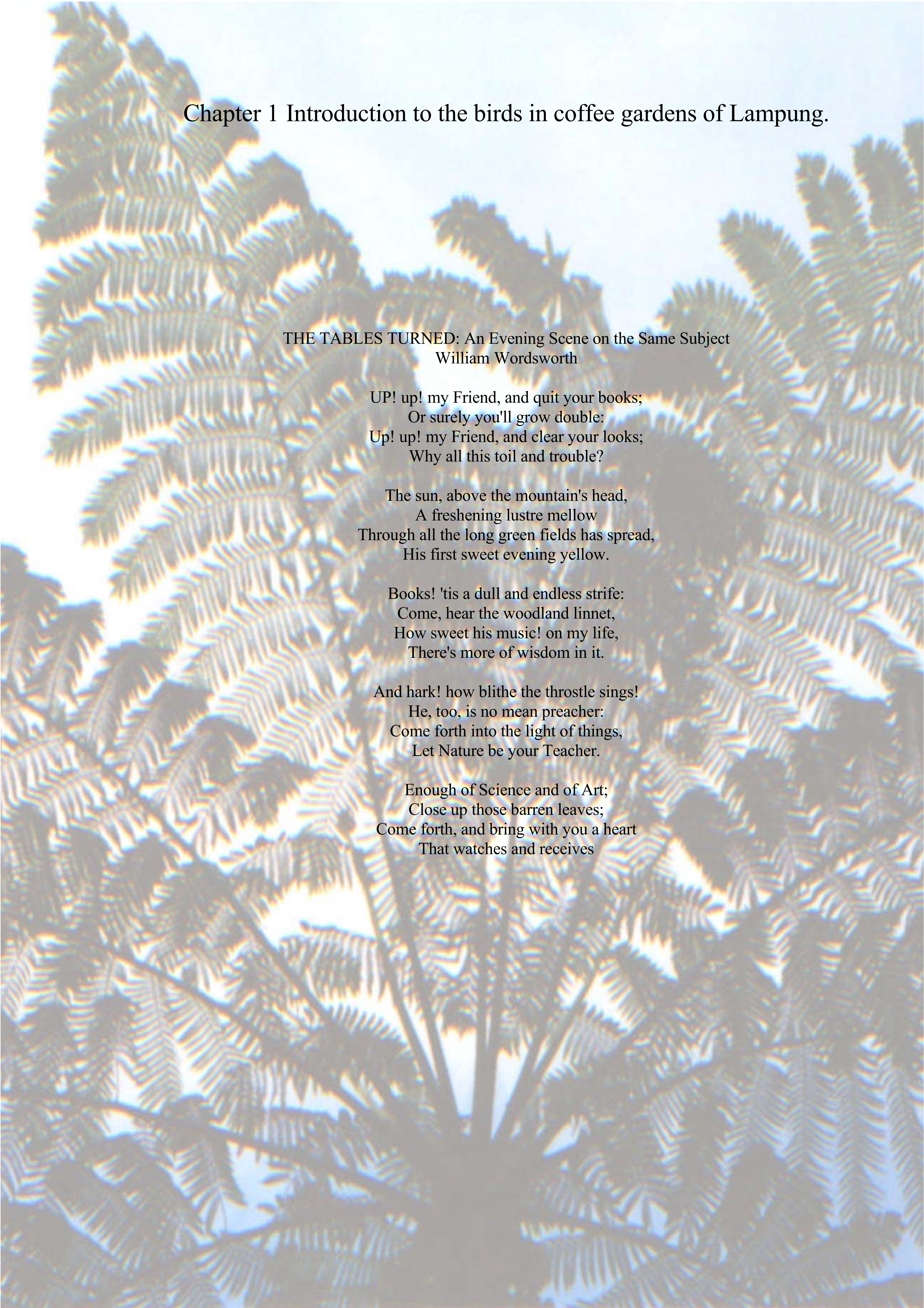


Chapter 1 Introduction to the birds in coffee gardens of Lampung.

THE TABLES TURNED: An Evening Scene on the Same Subject
William Wordsworth

UP! up! my Friend, and quit your books;
Or surely you'll grow double:
Up! up! my Friend, and clear your looks;
Why all this toil and trouble?

The sun, above the mountain's head,
A freshening lustre mellow
Through all the long green fields has spread,
His first sweet evening yellow.

Books! 'tis a dull and endless strife:
Come, hear the woodland linnet,
How sweet his music! on my life,
There's more of wisdom in it.

And hark! how blithe the throstle sings!
He, too, is no mean preacher:
Come forth into the light of things,
Let Nature be your Teacher.

Enough of Science and of Art;
Close up those barren leaves;
Come forth, and bring with you a heart
That watches and receives

Introduction to the birds in the coffee gardens of Lampung.

The tropical rainforests of Indonesia have inspired generations of biologists, including luminaries such as Alfred Wallace. However, in recent decades, their plight has engendered widespread gloom, as reports of rapid deforestation have become so incessant as to be overwhelming. This condition is one caused by human behaviour, driven variably by need, aspiration and ignorance. Yet over a vast area, the potential to retain the rainforests' riches within landscapes that also meet human needs, remains a field in which research lags well behind the rate of forest conversion.

This is a study of the bird assemblages found in coffee gardens, and the potential for their conservation, in West Lampung, on the Indonesian island of Sumatra. It was a field-based project, which, being located in a working farming region, Sumberjaya, encounters many human and environmental variables. In the interests of providing a realistic and useful interpretation of the situation, I have attempted to take into account as many of these relevant factors as possible. Indeed, being a human-dominated landscape, the knowledge, attitudes and behaviour of the local residents and landusers are as important to questions of conservation as are biophysical characteristics.

Figure 1.1 Indonesia, indicating Lampung and the main study area in Sumberjaya.

The Pesisir is located on the coast to the west of Sumberjaya

1.1 The threatened rainforests of Sumatra

"Indonesia is one of the two most biologically diverse nations on earth" according to Wells *et al.* (1999). In keeping with this, Sumatra, Indonesia's 'island of gold' is rich in natural resources, including biodiversity. Faunally, it is considered "one of the richest islands in Indonesia" (Whitten *et al.* 2000, p.36), having the highest number of mammal species and the second highest number of bird species of the Indonesian islands. In comparison with many neighbouring areas, more of this biological abundance remains intact, including populations of Sumatran rhinoceros, elephant and tiger (Ramono and Santiapillai 1993; Whitten *et al.* 2000). Reasons for Sumatra's high species richness include its large size, habitat diversity and past connections with the mainland of Asia (Whitten *et al.* 2000). Its tropical climate supports a suite of rainforest types over a range of altitudes. Tropical rainforests are endowed with species richness disproportionate to their area (Myers 1988). Sumatra is thus recognised by IUCN (the World Conservation Union) as part of the Sunda 'hotspot', which also includes Borneo and the Malay Peninsula (Mittemeier *et al.* 1998; Conservation International 2005). The great concentration of species in such areas has led to suggestions that these should be priority areas for conservation (Mittemeier *et al.* 1998). However, many such biodiverse areas are under the greatest threat in modern times, due to exploitation by people both near and far.

1.2 The urgency of conservation

The environmental productivity of Sumatra has led to a long history of exploitation and development, involving timber extraction, colonisation and commodity trade. Deforestation has been identified as a major threat to fauna, including birds. While four fifths of the lowland forest is thought to have been lost it has also been claimed that "natural vegetation is probably being lost faster than in any other part of Indonesia" (BirdLife International 2000). Indeed, within Lampung province alone, between 1985 and 1997 the area under forest reduced by 23,873 hectares per year, which is a 44.2% reduction over the period (Tjondronegoro 2002, after Holmes 2002). By its rarity, the remaining forest in the region is now very precious, but there is also reason to consider the conservation impact or value of the broader landscape.

In recognition of the needs and aspirations of local people, as well as their great influence on land management, in many countries in the developing world, including Indonesia, the focus of conservation has turned towards integration with development (e.g. Adams 1995; Africa Resources Trust and Campfire Association 1996; Salafsky and Margoluis 1999). Indeed, Indonesia is a populous and developing country, in which much of the population is dependent on the utilisation of natural resources. Thus, to ignore the factors driving processes such as deforestation may be dangerously naive. In Sumatra, an integrative approach is embraced by BirdLife, whose "conservation action points" include integrating biodiversity conservation with regional development, reducing the impact of subsistence agriculture and developing community participation in forest management (Sujatnika *et al.* 1995). However, experiences with integrating conservation with development objectives have often been met with difficulties, and have disappointed investors, residents and conservationists (Salafsky 1999;

Wells *et al.* 1999). There have also been claims that the swing towards more inclusive strategies has sometimes gone too far, and that conservation programs that do not concentrate on core habitat areas will be ineffective (Oates 1999; Waltert *et al.* 2004). Likewise, there is increasing acknowledgement that there will never be a widely applicable prescription for conservation, but that approaches must be tailored to individual circumstances (Abensperg-Traun *et al.* 2004). In recommending future actions for design of such projects in Indonesia, Wells *et al*. (1999) stated

"the people who direct projects need to have much better skills in mainstream management. In the past, they have been trained to make lists of birds and mammals, and so forth, but they have not been adequately trained in the skills needed to build collaborative alliances with the variety of actors who influence the use of land in and around protected areas".

Thus, the problems are complex ones, involving triangles of interaction involving every combinations of groups of people and landscapes. These issues are also urgent; if means to conserve the majority of Indonesia's biodiversity within a context of a human-dominated lanscape are to be found, they must be found soon.

1.3 The birds

Many of the bird species are unique to Sumatra, where BirdLife International has defined two 'Endemic Bird Areas' (EBAs) (Sujatnika *et al.* 1995). This also makes it a popular destination for birdwatchers (Jepson and Ounsted 1997). Together, the EBAs contain 37 Indonesian endemic species, 20 Sumatran endemic species and 36 range restricted species. The range restricted species birds in the area are mainly found in montane forest, but also in hill dipterocarp forest, down to 500 m in altitude (Sujatnika *et al.* 1995). One of these areas runs the length of the Barisan Range, which forms a spine down the western side of Sumatra. Fourteen of the twenty species confined to this area are endemic to Sumatra (BirdLife International 2000). These include the Fire-tufted Barbet (*Psilopogon pyrolophus*), which is monotypic in its genus (Sujatnika *et al.* 1995). All of these birds are thought to be primarily forest affiliated, with some localisation by latitude and altitude. Yet there is less known about the habitat needs and distributions of these species, than those of the birds of the Malay Peninsula's mountains (BirdLife International 2000). Five of the range-restricted bird species of the Bukit Barisan EBA are now classified as 'threatened'. Whilst BirdLife International acknowledge that agricultural encroachment is problematic, they consider that montane forests are adequately covered by the conservation area network. However, it is alleged that much of the area that is officially considered to be protected, has already been subject to intensive and widespread de-forestation (Tjondronegoro 2002).

