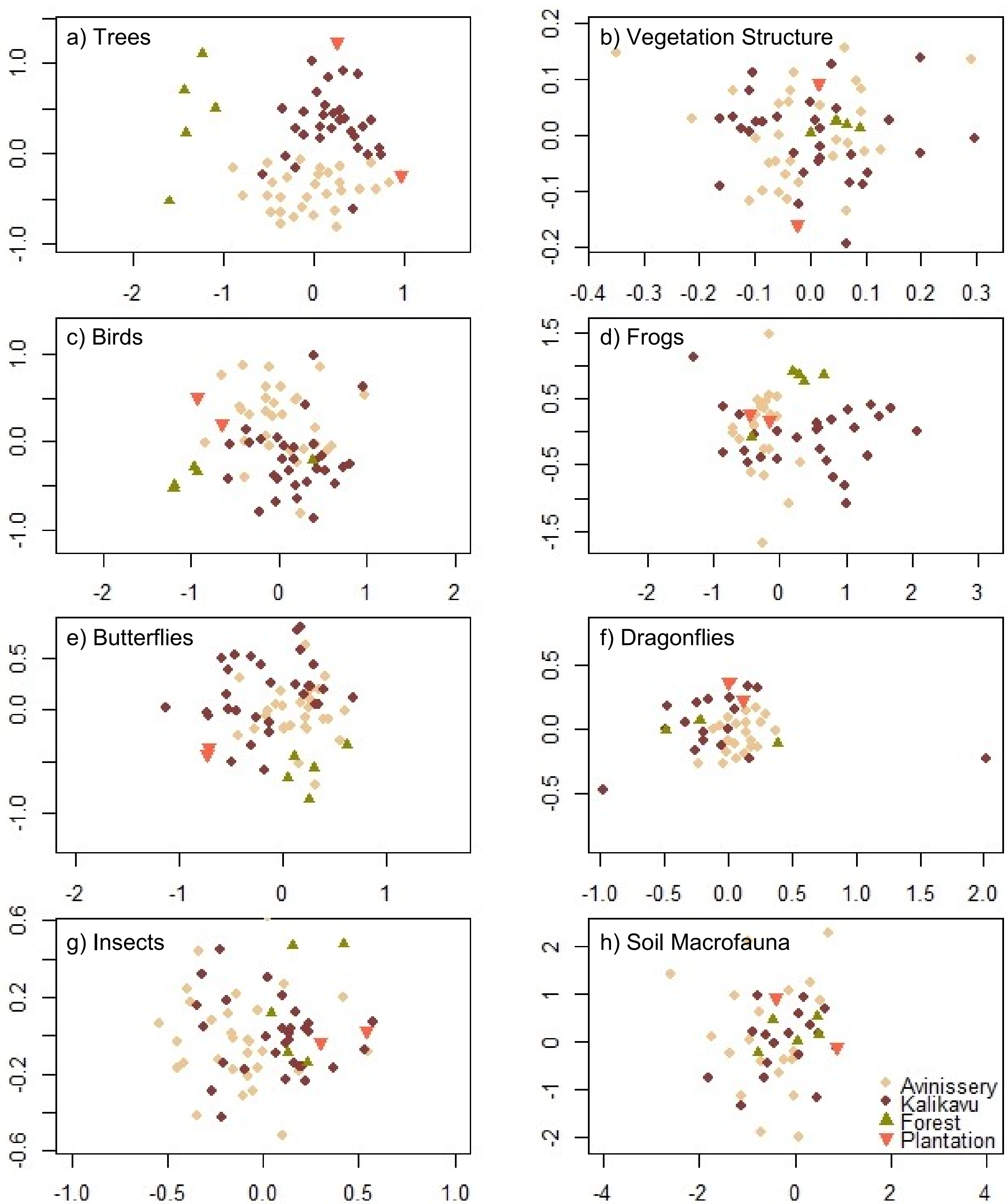

Figure 2.4. NMDS plots illustrating similarity in community and vegetation structure between sites. Vegetation structure includes the mean and standard deviation of canopy cover, canopy height, understory cover and understory height, as well as mean tree DBH and basal area. The following sites were removed due to zero values or extreme outliers – Frogs: 2 from Kalikavu; Butterflies: 1 from Avinissery; Dragonflies: 9 from Avinissery, 13 from Kalikavu; Soil Macrofauna: 1 from Avinissery, 1 from Kalikavu. Final stress – Vegetation: 0.188; Trees: 0.197; Birds: 0.184; Frogs: 0.170; Butterflies: 0.198; Dragonflies: 0.126; Insects: 0.171; Invertebrates: 0.183. R2 – Vegetation: 0.965; Trees: 0.961; Birds: 0.935; Frogs: 0.971; Butterflies: 0.931; Dragonflies: 0.984; Insects: 0.939; Invertebrates: 0.966 (Source: Author).

2.3.3 Environmental Relationships

The factors which constitute the best model for each GLM, as determined by AIC_c values, vary by taxa and by region (Appendix D). Both local and landscape factors are important in the GLMs, but birds and soil macrofauna are most affected by landscape factors, while butterflies and insects are most affected by local factors (Table 2.4).

Table 2.4. Explanatory variables with the strongest correlation coefficient for each GLM for each taxa and region. Parameters were ranked according to their standardized coefficients to determine the factors with the greatest effect on each taxon. Bold face factors indicate landscape variables while standard face factors indicate local variables.

	Avinissery	Kalikavu
Birds	SD Canopy Cover **Human Structure Area (250 m)**	**Distance to Road** **Human Structure Area (1 km)**
Frogs	**Distance to Rice Paddy** SD Understory Height	Mean Canopy Height **Human Structure Area (250 m)**
Butterflies	SD Canopy Cover Property Size	Mean Understory Cover Tree Diversity
Dragonflies	SD Canopy Cover **Open (Rice Paddy) Area**	Mean Canopy Height Mean Understory Cover
Insects	Mean Understory Cover Mean Understory Height	SD Canopy Height Mean Understory Cover
Soil Macrofauna	**Distance to Rice Paddy** **Open (Rice Paddy) Area**	SD Canopy Height **Open (New Agricultural) Area**

Of the local factors, structural variables (including mean understory cover, standard deviation of canopy cover and mean and standard deviation of canopy height) appear more often in the best models than variables pertaining to tree community composition (such as tree richness, abundance and diversity). Mean understory cover is significantly positively correlated with insect diversity and butterfly abundance, richness and diversity in Kalikavu, and negatively correlated with insect abundance in Avinissery and dragonfly presence in Kalikavu. Canopy height (mean and standard deviation) is an important factor in Kalikavu, positively affecting frogs, insects, dragonflies and soil macrofauna, while the standard deviation of canopy cover positively affects birds, butterflies and dragonflies in Avinissery.

Of the landscape factors, the percentage of open and development area, and the distance to the nearest road and paddy are included in the final models. Distance to the nearest forest reserve shows no significant correlations with any independent variable. The percentage of developed area in the surrounding landscape significantly affects bird abundance, richness, diversity and community composition in both Avinissery and Kalikavu, as well as frogs in Kalikavu, though frogs and birds in Avinissery responded more strongly to the 250 m landscape context while those in Kalikavu responded more strongly at 1 km (Appendix D). Paddy area positively influences frogs, dragonflies and soil macrofauna in Avinissery; frog abundance and diversity, and soil macrofaunal richness and diversity are negatively correlated with distance to the nearest paddy, while the presence of dragonflies is positively correlated with the percentage of paddy area in a 250 m radius. Soil macrofauna abundance is positively correlated with open agricultural area in both Avinissery and Kalikavu, while diversity is negatively affected.

2.4 Discussion

2.4.1 The Biological Communities of Kerala Homegardens

The evidence presented here illustrates that the homegardens of Kerala are capable of supporting a rich community of bird, amphibian and invertebrate species. The species assemblages observed in these gardens are made up of common species of low conservation concern. Human-influenced agricultural systems, including agroforests, typically attract synanthropic species – species associated with humans or areas of high anthropogenic influence – and do not usually include threatened native species (Francis and Chadwick 2012). The species identified in this study are not necessarily synanthropic (thriving in human-dominated areas), but given that Kerala is a highly populated landscape, and has been for thousands of years, the species that persist in agroforests are likely only those which have adapted to withstand a high level of human disturbance.

The ordination of the community data shows no apparent separation of any faunal communities between Avinissery and Kalikavu, suggesting that the species assemblages in the homegardens are not distinctly different between the highland and lowland regions. This provides further evidence that the species encountered in homegardens are generalists, capable of adapting to a broad range of environmental and anthropogenic influences. Meanwhile, the ordination of the avian community data suggests that the forest sites contain species assemblages of birds that are distinct from the homegardens. Only five forest sites were sampled in this study, yet they contained twenty-two bird species not found in any of the sixty homegardens. Had sampling in the interior of more remote forest reserves been feasible, this number would likely be much greater. Of these unique species, nine are known to be forest specialists, rarely encountered in agricultural areas. These species may be particularly sensitive to human disturbance, which is still more prevalent in agroforests than forests, or require specific symbiotic or prey species that are absent in agroforests. This closely mirrors results from Goodale *et al.* (2014), who found a greater abundance of birds, and a distinct avian community composition, in forests than agroforests in Kerala.

It is unlikely that my study has captured the full suite of animal species which make use of homegardens, because rare species are, by definition, less likely to be detected. Sampling also took place only during the wet monsoon season, excluding any seasonal migratory secies. Additionally, the sampling procedures used for faunal groups are imperfect, and observations can be influenced by a variety of factors including weather, temperature, time of day, observer bias and animal behaviours. This study was designed to provide a comparative analysis of relative biodiversity between different plots, as opposed to a measure of absolute diversity, and therefore the sampling techniques employed in this study were chosen such that sampling of several faunal groups could be completely quickly and simultaneously. But the lack of rare or vulnerable species does suggest that homegardens may not be effective for conserving specific species of concern. Converting forested land to agroforests could therefore prove detrimental to many forest specialist species and would not be recommended.

Although forest reserves continue to be a critical component of conservation management, homegardens can help maintain biodiversity where forests are already scarce. The species within the gardens are common generalists, but this does not negate the ecosystem services provided by these animals. For example, in his review of avian communities of forests and agricultural systems, Sekercioglu (2012) found a greater percentage of seed dispersing frugivore and pollinating nectarivore species in agroforests than in forests or traditional agricultural lands. Additionally, nearly one third of all bird species are known to make occasional use of agricultural lands, which may include use as foraging ground for large insectivorous and carnivorous species which prey on insect and mammalian pests (Sekercioglu *et al.* 2007).

Agroforests may also help prevent the proliferation of nuisance species such as granivorous birds, which are major crop predators and are much less common in agroforests than in traditional agricultural areas (Sekercioglu 2012). Finally, although forest specialists may not be common in agroforests, these systems may still supply important links between forests remnants (Graham 2001), as well as nesting grounds and microclimatic refugia (Sekercioglu *et al.* 2007).

2.4.2 Environmental Indicators of Biodiversity in Homegardens

While protected areas and forest reserves are critical for species conservation, agroforestry systems have the potential to supplement biodiversity and ecosystem service provisioning, particularly in highly populated landscapes with little to no remaining forest. In this study of homegardens, the predominant agroforestry system in Kerala, I found that biodiversity varies greatly among both gardens and taxa. While homegardens possess the ability to harbour a high diversity of organisms, the amount of diversity housed depends on the characteristics of the particular garden and the animal group of interest. For this reason, it is important to capture the full range of structural variability in agroforests, as well as consider multiple taxa when assessing the contribution of agroforestry lands to biodiversity conservation.

Homegardens in Kerala are highly variable in composition and structure. Tree abundance, on average, is greater in the homegardens of the more rural region of Kalikavu than in Avinissery, but tree species richness is lower. This result is contrary to the popular perception in conservation that more rural areas are necessarily more diverse. This is partially due to the densely organized plantation-style cropping of rubber and arecanut that is more common in Kalikavu. Additionally, agricultural properties in Kalikavu are larger on average, and studies have shown that smaller homegardens tend to have more tree species per unit area (Fifanou *et al.* 2011; Kumar *et al.* 1994, 2011; Mohan *et al.* 2007). The tree richness and diversity within the homegardens is lower on average than the forest sites, though not drastically so. This is consistent with findings from Kumar *et al.* (1994) and Mohan *et al.* (2007) that suggest the tree diversity of Kerala homegardens is similar, though lower on average, to that of nearby moist deciduous and wet evergreen forests of the Western Ghats. Despite having similar numbers of tree species, the tree community composition differs between homegardens and forest sites, as well as between the two homegarden regions, Avinissery and Kalikavu. This is partially influenced by a greater representation of rubber (*Hevea brasiliensis*), arecanut (*Areca catechu*) and cacao (*Theobroma cacao*) in Kalikavu, and a greater representation of nutmeg (*Myristica fragrans*), mango (*Mangifera indica*) and Garuga (*Garuga pinnata*) in Avinissery. Forest sites, meanwhile, lack most of the commercial and edible species found in homegardens, but house a variety of native trees that were not found in homegardens.

While the tree species housed within homegardens differ between the two regions, and both differ from forest sites, the overall vegetation structure does not. No consistent regional difference in canopy and understory structure was evident in the NMDS plot (Figure 2.4b), suggesting that agroforests across regions can sustain the vegetative complexity offered by forests, even if they are largely composed of more economically or socially valued tree species. Structural variables explain more of the observed variation in faunal diversity in our GLMs, and are therefore likely of greater importance to animal biodiversity in homegardens than tree richness or diversity. This may be a reflection of the prevalence of generalist fauna in these systems, which are not strongly associated with any specific tree species but are capable of utilizing a variety of different resources.

Bird diversity in this study is best explained by the standard deviation of canopy cover and proximity to human structures. This is consistent with Summers *et al.* (2011) and Griffith *et al.* (2010) who found decreasing bird abundance and richness with increasing proximity to roads, as well as Philpott *et al.* (2008; 2012) who demonstrated declines in bird abundance and richness with decreasing canopy complexity. Proximity to forest, tree size and tree density have also commonly been identified as important environmental factors influencing bird species abundance and richness in agroforestry landscapes (Clough *et al.* 2009; Maas *et al.* 2015; Naidoo 2004; Waltert 2005). In this study, however, tree size and abundance are less important than proximity to human structures, and I found no significant relationship between bird abundance or diversity and distance to the forest reserve. This may be due to a lack of sites immediately adjacent to the forest reserve (the closest site was 179 m away), as the effect of the forest may diminish as distance increases. Similarly, while several studies have found major differences in bird communities between forests and agroforests (Naidoo 2004; Waltert *et al.* 2004, 2005), my community analysis shows more overlap between homegarden and forest communities, and no regional differences. This may reflect a dominance of adaptive generalist species which are capable of utilizing agricultural spaces as well as forests, resulting in similar bird assemblages across the landscape. Bird species richness and abundance, however, is much greater in forest sites than in homegardens, and this is likely an underestimate due to the low number of forest samples and the reduced likelihood of visually detecting birds in tropical forests (Karr 1981). Together with the relative unimportance of forest distance in the GLMs, this suggests that many forest species may be much less common and highly specialized to forest interior habitat, resulting in little diffusion between the forest and surrounding agricultural habitat.

Few studies have addressed amphibian diversity in agroforestry systems, but those that exist have shown lower richness and abundance in agroforests compared to natural forests, and positive correlations with canopy complexity (Russell and Downs 2012; Murrieta-Galindo *et al.* 2013; Wanger *et al.* 2009, 2010). I found only twelve different frog species within the homegardens, with high overlap in community composition between the two regions. Frog species richness does not significantly differ between the two regions, though abundance is significantly lower in Kalikavu. This may be because Kalikavu lacks paddy wetland, which acts as important habitat for frogs who require both aquatic and terrestrial areas to complete their lifecycles (Naito *et al.* 2012), and is a strong indicator of frog abundance in Avinissery. While Kalikavu does contain some ponds, wells and other regularly saturated areas which support frogs, the majority of the wetland habitat has been eliminated due to infilling (Kumar 2005). The overall low diversity of frogs compared to other animal groups in this study may be compounded by the relative lack of taxonomic description for frogs in Kerala (Nair *et al.* 2012), which results in several different species being classified under the same name or only to genus. But it is more likely a result of substantial declines in frog populations that Kerala, and most tropical regions around the world, have experienced over the past several decades (Houlahan *et al.* 2000). Herpetologists speculate that the global loss may be a related to habitat destruction, climate change, chemical contaminants and disease (Collins and Storfer 2003; Skerratt *et al.* 2007; Stuart *et al.* 2004), and evidence from Kerala suggests pesticide use in rice paddy fields (Kittusamy *et al.* 2014) and fungal infections by *Batrachochytrium dendrobatidis* (Molur *et al.* 2015) may be at least partially to blame.

Of the invertebrates, butterflies are the most thoroughly described and most easily recognizable by species in this region. Almost all butterflies were identified to species, and overall species richness is greatest for this group. Richness and abundance of butterflies is significantly greater in Avinissery, but with little difference in community composition. Butterfly response variables are all strongly influenced by property size. This may reflect a negative association with human disturbance, which is likely greater in small properties, or possibly a greater abundance of flowering ornamental plants on large properties. The presence of nectar-bearing plants, which I did not directly account for in this study, is known to influence butterfly diversity in agroforestry systems (Pryke and Samways 2003). Butterfly richness and diversity are also strongly correlated with variation in canopy cover in Avinissery. This is similar to findings from Dolia *et al.* (2008) which show significant negative correlations between butterfly species richness and abundance and canopy cover in Kerala. However, Dolia *et al.* (2008) suggest low canopy cover is beneficial to butterflies while my results indicate canopy heterogeneity is more important. Interestingly, Dolia *et al.* (2008) also found proximity to a forest reserve to be a strongly correlated with butterfly diversity, whereas I did not. Instead, butterflies in Kalikavu show stronger correlations with tree diversity and understory cover, which are more limited in Kalikavu due to the prevalence of plantation style cropping.

Dragonflies, while mostly identified to species, are much less rich and abundant than butterflies, with no individuals detected in 37% of homegardens (9 in Avinissery and 13 in Kalikavu). Dragonfly presence in Kalikavu is positively correlated with understory cover and canopy height, while in Avinissery it is strongly driven by variation in canopy cover. This is consistent with results from Samways and Sharratt (2010), who similarly found that heterogeneity in canopy cover correlates with greater dragonfly species diversity, possibly because both sunlit and shade conditions are important for temperature regulation. Dragonflies in Avinissery were also strongly affected by the presence of paddy wetland, which provides necessary aquatic habitat known to be essential for *Odonata*. Water body characteristics, including degree of pollution, are also important indicators of dragonfly diversity (Kietzka *et al.* 2015), but were not assessed in this study.