1.4 Sumberjaya

Sumberjaya is a lower montane area in the foothills to the east of the Barisan range. It falls at the margin of the southern area of the Bukit Barisan EBA, and is close to the Bukit Barisan Selatan National Park. It appears to have largely escaped development until the 20th century, but in the second half of this century was subject to very rapid change. As part of a soldier re-settlement program in the 1950s, de-forestation occurred for the establishment of permanent agriculture. Later programs of transmigration of people from the densely populated Java island, (mainly people of Javanese and Sundanese ethnicity), intensified de-forestation, and for several decades this continued apace. The high prices available for coffee during the late 1970s also provided a strong financial incentive for forest conversion (Verbist and Putra 2002; O'Brien and Kinnaird 2003). It is now a largely agricultural region, with the main crop being coffee, but there are also some remnants of forest, perhaps acting as the last refuges for some of the forest-affiliated birds of the region.

Lampung has also become a target for bird trappers, who feed the markets for captive birds both locally and nationally. Throughout the tropical regions of the world, de-forestation and wildlife trade is causing alarm by its deleterious effects upon fauna. It seems likely that similarly in Sumberjaya, the pressure of forest conversion, degradation and bird trapping might place pressure upon local wildlife. Yet, there are no studies attempting to evaluate these effects locally, nor the potential for fauna to be maintained within the evolving landscape.

1.5 The importance of farming regions

Janzen (1998) argues that unless biodiversity is integrated into human gardens, it will be lost. He says that the separation of nature from human need, will be its downfall. Such an emphasis on areas outside of reserves has increased in past decades following greater consideration of factors such as the isolation and limited spatial cover of reserved areas, as well as greater recognition of locally relevant social dimensions. Miller (1996, p. 427) terms this new approach “bioregional management”. Indeed, in the context that 75 % of the earth is classified as “managed ecosystems”, including many agricultural areas, it seems salient to consider the role of these areas in supporting, or inhibiting, conservation of biodiversity (Bambaradeniya). Further, the inclusion of remnants of ‘original’ habitats, such as forests, within these areas, mandates the involvement of local communities in their care. Past attempts by authorities to exclude these people from management has met with allegations of social injustice, as well as failure to conserve the resources in question (e.g. McNeely 1989; Peluso 1993; Chidley 2002). This is also the case in Sumberjaya, where extensive deforestation, largely for the establishment of coffee farms, led to rather forcefully organised re-vegetation projects that have ultimately been unsuccessful. Tenure is also a complicating factor, with many farms established on land officially designated as protection forest (Kusworo 2000a). Given that deforestation is already extensive, it seems that this landscape may call for some rehabilitation. However, it is unclear what is possible within the economic and social context.

1.6 Why study birds?

1.6.1 Use of indicator groups

Birds are worthy of conservation attention within this region. Many species are endemic, spectacular, play important ecological roles and give pleasure to a great number of people. The popularity of birds has further advantages for their choice as a study taxon, such as the availability of historic information. In addition, it seems likely that both private and public policy changes in the interests of conservation are most likely to occur for the benefit of charismatic taxa. These changes may then benefit a range of other organisms (Williams 1994; Bibby *et al.* 2000). In this study, the central theme is not the conservation biology of individual species, but rather, the potential for a coffee growing landscape to locally support conservation of biodiversity. A full assessment of biological conservation value of any system involves the consideration of the full range of living organisms. Yet the very high species richness of tropical systems, place such a survey well beyond my scope, and that of most researchers. In such situations, indicator taxa are popular for inferring general ecosystem health and processes within constraints of time, money and expertise (Anderson *et al.* 1997 ; Stattersfield *et al.* 1998). General requirements for indicator groups include species richness, responsiveness to change, and available knowledge of ecological requirements (Johns and Marshall 1992 ; Turner *et al.* 1994). There is some disagreement regarding the validity of this use of indicators, due to differing ecological requirements of different taxa. Claims have been made of both high and low congruence between hotspots for different groups (Long 1993; Balmford 1998; Mittemeier *et al.* 1998). However, while possibly not the optimum way of choosing areas for reservation, the use of indicators and a focus on areas of high diversity, endemicity and vulnerability seems justified in the context of research, especially in poorly studied areas where funds for research are limited (Balmford 1998).

1.6.2 Birds as indicators

Within biotic communities, each group responds differently, but not necessarily independently, to disturbance. Thus it is difficult to infer community state from only one (Johns and Marshall 1992). However, birds are regarded as reasonable indicators of habitat quality and general faunal health (Furness and Greenwood 1993; Williams 1994; RAOU 1996). They represent a number of niches in several trophic levels, and by their diverse requirements, are good indicators of habitat quality. Moreover, they are often present in high numbers, are relatively visible and identifiable (Bibby *et al.* 2000). The relatively advanced state of ornithology in Indonesia, compared with the study of some other taxa, also should allow some interpretation of ecological status to be made (Stattersfield *et al.* 1998).

1.7 The role of coffee gardens

Coffee has a driving role in the Sumberjaya landscape, and in many other tropical locations. It is a very valuable commodity globally, "in many years second in value only to oil as a source of foreign exchange to developing countries" (International Coffee Organisation 2005). This makes it very important to numerous farmers, many of whom in Lampung are smallholders (Dietsch *et al.* 2004). However, the truly international nature of the market also leaves prices subject to many outside factors, leaving farmers vulnerable (Ponte 2002).

Coffee is also a promising crop for consideration as habitat, due to its potential to be grown as part of agroforestry systems. It can be grown as a monoculture, or as an understorey crop in a landscape with one or more species of trees, as well as other understorey plants. The biodiversity values of coffee-based agricultural systems have been the subject of substantial study in Latin America. The studies have focused largely on the role of traditional gardens providing habitat to birds, particularly migratory species (e.g. Perfecto *et al.* 1996; Wunderle and Latta 1998). Ecological sustainability of coffee gardens has thus become a prevalent concern in the region and in those of its markets. From this, conservation-oriented guidelines for coffee production have been developed (Mallet 2001). There has also been strong movement to recognise the roles these gardens play as bird habitat, and reward farmers by certification of coffee that is grown under a shading canopy.

In spite of interest in the story of birds and coffee in Latin America, outside of this region, there is a paucity of research in the field, and it remains undemonstrated whether similar benefits of shaded coffee exist for birds of other tropical bioregions (Donald 2004). Without field studies of bird assemblages it is not valid to infer that coffee gardens have the same benefits to avifauna in other regions. The robusta coffee growing situation in Sumberjaya appears rather different from that of Latin America. In the latter case, traditional arabica coffee systems are complex and long established, but in recent decades have become subject to simplification to monocultures (Moguel and Toledo 1999; Dietsch *et al.* 2004). Likewise, given a different social and ecological context, the most promising approaches towards conservation of birds in each area may be different. There may be potential to promote biodiversity conservation, in combination with Lampung farmers'security, by imitating the New World model. However, without sufficient research into the interactions between local landuses, and wildlife the likelihood of success remains unknown. Thus, this project attempts to address these gaps within the Sumberjaya context.

1.8 Aims of this project

The situation of coffee cultivation and bird conservation in Sumberjaya is clearly a complex one, with many variables, but the primary aim of this project is to answer the following questions.

What is the functional contribution of the coffee gardens to local bird habitats?
What is the difference in bird assemblages between different garden types?
What is the most promising approach to bird conservation in the area?

This is to be achieved by field-based studies of birds, vegetation and people throughout the Sumberjaya region. The landscape is a very patchy one, and so other habitats are also surveyed to provide some context, and an indication of the potential landscape alternative, as is relevant to any land management decision. Forest remnants provide a baseline against which the avifaunas of the coffee gardens can be compared. Additionally, surveys are undertaken in the Pesisir region, on the west coast of Lampung. There, the damar agroforests, which are the mature stage of a coffee-based agroforestry system, provide an interesting example of the long-term potential for development of other coffee gardens. Previous study has shown these to have relatively species rich bird assemblages, when compared with many agricultural systems (Thiollay 1994).

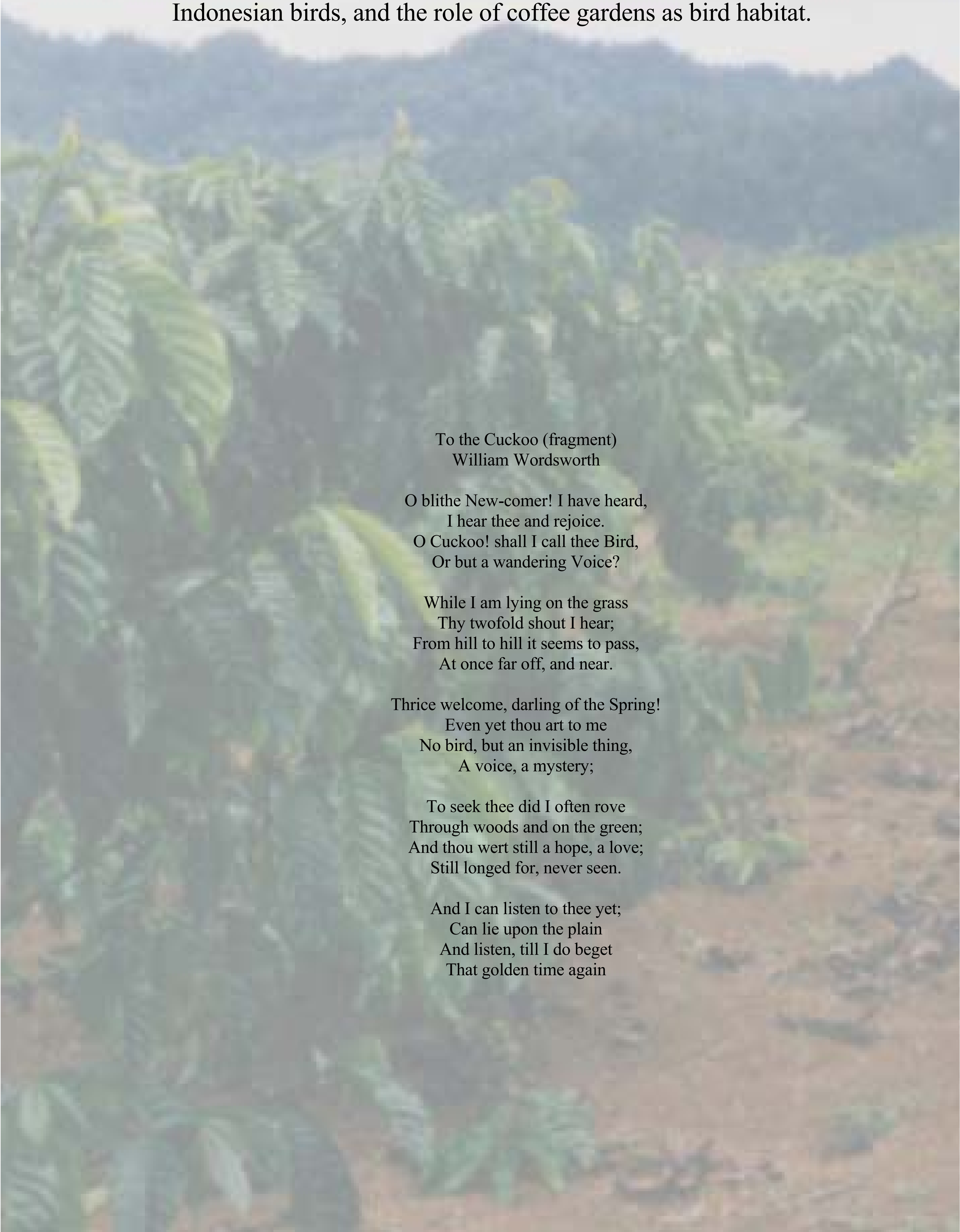
My bird surveys were carried out during wet and dry seasons in 2001 and 2002, recording the assemblages present, as well as visible characteristics of habitat use. Vegetation was also described in terms of structure and composition. These vegetation records were the basis for the coffee garden categorisation. Other land management features that might explain differences between bird assemblages at different sites were also recorded. Additionally, invertebrates were trapped, to make possible some broad comparison of food resources potentially available to insectivores, some of which are frequently identified as being vulnerable to habitat disturbance (Johns 1986).

I also conducted interviews with the farmers responsible for these same gardens, as well as with other community members. These were made to gain information about the management currently undertaken, and its limitations. I explored the perceived advantages and disadvantages of shade trees, perceptions of the role of birds in the environment and their conservation situation. I also asked respondents about their interest in involvement in conservation programs, their opinions regarding responsibility for conservation and their preferred model by which conservation could be achieved, including incentives of tenure or increased payment for coffee by certification. This information seemed essential for addressing the local conservation situation, as the landscape is such a human-dominated one.

1.9 Summary

There is great urgency for more information regarding the potential for applied conservation in this region that is being rapidly deforested. The model that has been established in coffee growing areas of Latin America may have local potential for integrating conservation concerns with commercial opportunities. However, the different ecological and social situations in Sumberjaya allow few assumptions to be made regarding its applicability in that context, as very little research has been conducted in the field. Any other approaches to biodiversity conservation must also take into account biogeographic, ecological, agronomic and social concerns. What follows is a preliminary attempt to answer some of the questions concerning birds' use of a landscape that is largely human dominated, but also contains some of the last forest remnants in this biologically rich region.

Chapter 2 Current knowledge of the effects of habitat modification on Indonesian birds, and the role of coffee gardens as bird habitat.



To the Cuckoo (fragment)
William Wordsworth

O blithe New-comer! I have heard,
I hear thee and rejoice.
O Cuckoo! shall I call thee Bird,
Or but a wandering Voice?

While I am lying on the grass
Thy twofold shout I hear;
From hill to hill it seems to pass,
At once far off, and near.

Thrice welcome, darling of the Spring!
Even yet thou art to me
No bird, but an invisible thing,
A voice, a mystery;

To seek thee did I often rove
Through woods and on the green;
And thou wert still a hope, a love;
Still longed for, never seen.

And I can listen to thee yet;
Can lie upon the plain
And listen, till I do beget
That golden time again

Current knowledge of the effects of habitat modification on Indonesian birds, and the role of coffee gardens as bird habitat.

2.1 Introduction

The physical context in which this project was conducted is one of a heavily modified landscape, subject to extensive forest loss and degradation. However, it is also a social landscape in which many people seek a livelihood, largely by the cultivation of coffee.

In order to understand the framework in which this project exists, it is necessary to explore a wide range of issues. Firstly, one must understand the conservation situation of the region, which has over recent decades, been subject to rapid and extensive deforestation, like much of the tropics. The impacts of some particular types of disturbance to tropical forest may indicate taxa that are generally vulnerable. In locations such as Sumberjaya, where deforestation has been very extensive, restoration is a valid goal, and indeed is one that has been attempted previously. However, rehabilitation of such rainforest areas is dependent upon a number of limiting factors including the inherent ecology and renewal traits of the system, as well as social factors determining human land-use in the area. The need to integrate conservation objectives and livelihood objectives within land management planning is self evident. However, the manner in which this should occur is less clear, with proposed strategies variously emphasising integration or separation of land functions. Agroforests are a class of systems that attempt to increase the ecological sustainability of plantations while also providing secure livelihoods. There has already been substantial research regarding the value of coffee based agroforestry systems for migratory birds in Latin America (e.g. Perfecto, Rice et al. 1996; Greenberg, Bichier et al. 1997; Wunderle and Latta 1998). This indicates some of the successes and limitations of such a system. Some of the coffee gardens found in Sumberjaya also appear to fit within this model. However, their contribution to maintenance of local avifauna remains unknown. Furthermore, the practical means by which this contribution could be maximised, in consideration of social and economic factors, has not yet been addressed. One of the common stumbling blocks for biodiversity-targeted initiatives is the lack of immediate incentives for the stewards (Brandon and Wells 1994; Caldecott 1996). In the context of Sumberjaya, some of the possible options to be explored are market-based systems of eco-certification of shade-grown coffee, as well possible incentives of tenure arrangements in protection forest areas. One other model that will be explored is the situation of the damar agroforests in the Krui region of West Lampung, where many of the barriers to economically and ecologically sustainable agriculture, appear to have been breached.

2.2 Landcover change and biodiversity in tropical environments

Throughout the tropics, increasing human populations and changing aspirations are contributing to a recent increase in the demands on rainforests. Everyday concerns such as food production often override environmental ones (Yamada 1997). Large foreign and in-country commercial interests also often play a role in conversion of forests to more immediately profitable land uses (Carrere and Lohmann 1996). For consumers of the commodities produced, the impacts of their consumption are often far away and unseen. Indonesia is no exception to these patterns as forest clearance occurs to provide timber and land for agriculture and plantations of high value crops such as coffee, rubber and oil palm (CIFOR 2000). However, while deforestation continues apace, accurate monitoring of change in forest cover is a difficult task and subject to political influences and technical difficulty. According to the Food and Agriculture Organisation (FAO) definition of deforestation as "change of land-use or depletion of crown cover to less than 10%", the estimated rate of deforestation for Indonesia in 2000 was 1% annually, amounting to 12, 000 km^2 (World Conservation Monitoring Centre 2004). An estimated 30% of the country's forest cover has already been lost. Furthermore, given the wide scope for forest change unrecognised by official definitions of deforestation it seems likely that these figures underestimate the anthropogenic impacts on Indonesia's forests.

Amongst the less easily measured impacts on forests are fragmentation and loss of structural complexity. Newly cleared areas may also be more vulnerable to fire (Whitmore 1998). The devastating fires in Indonesia in 1997 were due to efforts to clear land for oil palm plantation establishment, and burned out of control for many months (Donald 2004). Change in quality of the forest can include changes to species composition, canopy cover and age structure (World Conservation Monitoring Centre 2004). Vegetation changes giving a more open structure can have further effect by changing microclimates. Higher temperatures, lower humidity, higher light intensity and increased windiness can change seedling regeneration, invertebrate distribution and consequently, success of animals at higher trophic levels (MacKinnon, Hatta et al. 1996).

To a great extent, the effects of forest disturbance and conversion in South-east Asia are poorly known. Logging is one of the best documented modes of alteration to rainforest areas and their fauna. Thus, in the absence of a comprehensive regional literature of the effects of activities such as enrichment planting, plantation or agroforest establishment, the studies of logging impacts may indicate some of the taxa most vulnerable to disturbance. Comparison of primary, lightly logged and heavily logged forest, as well as plantation habitats in Riau Province of

Sumatra, found the birds of primary and lightly logged forest to be similar. However 16% of the bird species found in the entire study were only found in unlogged forest (Danielsen and Heegaard 1993). Studies at Danum Valley in Sabah showed faunal communities to be surprisingly resilient following single episodes of logging, apparently due to the ability of animals to seek refuge in relatively untouched areas and later re-colonise the logged areas (Johns 1996; Whitmore 1998). Similarly, Wilson and Johns (1982) found recovery of most bird species following logging in East Kalimantan, although some taxa with specialist food needs may be vulnerable at least in the short term. The interactions between these animals seeking refuge in forest and those already resident in remnant patches are unclear.

2.2.1 Vulnerable taxa

While many species return following logging, some of the more sensitive taxa fail to do this consistently (Johns and Marshall 1992). These are often specialist, rather than generalist taxa. For example, large-bodied hornbills (Bucerotidae) and Argus Pheasants (*Argusianus argus*) are found in greatly reduced densities following logging (Wilson and Johns 1982). Studies vary in findings due to many circumstances, including geographical and methodological factors. Nevertheless, there are certain features common to many study findings. Frequently, these are recognisable by grouping of birds in ‘guilds’ that define birds by feeding method or substrate, or by the main type of food eaten (Wiens 1989). Most notable amongst the studies of logging impacts is that some insectivores, particularly those of the ground and understorey, are vulnerable to disturbance and large frugivores may also be susceptible (Thiollay 1994; Bawa and Seidler 1998; Corlett 1998; Roberts, Cooper et al. 2000). Logged areas have generally lower numbers of foliage insects, and they are a less predictable resource than in unlogged forests. While omnivores can shift the balance of their diet in response to this, obligate insectivores such as trogons (*Harpactes* spp.) and foliage-gleaning babblers (Timaliidae) are vulnerable. Sallying insectivores such as the flycatchers of *Muscicapa* and *Philentoma* genera may be reduced by the structural simplification of the forest denying them suitable perches (Johns 1986). In a long term study of the effects of logging in the Tekam Forest reserve in Malaysia, Johns (1989) found that after twelve years, some insectivorous groups, such as terrestrial feeders, remained vulnerable. Babblers increased in abundance over time, while understorey plants such as bananas and ginger supported spiderhunters. Reestablishment of a closed lower canopy allowed increased proportional abundance of understorey flycatchers, although these were still less common than in unlogged forest. In Seram, the resident Rusty-breasted Cuckoo (*Cacomantis sepulchralis),* may be rare in logged forest due to declines in the insectivores that act as hosts (Marsden 1998).