The true diversity of invertebrates in Kerala homegardens is not well captured in this study due to our inability to identify all individuals to species, as tropical invertebrates in general are poorly described relative to other taxa. This also contributes to the high overlap in community composition of insects and soil macrofauna observed between sites, as individuals were classified by order rather than species. However, this may better represent the functional diversity of invertebrate groups, as species-level metrics may be easily skewed by highly abundant and species-rich families, such as ants (*Formicidae*). Insects (which includes *Araneae* but not *Odonata* or *Rhopalocera*) were by far the most abundant taxa in this study, with up to 12994 individuals at a single site, which is partially because this group contains 22 different orders. Of these, the *Hymenoptera*, followed by *Diptera*, were most abundant, and *Haplotaxida* and *Sphaerotheriida* were least. Overall, the diversity of this group was most influenced by understory height and cover, and variability in canopy height. This result however, fails to identify other local and landscape factors which may be more important in determining diversity within any one particular insect order. For example, Bisseleua *et al.* 2009 show that ant richness responds to tree richness and density in cacao agroforests in Camaroon, while Jha and Vandermeer (2010) show that bees respond to canopy cover, tree richness and the number of flowering trees in Mexican agroforestry landscapes. An order-specific study of insects would be necessary to determine if similar patterns exist in Kerala homegardens.

Soil macro-invertebrates are low in abundance relative to other taxa, and heavily dominated by earthworms (*Haplotaxida*). The abundance and diversity of soil macrofauna is strongly related to landscape context, exhibiting a positive relationship with open agricultural area. This may reflect differences in physical and chemical soil properties, which are known to influence earthworm abundance in agroforestry systems (Geissen *et al.* 2009). For example, gardens that are surrounded by paddy wetland may have greater soil moisture and nutrient retention, whereas heavily treed areas may be drier and have lower soil nutrient content due to increased drainage. Alternatively, the pattern may be driven by interactions with predatory species; for example, treed areas may support specific bird or mammal species which feed on soil macrofauna. Further research will be necessary to determine the causal link between soil macrofauna abundance and landscape context in Kerala homegardens.

2.4.3 Managing for Biodiversity

This project has illustrated that while homegardens are highly variable in species richness and abundance, there are no systematic differences in species assemblages or vegetation structure across the landscape. This suggests that a similar community of wild species, consisting mainly of common generalist species, inhabits homegardens across Kerala regardless of the proximity to forest reserves or urban centres. Instead, the observed variability in species diversity depends largely on local factors, particularly canopy and understory complexity, as well as fine-scale landscape factors, including proximity to paddy wetland and lack of human structures.

Homegardens in Avinissery and Kalikavu differ mainly in tree composition, which is influenced by both physical factors (elevation and water availability) and socioeconomic factors (property size and management decisions). The overall vegetation structure does not consistently differ between regions; both areas have a range of canopy and understory characteristics. However, different local and landscape factors affect the diversity of different taxa in each region. The standard deviation of canopy cover and proximity to paddy wetland are the strongest drivers of biodiversity across taxa in Avinissery, while understory cover and canopy height are more influential in Kalikavu. The lack of paddy wetland in Kalikavu accounts for part of this difference, but it may also be explained by differences in tree density. Kalikavu homegardens, which have higher abundance but lower richness of trees, have a greater mean canopy cover and a much smaller range. This may result in a lack of sufficient variation to capture the effects of canopy cover on biodiversity in this region. It is also important to note that the effect sizes of our models were generally small (Appendix D), meaning that an increase in any of the significant environmental factors will result in only a small change in animal abundance, richness or diversity. This may be due in part to our low sample sizes, but it suggests that multiple influences shape the observed patterns in biodiversity, and no single factor is an ideal indicator of biodiversity in homegardens.

To promote animal diversity in Kerala homegardens, our results indicate that influencing management of both individual homegardens and the surrounding landscape may be necessary. Within gardens, complex canopies and understories, with high variation in height and cover, are associated with greater faunal diversity. Conservation strategists who wish to maintain biodiversity could focus on encouraging both spatial and temporal intercropping, to increase variation in canopy height and cover, as well as dissuading understory management. Traditional Kerala homegardens include a diverse array of tree species which are relatively unmanaged and therefore create a more complex canopy. However, increasing focus on cash crops has resulted in an increase in plantation-style mono-species cropping (Kumar 2005), which creates a highly uniform canopy. While tree diversity is also a valuable feature of homegardens, owners who wish to maximize their economic gains could be encouraged to intercrop their rubber or areca with other useful species, or alternate tree planting times to simultaneously promote biodiversity and reduce risks associated with disease, drought, and market fluctuations (Schroth *et al.*2004). The homegarden understory is typically not of any concern to homegarden owners, unless they are actively growing vegetables and spices. Many owners allow uncontrolled understory growth and harvest valuable medicinal plants that grow voluntarily. However, routine cutting occurs in the wet season to control mosquito and snake populations, and also during rotations of rubber and areca trees. Dissuading understory removal may therefore be difficult unless a viable alternative to controlling harmful species is provided.

In the areas surrounding homegardens, a high number of paddy wetlands and low number of human structures are required to promote animal diversity. However, influencing the landscape to contain more desirable features will likely be difficult. While the Kerala government has already taken measures to stop conversion of paddy wetlands into new housing developments (Kerala Conservation of Paddy Land and Wetland Act 2008), this has failed to prevent the rapid loss of paddy land (Fox 2015). To further complicate this matter, efforts to encourage rice cultivation, and therefore promote wetland conservation, could effectively reduce the benefit of the wetland to wildlife by promoting agrochemical use and human disturbance. Additionally, dissuading construction is a difficult and complex problem, which will require a high level of strategic socioeconomic planning to minimize the negative impact on local peoples.

2.5 Conclusions

Agroforestry is a broadly defined term; much variability exists in what constitutes an agroforestry system. In Kerala, homegardens (small-scale agroforestry systems within a homestead) dominate much of the landscape and are highly variable in size, composition and structure. This has important implications for their potential to conserve wild animal biodiversity.

My study indicates that the homegarden features which best support biodiversity depend both on the region and taxa of interest. However, common factors across taxa include canopy and understory complexity and proximity to paddy wetland. Additionally, the proximity to human structures negatively influences birds. These results suggest that biodiversity in Kerala homegardens could be increased by promoting management activities that increase canopy and understory complexity, such as increased intercropping and reduced understory cutting, and by implementing landscape management policy that aims to reduce the destruction of paddy wetland and rapid expansion of housing construction. The latter issue is already being addressed by the Kerala government, but the continuing decline of agricultural lands in the region suggests more needs to be done.

While agroforests can act as important refugia for wild species, it is clear from this, and other, studies of biodiversity in agroforests that these systems are not a viable replacement for natural forests. Forest reserves house a multitude of specialized species that do not persist in human influenced lands. I do not suggest that agroforestry is a solution for global biodiversity conservation; rather I suggest that it has conservation value where it already exists, particularly in landscapes such as Kerala where the few remaining forest reserves are highly protected and highly static, and the only other habitat available for wild species exists within agricultural properties. Deforestation is no longer a substantial threat in Kerala, but homegardens are rapidly disappearing to make way for larger and larger housing developments. If this unbridled landscape conversion continues unchecked, Kerala stands to lose much of its faunal diversity, and the ecosystem services it provides.

Chapter Segue

In the previous chapter, I have described my use of biological sampling techniques to estimate the faunal diversity of homegardens in Kerala, and to identify the garden characteristics correlated with this diversity. I found that the diversity of organisms varies both between individual gardens and between animal groups, and that this variability can be linked to a variety of different homegarden characteristics. There are, however, some characteristics which appear to promote richness and abundance of multiple taxa; these include canopy and understory complexity and proximity to paddy wetland. Based on this finding, I have suggested that a manager wishing to sustain local wildlife in this agricultural landscape could focus on encouraging intercropping and discouraging understory cutting and infilling of wetlands. This recommendation, however, fails to account for the values and interests of the homegarden owners; a far too common occurrence in research on agroforestry systems. As it is the individual land owners who protect, manage, and ultimately determine the fate of homegardens, it is important to understand their attitudes toward biodiversity conservation, what they perceive to be the benefits and drawbacks of local wildlife, and their motivations for maintaining homegardens in the face of ongoing land-use change. Through the use of sociological survey and semi-structured interview techniques, the next chapter addresses this concern by analysing the perspectives of the homegarden owners on wildlife, agriculture, conservation and the environment.

Chapter 3

The Human Face of Homegarden Conservation

3.1 Introduction

Over the past two decades, habitat loss has been the primary focus of global biodiversity conservation efforts (Brooks *et al.* 2006; Myers *et al.* 2000). Parks, reserves and protected areas have been the leading strategy for conservation managers (Joppa *et al.* 2008; Pimm *et al.* 2001; Naughton-Treves *et al.* 2005), and countless studies have shown that preserving large tracts of natural ecosystems is the most effective conservation strategy for most species (*e.g*., Andren 1994; Bender *et al.* 1998; Pardini *et al.* 2005). However, in ecologically sensitive, but highly populated landscapes, land reserves are not always possible due to the conflicting needs of local people (Alers *et al.* 2007), and sufficient space may not be available for effective conservation of wide-ranging or migratory species (Poiani *et al.* 2000). In these cases, conservation managers must consider the entire landscape matrix as a whole in order to create a network of habitat patches (Poiani *et al.* 2000).

Conservationists have thus begun exploring private lands as a potential option to increase available habitat, with governments and NGOs offering conservation easements and ecosystem service payments to land owners in exchange for maintaining viable habitat on their properties (Doremus 2003; Fishburn *et al.* 2009). But this strategy has rarely been extended to include agricultural or multi-purpose lands (Harvey *et al.* 2008). Agroforestry systems, which typically exist on privately owned lands, may provide much needed habitat or forest corridors for wild species (Schroth *et al.* 2004). Broadly defined as an agricultural system that integrates trees with other crops or livestock (Huxley 1983), agroforests can house a rich diversity of small mammals, birds, amphibians and insects, in addition to providing food and other resources to local families (Schroth *et al.* 2004). These heterogeneous and structurally complex systems have been heralded as sustainable methods of food production that maintain the ecosystem services and habitat provided by natural forests (Steppler and Nair 1987). In addition to reducing pests and disease, sequestering carbon, and regulating water and air quality, agroforestry systems are believed to promote biodiversity by creating fully functioning ecosystems that resemble the natural forest environment (Schroth *et al.* 2004).

The management of private agroforestry lands, however, is subject to the decisions of individual land owners, whose needs and interest may vary. Understanding the social drivers of land-use change in agroforestry landscapes is therefore critical if we wish to promote the maintenance of these systems. Further, convincing land owners to abide by environmental or conservation based laws or agreements can be difficult if they do not fully understand or appreciate the motivations behind such mandates (Ferranto *et al.* 2012; Lemke *et al.* 2010). Human-wildlife conflict is prevalent among agricultural land holders, and it can therefore be difficult to promote wildlife conservation in communities where the benefits of biodiversity are not recognized (Gadd 2005; Suryawanshi *et al.* 2014).

Understanding the attitudes and concerns of local land owners can aid the implementation of conservation strategies (Conradie *et al.* 2013; Mir and Dick 2012). Most studies of attitudes toward wildlife, however, have focused solely on the response of local communities to controversial or newly implemented conservation strategies, particularly the establishment of parks and reserves (*e.g*. Amoah and Wiafe 2012; Moswete *et al.* 2012; Ogra 2009). These studies also tend to focus on the economic gains provided by community conservation programmes, or access to natural forest products; rarely have researchers addressed attitudes toward the fundamental concepts of biodiversity and wildlife conservation (but see Teel and Manfredo 2010, Kaczensky 2007, Zinn and Shen 2007, for examples).

Kerala, a tropical state in southern India, has a long history of tropical agroforestry as well as a rich diversity of indigenous species. The area is of high global concern to conservationists, for both its abundance of wild species and the high level of risk those species currently face (Myers *et al.* 2000). The region is heavily populated, with approximately 35 million people, and has 2449.23 km^2 (6.3% of the total state area) in protected areas, almost exclusively in the mountain highlands. The majority of the remaining landscape is occupied by privately owned agricultural lands, which include rice paddy wetlands; plantations of rubber, coconut and arecanut; and a variety of mixed agroforestry systems including homegardens and coffee, tea or cocoa based agroforests. The area is currently undergoing rapid expansion of housing developments, at the cost of both homegardens and paddy wetlands (Fox 2015), as well transitioning away from traditional agroforestry practices toward commercial plantations of coconut and rubber (Kumar and Nair 2004).

While some programs are in place to promote sustainable agriculture, there is little to no information available on the perspectives of local peoples towards the loss of agricultural land, wildlife conservation or environmental issues in general. This type of information is necessary to help inform conservation strategies, anticipate public response to conservation programs or legislation, and predict the potential consequences of conservation measures for local peoples. As the owners are ultimately responsible for the maintenance of homegarden systems, it is important to know what motivates them to maintain their gardens, what might cause them to convert these lands for other purposes, how they view local wildlife on their property, how they feel about ongoing efforts to address environmental degradation (both locally and globally), and whether they are willing to participate in such efforts. Here, I attempt to address this knowledge gap by soliciting opinions from local land owners who maintain homegardens around their primary residence. These traditional agroforestry systems contain a variety of crop species that are used both for sale and personal consumption, as well as a multitude of wild animal species that can be beneficial or problematic to the land owner. Using surveys and semi-structured interviews, I address the following questions:

1. What are the attitudes of homegarden owners in Kerala to ongoing changes to the landscape?
2. What incentives do they have to maintain their homegardens and what do they feel drives the conversion of agricultural lands to other land uses in the area?
3. What are their attitudes toward wildlife, and have they observed changes in the abundance of wild animals over the past decade?

4. Which, if any, environmental issues concern them, and do these concerns impact the way they manage their land?

3.2 Methods

3.2.1 Study Context

This study was conducted in the state of Kerala in southern India. The 39, 863 km^2 coastal mountainous area receives 2900 mm of rainfall annually, and is home to an estimated 5725 endemic species (Kerala Forests and Wildlife Department 2009). Kerala boasts the highest Human Development Index in India, as well as the highest literacy rate (93.91%, 2011), but falls tenth (of 29 states) in Gross Domestic Product. The economy is primarily service based (60.66% of Net State Domestic Product in 2003-2004) with tourism related industries (trade, hotels and restaurants) contributing 23.33%. The sector is heavily influenced by remittance income obtained from some 2.2 million Keralites working abroad, particularly in Persian Gulf countries, which contributes nearly one third of the state domestic product (500 billion rupees; Raman 2012). Agriculture is the second largest sector, contributing 13.15% (India Planning Commission 2008). Approximately 76.6% of the total land area is under agricultural use, with over half of that land being occupied by coconut, rubber and rice. Homegardens are the dominant agroforestry system in Kerala, with approximately 4.32 million homegardens covering an area of 14,000 km^2 (Kumar 2006).

Two agricultural landscapes were chosen as study areas. Avinissery is a densely populated (3393 persons/km^2) lowland region, six kilometers from the city of Thrissur, the fourth largest city in Kerala (Figure 2.1). The landscape is a highly fragmented mixture of small rice paddy wetlands and homegardens, evenly dispersed with houses, roads and other developments (Figure 2.2a). Rice and coconut are the dominant crops produced in the region, and residents are predominantly Hindu and Christian (Kerala Department of Economics and Statistics 2011). Kalikavu, on the other hand, is a relatively sparsely populated (807 persons/km^2) highland region, close to the Silent Valley forest reserve. The major crops include rubber, coconut and arecanut (Kerala Department of Economics and Statistics 2011), and the landscape features a more patchy distribution of large rubber plantations and homegardens, with fewer roads and developments spread throughout (Figure 2.2b). Residents here are primarily Muslim.

3.2.2 Sampling Procedure

I conducted 30 surveys and 30 semi-structured interviews in each of the two regions. Prior to sampling, I met with the local government representatives to alert them of my presence and purpose. I was provided with official letters from each office to aid in recruiting participants.

Potential participants were selected based on the suitability of their homegardens for biological analysis, as this study was paired with that of Chapter 2. The garden was required to: 1) be at least 900 m^2, 2) include a minimum of two different tree species 3) be located on the same property as the primary residence of the owners and 4) be a minimum of 200 m from all other samples. Appropriate households were located using a variety of techniques, including using the satellite imagery to identify suitable areas, seeking help from local government representatives and asking home owners for recommendations (snowball sampling). Potential participants were approached at their residence, informed of the purpose and procedures of the study, and invited to participate. Participants were required to give oral consent and be over the age of eighteen (Appendix E). Female house members were encouraged to participate in the study but were often less willing than male house members.

3.2.3 Data Collection

After obtaining consent from the participant, I conducted a short survey including both closed and open ended questions (Appendix F). Surveys typically took twenty minutes. Due to regulations concerning social data collection in India, demographic information was not collected. Participants were not asked for their age, marital status, religion, caste or income, although this information was noted if freely provided. Participants did not appear offended by or uncomfortable with any of the questions.

Translators were required in almost all interviews. Prior to initiating the study, translators reviewed the survey questions, as well as the overall goals of the project. Some participants spoke partially in English, and two spoke exclusively in English. Translators were instructed to translate as close to verbatim as possible, and I transcribed all information immediately exactly as provided in English. The surveys/interviews were not recorded. Many questions required additional clarifications, but I was careful not to suggest possible answers and thereby provide leads to the participant. Quotations presented in this thesis are translated from Malayalam unless otherwise indicated, and grammar has been corrected for ease of reading.

Immediately following each survey, I conducted semi-structured interviews using topics covered in the survey as discussion points. Typical beginning questions included "Why do you use organic/chemical pesticides/fertilizers?" "Why do you think frogs/birds/snakes are increasing/decreasing?" "Are these changes good or bad?" or "Are there any environmental problems in your area". Interviews ranged from fifteen minutes to one hour, depending on the enthusiasm of the participant.

In total, 67 individuals from 60 households were surveyed and interviewed. In seven cases, two heads-of-households contributed information to the study (Figure 3.1), and all data were included and treated as one sample. Age, gender and religion were inferred based on visual cues. The majority of participants were male and between the ages of 40 and 60. Size of land holdings serves as a reasonable proxy for wealth; as participants were required to own at least 0.1 hectares with a house on the property, and most participants held less than one hectare, it is likely that they had similar financial worth. Most households relied on agriculture as their primary or only source of income, and ten participants in Avinissery and three participants in Kalikavu reported owning additional agricultural land elsewhere.