Specialised frugivores are also commonly found to be disadvantaged by disturbance. Studies of the logged forests of Halmahera and Buru, in the Indonesian Province of Maluku, identified seven species of frugivorous birds (including five species of pigeon (Columbidae) and a hornbill) that disperse seeds and were significantly more common in primary than disturbed forest (Poulsen and Lambert 2000). Hornbills are a family that are potentially vulnerable to forest disturbance, due to nest-hollow requirements and dependence on fruits of the canopy, including logging-susceptible *Ficus* species (Wilson and Johns 1982; Lambert 1991; Johns 1997). Additionally, it is noted that large-body size is thought to be frequently associated with food specialisation (Johns 1986). Studies in Malaysia (Johns 1986) and Seram (Marsden 1998) found hornbills surprisingly tolerant of selective logging, but Marsden cautioned that as these birds are long-lived, the effects of disturbance on populations may be delayed. Hunting pressure may be an added threat to these large and spectacular birds. This may be compounded by the increased access allowed by logging trails and roads for other resource extraction (Bennett, Nyaoi et al. 1997). Other frugivores vulnerable to disturbance include small birds such as Green Broadbills (*Calyptomena viridis*) that feed on fruits rich in lipids, which are uncommonly found in early successional trees. Similarly, flowerpeckers (Dicaeidae) that specialise on eating fruits of mistletoes frequently hosted by large canopy trees are relatively uncommon in logged forests (Johns 1986).

While there are groups of birds that suffer disproportionately from the effects of disturbances such as logging, there are also some beneficiaries. These are frequently generalist species. Marsden's (1998) study in Seram compared unlogged forest areas with those selectively logged in the previous six years. The only significant beneficiaries of logging were the Olive-backed Sunbird (*Nectarinia jugularis*), a nectarivore, and a small parrot that is a frugivore/nectarivore. This result was similar to Johns' (1997) report of change in relative abundance of species and guilds, including increases in generalists such as arboreal insectivore-frugivores and insectivore-nectarivores. In Tekam Forest Reserve, after a maximum of six years following logging, findings included the increase of colonising insectivore/frugivores such as Yellow-vented Bulbuls (*Pycnonotus aurigaster*)(Johns 1986). Insectivorous beneficiaries of logging include sweeping aerial foragers such as Barn Swallows (*Hirundo rustica*) and Blue-throated Bee-eaters (*Merops viridis*) and swifts (*Apodidae*), that are advantaged by the more open conditions (Johns 1986; Danielsen and Heegaard 1993).

The effects of disturbance may be mitigated by time, although in some circumstances this could take a long time to occur fully. A study of successional recovery in cleared rainforest in India showed birds to follow the non-linear successional changes in floristics and structural features of the vegetation (Beehler, Raju et al. 1986). While there was a progressive increase in bird species richness, the changes in guild representation were more complex. During mid-succession, granivores and understorey insectivores were common, while during late succession canopy insectivores, frugivores and bark feeders increased in abundance. Some species were only found after 100 years of regeneration, indicating their specialist needs, while the importance of floristics for frugivores and nectarivores was highlighted.

In contrast with many studies, in Riau, Danielsen and Heegard (1993) found greater abundance of arboreal frugivores and insectivores in heavily logged than in primary or lightly-logged forest. Differences in the findings of studies may be due to such factors as variation in the rules for guild definition, in the amount of cover retained in the disturbed forest, in the available source populations for re-colonisation or simply biogeographical distinction. The relevant research, however, is sparsely distributed geographically, and thus any general lessons are subject to inaccuracies of extrapolation. This is particularly evident when the individuals of species are observed to have varied responses in different regions, when dissimilar resources are available or where competition varies. Such intra-specific variation has been noted by Johns (1986), Hayes and Samad (1998), Wunderle and Latta (1998) and Poulsen and Lambert (2000). Additionally, it seems that an over-emphasis on guilds defined by feeding behaviour may overlook other habitat requirements such as availability of suitable nest sites. The vertical distribution of nests may be contrary to that expected from foraging behaviour, possibly as a strategy to reduce predation (Wiens 1989). Thus, the stratum requirements of species may be broader than those recognised by studies of feeding location. Bawa and Seidler (1998) noted that the arbitrariness of guild divisions makes study findings site-specific.

Re-colonisation by fauna seems dependent upon the proximity of undisturbed habitat, but species-specific abilities of tropical birds to migrate across hostile habitats are somewhat uncertain (Johns 1996). Some birds have very large home ranges (Terborgh 1986), but the traditional view is that many species are unwilling to travel great distances, especially across open spaces (Benitez-Malvido 1998). Others suggest that birds' ability to re-colonise and disperse is surprisingly high (Wilson and Johns 1982; Johns 1996; Renner 1998). Poulsen and Lambert (2000) cautioned that there were no studies in the Asia-Pacific region indicating the long-term effects upon avifauna isolated from source populations. The debate regarding the importance of connectivity and value of corridors is thus salient to any rehabilitation attempts in areas where forest cover is fragmented.

2.2.2 Fragmentation effects

In addition to habitat loss, forest fragmentation is believed to be critical. In Lampung Province in Sumatra, large mammals have been observed to avoid edge areas of forest with a width of up to three kilometres (Kinnaird 2002). Principles of island biogeography state that the number of species which can be supported by a habitat patch is related logarithmically to its area (Diamond 1975). Thus, the fragmentation of forest associated with activities such as logging or plantation establishment may cause the loss of a greater number of species than expected due to the total area loss alone. Fragmentation effects on seed rain and dispersal may limit seedling density and thus the ability of forest to regenerate (Benitez-Malvido 1998). The sensitivity of species to changes in available habitat area vary with taxonomic and ecological group. For some taxa such as raptors, which have high trophic needs, and also for hornbills, their areal requirements may simply exceed intact habitat (Terborgh 1986; MacKinnon, Hatta et al. 1996; Thiollay 1996). Although these large-bodied birds may also be able to fly long distances to find other suitable habitat patches, the increased energy costs of travel between patches and a potential unwillingness to cross gaps may then cause problems. Adaptation of birds to travel large distances to forage may depend on their food type. Johns (1986) suggested that those that feed on small fruit, typically produced in clumped distribution in association with colonising plants, are less adapted to travel, but may exploit early successional plants in logged patches. Conversely, those that eat large fruits are often large-bodied species, such as Mountain Imperial Pigeon (*Ducula badia*), that are adapted to travel between the widely distributed canopy trees that produce these fruits. However, logging may target such mature trees and further increase the distances needed to be travelled.

Isolation has other effects such as local extinctions that can result from long-term inbreeding depression and the inability of small populations to recover from stochastic events (Begon, Harper et al. 1986). Further, losses may be delayed, and in isolated fragments, these are less likely to be balanced by immigration (Turner, Tan et al. 1994). ‘Edge-effects’ involving increased light, predation (including that upon eggs) and weed invasion, are additional causes for avifaunal change, because fragmentation increases the ratio of edge to core areas (Turner 1996; Benitez-Malvido 1998). Foliage insectivore birds, and in general, species requiring forest interior conditions, are particularly sensitive (Blake, 1983 and Whitcomb et al., 1981 cited in Wiens 1989). Microclimate change has been reported to particularly affect birds such as babblers, which suffer easily from heat-stress. In contrast, some taxa such as drongos (*Dicrurus* spp.) and leafbirds (*Chloropsis* spp.) are less sensitive to microclimate variation due to their adaptation to forest edges. Additionally, terrestrial foragers such as some babblers may suffer from reduced availability of arthropods following the drying and hardening of the soil that occurs with canopy opening (Johns 1986). An additional disturbance upon forest avifauna that may be considered, to some degree, an 'edge effect' is that of hunting and trapping of birds. In the Atlantic forests of Brazil, hunting of birds for food and trapping for the captive bird trade has been identified as further threatening bird populations in the largely de-forested and fragmented landscape (Teixeira 1986). Similarly, in Guinea, hunting has been considered to "reduce the effective size of the protected area" (Rainey 1999, p.2). In the damar agroforests in Lampung in Sumatra, Thiollay (1994) regarded hunting pressure on mammals to be low, but on birds it was high. These observed patterns of forest disturbance and faunal decline mandate the protection of remaining forests. Furthermore, warnings of a possible time-lag between habitat loss and species extinction suggest that the situation may, in fact, be even more dire than currently observed (Brooks and Balmford 1996). In such a context issues of ecosystem restoration and landscape re-organisation are pressing.

2.3 Landscape re-habilitation

In many of the de-forested and degraded areas of Southeast Asia, the return of forest conditions may be limited, as colonising species such as the grass *Imperata cylindrica* ('imperata' or *alang-alang*) have become invasive. Indeed there are examples of locations dominated by such a disclimax community since the late 1800s (Potter, 1997, cited in Otsamo 1998). Garrity *et al.* (1997) have suggested that as these areas are under-utilised, more effort should be made to reclaim them into productivity. The intense competition for soil space, water and nutrients may impede forest regeneration and crop growth in highly disturbed areas. Although herbicides are sometimes effective, fire tolerance also makes imperata control difficult (Bacon 1988). Areas of imperata are likely to be poor in faunal species due to the low structural and floristic diversity in habitat. In Jambi Province in Sumatra these areas are found to have a depauperate bird fauna, dominated by granivores (Jepson and Djarwadi 1999). Thus, the faunal dispersal of other plants is further impeded.

The ability of rainforest to regenerate is clearly compromised by broad-scale and long-term land clearance, especially when involving soil-loss. When not subject to profound human influence, only small areas of rainforests are occupied by pioneer species (Whitmore 1998). However, the ability of plants from later successional stages to re-colonise larger patches of scrubby pioneer vegetation may be limited. Seed distribution is a key factor, especially if tree roots are destroyed, as is likely following agriculture. Without local seed sources, climax species may not be able to regenerate. For example, an abandoned field in Kepong, Malaysia, took 32 years for the first dipterocarp to germinate, despite a distance of only 180m from the nearest parent tree (Whitmore 1998). This raises a number of issues, including the importance of maintaining a local dispersing fauna (although dipterocarps are largely wind-dispersed), and the need for refuges for sedentary species. In a submontane forest in the Philippines, Hamann and Curio (1999) found that 80% of individual trees were zoochorous, and thus the forest's regeneration would be endangered by the loss of its frugivores. While early successional trees are visited by a wide variety of frugivores, those that are 'late successional' are mostly visited by hornbills and fruit pigeons. More conservatively, some suggest that there is limited evidence for the operation of such an 'extinction vortex' in tropical rainforests, and that most plant species do not seem highly specialised in their relationships with pollinators or dispersers (Turner 1996). However, for some species, a close and even obligate relationship exists (Leighton 1992; Hartshorn 1995). Amongst the other challenges to forest re-generation are the predation of seeds and seedlings, the absence of appropriate microhabitats, drought, inadequate availability of soil nutrients and absence of required symbionts (Parrotta 1993). Whitmore (1998) doubted the ability of isolated areas of rainforest to return to a climax stage without the help of humans. The rapidity at which forests are being fragmented may mean that the full implications of this change will not be evident for some time, especially as scientific studies of plant-animal interactions are clearly incomplete. Long-lived trees may exist long after their pollinators and seed dispersers have disappeared (Turner 1996). These will be relicts of a system which has collapsed; "landscapes of the living dead" (Natural Heritage Trust 1998). Investigations into means of conserving species richness in a fragmented and degraded landscape are thus seen as being of high priority (Whitmore 1998).

2.3.1 Approaches to mitigation

There is broad agreement that the replacement of native vegetation assemblages for agriculture, or its removal for other types of resource extraction, is damaging to faunal biodiversity. However, the means by which these impacts should be ameliorated is more contentious. There is uncertainty as to whether the most effective model is to integrate or separate reserves from surrounding agricultural land. There is certainly overlap between the approaches in that proponents of each would seek to maximise areas of high quality habitat. However, while the 'integrate' approach may seek to maximise the numbers of species across the broad landscape, the 'separate' approach places higher emphasis on habitat quality in selected areas. Somewhat paradoxically, it seems that island biogeographic theory can be interpreted variably to support either model. The 'integrate' model emphasises spatial coverage, connectivity and involvement of landholders over the broad landscape. It is justified on the grounds that the majority of land is already used for agricultural production, and so this area must also be enlisted for biodiversity conservation (Siebert 2002; Bambaradeniya undated). In describing the development of indigenous subsistence systems to include commercial crops, Toledo *et al.* (2003) state that "Multiple use, compared with specialized *(sic)* use, signifies a lower production per land-use unit, but a higher production of the aggregate landscape". They also claim that the somewhat disturbed and patchy matrix of this landscape, that integrates land-types ranging between agriculture and forests, supports maximal levels of biodiversity. The rotational nature of the system, which implements the characteristics of vegetation succession to restore land to productivity, is described as 'dynamically permanent'. Indeed, highest local species richness is often found in areas with intermediate levels of disturbance, a factor that has been given credit for the maintenance of high species richness in tropical forests (Connell 1978; Hartshorn 1995). However, consideration of scale is important. High local species richness may not, in fact, be the answer to maintaining a high total number of species, if those high diversity disturbed systems, in fact, consist largely of 'tramp' species, while those sensitive to disturbance are lost (Johns 1996; Bawa and Seidler 1998). In Sri Lanka, the long-established home garden and "rice field integrated agro-ecosystem comprise a rich mosaic of ecotones harbouring a rich biological diversity" (Bambaradeniya undated). It is commonly noted that transitional ecotone areas have high species richness (e.g. Moguel and Toledo 1999), but again, this does not necessary imply that they have high conservation value, as they are unlikely to support species with specialist needs, such as forest interior birds (Poulsen and Lambert 2000). In Malaysian rainforest re-generating after logging, planted exotics were found to be of limited use to birds, suggesting that multiple-use may come at the expense of biodiversity (Johns 1989).

2.3.1.1 The 'integrate' model

The model for integrating land uses such as conservation areas and agricultural areas is supported by the emphasis that island biogeographic theory places on issues of scale and connectivity. Within this theory, habitat corridors are seen as important in linking core habitat areas (e.g. Bierregaard 1985). However, this emphasis has also been criticised as being an ecologically and financially expensive one, due to factors such as the 'edge effects' of increased predation and competition and compromised microhabitats, while the empirical evidence for their effectiveness is limited (Hobbs 1992; Simberloff, Farr et al. 1992). Studies in habitat gradients between forests and grasslands in Ivory Coast and French Guiana suggested that for forest bird conservation, the creation of more, but smaller cleared areas in the forest are preferable to fewer but larger clearings. Additionally, the retention of clumps of trees in agricultural land allows forest birds to cross or hunt in the more open areas (Thiollay 1986). ‘Buffer zones’ around areas of core habitat are other means by which economically productive areas are graded seamlessly into higher quality habitat, avoiding sharp boundaries (Siebert 2002). This can protect habitats such as forest cores from edge effects, although it is also possible that such areas could allow increased competition from outside. However, according to Thiollay’s (1986) Ivory Coast and Guiana study, disturbance leads to loss of sensitive forest birds before interspecific competition becomes a factor. The provision of buffer areas may also allow local people to cultivate and exploit forest-type resources without disturbing central areas. Other benefits may also accrue to agriculture from proximity to forest, including the increased pollination of coffee that sometimes occurs due to higher insect diversity supported by neighbouring forests (Ricketts 2004). However, there were converse findings in Central Sulawesi, where coffee pollination and fruit set increased with bee diversity which in turn increased with light intensity and distance from forest (Klein, Schulze et al. 2002). Additionally, ecotonal buffer areas such as plantations or secondary habitats may form population ‘sinks’ for forest species, either because of insufficient resources for breeding success or higher predation, including by humans (Poulsen and Lambert 2000; Waltert, Mardiastuti et al. 2004). Furthermore, proximity to forest may cause conflict between local people and forest animals that may raid or damage crops. This is evident in the area surrounding a tree plantation in Sabah, where pigs and other wildlife damage young trees (Duff, Hall et al. 1984). However, Ramono (1993) also claimed that zoning in multiple use reserves can reduce the potential of conflict between humans and Sumatran tigers.

2.3.1.2 The ‘separate’ model

The ‘separate’ approach seeks to identify the habitats and species that are most vulnerable to disturbance, and prioritise the protection of these critical areas. Reserves such as national parks also seek to provide representation of the habitats that once spread across the landscape. There is a greater emphasis upon protecting these areas from human disturbance and resource use. In contrast, agricultural production is intensive, theoretically allowing maximal areas of high quality habitat to be maintained in reserves (van Noordwijk, Tomich et al. 1997). Such an approach seems implicit in the focus of organisations such as BirdLife International on ‘Endemic Bird Areas’ and ‘Important Bird Areas’ (Long 1993; Stattersfield, Crosby et al. 1998; BirdLife International 2000). However, in Indonesia, within this model some concessions are made to involve local people in forest management (Sujatnika, Jepson et al. 1995).

Given the urgency of conservation in many tropical locations, and the sometimes perverse impact of encouraging local development, some authors, such as Oates (1999) suggest that separation of functions across the landscape is a more effective approach. This is supported by studies showing extreme differences between the biological communities in reserved and modified areas. In a study of birds in montane habitats in Sulawesi, Waltert (2004, p.1341) found "a pronounced decline" in bird species richness with increasing habitat modification, with endemics being particularly sensitive. There were not significant differences in overall abundance, species level response and species richness between the agricultural systems of cocoa-based agroforestry and annual cultures. However, each of these systems had avifaunal characteristics markedly different to those of primary or secondary forest. The authors argue that in order to protect the entire avifauna, the focus of conservationists must be upon these high integrity forest areas, rather than on improving the value of the surrounding landscape. Indeed, some species are dependent on large areas of intact forest, with "most frugivorous and mammal populations" in Borneo only observed to reproduce during mast fruiting periods (Leighton 1992). Concurrently, these same frugivores are necessary for the forest regeneration, due to their role of dispersing seeds of these tree species that are density dependent. Thus, in an argument that is not quite as circular as it sounds, the long-term survival of forest depends on current preservation of *large* tracts of forest. Island biogeographic theory also provides support to this model by its provision that larger areas of habitat are preferable to smaller ones (Terborgh 1986). In this manner, edge areas are minimised, and thus disturbance reduced. Additionally, upon fragmentation, habitats are seen to suffer species extinctions until a new equilibrium is reached consistent with the new area (Turner, Tan et al. 1994; Magsalay, Brooks et al. 1995). Evenly distributed blocks of remnant habitat are, however, likely to suffer higher rates of extinction than those that are clumped (Diamond 1975; Tilman, Lehman et al. 1996).

Few would argue that it is not important to retain existing forest areas, although some maintain that human livelihoods must be given at least equal consideration (e.g. Peluso 1993). In reality, a composite model may be the best approach. However, there is uncertainty about the relative trade-offs between biodiversity and productivity, and the rate at which the balance between these alters (van Noordwijk, Tomich et al. 1997). Also, as implied by Waltert (2004), there is still 'competition' for the efforts of conservationists, between remnant areas of high quality habitat and the broader landscape. Such a composite approach may be "Traditional land-use mosaics containing woodlands, forests, and agroforests" subject to intermediate levels of disturbance that maintain high local biodiversity (Gillison, Liswanti et al. 2004, p. 2). At some level, the argument depends upon which taxa are the main targets for conservation. It might be politically unacceptable for Governments to take a public course other than aiming to retain all species. However, some theorists argue that at least without "unrealistic shifts in the pace and direction of regional development" (Beehler, Raju et al. 1986, p.209) not all species can be saved, and so in order to conserve the maximum possible biodiversity, triage must be exercised (Vane-Wright, Humphries et al. 1991; Quammen 1996; Amos 2000).

2.3.1.3 Involving people

The effects of various land-development and forest protection strategies are complex, varying with factors including the needs and sensitivity of the species locally present, social and political dynamics, tenure and other constraints on land management, local and international financial and economic conditions. In Australia, attempts to integrate social , economic and environmental concerns into natural resource management planning have fallen short of expectations, due to factors such as fragmentation of responsible Government agencies, and lack of regional delivery of funds (Morrison, McDonald et al. 2004). In Bolivia, the high value of plantation timber leads to its protection against early felling. Instead, local landholders use forest timber to fill their everyday needs (Hjarsen 2000). Similarly, in Indonesia, the policies for timber plantation development are seen to 'legitimate the degradation of natural forests' (Kartodihardjo and Supriono 2000).

The traditional approaches of "fences and fines" have been criticised due to their insensitivity to human needs, while some also claim that they are inherently ineffective and politically infeasible (Peluso 1993; Brandon and Wells 1994; Wells, Guggenheim et al. 1999). In their place Integrated Conservation and Development Projects (ICDPs) became popular during the 1990s. These aimed to fulfil conservation objectives while meeting the needs of local populations, and thus reduce incentives for encroachment on protected areas, including activities such as poaching. The strategy aims to give local people both ownership of local biodiversity resources and incentive to protect these (Barrett and Arcese 1995; Caldecott 1996). However, in practice, these projects face many challenges due to issues such as incompatibility between development and conservation goals, difficulty in targeting benefits and the potential for local incentives to increase in-migration and thus population density and resource needs (Brandon and Wells 1994). Barrett and Arcese (1995) and Salafsky (1999) have also cautioned that progress must be monitored and incentives must be clearly linked to biodiversity conservation goals for the results to be maintained. Oates criticises the emphasis placed on links between development and conservation, based on his experience in West African forests.

He says that "there are serious flaws in the theory that wildlife can best be conserved through promoting human economic development" and that the myth underpinning this linkage has had "disastrous consequences for many wildlife populations"(Oates 1999, p. xv). He believes that economic growth can increase the demand for many products, and thus, the exploitation of biological resources. Meanwhile, enforcement of regulations instituted for the purposes of conservation may not be effective. Furthermore, he asserts that the approach that emphasises the empowerment of communities often does not take sufficient heed of differences between mobility of human groups, and their commitment to an area of land. Wells *et al.* (1999, p.2) also alleged that "Very few ICDPs in Indonesia can realistically claim that biodiversity conservation has been or is likely to be significantly enchanced as a result of current or planned project activities". Yet they do not blame the basic ICDP concept for these failures. The under-performance of ICDPs in Indonesia has been partly attributed to poor planning and a "lack of clear linkages between the conservation importance of a reserve and rural development activities" (Jepson and Djarwadi 1999, p. 52). Thus, for these projects to succeed, the local interaction between biodiversity and land-use must be well understood.