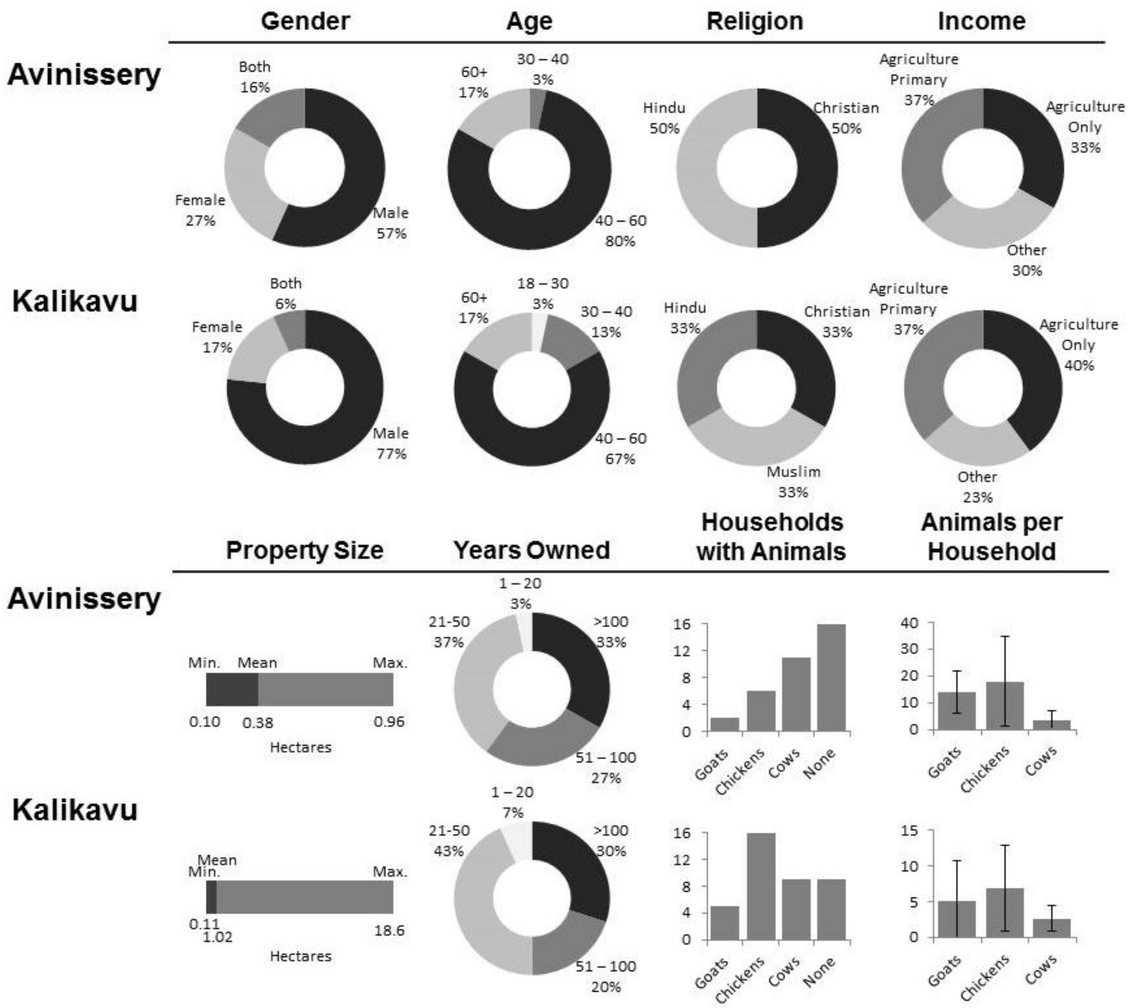

Figure 3.1. Demographic distribution of participants and description of agricultural properties in each of the two study regions. Gender, age and religion were inferred, while the primary income source, the number of years the property has been owned by the family, and the number of animals were specifically asked during surveys. Property size was measured using GPS. One extreme outlier in number of chickens (3000) in Kalikavu has been removed for ease of representation (Source: Author).

3.2.4 Data Analysis

Quantitative survey data were analysed in RStudio™ (version 0.97.551, RStudio 2012) using primarily descriptive statistics and frequency analysis. Where applicable, Chi-squared goodness of fit tests were used to examine relationships between categorical variables, and non-parametric Mann Whitney U tests to examine relationships between numerical and categorical data. Qualitative data were transcribed and analysed in Nvivo™ (version 10.0.638.0 SP6, QSR International Pty Ltd. 2014). Open coding was applied to both survey and interview responses using primarily *in vivo* codes. Codes were based directly on topics discussed by participants in their responses. Selective coding was then used to sort coded text into twelve distinct categories based on the *a priori* research questions (Table 3.1). These were subsequently sorted into the three broad research themes of agriculture, wildlife and management.

3.2.5 Positionality

Qualitative data collection, particularly in a cross-cultural context, necessitates a critical examination of the subjectivity of the researcher as personal characteristics and social position will influence the dialogue between researcher and participant, and thereby the data (Dowling 2005). I conducted my field work in Kerala as a 25 year old, white, female, Canadian, Anglophone Master's student. This was my second visit to Kerala; I had spent two months in the area the previous year. I had therefore had some prior experience interacting and conversing with locals in the region.

Being visibly foreign in Kerala substantially affected my experiences. As the work was conducted primarily in rural communities, many of the locals had rarely, if ever, encountered non-Indian persons. I frequently attracted a lot of unsolicited attention, which typically included being followed and questioned by groups of women and children. My presence and purpose therefore quickly became widespread knowledge in my research communities, which seemed to increase curiosity and interest, and reduce suspicion, among participants. In Kalikavu, my research team was featured three times in local newspapers, after which most of the community knew me by name. In most cases, potential participants were extremely hospitable and accommodating, often inviting us to stay for lunch or tea and requesting to take photos together. I suspect that being visibly foreign increased the willingness of recruits to participate in the study, although it is possible that it may have also altered their responses to questions. Some participants may have been reluctant to discuss some topics for fear of creating a negative impression of Kerala, although most seemed to speak very freely and openly, even critizing the local government and other community members.

Although Kerala has had many achievements in the advancement of women, including high female literacy and education, gender inequality issues still exist in the region. As a foreign woman however, I felt that I was not at all subjected to the same standards or treatment as local

Table 3.1. Major themes, categories and codes used in the data analysis.

Themes	Categories	Sub-Categories	Example Codes
Agriculture	Maintenance	Feasibility	*Labour scarcity, old age, easy, close by, cost, affordable, reliable, land scarcity, profit*
		Income/Livelihood	*Income, livelihood, job*
		Self-Sufficiency	*Self-sustaining, produce, market, food*
		Tradition and Legacy	*History, tradition, family, children, father, hereditary*
		Other	*Medicinal plants, disease, norm, ability, water, preference, value, aesthetic, enjoyment*
	Land Management	Chemical	*Cost, edible, health, availability, subsidies, yield*
		Organic	*Cost, health, availability, manure, soil, worms, natural, harmless, compost*
	Problems	Climate and Water	*Temperature, rain, water, flooding, hot, wind*
		Labour	*Labour, workers, cost, profitable, affordable*
		Markets and Income	*Cost, income, yield, economical, market*
		Pests and Disease	*Pesticides, pests, disease, maholy, chemicals, boar, elephant, rats, birds*
		Yields	*Yield, production, fertilizers, soil, time*
		Other	*Officials, government, subsidies*
	Landscape Change	Types of Change	*Agriculture, paddy, homegardens, buildings, roads, houses, electricity, shops,*
		Reasons for Change	*Fragmentation, filling, construction, young people, Middle East, profitable, cost*
		Attitudes to Change	*Concerned, future, children, poisoned food, pesticides, health, importance, space*
Wildlife	Problems		*Boar, elephant, tubers, cassava, rats, birds, fencing*
	Benefits		*Children, birds, butterflies, mental satisfaction, pollinate, ecological balance*
	Changes in Abundance		*Trees, paddy land, frogs, bees, habitat, chemicals, snakes, climate change, weeds*
	Attitudes to Change		*Harm, conserve, forest reserve, government, don't care, important, life, right*
Environment	Pollution and Pesticides		*Pollution, pesticides, cars, construction, mines, chemicals, future*
	Climate Change		*Climate change*
	Conservation		*Help, biodiversity, future, animals, trees, hills, forest reserve, government*
	Other		*Trees*

women. I felt that I was granted a greater level of respect, as evident by my meetings with local government officials and police officers, and I did not receive any comments or responses which I suspected were influenced by my gender. But simultaneously, I also felt that many participants, particularly female participants, may have been less intimidated by me because I am female. This may have encouraged some females to participate in the study, who may not have if approached by an all-male research team.

An important potential source of personal bias in this study, which should not be overlooked, is my interest and experience in biology. Although I did not necessarily introduce myself as a biologist, participants were informed that I was a student associated with Kerala Agricultural University, and although I attempted to keep my survey questions neutral, the focus on wildlife and environmental issues would have made my field of interest obvious. It is possible that some participants, knowingly or not, may have altered their responses to be more in favor of organic agriculture and environmental conservation, simply because they suspected I would biased in this direction. However, as so many participants freely offered information about their use of chemical products, and as the majority of participants expressed apathy or negativity toward wildlife, I do not suspect that this bias has substantially influenced the overall results of this study.

3.3Results

3.3.1 Agricultural Decline

> *We used to cultivate everything in the panchayat [town], now agriculture is restricted to [rice paddy] lands. Other agricultural lands have disappeared due to the lack of labour. Now they bring machines from Punjab to cultivate the paddy fields. Labour is so scarce they can't even find machine operators. People in Kerala don't want to do these jobs. They want easy jobs. They are only interested in wages.*
>
> – Participant A16: male, aged 40-60, 20/07/2014

3.3.1.1 Perceptions and Attitudes toward the Changing Landscape

Almost all participants recognize that agriculture in general has decreased in the region over the past decade (Figure 3.2), and many participants put particular emphasis on the loss of rice paddy wetlands. In Avinissery, most participants feel that homegardens in the region have also decreased and overall construction developments have increased. The construction, however, is mostly attributed to increases in housing rather than infrastructure, and some participants suggested that "there is an increase in houses, but no new roads or other developments" (Participant A05: male, aged 40-60, 09/07/2014).

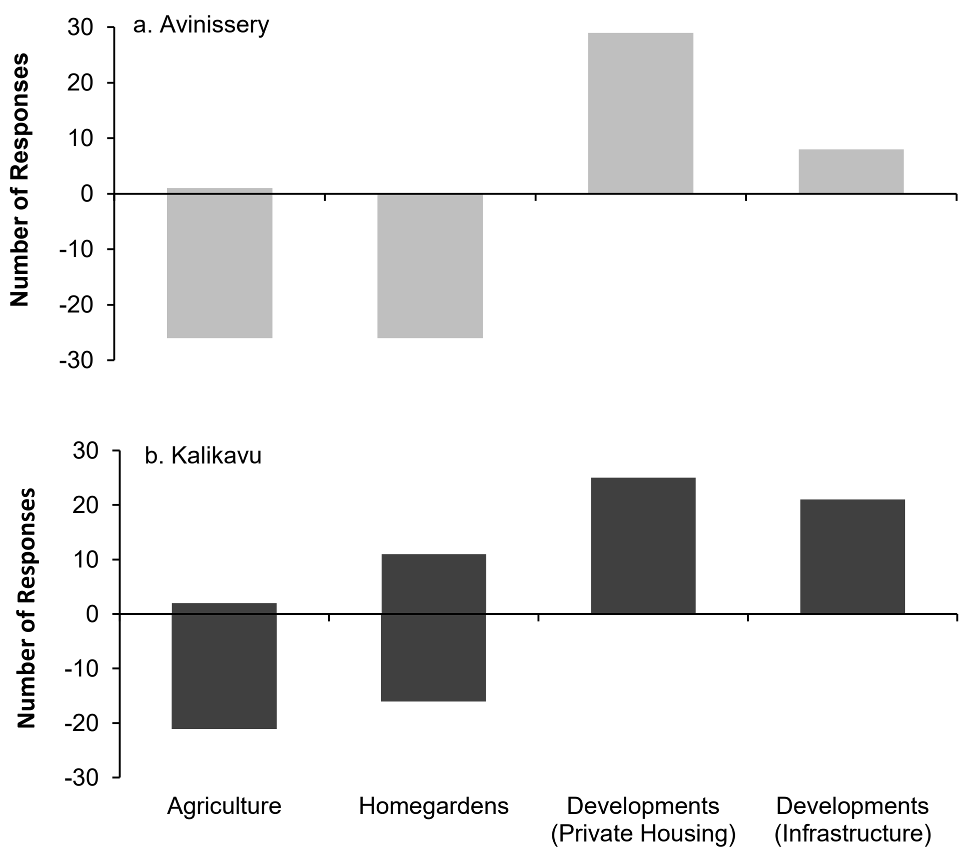

Figure 3.2. Number of respondents indicating that agriculture, homegardens and construction developments are increasing, staying the same or decreasing in a) Avinissery and b) Kalikavu. Participants who chose "increasing" are assigned a value of 1, while those who chose "staying the same" or "decreasing" are assigned a value of 0 or -1, respectively (n=30 for each category) (Source: Author).

Of the two participants in Kalikavu who suggested that agriculture has increased, one suggested that "the increase is only in rubber, everything else has decreased", while the other felt that agriculture has been expanding due to encroachment on "barren [un-owned or unmanaged] lands". Participants also noted a decline in the rearing of domestic animals, as well as increased mechanization of the remaining agriculture. More than half of participants in Kalikavu suggested that homegardens are declining, while others suggested that the number of homegardens is increasing, but they are getting smaller due to land partitioning. Participants also noted that within agricultural lands, many homegardens have been converted to plantations, replacing fruit trees with rubber and arecanut: "We used to have lots of tree species like cocoa, jackfruit, and mango, now it is all replaced by areca and rubber" (Participant K18: male, aged 40-60, 13/08/2014). As in Avinissery, there was a general consensus that construction developments have increased. But unlike Avinissery, participants in Kalikavu listed many other infrastructure developments, in addition to the increase in new houses. These included new roads, electricity, hospitals, and shops.

In general, participants seem to lament the loss of agricultural land. There is a strong sense of attachment to homegardens in particular, as well as a feeling that the people of Kerala are failing to grasp their importance. As one participant noted, "People are not concerned about agriculture and homegardens, they are not knowing the importance of it" (Participant K20: male, aged 18-40, 16/08/2014). The primary concern surrounding the loss of agriculture is the potential loss of food sovereignty. Participants fear that Kerala might become dependent upon other states for food; food which they feel is unhealthy or "poisoned" due to heavy chemical fertilizer and pesticide use. Many stated that agriculture is a "part of their culture" and expressed a strong sense of pride in their ability to be self-sufficient:

> *I am concerned about the future of agriculture in Kerala. I am worried that Kerala will soon become a consumer state because we are already importing vegetables from Tamil Nadu. We will depend on other states, and those farmers use a lot of pesticides which will affect the health of Kerala people. We need to start cultivating in homegardens. Our family is mostly self-sufficient, other people should also try to grow their own food.* – Participant A17: female, aged 40-60, 21/07/2014

Other concerns regarding the loss of agriculture include the loss of traditional medicinal plant species from homegardens, ground water depletion as a result of the loss of paddy wetland, and an increase in mosquitos and related diseases due to increased rubber cultivation.

Attitudes toward ongoing construction developments, however, are varied. Many participants, particularly those who feel strongly about agricultural conservation, have a negative opinion of the changes, stating that "there is too much developing and no return back to the forest" (Participant A12: male, aged 60+, 16/07/2014), and that "people [should] develop in cities to preserve agriculture and the forest" (Participant K20: male, aged 18-40, 16/08/2014). Others have a more pragmatic view of the changes, expressing concern for the loss of trees and lack of interest in agriculture, but understanding that "people need space" (Participant K19: female, aged 18-40, 15/08/2014). However, many participants in both regions feel very optimistic about the construction developments, suggesting that "development is good for rural people" (Participant K11: male, aged 40-60, 09/08/2014). Often, participants do not recognize any trade-off between agricultural conservation and construction developments; one participant expressed a desire for Kerala to become like other major metropolitan areas of the world:

> *[I am] not worried about loss of agriculture lands and increase in population in this area. [Places] like China, Tokyo, Japan, Peking, Washington, let it be like that, better health care, education, food. Our population is reducing, only less than 1% increase. Life standard is improving. In my childhood I walked on foot seven kilometres to get English paper, now everywhere we have English paper…Now every people having one or two scooters* [English].
>
> – Participant A24: male, aged 40-60, 25/07/2014

The responses obtained from interviewees regarding landscape change illustrate that their perceptions are consistent with evidence from satellite imagery (Fox 2015). Almost all participants are aware that agricultural lands are declining in their respective regions, giving way mainly to new housing. Most participants regret this loss, suggesting a strong attachment to local agriculture. Feelings toward the ongoing construction developments, however, are mixed. While some disapprove of the rapid expansion, many participants recognize a need for increased housing to meet the demands of an increasing population, and some, particularly in the more rural region of Kalikavu, celebrate the improvements in infrastructure and economy that have accompanied the expansion.

3.3.1.2 Perceived Drivers of Agricultural Decline

The perceived motivations for land-use change are based on economic incentives or cultural values. The vast majority of explanations for the general shift away from agriculture and toward housing throughout Kerala involve a combination of declining profitability of agriculture and a change in cultural values.

By far, the predominant issue brought up in discussions was the lack of affordable labourers to cultivate crops. Many participants cited this as the direct cause for declines in agriculture, saying "The labour problem is the major problem faced by the agriculture sector. It is expensive, and no one is available. This is causing the decrease in agricultural land. People started abandoning and fragmenting the land." (Participant A21: female, aged 60+, 23/07/2014). Labour issues have also reportedly led to conversions of both paddy fields and homegardens to plantations of rubber and arecanut in Kalikavu, as these plantation crops are less labour intensive to cultivate: "Agriculture is changing. Before everything was cashew, now it is rubber. Earlier there was paddy. It has been replaced by areca due to the scarcity and expense of labour" (Participant K28: male, aged 40-60, 26/08/2014).

The labour issue in Kerala is twofold, involving both changing social values and increasing labour wages. This has led to a scarcity of skilled labourers and a rise in the cost of employing labourers, the latter likely exacerbated, if not caused, by the former. The sense among participants is that the shortage comes as a result of young Keralites rejecting the manual labour required for agriculture, instead choosing higher paying and less physically demanding careers; as one participant remarked "Younger generations only want white collar jobs, not dirty jobs; they don't want to get dirty. They've lost interest in agriculture because everything is available in stores." (Participant A21: female, 60+, 23/07/2014).

Participants are highly aware of the ongoing labour migration dynamics in the state, noting both the high emigration of Keralites to Middle Eastern countries, and the resulting influx of migrant workers from other states, including Tamil Nadu and West Bengal. Participants suggested that these migrant workers typically choose higher paying construction jobs over agriculture, and many expressed dissatisfaction or distrust with the workers, suggesting that "Bengalis are not well skilled for agriculture, they are only good for construction labour" (Participant A16: male, aged 40-60, 20/07/2014), and that "[they] don't trust Bengalis because of theft, [they] only want locals" (Participant K09: female, aged 60+, 08/08/2014). Many participants accused young Keralites of being lazy, and rebuked those seeking overseas employment, saying "People are more lazy, that's why they are importing labour from Bengal. People are not working hard, they are moving away to Gulf countries to make money." (Participant K22: male, aged 40-60, 23/08/2014).

In addition to career priorities, there is a sense that younger generations have shifted away from traditional family values and agriculture in general. Participants suggested that young Keralites are not interested in maintaining traditional family land, instead choosing to move into larger homes closer to urban areas. They blamed these attitudes for the increase in both the number and size of houses, and the resultant contraction of arable space:

> *Fruit trees have decreased because …the attitude toward agriculture has changed. People have lost interest…households are very closely constricted; there is no way to raise any trees. We are trying to protect the joined family, it is better to keep families close but now everyone is spreading.*
>
> – Participant A01: female, aged 60+, 30/06/2014

Coupled with an ever increasing population density, this has led to a substantial rise in real estate value, further prompting land owners to abandon agriculture and sell off their land in pieces. As one participant remarked "it is very profitable to sell land. No effort was put into acquiring the land, so selling it is easy." (Participant A13: male, aged 18-40, 16/07/2014).

In addition to rising labour costs, participants suggested that fluctuating market prices have made agriculture increasingly unpredictable, and many participants felt that agriculture has simply become too risky:

> *We are not getting a good price for our produce. Sometimes we are not even taking these crops because [the markets] have supply from other sources. Now I have ripe bananas I am not even harvesting because there are no buyers, so animals are eating them.* – Participant A29: male, aged 40-60, 13/09/2014

Increasing costs of agricultural inputs, including seeds, pesticides and fertilizers, and increases in the cost of living, have further challenged the economic viability of agriculture. Many participants expressed feelings that “agriculture is not [a source of] income, it is an expense” (Participant A27: male, aged 40-60, 05/09/2014), suggesting that alternative sources of income from employment are necessary to maintain agricultural lands:

> *We can’t solely depend on agriculture for our existence. Even people having two to three acres can’t cope with the daily expenditures because the income is so low…For a common farmer it is very difficult to stay in agriculture without an extra source of income*. – Participant A04: male, aged 60+, 07/07/2014

In addition to economic influences, many participants cited environmental reasons for the decline in agriculture, including water availability, temperature, soil fertility and pests and disease. Increased temperature and water shortages are of concern to many participants, and many commented on the increasing irregularity and extremity of the wet and dry seasons. In some cases, availability of water was given as both a reason for, and result of, the loss of paddy land. Participants believe that the filling of wetlands reduced the overall water retention of the landscape, forcing other farmers to abandon water-intensive rice cultivation, or replace it with rubber, which is less water demanding. As one participant remarked, “I was previously a paddy cultivator... Now there is no rain when this season should have heavy rain, I have two acres of paddy nearby but they not cultivated.” (Participant A03: male, aged 40-60, 04/07/2014). In Kalikavu, pests, including wild boars and insects, are said to have caused abandonment of agricultural crops or lands, while in Avinissery, problems with pests and disease, while present, are less of a concern. A few participants also suggested that declines in soil fertility were affecting production, further complicating the viability of agriculture: “The productivity of land has decreased, people are using more chemicals. [Soil] fertility decreased because they are cultivating the same crops over and over. Before there was [less] demand for chemical fertilizer…nowadays the demand is high.” (Participant K16: male, aged 60+, 12/08/2014).

While the precise causes of agricultural decline in Kerala have not been empirically studied, the dominant narrative is consistent with documented evidence of the large-scale emigration of Keralites and high influx of Indian migrants (Raman 2012). The overwhelming discussion of labour and profitability issues among participants indicates that this is a widespread problem which many farmers are facing. The lack of young people in our sample is consistent with the dominant narrative that younger generations are not involved in agriculture, though without adequate representation from the younger age class it is not possible to confirm whether this is caused by lack of interest, cultural shifts, or other societal pressures.

3.3.1.3 Economic and Cultural Incentives for Homegarden Maintenance

As with drivers of landscape change, participants’ reasons for keeping homegardens are based mostly on income or cultural values. The most common reason among participants in Kalikavu involves the income gained from homegarden products or maintaining a farming livelihood (Figure 3.3). These two explanations were combined into a single category (income/livelihood) as the concepts of livelihood and source of income are not easily distinguished in Malayalam. In Avinissery however, most participants suggested that they keep a homegarden due to economic constraints. This category includes all responses in which the participant suggested that it would not be profitable to use the land for any other purpose. This is typically due to a lack of sufficient land to make redevelopment, partitioning or a plantation economically viable, but other reasons include a lack of affordable labour to cultivate a plantation and fluctuating market prices for produce. Some participants also suggested that homegardens are low maintenance and the most reliable source of income, but it is important to note these participants typically also had additional sources of income.

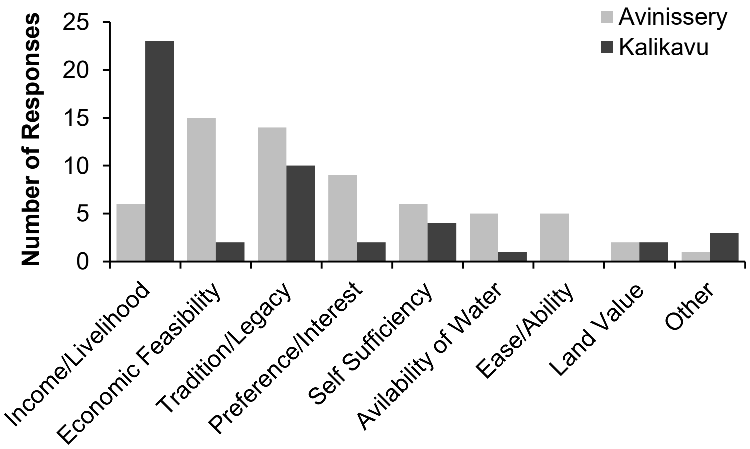

Figure 3.3. Participant responses to the question “why do you have a homegarden?” Open ended responses were coded based on common themes. Individual responses may fall into multiple categories (Source: Author).

The second most common reason overall for homegarden maintenance is based on cultural values of tradition and legacy. Participants maintain their homegardens for the purpose of continuing learned family or cultural practices which have been passed through multiple generations, or for the purpose of passing down the land and practices to future generations. Many of these participants also expressed a strong desire to keep the land within their family and had no plans to sell any of it. One farmer stated that he was even “trying to buy shares from other family members to maintain the land” (Participant K20: male, aged 18-40, 16/08/2014), while another asserted that “we are a Brahmin family [traditional Hindu upper caste]…we are not giving this land to anyone of another religion” (Participant A01: female, 60+, 30/06/2014).

Eleven participants also expressed a strong preference for, or interest in, engaging in gardening activities. These participants typically own smaller plots of land and have additional, non-agricultural sources of income. Of these, two participants suggested that they have no need to sell or change the land, and three said this was because they own other agricultural land elsewhere. One woman stated that her husband “celebrated his birthday by planting trees” and “planted trees for his family also” (Participant A23: female, aged 40-60, 24/07/2014). Ten participants cited a desire for self-sufficiency as their reason for maintaining a homegarden, typically referring to commercially available products as “poisoned food”. Other reasons include an excess or lack of water to allow for other types of agriculture, a lack of desire or physical ability to manage anything other than a homegarden, a preference to hold onto the land due to its high value, the risk for pest infestation associated with monocultures, the preferred aesthetic of a homegarden, and finally, because having a homegarden is the norm.

Despite being similarly dependent on agriculture for income, participants in Kalikavu are more likely to cite income and livelihood as their rationale for maintaining homegardens. This may reflect a lack of employment opportunities consistent with being located further from a major urban center. The similarities between participants' incentives to maintain homegardens and their perceived drivers of landscape change highlight the risk that homegardens in Kerala are facing. If income and economic feasibility are the main reasons for keeping homegardens, but they are becoming increasingly unprofitable, it is unlikely that people will continue to maintain them. Similarly, if tradition is the primary reason for homegarden maintenance, but younger generations are losing interest in continuing these traditions, homegardens will face destruction.

3.3.2 Attitudes toward Wildlife

3.3.2.1 Benefits and Enjoyment of Wildlife

Participants frequently expressed great appreciation for domesticated animals, including cows, chickens and goats, but rarely for wild animals. Half of participants in Kalikavu and a third of participants in Avinissery said that wild animals had no benefits (Figure 3.4). For some, this is influenced by the overwhelming problems caused by wild animals, while others feel that the beneficial wild species, including bees and rabbits, have disappeared.

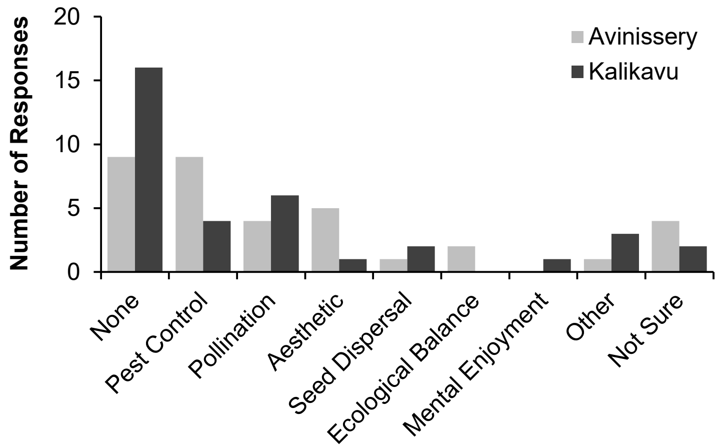

Figure 3.4. Benefits from wild animal species as listed by participants. As this question was open ended, participants were able to list more than one benefit (Source: Author).

Of those who listed benefits, the most popular responses were pollination and pest control. Participants listed small insects, but not birds or bats, for pollination, and birds and frogs, snakes and mongooses for controlling populations of insects, rats, and snakes, respectively. Five participants suggested aesthetic beauty as a benefit, and two suggested that all wild animals are necessary to maintain “ecological balance”. Other responses include using worms for fishing, bat guano for fertilizer, and soil biota for maintaining soil health. Personal enjoyment was cited as a benefit of wild animals by only one participant.

In Avinissery, two-thirds of participants, including some who did not list any other benefits, suggested that they enjoyed having animals on their land, typically referring to birds and butterflies. In Kalikavu however, most stated that they did not enjoy animals, typically citing damages caused to their crops. Some suggested they enjoyed only those that did not cause harm, while the rest were generally apathetic, stating that they “don’t really care about them” (Participant K21: male, aged 60+, 16/08/2014). Six participants, mostly in Kalikavu, suggested that animals have an intrinsic right to live, stating that “no one has the right to tell them whether to be here or not” (Participant K25: male, aged 40-60, 24/08/2014).

The general appreciation for domesticated animals, but lack thereof for wild animals, suggests a highly utilitarian view amongst participants, particularly in Kalikavu. Because secondary education is nearly ubiquitous in Kerala, it is less likely that these participants are unaware of the ecological role of wild species, and more likely that they do not feel they benefit personally from wildlife.

3.3.2.2 Problems with Wildlife

All participants listed at least one problematic animal species, though the severity of concern varied. Most of the problems involve animals consuming or destroying agricultural crops. Kalikavu, which is more rural and closer to a forest reserve, experiences much more severe and frequent animal attacks, as well as attacks by larger, potentially more dangerous, animals. Almost all participants in the region reported having problems with wild boars (Figure 3.5), typically destroying bananas, cassava and other tubers. Many farmers have installed netting or fencing around their property to reduce the frequency of attacks, while others have stopped growing tuber crops all together. Participants expressed great frustration with wild boars, suggesting that they were “devastating agriculture” (Participant K12: female, aged 40-60, 09/08/2014) and “should be culled” (Participant K15: male, aged 40-60, 12/08/2014).

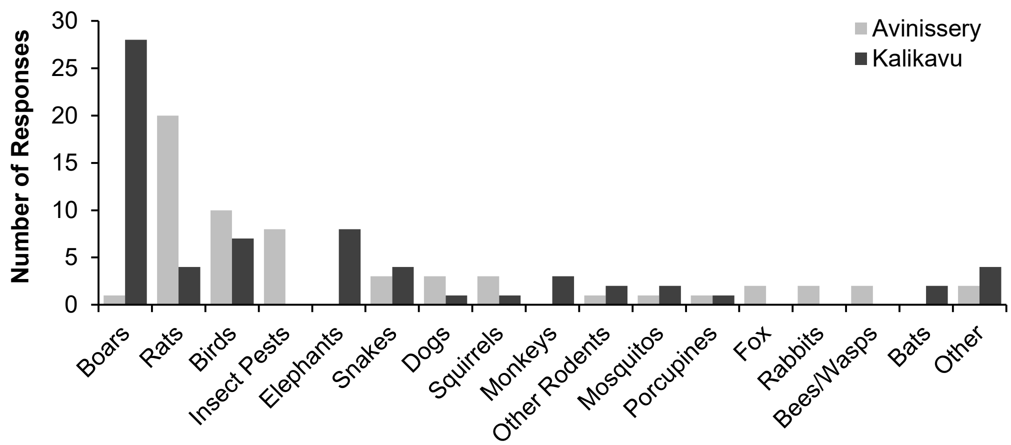

Figure 3.5. Number of respondents listing each animal as problematic. As this question was open ended, participants were able to list more than one animal (Source: Author).

Elephants are also reportedly problematic in Kalikavu; however, it is worth noting that incidents involving elephants trampling agricultural crops had been widely publicized in local papers in Kalikavu at the time of the study. Half of the participants who listed elephants also mentioned that they have never had first-hand experience with elephants on their property, but the issue is nonetheless pervasive in the region. The overall attitude toward wildlife is more negative in Kalikavu than in Avinissery, with some participants expressing firm opposition to wildlife conservation measures. One participant suggested that "wildlife protection is bad for common people, there are very vigorous attacks from wild animals. The government can do something, they did some fencing but it was all destroyed by elephants. People are abandoning their houses and leaving" (Participant K07: male, aged 40-60, 07/08/2014).

In general, participants in Avinissery expressed less concern about wild animals, even suggesting that "problems are natural things" (Participant A12: male, aged 60+, 16/07/2014). The most problematic animal was rats, also for destroying cassava and other tubers. However, only two participants had changed their agricultural management as a result. Birds were listed for consuming ripened peas and bananas, while various insects infect different crops. While farmers in Avinissery do experience some pest problems, they typically do not identify them as the cause for abandonment of any agricultural crops.

The increased prevalence of human-wildlife conflict in Kalikavu is consistent with the lack of wildlife benefits perceived among these participants. This suggests a generally negative culture toward wild animals, in which the problems they cause outweigh any potential benefits. This negative attitude is important in the context of wildlife conservation, as homegardeners are unlikely to support efforts to conserve problematic animals.

3.3.2.3 Changes in Wild Animal Abundance

Most participants in both regions feel that most animal species have declined over the past decade, particularly bees and frogs (Figure 3.6). The only animals which are generally felt to be increasing are spiders and lizards, which are both frequently found inside of homes. Most participants attributed the changes to habitat loss, particularly the loss of paddy wetlands and homegardens, while others suggested climate change, land fragmentation, chemical use and pollution as potential causes for the loss of wildlife.

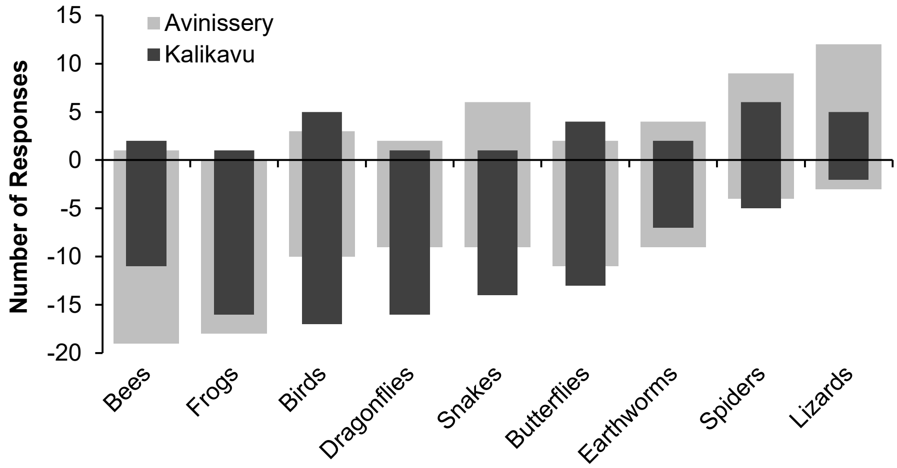

Figure 3.6. Number of respondents indicating that animal groups have increased, stayed the same or decreased. Participants who chose "increasing" were assigned a value of 1, while those who chose "staying the same" or "decreasing" were assigned a value of 0 or -1, respectively (n=30 for each region and animal group) (Source: Author).

Apiculture is popular throughout Kerala, particularly in areas of heavy rubber cultivation, as hives can be easily maintained in rows between rubber trees. Because of this, it is difficult for participants to distinguish between wild and cultured bees. Many suggested that the total number of bees had remained constant due to the prevalence of apiculture, while others reported having previously been able to spot wild hives in large trees, suggesting that native species have declined while cultured bees have increased or remained constant. Still others feel that even cultured species are in decline, as a result of reductions in agricultural land.

There is a high level of agreement among participants that frog species are in decline. Many participants remember hearing more frogs in the past, stating that there is "less sound at night now" (Participant A02: female, aged 40-60, 03/07/2014). Most attributed the loss to the decrease in agricultural lands, predominantly paddy land but also the loss of trees in homegardens: "Frogs have decreased because the paddy land has decreased. Now there are only big ones during the rains; the small ones are gone" (Participant K21: male, aged 60+, 16/08/2014). Similarly, participants feel that not only have birds decreased overall, but that native species in particular have dramatically declined. Crows, doves and small nectarivorous birds are said to have remained stable, while parrots, owls and large carnivorous species have almost disappeared:

"New migratory species [of birds] are coming seasonally, but indigenous species are disappearing at an alarming rate" (Participant A22: male, aged 40-60, 24/07/2014).

The loss of dragonflies and butterflies is also largely attributed to the loss of paddy land, while the changes in snakes and earthworms are thought to be related to understory growth and chemical use, respectively, in homegardens. Those who feel snakes have decreased typically cited the clearing of thick underbrush in surrounding areas, while those who feel they have increased suggested that an abundance of understory plants provides ample habitat and protection. Many of the latter also reported recent encounters with dangerous snake species. Changes in earthworms, which are often associated with soil health, were largely attributed to the use of chemical products in agricultural lands. Those who said earthworms are the same or increasing suggested this is because they are using only organic fertilizers and pesticides, while those who said they are decreasing blamed heavy chemical use in surrounding properties, as well as the loss of paddy land.

Despite the perceived losses of so many wild species, most participants (15 in Avinissery and 9 in Kalikavu) are generally apathetic toward wildlife. They expressed little to no concern for the disappearance of animals, suggesting that the changes had no effect on them or their agriculture: "My feeling is I get mental pleasure from seeing birds, but I'm not taking any measure to conserve, I'm not very concerned" (Participant A03: male, aged 40-60, 04/07/2014). Four participants in Kalikavu suggested that it is good that wild animals are declining, and opposed conservation efforts: "For people [the decline] is good because wild animals cause problems" (Participant K02: male, aged 40-60, 06/08/2014).

Approximately one third of participants (12 in Avinissery and 10 in Kalikavu) are generally in support of wildlife conservation, expressing feelings that wildlife and biodiversity are important and warrant conservation. Many commented on the importance of maintaining ecological balance, stating that "every animal is important [and] has a role in nature" (Participant A27: male, aged 40-60, 05/09/2014) and suggesting that "if you exclude them, there will be problems" (Participant A09: male, aged 40-60, 14/07/2014). Some feel that society has an obligation to conserve species for the coming generations, stating that "if these animals are not there, the future generation will not enjoy the benefits of them" (Participant A21: female, aged 60+, 23/07/2014), while others cited the intrinsic rights of the animals themselves: "The world is not only for those walking on two legs, but also for four legs and those who fly. They also have a right to live" (Participant A29: male, aged 40-60, 13/09/2014).