2.4 The role of plantations

One of the common reasons for land conversion from forest in southeast Asia, is for establishment of various types of plantations, as homogenous stands provide higher short-term returns than do diverse forest (Carrere and Lohmann 1996). In Indonesia, the effects of forest policies that facilitate conversion to timber and tree crop plantations are said to have "significantly increased in the 1990s" (Kartodihardjo and Supriono 2000, p.1). The area under oil palm plantations alone increased from approximately 700,000 hectares to 1,900,000 hectares between 1987 and 1997. Much of this development occurred in Sumatra (Kartodihardjo and Supriono 2000). In addition to oil palm *(Elaeis guineensis)*, the main plantation crops planted in Indonesia are rubber *(Hevea brasiliensis*), and cocoa *(Theobroma cacao*) (Whitmore 1998). Coffee is also very important, covering 1,160,000 hectares (van der Vossen, Soenaryo et al. 2000). In addition, trees such as *Gmelina arborea*, *Paraserianthes falcataria* and *Acacia mangium* are grown for timber and pulp wood (Whitmore 1998). Potential impacts of plantation establishment, in place of forest, include lowering of water-tables, soil compaction during establishment and introduction of weeds and disease (Jusoff 1992; Carrere and Lohmann 1996). In addition, the process can often be disempowering to local communities and have negative social consequences (Kartodihardjo and Supriono 2000). However, the perceived impacts must be considered in the context of the alternative or previous state, as comparison with primary forest will yield very different results compared with degraded or agricultural areas.

Reclamation of degraded areas seems increasingly important as shortage of productive land causes invasion and fragmentation of the last forest remnants. In some circumstances, tree plantations are used as a tool for recovery of lands occupied by such non-climax vegetation, and at best, may provide more forest-like conditions (de Foresta and Michon 1997). Plantation trees may also be used as nurseries for forest species, which while commercially valuable, have regeneration dependent upon darker, moister conditions (Parrotta 1993). Characteristics of *Acacia mangium* include quick growth, success at colonising poor soils and nitrogen fixation (Peluso 1993). Thus, they may shade out grasses that are dependent upon open conditions (MacKinnon, Hatta et al. 1996). The use of secondary forest species in plantations, and their subsequent role as nursery trees, has been described as implementing vegetational succession in a cost-minimising line "of lesser resistance" for restoration (Maury-Lechon 1993, p.38). *Paraserianthes falcataria* is one leguminous species recommended as a nursery tree to aid in the growth of forest trees such as dipterocarps in Imperata dominated areas (Otsamo 1998). In addition, such leguminous species may increase soil fertility in degraded areas, by nitrogen fixation, although phosphorus is commonly a limiting nutrient (Parera 1986).

2.4.1 Plantations and biodiversity

While the role of soil-stabilisation and reduction of weed dominance of plantations established on de-forested land has been studied, biodiversity benefits may be few unless deliberately planned. However, the relevant research is limited (Lamb 1998). Birds are one of the best-studied groups due to their reported merits as 'indicator species'. Contrasts with natural forest are more common than comparisons with degraded land and these create a generally negative impression. Such comparisons of industrial plantations with 'natural' forest have revealed them, unsurprisingly, to be depauperate in fauna (Mitra and Sheldon 1993; Carrere and Lohmann 1996). This is often thought to be due to their low structural diversity. MacArthur and MacArthur's formative study on the influence of vegetation structure and diversity on avifaunal diversity in temperate deciduous forests and tropical savannah, concluded that species diversity could best be predicted by the height profile of foliage density (MacArthur and MacArthur 1961). Strikingly, floristic diversity was found to have no influence beyond its supply of structural diversity, with the suggestion that very few birds are specialised to the level of only using a single species of tree. Birds were found to respond to habitat of different types following their recognition of foliage strata present in pairs, that framed a particular space. In contrast, in Australian woodlands, Milledge and Recher (1985) found structural components to be of far less importance than floristics for predicting species diversity (cited in Furness and Greenwood 1993). A study of Australian pine plantations had intermediate findings; changing structure with succession was thought of high importance, but absence of certain food resources excluded some species. The differences in habitat and avifaunal assemblage between core and edge were also emphasised (Gepp 1986). In agricultural habitats in Uganda, bird species richness was found to relate poorly to vegetation structure. Factors such as availability of suitable nesting sites, predation risk and tolerance of human activities and structures were considered possibly of greater relevance. However, tree density was associated with increased species richness, suggesting this as an easy way to raise local bird biodiversity (Naidoo 2002). A study of exotic plantations in Sabah found bird community change over time, but also suggested that some structural features were relict from the forest formerly at the site. These features such as stumps and snags, created feeding sites for mynas, nuthatches, woodpeckers and tree-creeping babblers, but were considered to be only temporarily available (Sheldon, Mitra et al. 1992; Mitra and Sheldon 1993). At the time of Beehler *et al.*'s (1986) Indian study comparing birds in various habitats, including forest and teak plantation, the authors claimed that evidence confirming the importance of structure for bird composition in Asia was lacking. The study found birds responsive to structural differences between habitats, but also attributed some differences to apparently floristic factors such as fruit availability. Possibly the dominant position of structure in determining habitat is tempered by the role of keystone food providers, such as the often-cited *Ficus.* Wiens (1989) commented that while it has long been assumed that structure provides the dominant influence over bird assemblage, there are sufficient findings that floristics are also important, and thus should not be overlooked. Certainly, the two are not independent, as there are differences in plant architecture with species. In view of uncertainty regarding the relative importance of these factors, and likelihood of variation with location and taxa, it seems wise to appreciate the emphasis Furness and Greenwood (1993) place upon the complexity of habitat relations, and avoid over-generalisations.

2.4.1.1 Plantations and birds in tropical regions

Much of the initial research regarding general habitat relations in plantations and other vegetation assemblages has been located in temperate zone forests and plantations but there are some equivalent tropical studies. In Jambi Province in Sumatra, comparison of species accumulation curves for bird counts in various habitats showed those in forest to be steepest, followed by those in diverse *Paraserianthes falcataria* timber plantations, Imperata, industrial *Paraserianthes* plantations and finally, a rubber plantation (Jepson and Djarwadi 1999). Thus, the avifuana became more depauperate with intensity of management. There were also differences in the types of birds, with the non-wooded plots having a "largely open-country species assemblage" (Jepson and Djarwadi 1999, p.44). The forest families that were absent from commercial plantations and agriculture included hornbills, trogons and tree-swifts (Hemiprocnidae). These were replaced by families such as Ardeidae (herons), Turnicidae (quails) and Estrillidae (finches). Migratory species were more common in the locations where there had been alteration or disturbance of the original forest (Jepson and Djarwadi 1999). In the West Indies, bird counts in *Pinus caribaea* plantations produced more shallow species accumulation curves than did those in native broad-leafed forest, and the final species richness was significantly higher in forests than in plantations. Additionally, those birds found in the plantations were more commonly of generalist forest-edge species. More individuals of nectarivores, and also aerial and understorey foragers, were found in the plantation, while more insectivores and canopy-foraging individuals were in the forest. On a species basis, there were more aerial foragers in the pine plantation and more understorey foraging species in the native forest. The differences were attributed to higher habitat heterogeneity and species availability in the forest, although these characteristics were not measured (Hayes and Samad 1998). The previously mentioned Sabah study of various ages of *Paraserianthes falcataria* timber plantation found that the ability of pioneer tree species to quickly colonise the area below the fairly open *Paraserianthes* canopy allowed quite a rich bird assemblage to use the area. This bird assemblage was augmented by the presence of nearby primary forest that provided resources lacking in the plantation. While some species were advantaged by the habitat modification and simplification, these were mostly generalists. Flycatchers and large frugivores were poorly represented in the plantations, compared with forest assemblages (Mitra and Sheldon 1993). Kenyan pine plantations were also found to contain few forest specialist birds, in comparison with mountain forest, but provided habitat for palearctic migrants (Carlson 1986). In the Bolivian Andes, exotic *Eucalyptus* and *Pinus* plantations held only 23% of the landscape's bird species, in comparison with 77% found in the native *Polylepsis* forests. In particular, insect, nectar and fruit eaters were found only in very low abundance within the plantations, and raptors and owls were absent (Hjarsen, 2000). Fauna was likewise generally depauperate in two-year-old plantations of various species in an east Kalimantan timber concession (Wilson and Johns 1982). In India, teak monocultures have been found to support a low number of bird species, with large bodied birds being relatively uncommon (Beehler, Raju et al. 1986).

Rubber plantations in Riau Province of Sumatra yielded 29 bird species after 20 hours of transect survey, in comparison with 18 species found in the same time in oil palm plantations (Danielsen and Heegaard 1993). More limited still, plantations of oil palms, coconut and rubber in west Sumatra, Thiollay (1994, p.345) found "rarely more than 3 - 4 bird species…all of them being common and widespread generalists". Industrialised rubber plantations were described as 'deserts' for fauna due to their homogeneity of species composition and stand age, and hence structure. Tea plantations were found particularly depauperate, although higher biodiversity was observed along more scrubby edges. In contrast, Rainey (1999) cites observations of quite diverse assemblages in tea plantations in Guinea. Thus, species diversity is not equally depauperate in all plantations, and Thiollay (1994) concedes that plantations can make useful contributions to supporting birds when forest cover is removed. Field studies in Indonesia's South Kalimantan indicate that Imperata areas replanted with *Acacia mangium* and *Gmelina* support more bird and insect species than the open grasslands. MacKinnon *et al.* (1996) also suggested that potential propagation of native hardwoods, such as the fast-growing *Shorea johorensis,* may have still greater ecological benefit. The rotation time of 30 to 40 years for this species compares favourably for conservation purposes with the eight year rotation for *Acacia mangium*, but the long wait for profit may discourage some investors. Also, harvesting at any stage must cause severe disruption to animal communities present.