The remaining participants (3 in Avinissery and 7 in Kalikavu) took a more pragmatic perspective, expressing concerns for wildlife conservation but emphasizing the importance of human needs over those of animals. This view is particularly common in Kalikavu, where ongoing human-wildlife conflict occurs with elephants and wild boars. Many feel that more could be done to address these conflicts, including installing electric fencing around agricultural lands and forest reserves, selective culling of problematic species, and more government support for farmers impacted by wildlife. Often, participants suggested that there is too much focus on wildlife conservation, and not enough support for communities impacted by conservation efforts: "[Animals] are important. We have to protect animals, but humans too. We should protect human life from animals. They are only trying to protect the animals and not the humans. We must reduce interactions between humans and animals" (Participant K23: male, aged 40-60, 23/08/2014).

Despite an overwhelming consensus that wild animals are in decline, concern for species conservation is minimal at best. Kerala supports a wide variety of programs to enhance awareness of, and concern for, wildlife, but the conflicts between farmers and problematic animals dominate in the opinions of most participants. This suggests that many homegarden owners will not be receptive to conservation measures unless they also address these wildlife conflicts.

3.3.3 Environmental Awareness and Land Management

> *The main problem is unprecedented changes in climate. Normally I can predict when the rain comes, but now I can't plan, the planning procedure is entirely collapsed. I am waiting for rain to cultivate the vacant paddy…I will continue doing agriculture*

> *even if climate change gets worse. If nature is not on the side of the farmer, agriculture will not be successful.* – Participant A03: male, aged 40-60, 04/07/2014

3.3.3.1 Environmental Concerns

Just over half of all participants (34/60) reported having concerns about environmental issues. The most common topics of discussion were climate change, pollution and pesticide use. Several participants described changes in the amount or timing of rains, suggesting that seasonal fluctuations have become more extreme and sporadic. This has created concern not only for agriculture, but for water availability as well: "I am concerned about climate change. Rain is much less than previous years. During this season it used to flood. Previously we had two wells that would over-flow, now it is less than usual… I fear that Kerala will become a desert due to climate change" (Participant A10: female, aged 40-60, 15/07/2014). Participants also reported fears that climate change will bring about "new diseases" and blamed construction and mining activities, as well as the loss of agricultural land, for causing climate change:

> *The environment is losing. There is soil erosion, so no rainfall, so drought, so it is a concern for agriculture. There is controversy because somebody always wants to exploit [the environment]. They are converting land for other use; quarry work is encroaching on land. They say they are developing, but actually it is spoiling the nature*. – Participant K14: male, aged 40-60, 11/08/2014

Many feel that the effects could be mitigated by reducing these activities, planting more trees and protecting forest reserves. Others however, demonstrated a feeling of powerlessness regarding climate change, suggesting that "it is as God wishes" (Participant A01: female, aged 60+, 30/06/2014) and "we can't do anything for climate change, just sit back and pray" (Participant A22: male, aged 40-60, 24/07/2014). There is a general sense that environmental matters are "a government responsibility" (Participant K13: male, aged 40-60, 10/08/2014) and that "laymen cannot do anything" (Participant K05: male, aged 40-60, 07/08/2014).

Pesticide use in agriculture, particularly in the neighbouring state of Tamil Nadu, is also a common topic of concern. Primarily, the concern is focused on the effects of consuming pesticide-laden foods, but also extends to the broader effects on soil quality, pest resistance, wildlife and air and water quality:

> *Pesticides are causing the decrease in animals, due to bio-magnification. They are eaten by fish and birds; pesticides spread with the water. These pesticides are recommended by the agricultural officers. They are not bothered by the side effects of pesticides, only crop production…We don't know what [new born babies] will suffer.*
>
> – Participant A09: male, aged 40-60, 14/07/2014

Concern around pesticide use is one of the main reasons participants cited for growing their own food and minimizing the use of chemicals on their own land. Other concerns about pollution include air and noise pollution from vehicles and construction, as well as plastic use and the lack of waste management.

> *I have concerns about air pollution, noise pollution from vehicles, chemical fertilizers, and construction. This is causing problems for the environment in Kerala. It will be difficult for the future to have an environment like this, cutting trees, polluting, etc. Some organizations are trying to stop these things, but I am doubtful about their efficacy.* – Participant A06: male, aged 40-60, 09/07/2014

Generally, participants support efforts to protect forest areas, particularly for mitigating pollution and climate change. There is a strong sense that forest reserves are necessary for providing "rain and good air". However, as with wildlife conservation, many participants took a more pragmatic perspective, recognizing trade-offs between human needs and forest protection, and emphasizing the importance of providing space for people and agriculture:

> *Now there's a report passed by the government saying no development near forest area, so no mechanized operations in this area, but now people can't do agriculture there. The government should take actions to protect the forest, but not extend that to*

people's farmland. The government should not try to add more forest to forest areas; the nearby lands are farmlands, so it is causing problems for these people.

– Participant K25: male, aged 40-60, 24/08/2014

This widespread concern climate change and pollution suggests that participants are in favor of environmental conservation, so long as it for the purposes of human health and well-being. Support for forest reserves was also widespread, though even this was only in so far as it related to human health. This further emphasizes the general utilitarian view of the environment among participants, and suggests that they are likely to be receptive to conservation measures that are directly linked to human well-being.

3.3.3.2 Consequences for Land Management

While not a major factor in land-use decision making, concerns about environmental health did play into some management decisions among homegarden owners, most notably the use of organic over chemical fertilizers and pesticides. More than half of participants use chemical fertilizers, mostly in addition to organic fertilizers (Figure 3.7). Many reserve chemical fertilizers for cash crops, including rubber, arecanut, coconut and banana, while others use chemical fertilizers for all crops. Reasons for using chemical fertilizers include improved yield and the availability of government subsidies for chemical products, but many participants stated that they prefer to use them only in small quantities or to alternate with organic fertilizer, as they believe that overuse is harmful to their livestock, soil, or crops. Those who exclude chemical fertilizers typically cited lack of availability, cost, and concerns about potential negative health effects for themselves, their soil and their crops; for example, one participant noted that "Organic fertilizer…increases immunity of trees against disease. Chemicals decrease the thickness of skin [on trees], increase breakage and the probability of damage, destroy soil properties and are harmful for earthworms" (Participant K27: male, aged 40-60, 26/08/2014).

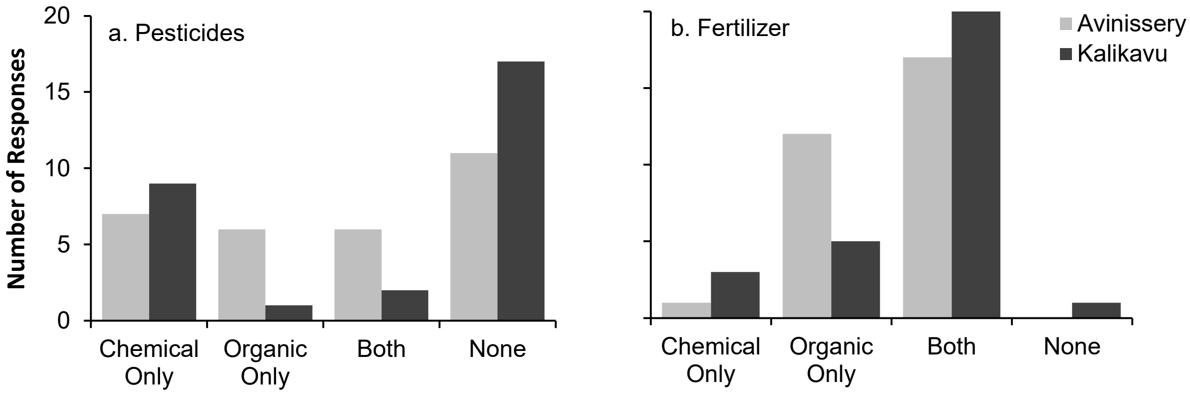

Figure 3.7. Number of participants who report using chemical, organic, both or neither for a) pesticides and b) fertilizers. Participants were allowed to select only one option for each category (n=30 for each in Avinissery and n=29 for each in Kalikavu as one participant was unable to comment (Source: Author).

The vast majority of participants use organic fertilizers, typically including cow manure, charcoal, green leaves and compost. Those who exclude organic fertilizers typically do so due to lack of availability. Reasons for using organic fertilizers include local availability, enhancing yield, improving or maintaining soil health, reducing environmental impact, and a general sense that organic products are beneficial to human health. One respondent suggested that organic is "less work than chemical…letting them grow naturally" (Participant A23: female, aged 40-60, 24/07/2014), while others use organic "because it is harmless [to people and the environment]" (Participant A24: male, aged 40-60, 25/07/2014) and because "[you can] put as much as you can; [there are] no consequences" (Participant K16: male, aged 60+, 12/08/2014). This perspective is disconcerting, however, as it suggests farmers may be over-applying fertilizers. Qualifying a fertilizer as "organic" may lead farmers to believe that they are environmentally benign, when in fact manures and compost pose considerable risk of nutrient leaching, particularly near water ways (Hansen *et al.* 2001).

Only a quarter of participants reported using organic pesticides, while about forty percent use chemical pesticides. Nearly half of all participants do not use any pesticides. Reasons for excluding chemical pesticides include cost, lack of necessity, and concerns for human, crop, soil and environmental health, while reasons for excluding organic pesticides include lack of effectiveness, lack of necessity and cost. There is, however, obvious confusion concerning the classification of products, as participants listed several compounds, including calcium carbonate, copper sulphate, urea and Borax, as both "chemical" and "organic". This confusion is understandable, given that the classification of 'organic' agricultural products is not based on any standard criteria. Many of these pesticides are listed as "restricted" under the Indian National Programme for Organic Production (India Department of Commerce 2005), meaning "the conditions and the procedure for use shall be set by the certification programme". This may serve to further the environmental impacts of agriculture, as "organic" pesticides are used more freely than "chemical" pesticides, despite the fact that the definition is not based on the potential harmful effects of the product in question.

The most important finding here, however, is that farmers are willing to modify their land management for the sake of environmental protection, if they feel that it is also beneficial to their own health and well-being. Because most participants do not perceive wild animals as being beneficial, any attempt to encourage specific management practices for the sake of biodiversity should also be explicitly linked to human health.

3.4 Discussion

3.4.1 Land-Use Change

Agricultural land-use transitions have been rapidly occurring around the globe over the past few decades. Throughout Southeast Asia, Eastern Europe and Northern Africa, increases in wealth and human development have sparked transitions from rural farming communities to suburban working class neighbourhoods (Imbernon 1999; Shalaby and Moghanm 2015; Yeh and Li 1999; Zomeni *et al.* 2008). In Kerala, improved access to education and employment opportunities abroad has reduced dependency on agriculture for livelihoods, altering land-use dynamics in the region by promoting land division and sale among large land holders. As regional affluence grows, so too does the cost and standard of living, making traditional small-scale agriculture both unnecessary and unprofitable. Only intensified systems of commercial cash-crops can be made economically viable (Joseph and Joseph 2005), while other agricultural lands are being sold, cleared for development, abandoned or maintained only by retired household members for personal use and enjoyment. The quickening pace with which agricultural lands are being eliminated or intensified has created a pressing need for research on the importance of agricultural systems, particularly traditional diversified agroforestry systems, for the maintenance of biodiversity and ecosystem services.

Empirical evidence based on satellite imagery demonstrates that agriculture in Kerala, which includes both rice paddy wetland and agroforestry systems, is rapidly being replaced by new housing developments (Fox 2015). Other researchers have speculated that Kerala is simultaneously undergoing rapid intensification of agroforestry systems, moving from highly diversified homegardens to more modern plantation-style systems in which a few commercial cash crops dominate the space (Depommier 2003; Guillerme *et al.* 2011). Participants' perceptions of the ongoing changes in their area closely correspond with these reports. In Avinissery, housing development is the driving force behind the land-use changes. Rice paddy still occupies a large portion of the landscape, but much of the cultivation has been abandoned, according to participants. Although it is illegal, wetland is being drained, filled, and used for construction (Guillerme *et al.* 2011). As family land is divided among children, new homes are built on each new plot, or parts of the land may be sold to other families, creating an increasingly fragmented landscape. In Kalikavu, however, it is agricultural intensification that locals note as the predominant change in the landscape. Rubber and arecanut, which are the most profitable crops due to their high market price, low input requirements and ability to be harvested continually throughout the year, are said to have replaced a variety of edible and culturally important tree species, including cashew and fruit trees. Meanwhile, improved road access is also encouraging a steady influx of real estate developments.

While homegardens are being increasingly fragmented, modernized or removed all together, these traditional systems still cover much of the Kerala landscape. Those that remain are typically being maintained by older household members as a traditional practice or as a source of income. In both of these cases, however, the homegardens face a very real risk, given the drivers of change identified in this study. If younger generations are not interested in agricultural traditions, they will have little motivation to refrain from redeveloping the family properties after inheriting them. Similarly, if agriculture becomes increasingly unprofitable, especially as real estate is becoming increasingly lucrative, owners may be forced to sell the land for development and seek other livelihood opportunities. Although our sample was biased towards participants who still maintained homegardens, their perceptions of the drivers of land-use change are alarming given their rationale for maintaining homegardens. Continuing in this direction will no doubt have consequences for the remaining wildlife in Kerala.

3.4.2 Attitudes toward Wildlife Conservation

Homegardens provide much needed wildlife habitat in the highly populated Kerala landscape, as well as a large suite of ecosystem services including carbon sequestration and pest control (Kumar 2011; Kumar and Nair 2004). This system is ideal for studying local attitudes toward biodiversity and wildlife, as land owners live in close proximity to their agroforests and have regular encounters with local wildlife which causes both direct benefits and direct hindrance to their agriculture. Whether or not they are aware, homegarden owners are making a substantial contribution to the preservation of wildlife in Kerala.

Understanding local attitudes toward wildlife in biodiversity hotspots is critical for global conservation efforts, particularly as western developed countries are increasingly becoming involved in species and environmental management in developing countries (Manfredo *et al.* 2009). Few studies have explored the fundamental attitudes of local people toward wildlife, as opposed to reactions to controversial species or conservation measures. Of those studies which exist, most have been conducted in the United States or other western developed countries (Teel and Manfredo 2010, Hermann *et al.* 2013). Preliminary studies of wildlife values in Asian countries have shown a range of attitudes which are influenced by unique cultural factors, and do not fit well within the North America model of wildlife value orientations (Tanakanjana and Saranet 2007; Kaczensky 2007; Zinn and Shen 2007). Teel and Manfredo (2010) argue that the historically dominant attitude toward wildlife in America is a utilitarian one – that wildlife should be preserved solely for the use and benefit of humans – but that attitudes are becoming more mutualist – promoting the coexistence of humans and wildlife – as communities become more modernized and have fewer direct dependencies on natural resources. Tanakanjana and Saranet (2007) however, found that rural people residing in national parks in Thailand were predominantly mutualist despite being less industrialized, and suggested that these attitudes may be heavily influenced by the strong Buddhist culture in the region. Similarly, Kaczensky (2007) found that although rural Mongolians depend heavily on wildlife resources, they are highly aware of environmental issues, concerned about the persistence of animal populations, and opposed to the use of wildlife for anything other than subsistence. Finally, Zinn and Shen (2007) showed that people in both rural and urban China were much more concerned with human safety and welfare, particularly in poor communities. These examples highlight the diversity of wildlife attitudes that exist throughout Asia, and the variety of cultural and environmental factors which can influence them. While it is easy to assume that the appreciation and concern for animals that is prevalent in developed countries is ubiquitous, it is important to recognize that in reality this is a relatively recent development in many cultures, and is not necessarily the case in all cultures, particularly those who must endure conflicts with wildlife.

The results of this study suggest that the overall attitude toward wildlife and conservation in Kerala is neutral to negative. While some participants did express concern for the welfare of animals, the majority showed interest only in those issues which could directly affect their own personal health or well-being. These results somewhat mirror the results of other studies of participant attitudes toward conservation in that respondents are typically concerned only with the direct effects of wildlife on their livelihoods and property (Gillingham and Lee 2003; Hemson *et al.* 2009). Support for wildlife conservation depends heavily on perceived benefits, which usually entails direct economic benefits from either tourism or hunting and extraction (King and Peralvo 2010; Mbaiwa and Stronza 2011; Sekhar 2003), neither of which are applicable to Kerala homegarden owners.

Negative attitudes toward wildlife were more common in Kalikavu than in Avinissery. While it is possible that these observed differences are based on education, this is unlikely given the widespread accessibility of schooling in Kerala. Rather, the difference between those who consider wild species beneficial or enjoyable and those who do not is likely a result of the general culture toward wildlife, influenced by problems encountered with both animals and conservation managers. Farmers in Kalikavu face real threats to their livelihoods due to wildlife conflicts, and must also endure the consequences of living close to a forest reserve, which include development restrictions and regulations on the use of farming machinery. A study by Ogra (2009) in northern India describes similar issues of human-wildlife conflict on agricultural lands, and a general perception of powerlessness and disregard by government agencies among participants. Despite being more conscious of wildlife benefits, participants in Avinissery were generally more apathetic toward wildlife. This may be influenced by the age of participants, who were typically older, as the growing emphasis on species protection has been more heavily directed at younger generations.

3.4.3 Managing for Biodiversity

Although regard for wildlife is minimal among participants, concern for trees and forests is relatively high. Land owners value tree and plant diversity, which may provide an opportunity to promote diversified homegardens. This could potentially result in greater support for wild animal species, as large gardens with variable canopy and understory cover house greater animal diversity (Chapter 2). While reducing human-wildlife conflicts and educating locals on the benefits of biodiversity is still necessary, promoting tree diversity may prove easier and more effective given the local culture.

As with concern for wildlife, overall awareness and concern for environmental issues was centred on human health and agricultural viability. Comparable studies of environmental awareness in developing countries are scarce; however, this mirrors the results of Li *et al.* (2009), who found that the environmental issues of greatest concern to the public in Liaoning, China, were pollution and climate change, and predominately concerned with effects on human health. Many farmers noted their willingness to adjust their agricultural management toward organic methods for the benefit of human well-being, though this may also be largely dictated by cost and availability of products. This suggests that there is opportunity to further education and incentive campaigns in the region to promote sustainable farming practices and reduce the environmental impacts of agriculture. Given the large number of participants who are reliant on agriculture as their primary source of income, economic incentives will likely be necessary. This could include the expansion of organic certification programs to increase the value of homegarden products, or ecosystem service payments to promote low-intensity farming. However, such strategies may not be very effective in the context of such a high-value real estate market. These strategies could be more successful if paired with legislative action designed to manage the rapidly expanding housing market.

3.5 Conclusions

It is obvious from the continuing rapid expansion of suburban developments into rural lands that agroforestry in Kerala is at risk. This poses serious threats for wild species which depend on these remaining fragments of habitat, but also has potential consequences for health and food security in the region. Kerala boasts a long tradition of agrarian culture and intricate botanical knowledge, and this study suggests that Keralites feel strongly about conserving traditional agriculture and tree species, as a means of preserving their culture and promoting their own health and well-being. However, this concern does not extend to wild animals, which are typically seen as useless or problematic. Attempts to promote agroforestry, therefore, are not likely to succeed if biodiversity conservation is used as the primary motivation, unless people can be convinced that wild species serve them a direct benefit. Rather, individual health, food security, cultural preservation, and more importantly, economic incentives, are much more likely to convince individuals and families to maintain their agricultural lands.

Despite demonstrating awareness and concern for environmental issues, many of our study participants felt that they were incapable of having any impact on mitigation efforts. On the contrary, participants felt that conservation management decisions were being made in complete disregard to the needs of common people, and that there was no way for them to be involved in the process. This suggests room for improvements in public consultation and community engagement among government and conservation groups in Kerala, as well as potential for education and awareness programs directed toward individual contributions to environmental efforts, the importance of maintaining trees, the benefits of wild species, and resolving human-wildlife conflict. While many education campaigns and subsidy programs are already being put in place, the increasingly recognized value of homegardens, as well as their rapid decline, demands that more attention and resources be dedicated to these systems.

Chapter 4

Conclusion: Biodiversity in Kerala Homegardens

Homegardens are small-scale mixed agroforestry systems that surround households, and are believed to provide a multitude of socioeconomic and ecological benefits to both local people and wildlife (Fernandes and Nair 1986; Kumar and Nair 2004; Galluzzi *et al.* 2010). Using both qualitative and quantitative research methods, this thesis has examined the homegardens of Kerala, a tropical state in southern India, with particular attention to their value to wild animal species and the relationship between these animals and the homegarden owners. Here, I revisit the objectives set out at the start of this thesis in light of the evidence presented in the preceding chapters, and discuss potential future avenues of research which would further our understanding of the contribution of homegarden systems.

4.1 Factors Driving Homegarden Diversity

The first objective presented in this thesis was to help guide conservation efforts by identifying homegardens which are most likely to support high diversity. In chapter two, I address two main questions: first, how much variability in faunal diversity exists between home gardens, and second, which local or landscape characteristics of homegardens are likely to contribute to the amount of faunal diversity. I used biological surveys of six different taxonomic groups (birds, frogs, butterflies, dragonflies, other arthropods and soil macrofauna) to quantify animal diversity, metrics of vegetation structure to assess local homegarden characteristics, and GIS and remote sensing to measure landscape characteristics. The results of the study suggest that homegardens vary widely in the amount of diversity they house, and that some of the differences are regional. The species assemblages of the gardens, however, do not differ consistently between regions. The results of my statistical models suggest that the factors which are most likely to influence diversity vary depending on the taxa and region of interest. For example, birds appear to be sensitive to human structures (including roads and buildings) and canopy cover, while insects respond more to understory complexity. Similarly, frog diversity in Avinissery is related to understory complexity and the distance to the nearest paddy wetland, while frog diversity in Kalikavu is related to canopy height and the proximity of human structures.

The results of this study highlight the importance of conducting studies across taxa and regions. Too much of agroforestry research has focused on comparing the diversity of a single taxa between agroforests, conventional agriculture and forests. This approach fails in two aspects: first, it fails to recognize the incredible range of systems which fall under the heading of "agroforest", and second, it fails to recognize how different taxa respond to different environmental variables. It is obvious that, on average, an agroforest is not the ecological equivalent of a natural forest, and that conventional agriculture is even less so. An agroforest is not a viable replacement for a forest, and deforestation for the sake of agroforestry should not be encouraged. Rather, the focus of biological research in agroforestry systems should be to maximize the ecological value of these systems, both by determining where in the landscape agroforests are the most valuable, and how agroforests can be managed to promote biodiversity.

4.2 Human Relationships to Homegardens and Wildlife

The second objective of this thesis is to understand the attitudes of the homegarden owners toward local wildlife, agriculture and the environment, in order to help anticipate how locals might respond to different conservation measures. Chapter three presents the results of my surveys and semi-structured interviews of sixty homegarden owners in Kerala. The findings suggest that homegardeners in Kerala generally lament the loss of agricultural lands in the region, and maintain their homegardens primarily for reasons pertaining to income and livelihood, economic feasibility or tradition. Most of the interviewees feel that local wildlife is of limited or no benefit, and mainly causes problems for themselves and their agriculture. Despite this, the homegardeners are generally concerned about the environment, and feel that environmental conservation efforts are necessary, though this concern rarely extends to the well-being or long-term survival of animal species.

This study illustrates the importance of incorporating human perspectives into conservation planning. The attitudes of the land owners are of particular importance when exploring the potential for conservation on private lands. In this case, homegarden owners do not show a propensity for caring about wild animal species, so any attempt to motivate them to modify their land management practices for the purposes of wildlife conservation are unlikely to be successful. Instead, a manager wishing to promote homegarden conservation in this particular community may find more success by emphasizing the traditional importance of homegardens and their benefits to human health, or by introducing economic incentives for homegarden maintenance. Alternatively, one might consider educating homegardeners on the ecosystem service benefits of local wildlife to improve attitudes toward biodiversity.

4.3 Conserving Biodiversity in a Homegarden Landscape

Kerala is currently undergoing rapid land-use change with respect to agriculture. A recent study by Fox (2015) shows that agroforests have declined by as much as 9% over the past decade due to ongoing construction, and previous work has suggested that traditional homegardens are transitioning toward more conventional styles of monoculture agriculture (Depommier 2003; Guillerme *et al.* 2011). This ongoing sub-urbanization and homogenization of agroforestry lands threatens wild species already pressured by dense human populations. But this process also reflects an increasing demand for space and reliable income which cannot be discounted. Policy makers in this region face a difficult task of balancing the immediate needs of the local people with the long-term consequences of biodiversity and agroforestry loss. It is my hope that this thesis might help inform the development of conservation strategies in Kerala, or at least provide convincing evidence that homegardens are worth protecting.

In addition to local policy-makers in Kerala, the insights developed in this thesis may also prove useful to ecologists and conservation managers in other homegarden landscapes. There are two broadly-applicable, important messages that have arisen through this work. First, that the best conservation strategy will depend on where and what you wish to conserve. Not all homegardens, and certainly not all agroforests, are created equal. Some will provide a much greater contribution to local wildlife, and this may depend both on the structure of the given homegarden or agroforest and where it is situated within the greater landscape. Even within a slightly different region, as was the case in Kerala, the most influential local and landscape variables may change. Additionally, the ‘best’ homegarden or agroforest will depend on whether you are interested in conserving birds, small mammals, insects, reptiles, amphibians, fungi or plants. It may be necessary to prioritize a specific group of concern, or compromise between different taxa. Second, not all people are concerned about conserving wildlife; on the contrary, wildlife is still a threat to the livelihood and well-being of many. As biologists and conservationists who care deeply about biodiversity conservation and the plight of wild species, it is easy to assume that these sentiments are shared among the general public. This, however, is not necessarily the case, and may be an important factor to consider when designing conservation strategies that involve public participation or will have consequences for local land owners. There may still be a need to improve awareness of the benefits of biodiversity in some communities.

4.4 Future Directions

Despite a wealth of literature on biodiversity in agroforestry systems (Jose 2012; Perfecto and Vandermeer 2008; Schroth *et al.* 2004), there are still significant gaps in the research. Effective land management strategies will require a better understanding of the ecosystem services provided by local wildlife in homegardens, and of the economic conditions required to make homegardens feasible. Possible future avenues of research could include a quantification of the various ecosystem services provided by homegardens and their associated fauna, and assessment of their total monetary value. This would provide a more concrete basis for promoting homegardens in local communities. Further, we require a better understanding of the trade-offs between productivity and biodiversity. As traditional homegardens shift toward more conventional plantations, the total production (including food, timber and other marketable products) is increased, but at a cost to biodiversity. By measuring both total production and total biodiversity under a variety of different management strategies, we can develop strategies that are more successful at balancing conservation with human needs. More in-depth analyses of individual faunal groups, or of the interactions between different local and landscape variables and their effects of biodiversity would also further our understanding of the human impacts on ecological communities. Finally, a detailed economic analysis of the conditions under which homegardens can be made financially feasible will vastly improve our ability to design incentive programmes for local farmers and legislation that would slow rapid land-use change without proving detrimental to local livelihoods. Continuing to apply mixed-methods approaches which integrate the various relevant disciplines will provide us with a more holistic understanding of homegarden landscapes, and improve our ability to make meaningful recommendations to policy makers and land managers.

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Appendix A: Univariate Linear Regression Results

Results of linear regression models of biological response variables and environmental explanatory variables. Only significant models (p<0.05) are shown. Results of dragonflies indicate results of binary logistic regression models. NMDS: Non-metric multidimensional scaling; df: degrees of freedom.

Response Variable	Explanatory Variable	Intercept	Slope	df	R^2	p
Avinissery						
Bird Abundance	Distance to Road	16.043	0.026	28	0.109	0.042
	SD Canopy Cover	16.016	0.701	28	0.182	0.011
Bird Richness	Property Size	4.513	0.001	28	0.185	0.010
	SD Canopy Cover	5.597	0.174	28	0.163	0.015
Bird Diversity	Property Size	1.434	0.0001	28	0.109	0.042
Bird NMDS axis 1	SD Canopy Height	-0.386	0.093	28	0.130	0.029
	Percent Cover of Human Structures (250 m)	-0.486	0.030	28	0.129	0.029
Bird NMDS axis 2	None					
Butterfly Abundance (log)	Property Size	2.414	0.0003	28	0.205	0.007
Butterfly Richness	Property Size	7.043	0.001	28	0.169	0.014
	SD Canopy Cover	9.667	0.313	28	0.107	0.044
	Mean Under Cover	8.509	0.090	28	0.144	0.022
Butterfly Diversity	Property Size	1.596	0.0001	28	0.152	0.019
	SD Canopy Cover	1.747	0.038	28	0.194	0.009
	Mean Under Cover	1.736	0.008	28	0.124	0.032
Butterfly NMDS axis 1	Percent Cover of Open (non-treed) Area 1 km	0.341	-0.011	27	0.288	0.002
	Percent Cover of Human Structures 1 km	-0.295	0.022	27	0.108	0.045
Butterfly NMDS axis 2	Mean Canopy Cover	-0.910	0.010	27	0.368	$2.91e^{-4}$
	SD Canopy Cover	0.096	-0.017	27	0.252	0.003
	Mean Understory Cover	0.098	-0.004	27	0.169	0.015
	Tree Abundance (log)	-0.673	0.382	27	0.164	0.017
Frog Abundance (log)	Distance to Paddy (log)	5.728	-1.428	28	0.290	0.001
	Understory Height	1.966	2.090	28	0.149	0.020
	SD Understory Height	1.929	3.121	28	0.186	0.010
Frog Richness	Percent Cover of Open (non-treed) Area (1 km)	1.723	0.051	28	0.129	0.029
Frog Diversity	Percent Cover of Open (non-treed) Area (1 km)	0.411	0.017	28	0.109	0.042
	Distance to Paddy (log)	2.022	-0.572	28	0.176	0.012
Frog NMDS axis 1	None					
Frog NMDS axis 2	Percent Cover of Human Structures (1 km)	1.166	-0.066	28	0.127	0.030
Insect Abundance (log)	Mean Understory Cover	6.080	-0.007	28	0.126	0.030
Insect Richness	None					
Insect Diversity	Mean Understory Cover	0.837	0.006	28	0.309	0.001
	Mean Understory Height	0.703	1.289	28	0.328	0.001
Insect NMDS axis 1	None					
Insect NMDS axis 2	Mean Understory Cover	0.153	-0.004	28	0.234	0.004
	Mean Understory Height	0.220	-0.706	28	0.226	0.005
	Mean Canopy Height	0.391	-0.042	28	0.130	0.028
Soil Macrofauna Abundance	Percent Cover of Human Structures (500 m)	18.408	-0.555	28	0.100	0.050

	Percent Cover of Open (non-treed) Area (1 km)	0.821	0.337	28	0.233	0.004
Soil Macrofauna Richness	SD Understory Height	0.951	5.485	28	0.123	0.033
Soil Macrofauna Diversity	None					
Soil Macrofauna NMDS axis 1	Distance to Paddy	-0.921	0.003	27	0.157	0.019
Soil Macrofauna NMDS axis 2	None					
Dragonfly (binary)	Percent Cover of Open (non-treed) Area (500 m)	-2.606	0.217			0.049
	Mean Canopy Cover	43.871	-0.458			0.021
	SD Canopy Cover	-1.535	0.359			0.019
	Mean Understory Cover	-1.056	0.051			0.015
	Tree Abundance (log)	3.209	-0.049			0.023
Kalikavu						
Bird Abundance	Tree Abundance (log)	55.730	-21.461	28	0.117	0.036
	Mean Tree DBH	-1.945	1.210	28	0.186	0.010
Bird Richness (log)	Distance to Road	1.855	-0.001	28	0.107	0.044
	Tree Abundance (log)	3.311	-0.913	28	0.121	0.034
Bird Diversity	Distance to Road	1.623	-0.001	28	0.120	0.035
Bird NMDS axis 1	SD Canopy Height	0.547	-0.085	28	0.225	0.005
	Distance to Road	-0.026	0.001	28	0.144	0.022
	Percent Cover of Human Structures (1 km)	-0.097	0.081	28	0.108	0.043
Bird NMDS axis 2	None					
Butterfly Abundance (log)	Mean Understory Cover	2.241	0.016	28	0.181	0.011
	Tree Diversity	2.347	0.643	28	0.164	0.015
Butterfly Richness (log)	Mean Understory Cover	1.513	0.011	28	0.124	0.032
	Tree Diversity	1.552	0.440	28	0.134	0.026
Butterfly Diversity	Mean Under Cover	1.232	0.011	28	0.138	0.025
Butterfly NMDS axis 1	Mean Canopy Height	0.855	-0.082	28	0.172	0.013
Butterfly NMDS axis 2	Tree Diversity	0.347	-0.181	28	0.117	0.036
Frog Abundance	None					
Frog Richness	Mean Canopy Height	-1.173	0.372	28	0.181	0.011
Frog Diversity	Mean Canopy Height	-0.137	0.089	28	0.104	0.046
Frog NMDS axis 1	SD Canopy Height	1.578	-0.261	26	0.442	$6.79e^{-5}$
	SD Understory Cover	1.209	-5.371	26	0.139	0.029
Frog NMDS axis 2	None					
Insect Abundance	SD Canopy Height	163.806	34.119	28	0.101	0.049
Insect Richness	Distance to Road (log)	11.295	-1.613	28	0.256	0.003
	SD Canopy Height	6.396	0.346	28	0.421	$6.32e^{-5}$
	Tree Diversity	7.109	0.902	28	0.138	0.025
Insect Diversity	Percent Cover of Human Structures (250 m)	1.018	0.036	28	0.127	0.030
	Mean Canopy Cover	2.808	-0.018	28	0.102	0.048
	SD Canopy Height	0.954	0.039	28	0.097	0.052
	Mean Understory Cover	0.822	0.007	28	0.367	$2.34e^{-4}$
	Mean Understory Height	0.665	1.751	28	0.326	0.001
	SD Understory Height	0.879	1.680	28	0.180	0.011
Insect NMDS axis 1	Road Distance (log)	-0.483	0.267	28	0.219	0.005
	Mean Understory Cover	-0.131	0.005	28	0.191	0.009
	SD Canopy Height	0.240	-0.038	28	0.140	0.024
	Mean Understory Height	-0.200	1.00	28	0.129	0.029
Insect NMDS axis 2	None					
Soil Macrofauna Abundance (log)	Percent Cover of Open (non-treed) Area (500 m)	0.801	0.035	28	0.135	0.026

	SD Canopy Height	1.555	0.145	28	0.168	0.014
	Tree Abundance (log)	3.106	-0.014	28	0.215	0.006
Soil Macrofauna Richness (log)	Distance to Road (log)	1.833	-0.414	28	0.141	0.023
	SD Canopy Height	0.494	0.107	28	0.366	$2.36e^{-4}$
	Tree Diversity	0.624	0.373	28	0.238	0.004
Soil Macrofauna Diversity (log)	None					
Soil Macrofauna NMDS axis 1	SD Canopy Height	0.848	-0.132	27	0.125	0.034
	Distance to Road	-0.078	0.002	27	0.106	0.048
Soil Macrofauna NMDS axis 2	None					
Dragonfly (binary)	Mean Canopy Height	-5.207	0.500			0.032

Appendix B: List of Species Recorded in Homegardens

Species	Family	Number sites detected in:				
		Avinissery	Kalikavu	Forest	Plantation	Total
Birds						
Accipiter badius	Accipitridae	0	1	0	1	2
Acridotheres tristis	Sturnidae	5	7	0	0	12
Acritillas indica	Pycnontidae	0	0	2	0	2
Aegithina tiphia	Aegithinidae	0	0	2	0	2
Alcedo atthis	Alcedinidae	2	0	0	0	2
Amaurornis phoenicurus	Rallidae	1	0	0	0	1
Anastomus oscitans	Ciconiidae	2	0	0	0	2
Apus nipalensis	Apodidae	0	0	0	1	1
Ardeola grayii	Ardeidae	6	0	1	0	7
Athene brama	Strigidae	0	1	0	0	1
Bubulcus ibis	Ardeidae	5	0	0	0	5
Centropus bengalensis	Cuculidae	0	0	0	1	1
Centropus sinensis	Cuculidae	14	14	2	2	32
Chalcophaps indica	Columbidae	0	0	4	0	4
Chloropsis aurifrons	Chloropseidae	3	0	3	0	6
Chloropsis sp.	Chloropseidae	0	1	1	0	2
Chrysocolaptes lucidus	Picidae	0	6	1	0	7
Circus aeruginosus	Accipitridae	1	0	0	0	1
Columba livia	Columbidae	8	0	2	0	10
Copsychus saularis	Muscicapidae	7	2	4	0	13
Corvus macrorhynchos	Corvidae	3	4	3	0	10
Corvus splendens	Corvidae	27	27	3	2	59
Cuculus micropterus	Cuculidae	1	0	0	1	2
Dendrocitta vagabunda	Corvidae	17	20	4	1	42
Dicrurus leucophaeus	Dicruridae	0	0	3	1	4
Dicrurus macrocercus	Dicruridae	2	6	4	1	13
Dicrurus paradiseus	Dicruridae	0	13	4	0	17
Dicrurus sp.	Dicruridae	0	1	1	0	2
Dinopium benghalense	Picidae	5	0	0	1	6
Dinopium javanense	Picidae	2	0	1	0	3
Egretta garzetta	Ardeidae	3	0	0	0	3
Elanus axillaris	Accipitridae	0	0	1	0	1
Eudynamys scolopacea	Cuculidae	7	0	0	1	8
Galloperdix spadicea	Phasianidae	0	0	2	0	2
Gallus sonneratii	Phasianidae	0	0	3	0	3
Geokichla citrina	Turdidae	0	0	1	0	1
Gracula religiosa	Sturnidae	0	0	1	0	1
Halcyon smyrnensis	Halcyonidae	6	2	1	0	9
Haliastur indus	Accipitridae	2	0	0	0	2
Harpactes fasciatus	Trogonidae	0	0	1	0	1
Hemicircus canente	Picidae	0	0	1	0	1
Hierococcyx varius	Cuculidae	14	0	3	0	17
Lonchura striata	Estrildidae	0	0	1	0	1
Megalaima haemacephala	Megalaimidae	0	0	3	0	3
Megalaima viridis	Megalaimidae	18	11	4	2	35
Merops orientalis	Meropidae	1	0	0	2	3
Merops philippinus	Meropidae	2	0	0	1	3