2.5 Agroforestry models

While there is clearly variation between locations and tree types, the 'plantation' model generally emphasises species and structural homogeneity, often for the reasons of rapid establishment and easy maintenance and harvest. However, establishment of 'useful' trees does not always occur in this manner (Thiollay 1994; Michon 2005). Agroforestry models promote the establishment of diverse mixtures of subsistence and cash crops, trees for fruit, timber and other properties. In Indonesia, these systems have great importance in national agricultural production for local consumption and export. They are accredited with 70% of rubber produced, 80% of the damar resin and 80 to 90% of marketed fruits. There are also other tree crops the products of some of which are also exported, including cinnamon, cloves, nutmeg, coffee and candlenut (de Foresta and Michon 1997). Income spreading is often cited as a reason for developing a diverse agro-ecosystem (e.g. Taylor 1993; Smithsonian Migratory Bird Center undated). This reduces the risk of farmers lacking income following events such as disease affecting their main crop. The increased importance of auxiliary crops in these situations is illustrated by the expansion of the damar trade in Sumatra in the 1930s after a "violent disease" killed pepper vines (de Foresta and Michon 1997). Similarly, in the 1980s, many of the clove trees in Lampung were affected by disease, forcing farmers to rely on other crops (Mougeot and Levang 1990; Michon, Foresta et al. undated). Alternatively, a crash in the price paid for individual cash crops raises the importance of the other crops cultivated. This is demonstrated by the failure in the vanilla market in 1957-8, causing Mexican farmers to rely on other cash crops (Toledo, B.Ortiz-Espejel et al. 2003).

While agroforests vary enormously, basic definitions require only that the system is a sustainable one involving intercropping of woody plants with other crops. Some definitions imply that forest species native to the area should be involved (Castillo, Dalmaciao et al. 1994). Indeed, there is a gradient, rather than division, between various types of product extraction in natural forest and in agroforestry systems that may involve selective cultivation or increased concentration of these same ‘useful’ species. This cultivation may overcome some issues facing forest harvesters, including phenological limitations posed by characteristics of mast fruiting, as well as commercial non-viability due to the high diversity, and thus low density of individual species in Indonesian rainforests. It may also reduce the disturbance of these forests by collectors (Salafsky, Dugelby et al. 1993).

Many authors place particular emphasis on complex agroforestry models, with high floristic and structural diversity, having at least as much in common with natural forests as with industrial plantations (Thiollay 1994). Floral studies in durian, rubber and damar agroforests in Sumatra found that the total plant richness was approximately 50% of that in forests. This compared favourably with the 0.5% found in plantations. These species-rich systems often involve “an important spontaneous component” (Michon and Foresta 1995, p.95). This can result in very high vegetative species richness, such as in the home gardens of Sri Lanka, where one study found a total of 640 species, with a range of 22-170 and a mean of 53 plant species per garden (Hochegger 1998, cited in Bambaradeniya undated). Thus, the inclusion of native species that may have germinated from a soil seed bank or been transported from other habitats, such as remnant forests, may blur the line between ‘created’ and ‘natural’ habitats. Selective retention of these spontaneously growing plants may alter local species composition in a subtle way over generations. This is evident in the forest gardens surrounding the Lore Lindu National Park in Sulawesi. While high tree basal area, similar to that of forest, suggests a structurally stable system, the species composition changes by selective retention and ‘enhancement’ with species that have a local use or are marketable (Brodbeck, Weidelt et al. 2002).

The extreme case occurs when there is possible confusion regarding the natural state of an area that is actually subject to human stewardship. This is seen in Borneo, where what at first appears as primary forest, has had its composition substantially influenced by ‘enrichment’ with species useful to shifting cultivators (Brookfield, Potter et al. 1995). The role of humans as stewards in creating and maintaining the damar agroforests of Krui, on the west coast of Lampung province in Sumatra, has also been subject to confusion, due to their systems' apparent similarity to the dipterocarp forests native to the region. Their resultant classification as 'national forest' was problematic for residents who had managed the area under traditional tenurial systems for generations (Campbell 1998; Fay, Foresta et al. 2000). The damar trees are native hardwoods (*Shorea javanica*), which produce a resin that is tapped and collected for various uses, including as an ingredient in lacquers and paints. The land on which the system is established was initially cultivated with rice, and then with coffee and pepper. The original damar seedlings planted as part of these coffee agroforestry systems were collected from the forest and thus the necessary *Mycorrhizae* were also transferred (their absence being a common problem for dipterocarp cultivation) (Michon, Foresta et al. 1998). The requirement for trees to be mature before tapping, as well as the usually non-destructive mode of expoitation of the damar resource, intensive planting and selective tolerance of spontaneous germinants, has led to a long-lived and structurally and floristically diverse system. The structure of the agroforests is comparable with that of forest, although the silvigenetic cycle has been simplified due to the sustained dominance of damar trees and several other 'useful' species. Seedlings are cultivated in nurseries, and planted in gaps of various sizes according to local knowledge of their ecology (Torquebiau 1985). The species richness in these agroforests has been estimated as being between 25 and 40% of that in local forests (Sumarauw 2000). The dominant tree species, damar, makes up approximately 65% of the individuals, while another 20% consists of fruit trees including dukuh (*Lansium domesticum*), durian (*Durio zibethinos*) and petai (*Parkia speciosa*). The remaining 10-15% of trees are spontaneous germinants retained for use as timber (Smets 2002).

'Jungle rubber' is another Sumatran agroforest type described as being similar to secondary forests, due to tree longevity and diverse floristic assemblages. Its structure is described as "a more or less closed canopy between 20 and 25 m" in height, as well as a dense understorey to a height of 10 m (Gouyon, Foresta et al. 1993, p. 187). In this regard, it differs from coffee agroforests, which are commonly lacking in a native shrubby layer, having been replaced by the coffee crop. This 'jungle rubber' contrasts strongly with the homogenous plantations that also produce rubber.

2.5.1 Birds in Indonesian agroforests

The bird assemblages in 'jungle rubber' have been found to be particularly species rich and diverse, with comparatively low dominance by individual bird species (Thiollay 1994). Of the other Sumatran agroforests compared in the same study, those with higher vegetation species richness and structural diversity also supported more bird species. Nevertheless, all agroforests studied provided imperfect alternatives to primary forest, with bird species richness being greatly reduced. In particular, large frugivores and insectivores from the canopy and low understorey, as well as 'terrestrial interior forest specialists' were under-represented in the managed areas. Additionally, forest avifaunas were less dominated by the most common species, and thus are more equitable, while also having higher representation of rare birds (Thiollay 1994). These differences between agroforest and forest appear broadly similar to those described between logged and un-logged forests (see section 2.2.1). With particular regard to raptors, species richness and density were at least twice as high in the agroforests as in areas under cultivation. However, they were only half of that for primary forest. Thus, for the conservation of these predatory birds, agroforests may complement natural forests, but are a "poor substitute" for these (Thiollay 1996, p.259). Consequently, the idea that conservation and development can be reconciled through the widespread development of agroforests is questioned. Similarly in Sulawesi, the species richness of birds has been found to be low in both cocoa shaded with *Gliricidia sepium* and maize plantations, with fewer insectivores and endemics than in forests (Waltert, Mardiastuti et al. 2004). Additionally, nectarivore/frugivores were more common in the forest. The cocoa agroforest was seen as providing limited food resources and minimal additional contribution to local bird conservation to that of annual maize culture (Waltert, Mardiastuti et al. 2004).

2.6 Coffee

2.6.1 Plant characteristics and history of cultivation

Coffee is a crop that is cultivated in a wide range of systems, covering the entire spectrum from monocultural plantation to complex agroforest. This makes it suitable for comparisons of faunal responses to habitat variables. Furthermore, it covers a vast (and increasing) area of cultivation in tropical areas where fauna are especially vulnerable to rapid landscape change (Donald 2004). This spatial importance, as well as its flexible cultivation conditions, makes it a potential focus for conservation-minded landscape modification and restoration that is both economically feasible and allows the ongoing fulfilment of livelihoods. Thus, it is the focus of this study.

Coffea is a genus native to Africa, where wild varieties grow as understorey species in tropical rainforests. Some species have become domesticated and planted widely due to their use in preparation of one of the two most popular beverages in the world (International Centre for

Research in Agroforestry undated). The three most commonly used species are *Coffea arabica* ('arabica'), *Coffea canephora,*('robusta') and *C. excelsa* ('liberica').[1] Within these three species many horticultural varieties and hybrids have been developed. While the three species are all cultivated within the study area in West Lampung, by far the most commonly grown is 'robusta'.

Coffea is a member of the Rubiaceae family, with the characteristics of being evergreen shrubs or small trees with glossy, dark green leaves. Flowers are white and fragrant and occur in clusters in the leaf axils. The fruit (often called a berry or cherry) is a drupe with a shiny exocarp, a fleshy mesocarp and a tough endocarp enclosing two seeds (often called beans). These beans are the valued product. Fruits change colour as they ripen, from green, to yellow and finally red (Sosef and Boer 2000; van der Vossen, Soenaryo et al. 2000; International Centre for Research in Agroforestry undated). Differences between the species include bush size, size of leaves, number of flowers and their clustering and self-compatibility[2]. 'Arabica' grows to only 4-5 metres in height, whilst 'robusta' may reach 8-12 metres.

Wild forms of robusta coffee occur in equatorial lowland forests from Guinea to Uganda while the natural distribution of arabica is limited to Ethiopia's southwest highlands (van der Vossen, Soenaryo et al. 2000). Coffee has a very long history of local use as a masticatory stimulant (International Centre for Research in Agroforestry undated) but the development of the coffee drink from the roasting and grinding of arabica seeds occurred in Yemen, during the 12th or 13th Century. Popularity of, and trade in coffee greatly increased after the 16th Century following European exploration and colonisation of tropical regions. Plantations were established in these newly colonised areas as traditional producing regions could no longer meet demand (van der Vossen and Wessel 2000). In the 16th and 17th centuries arabica coffee was taken to India and Sri Lanka by Arabian travellers and subsequently was introduced to Java in 1699, by the Dutch East India Company (van der Vossen, Soenaryo et al. 2000).

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[1] *Coffea arabica* (1753) L., synonyms *C. vulgaris* Moench, *C. angustifolia* Roxb. (1814) and *C. sundana* Miquel (1856), commonly known as arabica coffee (*kopi arabika*, in Indonesian); *Coffea canephora* Pierre ex Froehn (1897), synonyms *C. robusta*, Linden (1900), *C. laurentii* De Wild.(1900), *C.ugandae* Cramer (1913), commonly known as robusta coffee (*kopi robusta* in Indonesian) van der Vossen, H. A. M., Soenaryo, et al. (2000). *Coffea* L. Plant Resources of South-East Asia No. 16 Stimulants. H. A. M. v. d. Vossen and M. Wessel. Leiden, Backhuys Publishers. **16:** 66-74.; *Coffea liberica* Bull ex Hiern, synonyms *C. dewevrei* De Wild. & T. Durand (1899), *C. arnoldiana* De Wild. (1900), *C. klainii* Pierre ex De Wild. (1900) *C.dybowskii* De Wild. (1901), *C. excelsa* A. Chev. (1903), *C. abeokutae* P.J.S. Cramer (1913), commonly known as excelsa coffee, Liberica coffee or *kopi nangka* (Indonesian) Sosef, M. S. M. and E. Boer (2000). *Coffea liberica* Bull ex Hiern. Plant Resources of South-East Asia No. 16 Stimulants. H. A. M. van der Vossen and M. Wessel**:** 74-78..