Microcarbo niger	Phalacrocoracidae	0	0	1	0	1
Muscicapa latirostris	Muscicapidae	0	0	1	0	1
Myophonus horsfieldii	Muscicapidae	0	0	1	0	1
Nectarinia asiatica	Nectariniidae	1	1	0	0	2
Nectarinia sp.	Nectariniidae	1	4	0	0	5
Nectarinia zeylonica	Nectariniidae	7	3	2	1	13
Ocyceros birostris	Bucerotidae	1	0	0	0	1
Ocyceros griseus	Bucerotidae	0	0	1	0	1
Oriolus oriolus	Oriolidae	1	0	3	0	4
Oriolus xanthornus	Oriolidae	0	2	1	0	3
Orthotomus sutorius	Cisticolidae	3	3	1	0	7
Passer domesticus	Passeridae	1	0	0	0	1
Pavo cristatus	Phasianidae	0	3	2	2	7
Pericrocotus cinnamomeus	Campephagidae	0	0	1	0	1
Pericrocotus flammeus	Campephagidae	1	1	3	0	5
Phylloscopus trochiloides	Phylloscopidae	1	0	4	0	5
Psittacula cyanocephala	Psittaculidae	0	0	2	1	3
Psittacula krameri	Psittaculidae	7	0	0	0	7
Psittacula sp.	Psittaculidae	0	3	0	0	3
Pycnonotus cafer	Pycnonotidae	2	3	2	1	8
Pycnonotus dispar	Pycnonotidae	0	0	1	0	1
Pycnonotus jocosus	Pycnonotidae	3	1	3	2	9
Pycnonotus luteolus	Pycnonotidae	0	0	0	1	1
Spilornis cheela	Accipitridae	0	2	0	0	2
Streptopelia chinensis	Columbidae	3	0	3	0	6
Strix ocellata	Strigidae	0	0	1	0	1
Sturnus sp.	Sturnidae	0	0	0	1	1
Terpsiphone paradisi	Monarchidae	1	0	2	0	3
Threskiornis melanocephalus	Threskiornithidae	2	0	0	0	2
Treron sp.	Columbidae	0	0	1	1	2
Turdoides affinis	Leiothrichidae	11	21	1	0	33
Turdoides leucocephala	Leiothrichidae	6	0	4	0	10
Turdoides sp.	Leiothrichidae	0	1	0	0	1
Turdoides striatus	Leiothrichidae	0	1	1	0	2
Vanellus indicus	Charadriidae	2	0	0	1	3
Vanellus malabaricus	Charadriidae	0	0	0	2	2
Unidentified	Unknown	0	3	1	0	4
Unidentified Duck	Anatidae	0	0	1	0	1
Unidentified Owl	Strigidae	0	0	1	0	1
Unidentified Pigeon	Columbidae	0	0	1	0	1
Unidentified Woodpecker	Picidae	0	6	0	0	6
Butterflies						
Acraea terpsicore	Nymphalidae	1	0	0	0	1
Acytolepis puspa	Lycaenidae	1	0	0	0	1
Ampittia dioscorides	Hesperiidae	2	6	0	0	8
Appias albina	Pieridae	0	1	1	0	2
Araschnia levana	Nymphalidae	0	0	1	0	1
Ariadne ariadne	Nymphalidae	7	1	0	0	8
Ariadne merione	Nymphalidae	5	2	0	0	7
Athyma perius	Nymphalidae	1	1	1	0	3
Atrophaneura hector	Papilionidae	3	3	2	0	8
Atrophaneura pandiyana	Papilionidae	3	6	0	2	11
Borbo cinnara	Hesperiidae	9	1	0	2	12
Caleta caleta	Lycaenidae	0	0	1	0	1

Castalius rosimon	Lycaenidae	10	7	0	0	17
Catopsilia pomona	Pieridae	16	5	1	2	24
Catopsilia pyranthe	Pieridae	5	0	0	0	5
Cheritra freja	Lycaenidae	1	0	2	0	3
Chilades pandava	Lycaenidae	2	0	0	0	2
Cupha erymanthis	Nymphalidae	11	0	3	0	14
Danaus chrysippus	Nymphalidae	1	0	1	0	2
Danaus genutia	Nymphalidae	8	2	2	0	12
Delias eucharis	Pieridae	4	1	3	0	8
Discolampa ethion	Lycaenidae	1	0	0	0	1
Elymnias hypermnestra	Nymphalidae	4	3	1	0	8
Euchrysops cnejus	Lycaenidae	6	4	1	0	11
Euploea core	Nymphalidae	16	8	5	0	29
Euploea sylvester	Nymphalidae	1	1	1	0	3
Eurema andersonii	Pieridae	1	0	1	0	2
Eurema hecabe	Pieridae	24	20	2	0	46
Euthalia aconthea	Nymphalidae	1	0	0	0	1
Graphium agamemnon	Papilionidae	1	0	0	0	1
Graphium sarpedon	Papilionidae	1	0	1	0	2
Hypolimnas bolina	Nymphalidae	5	1	1	0	7
Hypolimnas misippus	Nymphalidae	1	3	0	1	5
Idea malabarica	Nymphalidae	0	1	0	0	1
Jamides celeno	Lycaenidae	12	2	2	0	16
Junonia almana	Nymphalidae	7	0	0	0	7
Junonia atlites	Nymphalidae	7	2	0	0	9
Junonia iphita	Nymphalidae	13	10	3	2	28
Junonia lemonias	Nymphalidae	1	0	0	0	1
Leptosia nina	Pieridae	25	19	2	1	47
Loxura atymnus	Lycaenidae	1	1	1	0	3
Melanitis leda	Nymphalidae	5	2	0	0	7
Melanitis phedima	Nymphalidae	7	1	2	0	10
Moduza procris	Nymphalidae	1	0	1	0	2
Mycalesis perseus	Nymphalidae	21	15	2	0	38
Neptis hylas	Nymphalidae	1	2	1	0	4
Oriens goloides	Hesperiidae	0	2	0	0	2
Orsotriaena medus	Nymphalidae	10	19	2	1	22
Pachliopta aristolochiae	Papilionidae	17	6	4	0	27
Pantoporia hordonia	Nymphalidae	0	0	2	0	2
Papilio demoleus	Papilionidae	5	1	1	0	7
Papilio helenus	Papilionidae	4	2	4	0	10
Papilio paris	Papilionidae	1	5	1	0	7
Papilio polymnestor	Papilionidae	18	11	4	0	33
Papilio polytes	Papilionidae	22	14	5	0	41
Parantica aglea	Nymphalidae	0	1	0	0	1
Prioneris sita	Pieridae	0	0	1	0	1
Talicada nyseus	Lycaenidae	0	0	1	0	1
Tirumala limniace	Nymphalidae	9	1	3	0	13
Tirumala septentrionis	Nymphalidae	1	0	1	0	2
Troides minos	Papilionidae	12	4	4	0	20
Ypthima huebneri	Nymphalidae	16	22	1	0	39
Zizula hylax	Lycaenidae	1	0	0	0	1
Unidentified Skipper 1	Hesperiidae	0	6	0	0	6
Unidentified Skipper 2	Hesperiidae	1	2	0	0	3
Unidentified Skipper 3	Hesperiidae	0	1	0	0	1
Unidentified Skipper 4	Hesperiidae	0	1	0	0	1
Unidentified Skipper 5	Hesperiidae	0	1	0	0	1

	Unidentified Skipper 6	Hesperiidae	0	2	0	0	2
	Unidentified Skipper 7	Hesperiidae	4	1	0	0	5
	Unidentified Butterfly 1	Unknown	1	0	0	0	1
	Unidentified Butterfly 2	Unknown	0	1	0	0	1
	Unidentified Butterfly 3	Unknown	0	1	0	0	1
	Unidentified Butterfly 4	Unknown	0	4	0	0	4
	Unidentified Butterfly 5	Unknown	0	6	0	0	6
	Unidentified Butterfly 6	Unknown	0	1	0	0	1
	Unidentified Butterfly 7	Unknown	0	1	0	0	1
	Unidentified Butterfly 8	Unknown	0	1	0	0	1
	Unidentified Butterfly 9	Unknown	1	1	0	0	2
	Unidentified Butterfly 10	Unknown	1	0	0	0	1
	Unidentified Butterfly 11	Unknown	3	0	1	0	4
Dragonflies							
	Aethriamanta brevipennis	Libellulidae	2	0	0	0	2
	Agriocnemis pieris	Coenagrionidae	2	5	1	0	8
	Agriocnemis pygmaea	Coenagrionidae	1	0	1	0	2
	Ceriagrion cerinorubellum	Coenagrionidae	6	2	1	2	11
	Ceriagrion coromandelianum	Coenagrionidae	3	3	0	0	6
	Ceriagrion fallax	Coenagrionidae	1	1	0	0	2
	Ceriagrion rubiae	Coenagrionidae	0	1	0	0	1
	Copera marginipes	Platycnemididae	0	2	0	0	2
	Copera vittata	Platycnemididae	1	0	0	0	1
	Hylaeothemis fruhstorferi	Libellulidae	5	0	0	0	5
	Ictinogomphus rapax	Gomphidae	0	1	0	0	1
	Ischnura aurora	Coenagrionidae	0	2	0	0	2
	Neurothemis fulvia	Libellulidae	3	1	1	0	5
	Neurothemis tullia	Libellulidae	18	5	0	0	23
	Orthetrum chrysis	Libellulidae	0	2	0	0	2
	Orthetrum glaucum	Libellulidae	2	0	0	0	2
	Orthetrum pruinosum	Libellulidae	1	0	0	0	1
	Orthetrum sabina	Libellulidae	4	1	0	0	5
	Pseudagrion microcephalum	Coenagrionidae	0	2	0	1	3
	Rhyothemis variegata	Libellulidae	9	0	1	0	10
	Trithemis aurora	Libellulidae	2	0	1	0	3
	Unidentified	Unknown	1	0	0	0	1
	Unidentified Bambootail	Protoneuridae	1	3	0	1	5
	Unidentified Clubtail		0	1	0	1	2
	Unidentified Damselfly		6	4	0	0	10
	Unidentified Dragonfly		5	4	0	1	10
	Unidentified Marsh Dart		1	1	0	0	2
	Unidentified Reedtail		0	1	0	0	1
	Unidentified Skimmer		1	0	0	0	1
	Urothemis signata	Libellulidae	2	1	0	0	3
	Vestalis apicalis	Calopterygidae	1	5	4	0	10
Frogs							
	Duttaphrynus melanostictus	Bufonidae	3	1	0	0	4
	Duttaphrynus scaber	Bufonidae	0	7	0	0	7
	Duttaphrynus sp.	Bufonidae	7	4	0	0	11
	Euphlyctis cyanophlyctis	Dicroglossidae	0	8	0	0	8
	Fejervarya limnocharis	Dicroglossidae	10	1	3	0	14
	Fejervarya sp.	Dicroglossidae	15	9	5	0	29

Hoplobatrachus tigerinus	Dicroglossidae	16	8	4	2	30
Indirana beddomii	Ranixalidae	0	0	1	0	1
Indirana sp.	Ranixalidae	1	7	4	1	13
Microhyla sp.	Microhylidae	0	0	1	0	1
Polypedates maculatus	Rhacophoridae	2	3	0	0	5
Polypedates occidentalis	Rhacophoridae	0	1	0	0	1
Polypedates sp.	Rhacophoridae	0	1	0	0	1
Pseudophilautus kani	Rhacophoridae	28	19	3	2	52
Unidentified	Unknown	2	10	3	0	15
Unidentified Juvenile	Unknown	0	16	0	0	16
Zakerana keralensis	Dicroglossidae	0	0	2	0	2
Trees						
Adenanthera pavonina	Fabaceae	0	0	1	0	1
Aegle marmelos	Rutaceae	1	0	0	0	1
Ailanthus triphysa	Simaroubaceae	1	1	1	0	3
Alstonia scholaris	Apocynaceae	1	1	0	0	2
Anacardium occidentale	Anacardiaceae	9	2	0	0	11
Annona reticulata	Annonaceae	5	0	0	0	5
Annona squamosa	Annonaceae	1	0	0	0	1
Aphanamixis polystachya	Meliaceae	0	0	1	0	1
Aporusa lindleyana	Euphorbiaceae	0	1	0	0	1
Areca catechu	Arecaceae	17	26	0	0	43
Artocarpus communis	Moraceae	5	0	0	0	5
Artocarpus heterophyllus	Moraceae	10	10	0	0	20
Artocarpus hirsutus	Moraceae	0	10	0	0	10
Averrhoa bilimbi	Oxalidaceae	4	0	0	0	4
Azadirachta indica	Meliaceae	3	0	0	0	3
Bombax ceiba	Malvaceae	2	1	4	0	7
Bridelia retusa	Phyllanthaceae	1	0	3	0	4
Butea monosperma	Fabaceae	1	0	0	0	1
Butea parviflora	Fabaceae	0	0	1	0	1
Caesalpinia coriaria	Fabaceae	1	0	0	0	1
Caesalpinia pulcherrima	Fabaceae	1	0	0	0	1
Caesalpinia sappan	Fabaceae	1	0	0	0	1
Calophyllum inophyllum	Calophyllaceae	1	0	0	0	1
Calycopteris floribunda	Combretaceae	0	0	1	0	1
Cananga odorata	Annonaceae	1	0	0	0	1
Carallia brachiata	Rhizophoraceae	1	0	1	0	2
Carica papaya	Caricaceae	4	0	0	0	4
Caryota urens	Arecaceae	1	0	2	1	4
Cassia fistula	Fabaceae	3	0	0	0	3
Catunaregam spinosa	Rubiaceae	0	0	1	0	1
Ceiba pentandra	Malvaceae	1	0	1	0	2
Cinnamomum verum	Lauraceae	2	1	0	0	3
Citrus grandis	Rutaceae	1	2	0	0	3
Clausena anisata	Rutaceae	0	0	1	0	1
Cleistanthus collinus	Phyllanthaceae	0	0	2	0	2
Cocos nucifera	Arecaceae	30	25	0	1	56
Coffea arabica	Rubiaceae	1	0	0	0	1
Crataeva magna	Capparaceae	1	0	0	0	1
Cycas circilinias	Cycadaceae	0	0	1	0	1
Dalbergia lanceolaria	Fabaceae	0	0	1	0	1
Dalbergia sissoides	Fabaceae	0	0	1	0	1
Delonix regia	Fabaceae	1	0	1	0	2
Dillenia pentagyna	Dilleniaceae	0	0	1	0	1

Diospyros buxifolia	Ebenaceae	0	1	0	0	1
Drypetes venusta	Euphorbiaceae	0	0	1	0	1
Enterolobium cyclocarpum	Fabaceae	0	0	1	0	1
Erythrina indica	Fabaceae	1	1	0	0	2
Ficus callosa	Moraceae	3	0	0	0	3
Ficus exasperata	Moraceae	1	0	1	0	2
Ficus hispida	Moraceae	1	0	0	0	1
Ficus racemosa	Moraceae	1	0	0	0	1
Garcinia gummi-gutta	Clusiaceae	3	0	0	0	3
Garcinia mangostana	Clusiaceae	0	2	0	0	2
Garuga pinnata	Burseraceae	11	0	0	0	11
Gliricidia sepium	Fabaceae	5	2	1	0	8
Grewia tiliaefolia	Malvaceae	0	0	3	0	3
Hevea brasiliensis	Euphoribiaceae	0	20	0	1	21
Holarrhena pubescens	Apocynaceae	0	0	1	0	1
Holoptelea integrifolia	Ulmaceae	0	0	1	0	1
Hopea parviflora	Dipterocarpaceae	0	0	1	0	1
Hydnocarpus pentandra	Flacourtiaceae	1	0	0	0	1
Lagerstroemia microcarpa	Lythraceae	0	0	1	0	1
Lagerstroemia speciosa	Lythraceae	0	0	1	0	1
Lannea coromandelica	Anacardiaceae	6	0	0	0	6
Leucaena leucocephala	Fabaceae	2	0	1	0	3
Litsea coriacea	Lauraceae	0	0	1	0	1
Macaranga peltata	Euphorbiaceae	21	5	3	0	29
Mallotus philippensis	Euphorbiaceae	0	0	2	0	2
Mangifera indica	Anacardiaceae	21	7	0	0	28
Manilkara zapota	Sapotaceae	2	1	0	0	3
Mesua ferrea	Calophyllaceae	0	1	0	0	1
Michelia champaca	Magnoliaceae	1	0	0	0	1
Mimusops elengi	Sapotaceae	1	0	0	0	1
Morinda pubescens	Rubiaceae	1	0	0	0	1
Morinda tinctoria	Rubiaceae	2	0	0	0	2
Moringa oleifera	Moringaceae	10	5	0	0	15
Moringa pterygosperma	Moringaceae	3	0	0	0	3
Murraya koenigii	Rutaceae	2	1	0	0	3
Myristica fragrans	Myristicaceae	13	4	0	0	17
Nephelium lappaceum	Sapindaceae	0	2	0	0	2
Olea dioica	Oleaceae	2	0	0	0	2
Pajanelia longifolia	Bignoniaceae	1	0	0	0	1
Peltophorum pterocarpum	Fabaceae	0	0	1	0	1
Phyllanthus emblica	Phyllanthaceae	3	1	0	0	4
Plumeria rubra	Apocynaceae	0	1	0	0	1
Pongamia pinnata	Fabaceae	0	1	0	0	1
Pouteria campechiana	Sapotaceae	1	0	0	0	1
Psidium guajava	Myrtaceae	8	4	0	0	12
Pterocarpus marsupium	Fabaceae	1	2	1	0	4
Pterocarpus santalinus	Fabaceae	1	0	0	0	1
Punica granatum	Lythraceae	1	0	0	0	1
Sapindus trifoliatus	Sapindaceae	0	0	1	0	1
Schleichera oleosa	Sapindaceae	1	2	2	0	5
Spondias pinnata	Anacardiaceae	2	0	0	0	2
Sterculia guttata	Malvaceae	1	1	0	0	2
Stereospermum colais	Bignoniaceae	0	0	1	0	1
Streblus asper	Moraceae	0	0	1	0	1
Strychnos nux-vomica	Loganiaceae	2	0	1	0	3
Swietenia macrophylla	Meliaceae	1	0	0	0	1

Swietenia mahagoni	Meliaceae	2	1	0	0	3
Syzygium aqueum	Myrtaceae	1	0	0	0	1
Syzygium aromaticum	Myrtaceae	1	0	0	0	1
Syzygium cumini	Myrtaceae	9	0	0	0	9
Tabernaemontana heyneana	Apocynaceae	0	0	1	0	1
Tamarindus indica	Fabaceae	9	0	0	0	9
Tecoma stans	Bignoniaceae	1	0	0	0	1
Tectona grandis	Lamiaceae	6	13	3	0	22
Terminalia arjuna	Combretaceae	2	0	0	0	2
Terminalia bellirica	Combretaceae	0	1	0	0	1
Terminalia catappa	Combretaceae	2	1	0	0	3
Terminalia crenulata	Combretaceae	0	0	2	0	2
Terminalia paniculata	Combretaceae	0	2	4	0	6
Theobroma cacao	Malvaceae	0	3	0	0	3
Trema orientalis	Cannabaceae	2	0	0	0	2
Wrightia tinctoria	Apocynaceae	0	0	4	0	4
Xylia xylocarpa	Fabaceae	0	4	3	0	7
Zanthoxylum rhetsa	Rutaceae	0	0	1	0	1
Unidentified 1	Unknown	0	1	0	0	1
Unidentified 2	Unknown	1	0	0	0	1

Order	**Number sites detected in:**				
	Avinissery	**Kalikavu**	**Forest**	**Plantation**	**Total**
Insects					
Araneae	30	30	5	2	67
Blattodea	27	26	3	1	57
Coleoptera	30	30	5	2	67
Dermaptera	7	8	0	0	15
Diptera	30	30	5	2	67
Ephemeroptera	15	1	0	0	16
Haplotaxida	2	0	0	0	2
Hemiptera	29	30	5	2	66
Hymenoptera	30	30	5	2	67
Isoptera	4	9	3	1	17
Isopoda	11	8	0	0	19
Lepidoptera	29	30	5	2	66
Mantodea	23	20	3	0	46
Neuroptera	1	0	0	0	1
Orthoptera	30	30	5	2	67
Phasmatodea	3	2	2	0	7
Polydesmida	19	9	2	1	31
Pulmonata	15	25	5	1	46
Sphaerotheriida	1	0	0	0	1
Subclass: Acari	2	3	0	0	5
Thysanoptera	6	1	0	0	7
Tricladida	0	4	0	0	4
Unidentified	21	18	3	0	42
Soil Macrofauna					
Araneae	2	0	0	0	2
Blattodea	2	0	0	0	2
Chilopoda	4	4	2	0	10

Coleoptera	10	9	3	0	12
Dermaptera	3	2	1	0	6
Diplopoda	3	2	0	1	6
Haplotaxida	24	28	5	2	59
Isopoda	2	1	1	0	4
Polydesmida	3	2	0	0	5
Pulmonata	0	1	0	0	1
Spirobolida	6	4	4	1	15
Unidentified	1	0	0	0	1
Unidentified Grub	8	3	0	0	11

Appendix C: ANOVA Results

Results of ANOVA of abundance and richness of each taxon in Kalikavu and Avinissery. Bold values indicate significance ($p<0.05$).

	Mean Square	F(1,58)	p-value
Abundance			
Birds	294.8	3.060	0.086
Butterflies	3481	5.626	**0.021**
Dragonflies	336.1	7.251	**0.009**
Frogs	1118.0	5.902	**0.018**
Insects	1948322.0	0.681	0.413
Soil Invertebrates	96.3	2.229	0.141
Trees	5472.0	8.134	**0.006**
Richness			
Birds	29.4	4.469	**0.039**
Butterflies	286.0	9.529	**0.003**
Dragonflies	15.0	3.619	0.062
Frogs	2.0	0.880	0.352
Insects	7.4	1.977	0.165
Soil Invertebrates	2.8	1.545	0.219
Trees	194.4	11.200	**0.001**

Appendix D: Generalized Linear Model Results

Results of Generalized Linear Models of biological response variables and environmental explanatory variables. SE: standard error.

Response	Explanatory	Coeff.	SE	Std. Coeff.	p-value
Avinissery					
Insect Abundance (log)	Intercept	5.430	0.415	-	$3.37e^{-13}$
	Mean Understory Cover	-0.006	0.003	-0.356	0.046
	Percent Cover Structures (500 m)	0.033	0.019	0.286	0.104
Insect Richness	Intercept	8.84			
Insect Diversity	Intercept	0.703	0.121	-	$3.1e^{-6}$
	Mean Understory Height	1.289	0.331	0.593	0.001
Insect NMDS axis 1	Intercept	-0.029	0.101	-	0.822
	Mean Understory Cover	0.006	0.002	0.773	0.014
	Mean Understory Height	-1.190	0.469	-0.746	0.017
Insect NMDS axis 2	Intercept	0.153	0.064	-	0.023
	Mean Understory Cover	-0.004	0.001	-0.510	0.004
Butterfly Abundance (log)	Intercept	2.414	0.361	-	$2.9e^{-7}$
	Property Size	2.45e-4	8.4e-5	0.482	0.007
Butterfly Richness	Intercept	4.949	2.525	-	0.060
	Property Size	0.001	0.001	0.405	0.019
	SD Canopy Cover	0.271	0.137	0.321	0.058
Butterfly Diversity	Intercept	1.332	0.231	-	$3.84e^{-6}$
	Property Size	1.18e-4	4.93e-5	0.373	0.024
	SD Canopy Cover	0.034	0.013	0.425	0.011
Butterfly NMDS axis 1	Intercept	0.341	0.075	-	0.0001
	Percent Cover Open Area (1 km)	-0.011	0.003	-0.560	0.002
Butterfly NMDS axis 2	Intercept	0.096	0.066	-	0.156
	SD Canopy Cover	-0.017	0.005	-0.528	0.003
Bird Abundance	Intercept	20.958	7.207	-	0.007
	SD Canopy Cover	0.509	0.224	0.379	0.032
	Percent Cover Structures (250 m)	-0.442	0.327	-0.228	0.189
	Distance to Road	0.016	0.011	0.254	0.162
Bird Richness	Intercept	5.785	1.984	-	0.007
	SD Canopy Cover	0.148	0.058	0.389	0.017
	Property Size	0.001	0.0002	0.367	0.028
	Percent Cover Structures (250 m)	-0.119	0.085	-0.219	0.174
Bird Diversity	Intercept	1.720	0.280	-	$1.7e^{-6}$
	SD Canopy Cover	0.012	8.2e-3	0.258	0.142
	Property Size	5.1e-5	3.3e-5	0.267	0.140
	Percent Cover Structures (250 m)	-0.019	0.012	-0.274	0.127
Bird NMDS axis 1	Intercept	-0.373	0.245	-	0.139
	SD Canopy Cover	-0.013	0.009	-0.249	0.155
	Percent Cover Structures (250 m)	0.030	0.013	0.406	0.024
Bird NMDS axis 2	Intercept	0.201			
Frog Abundance (log)	Intercept	5.045	0.823	-	$1.5e^{-6}$
	Mean Understory Height	1.992	0.690	0.402	0.008
	Distance to Paddy (log)	-1.391	0.355	-0.546	0.001
Frog Richness	Intercept	0.749	0.606	-	0.227
	SD Understory Height	3.850	1.503	0.409	0.016
	Percent Cover Open Area (1 km)	0.058	0.020	0.455	0.008

Frog Diversity	Intercept	1.119	0.682	-	0.113
	SD Understory Height	0.909	0.565	0.272	0.120
	Distance to Paddy (log)	-0.367	0.241	-0.290	0.139
	Percent Cover Open Area (1 km)	0.012	0.009	0.272	0.166
Frog NMDS axis1	Intercept	0.182	0.342	-	0.599
	Distance to Paddy (log)	-0.254	0.154	-0.298	0.110
Frog NMDS axis 2	Intercept	0.886	0.633	-	0.172
	Distance to Paddy (log)	-0.422	0.285	-0.269	0.150
Soil Macrofauna Abundance	Intercept	0.821	2.512	-	0.746
	Percent Cover Open Area (1 km)	0.337	0.108	0.509	0.004
Soil Macrofauna Richness	Intercept	1.482	0.731	-	0.053
	SD Understory Height	5.417	2.386	0.386	0.031
	Distance to Paddy	-0.002	0.002	-0.258	0.140
Soil Macrofauna Diversity	Intercept	1.198	0.313	-	0.001
	SD Understory Height	1.187	0.699	0.280	0.101
	Distance to Paddy	-0.001	0.001	-0.425	0.028
	Percent Cover Open Area (1 km)	-0.020	0.008	-0.423	0.029
Soil Macrofauna NMDS axis 1	Intercept	-0.921	0.308	-	0.006
	Distance to Paddy	0.003	0.001	0.433	0.019
Soil Macrofauna NMDS axis 2	Intercept	-0.087			
Dragonfly (binary)	Intercept	-4.058	1.934	-	0.036
	SD Canopy Cover	0.334	0.1617	5.589	0.046
	Percent Cover Open Area (500 m)	0.170	0.107	4.099	0.114
Kalikavu					
Insect Abundance	Intercept	163.81	84.020	-	0.061
	SD Canopy Height	34.120	16.540	0.363	0.049
Insect Richness	Intercept	8.466	1.190	-	$1.19e^{-7}$
	SD Canopy Height	0.277	0.080	0.532	0.002
	Distance to Road (log)	-0.853	0.468	-0.281	0.079
Insect Diversity	Intercept	0.624	0.091	-	$2.96e^{-7}$
	SD Canopy Height	0.022	0.014	0.200	0.132
	Mean Understory Cover	0.007	0.001	0.608	$5.08e^{-5}$
	Percent Cover Structures (250 m)	0.033	0.011	0.371	0.007
Insect NMDS axis 1	Intercept	-0.404	0.209	-	0.065
	SD Canopy Height	-0.029	0.014	-0.313	0.050
	Mean Understory Cover	0.005	0.001	0.509	0.001
	Distance to Road (log)	0.188	0.081	0.350	0.028
Insect NMDS axis 2	Intercept	0.126	0.085	-	0.149
	Mean Understory Cover	-0.003	0.002	-0.285	0.127
Butterfly Abundance (log)	Intercept	2.241	0.679	-	0.003
	Tree Diversity	0.756	0.202	0.517	0.001
	Mean Understory Cover	0.017	0.005	0.475	0.003
	Percent Cover Open Area (500 m)	-0.018	0.013	-0.207	0.161
Butterfly Richness (log)	Intercept	1.099	0.281	-	0.001
	Tree Diversity	0.548	0.162	0.505	0.002
	Mean Understory Cover	0.012	0.004	0.459	0.005
	Percent Cover Open Area (500 m)	-0.053	0.031	-0.254	0.098
Butterfly Diversity	Intercept	1.011	0.273	-	0.001
	Tree Diversity	0.435	0.157	0.417	0.010
	Mean Understory Cover	0.012	0.004	0.458	0.005
	Percent Cover Structures (500 m)	-0.071	0.030	-0.352	0.026
Butterfly NMDS axis 1	Intercept	-0.312	0.158	-	0.058
	Mean Understory Cover	0.005	0.003	0.264	0.159
Butterfly NMDS axis 2	Intercept	0.347	0.090	-	0.001
	Tree Diversity	-0.181	0.082	-0.385	0.036

Bird Abundance	Intercept	1.182	7.407	-	0.874
	Mean Tree DBH	1.264	0.431	0.483	0.007
	Percent Cover Structures (1 km)	-1.261	0.842	-0.246	0.146
Bird Richness (log)	Intercept	3.271	0.684	-	$5.96e^{-5}$
	Tree Abundance (log)	-0.715	0.393	-0.304	0.080
	Distance to Road	-0.001	4.4e-4	-0.339	0.051
	Percent Cover Structures (1 km)	-0.051	0.036	-0.237	0.165
Bird Diversity	Intercept	1.828	0.143	-	$5.6e^{-13}$
	Distance to Road	-0.001	4.2e-4	-0.402	0.024
	Percent Cover Structures (1 km)	-0.061	0.034	-0.303	0.082
Bird NMDS axis 1	Intercept	-0.305	0.145	-	0.045
	Distance to Road	0.001	4.3e-4	0.436	0.010
	Percent Cover Structures (1 km)	0.085	0.034	0.393	0.019
Bird NMDS axis 2	Intercept	-0.137			
Frog Abundance	Intercept	-0.060	7.161	-	0.993
	Mean Canopy Height	0.0919	0.604	0.276	0.139
Frog Richness	Intercept	-1.173	1.618	-	0.475
	Mean Canopy Height	0.372	0.137	0.458	0.011
Frog Diversity	Intercept	0.126	0.484	-	0.796
	Mean Canopy Height	0.108	0.041	0.442	0.015
	SD Understory Height	-1.823	1.292	-0.239	0.170
	Percent Cover Structures (250 m)	-0.063	0.030	-0.340	0.048
Frog NMDS axis 1	Intercept	0.876	0.432	-	0.054
	SD Understory Height	-5.092	2.260	-0.392	0.033
	Distance to Road	0.002	0.001	0.275	0.127
Frog NMDS axis 2	Intercept	0.263	0.167	-	0.128
	Percent Cover Structures (250 m)	-0.068	0.029	-0.436	0.026
	Distance to Road	-0.001	0.001	-0.269	0.157
Soil Macrofauna Abundance	Intercept	0.358	0.596	-	0.554
(log)	SD Canopy Height	0.134	0.053	0.401	0.018
	Percent Cover Open (500 m)	0.031	0.014	0.359	0.033
Soil Macrofauna Richness (log)	Intercept	0.291	0.134	-	0.039
	SD Canopy Height	0.091	0.023	0.533	0.001
	Tree Diversity	0.284	0.098	0.392	0.007
Soil Macrofauna Diversity	Intercept	0.729	0.312	-	0.027
	SD Canopy Height	0.039	0.028	0.251	0.172
	Tree Diversity	0.173	0.116	0.265	0.147
	Percent Cover Open (500 m)	-0.011	0.007	-0.286	0.113
Soil Macrofauna NMDS axis 1	Intercept	0.100	0.658	-	0.880
	SD Canopy Height	-0.125	0.058	-0.374	0.041
	Tree Diversity	-0.324	0.241	-0.232	0.191
	Percent Cover Open (500 m)	0.025	0.014	0.293	0.096
Soil Macrofauna NMDS axis 2	Intercept	0.018			
Dragonfly (binary)	Intercept	20.056	14.213	-	0.158
	Mean Canopy Height	0.741	0.322	3.170	0.021
	Mean Understory Cover	-0.292	0.169	-3.037	0.084

Appendix E: Consent Form

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Title of Research: Landscape Fragmentation and Biodiversity Conservation in Ancient Home Gardens in Kerala, India

Principal Investigator: Theraesa Coyle, MSc Student, Department of Geography, McGill University

Supervisors: Dr. Jeanine Rhemtulla, Dr. Sarah Turner

Project Funding: National Geographic Foundation, Natural Sciences and Engineering Research Council of Canada, International Development Research Centre of Canada

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If you have any questions or concerns regarding your rights or welfare as a participant in this research study, please contact the McGill Ethics Officer at 514-398-6831 or lynda.mcneil@mcgill.ca

Participant Consent:

We are interested in exploring the plant and animal species that exist in home gardens to determine whether home gardening is an effective strategy for maintaining biological communities. We would like to invite you to participate in our study.

If you agree to participate in our study, we would like to interview you now for approximately thirty minutes. We will ask you about the animal species in your garden, and your opinions on wildlife and the environment in Kerala. We are also interested in some of the management practices you use in your garden. We would then like to take several measurements of the plant species in your garden, and collect five soil samples to take back to our laboratory. We would like to return this evening at 6pm to count and photograph frog species in your garden, and again at 6am to record the songs of birds in your garden.

Your participation is completely voluntary. You may feel uncomfortable answering some questions or allowing us to take some measurements or samples within your garden. You may refuse to answer any part of this study or withdraw at any time during or after the data collection. Please note that your identity and any information collected from you or your property will be kept strictly confidential, and will be known only to myself, my supervisors and my field assistants present here today. Our handwritten data will be kept in a locked filing cabinet in a locked office at our university in Canada. The information will be coded and kept on a password protected computer, and will only be accessible to myself and my supervisors, Dr. Jeanine Rhemtulla and Dr. Sarah Turner. With your permission, the data may also be made available to future students of Dr. Jeanine Rhemtulla. We will insure that you will not be identifiable from any released results. The data will be stored for a period of five years and then destroyed.

The information obtained in this study will be used to produce a Master's thesis, and may be presented at international conferences and in academic journals. We will supply brochures with a summary of our results to your local *panchayath* representative. We can also send you one by mail or email if you are interested. You will not receive any direct benefits from your participation in our study, but the information may provide you with more knowledge of the species in your garden and the state of biodiversity conservation in your region. Please contact us at any time if you have questions about the study. Are you willing to participate in any or all aspects of our study?

Please check and provide details:

- ☐ Participant has consented to the survey, with the following exceptions:

- ☐ Participant has consented to the field sampling, with the following exceptions:

- ☐ Participant has consented to secondary use of data collected during this study by future students of Dr. Jeanine Rhemtulla, with the following exceptions:

Appendix F: Participant Survey

Garden ID:
Date:
GPS Location:

Owner Name:
Gender:
Age/Religion:

1. What is the primary source of income for your household? Secondary?

2. Why do you have a home garden?

3. Do you have any:

	How Many?
Goats?	
Chickens?	
Cows?	

4. How long has your family owned this land?

5. In the past ten years, have any of the following changes occurred on this land?

Event	Yes/No	How long ago?	What was there before?
Partitioning of land			---
New house built			
New plantation			
Other ___________			

6. In your *panchayath,* in the past decade, have there been any changes in the amount of:

	Increase/Decrease/Stayed the Same
Home gardens	
Agricultural lands	
Buildings/Development	
Other ______________	

7. In the past decade, have you noticed any changes in the number of animals:
    a. In your home garden?

Animal	Increase/Decrease/Stayed the Same
Birds	
Butterflies	
Bees	
Dragonflies	
Frogs	
Lizards	
Spiders	
Snakes	
Earthworms	
Other ________________	

    b. In your *panchayath*?

Animal	Increase/Decrease/Stayed the Same
Birds	
Butterflies	
Bees	
Dragonflies	
Frogs	
Lizards	
Spiders	
Snakes	
Earthworms	
Other ________________	

8.
    a. What benefits do animals bring to you and your home garden? Which animals?

    b. What problems do animals cause in your home garden? Which animals?

    c. Do you enjoy having animals on your land? Why?

9. In your garden or house, do you use:

	(Yes/No)	How often?	Last Application?	Notes (ex. type of fertilizer, which crops)
Chemical Fertilizers?				
Chemical Pesticides?				
Organic Fertilizers?				
Organic Pesticides?				

10. Semi-Structured Interview Portion

Example Questions:

a. Why do you use/not use chemical/organic pesticides/fertilizers?
b. Why do you think frogs/birds/snakes/bees are increasing/decreasing?
c. Are these changes good or bad?
d. Are there any environmental problems in your area?
e. Is wildlife important?