[2] Leaves of *C. arabica* are smallest (10-15 cm x 5-10cm long) whilst those of *C. canephora* are 15-30 x 5-15 cm. Both are ovate. Flowers of *C. arabica* occur in clusters of 10-30 per node, whilst for *C. canephora* there are up to 80 per node. *C. canephora* flowers are self-incompatible, but *C. arabica* is self-fertile. This characteristic is unique within the genus van der Vossen, H. A. M., Soenaryo, et al. (2000). *Coffea* L. Plant Resources of South-East Asia No. 16 Stimulants. H. A. M. v. d. Vossen and M. Wessel. Leiden, Backhuys Publishers. **16:** 66-74..

Commercial coffee production was almost exclusively of arabica until the late19th century. However, heavy losses to diseases such as coffee leaf rust (*Hemileia vastatrix*) severely compromised production and encouraged transition to other species such as robusta and liberica (van der Vossen, Soenaryo et al. 2000). The latter species was introduced widely to countries including Indonesia (1875) due to expectations that it would resist leaf rust. This proved not to be the case, and it was largely replaced by robusta (Sosef and Boer 2000). This species was introduced to Java in 1900 and by selective breeding, high yielding varieties were developed. Indonesia is now a major coffee producer. It is the fourth largest exporter of coffee in the world, and for robusta coffee, has the second highest production, following Vietnam. Within Indonesia, Lampung, in Sumatra, produces the most coffee, with 30% of the national production of robusta coming from the Province.

2.6.2 Trade in coffee

The coffee trade involves many players between the garden and the cup. For coffee grown in Lampung, these include hullers, local and regional merchants, exporters and Indonesian roasters (Mougeot and Levang 1990). In Indonesia, there is also a board (*Assosiasi Exportasi Kopi Indonesia* -AEKI), that controls exports, and provides compulsory licences to all exporters (Budidarsono 2001, pers. comm.). International roasting companies, distributors and marketers, such as supermarkets and café chains, are also involved with coffee that is exported (Ponte 2002).

2.6.2.1 Global coffee market

For much of the 20th century, the coffee market was highly regulated by the International Coffee Organisation, which was established in 1963 with the backing of the United Nations. There were subsequently six International Coffee Agreements (ICA), which were signed by many producing and consuming countries. These agreements included establishment of projects to improve quality of coffee, combat disease, promotion, pricing and encouraging sustainability. In 1996, Article 35 of the agreement stated a requirement for "members to give due consideration to the sustainable management of coffee resources and processing, bearing in mind the principles and objectives on sustainable development established by the United Nations" (International Coffee Organisation 1996). The organisation is also responsible for the collection of statistics and other information important for producers and consumers. Member countries include 97% of coffee exporting countries and 68% of importing countries. Until 1989 most of the periodic agreements had included a quota system, which acted to control prices by stockpiling over-supply (International Coffee Organisation 2004). In 1989, the United States, the nation importing the most coffee, left the organisation and the agreement was dissolved in that year (Ponte 2002; O'Brien and Kinnaird 2003). The result was a sharp fall in international coffee prices, by approximately 50%, and prices remained low for at least four years (Nestel 1995; International Coffee Organisation 2004).

Since the cessation of the ICA, in the absence of production quotas and in response to a brief international price spike in 1997, areas under plantation have expanded, most notably in Vietnam, but also in other countries including Indonesia. This has contributed to a fall in real prices of coffee that has been cushioned at the retail end of the market and exaggerated at the production end; whilst between December 1999 and January 2001 US retail prices dropped 4%, the price paid to farmers nearly halved. Thus, the share in revenue from the total coffee market has become heavily skewed. Although in the 1970s, producing countries controlled 20% of the revenue, between 1989 and 1995 they received only 13%, whilst 78% was retained in consuming countries (Ponte 2002). There has recently been increasing interest in capturing the specialty coffee market, which may provide increased profits for both producers and marketers. This has been an area of growth in traditional coffee drinking countries where the regular market has reached a plateau (Ponte 2002).

There are multiple differentiating factors for coffee prices. These include region of origin, species or variety and method of processing. Quality is also measured by various characteristics including colour, size and completeness of grains and moisture content. High-altitude grown arabica coffee attracts premium prices, whilst poor quality robusta crops are bought in bulk for the instant coffee market.

2.6.3 Coffee cultivation

Arabica coffee is restricted to high altitudes (1000-2100 m) in equatorial areas, due to its requirement for average daily temperature to fall between 18-22° C. It cannot tolerate temperatures above 30° C. In contrast, robusta coffee is adapted to slightly warmer mean temperatures (22-26°C) and thus is suited to altitudes between 100-800 metres. Both of these species require well-distributed rainfall. For arabica, rainfall requirements are 1400-2200 mm annually, whilst 2000 mm is required for robusta. Soil requirements for coffee species are flexible within the limitations that they are deep and free-draining, but with good water-holding capacity. Soils should also be slightly acidic (van der Vossen, Soenaryo et al. 2000).

Coffee plants are usually propagated by seed, but sometimes by rooted cuttings or grafting. The seedlings are planted in large holes, at a density of 1100-1400 trees per hectare, for robusta coffee. This is equivalent to a spacing of 2.7 - 3 m. Pruning is considered essential for several reasons, including maximisation of the amount of new growth and to maintain the balance between leaf area and crop so as to prevent overbearing that can lead to fruiting becoming bienniel (van der Vossen, Soenaryo et al. 2000). In Indonesia the method followed creates a single stem of a height of between 1.5 and 1.8 m and an umbrella-like shape. Old plants can also be rejuvenated by being cut to a height of 30 cm, so that new shoots can grow. Weed suppression is important, and fertiliser requirements depend on the soil condition. While robusta coffee is usually resistant to leaf rust, it is prone to a range of other diseases including brown eye spot, tip dieback, vascular wilt, and root diseases. Additionally, there are various potential pest insects including coffee berry borer (*Stephanoderes hampei*), stem borers, scales and mealy bugs (van der Vossen, Soenaryo et al. 2000). Nevertheless, coffee is considered to be a crop relatively resistant to insect pests. Reasons for this include the high levels of alkaloids in young leaves, and the physical toughness of older leaves (Perfecto, Rice et al. 1996).

2.6.3.1 Shade trees

The shade requirement for the cultivation of productive coffee has become a somewhat contentious issue that lies near the heart of the question regarding plantation or garden design and management. Wild coffee is a rainforest understorey species, and thus will tolerate shading (van der Vossen, Soenaryo et al. 2000; van der Vossen and Wessel 2000). Shade may protect a young coffee plant, and improves growth of leaves and shoots. However, it may reduce root growth and coffee yields (International Centre for Research in Agroforestry undated). In Mexico, shade is found to increase yields in a complex manner, with the relationship between percentage shade cover and coffee yield fitting a quadratic equation. Thus, yields increase between 23% and 38% shade cover, and then are maintained until 48% cover is reached. Soto-Pinto *et al.* (2000) suggested that yields may then decline if shade cover is over 50%. However, there seems to be a general belief that open sun systems, in combination with the use of agrochemicals, lead to substantially increased yields (e.g. Greenberg, Bichier et al. 1997).

In a summary of relevant literature by Beer (1987), effects of shade are divided into four main groups. These can be described simply as crop management, effect on hydrological cycles, pathogen and pest interactions and affect on soil fertility and erosion. Amongst the crop management benefits are lower variation in annual yields, allowing more efficient management, control of crop maturation and improved coffee quality due to the greater time allowed to accumulate oils, as well as suppression of weeds (Beer 1987). A study of the physical, aroma and taste properties of arabica coffee grown under various shade treatments showed some differences between varieties but generally larger fruit and improved taste for the shade-grown coffee (Muschler 2001). Weed control by shade was demonstrated by a study in Mexico that found that, during a rainy season, sun plantations grew over twice the herbaceous biomass found in simple and complex-shaded plantations (Nestel and Altieri 1992). Hydrological benefits include reduced evapotranspiration, while damage caused by heavy rain may be reduced. Microclimates may be modified, preventing extreme conditions, and some diseases and pests may be reduced (Beer 1987). Staver *et al.* (2001) found that optimal pest control using shade trees was highly site specific. Perfecto *et al.* (1996) also suggested that structurally complex gardens support a diverse range of predators and parasites that help to control pests. Soil conditions may be improved by the improved drainage and aeration caused by the roots of shade trees breaking up densely packed soils (Beer 1987). Erosion may also be reduced. Leguminous shade trees fix nitrogen in the soil, while the cycling of nutrients through litter fall may increase soil organism activity and reduce the need for fertilisers. Tree species vary in their ability to provide soil nutrients. If pruned two or three times in a year, *Erythrina poeppigiana* has been found to provide nutrients equivalent to those found in typical application of inorganic fertilisers for cocoa and coffee cultivation, both through leaf decay and fixation of nitrogen in the root zone. Additionally, leaf litter production has been found to be more important for coffee growth than nitrogen fixation (Beer 1988). In Sumberjaya, Lampung, carbon stocks in coffee gardens with a shade canopy have also been found to be much closer to those typical of forests than were those of unshaded coffee (van Noordwijk, Rahayu et al. 2002).

Potential disadvantages of shade trees are also described by Beer (1987). Crop management may be impaired by the damage caused by fall of branches or harvest of tree crops. Sudden defoliation of shade trees, by pruning or seasonal leaf fall from deciduous trees, may cause shock to the understorey, particularly if the canopy is of a single species. Labour is also required for pruning of trees, and establishment of some structures such as terraces may be impaired by tree presence. Potential hydrological problems include competition by the roots of shade trees with coffee for water and oxygen. Microclimate changes such as increased humidity and reduced air movement may also encourage the growth of fungi. Insect problems may increase, and shade trees can act as hosts for pests and diseases. Additionally, there may be allelopathic interactions between shade trees and the coffee plants (Beer 1987). The quantity and quality of light reaching understorey plants are reduced by a shading canopy, thus reducing coffee production. Soil characteristics may also be compromised as shade trees compete for nutrients and the harvest of products from the shade trees removes nutrients (Beer 1987). These arguments regarding the desirable shade characteristics are focused on crop health and economic sustainability, and do not address ecological concerns in their own right. Indeed, amongst the characteristics proposed is "smooth bark that does not harbour epiphytes" (Beer 1987, p. 8). Given the descriptions of the important role that epiphytes fill in some tropical communities (e.g. Perfecto, Rice et al. 1996; Jones, Perazzi et al. 2000; Cruz-Angon and Greenberg 2005), there is potential for inconsistency and tension between practices of shade management for production and ecological aims.

Coffee garden types exist along a spectrum, ranging from coffee planted under a largely unaltered forest canopy, to complete monoculture[3]. The nature of gardens being cultivated has varied along this gradient, over both space and time. When coffee was introduced to Latin America in the 18th century, it was largely grown in unshaded areas. However, it was soon grown in small gaps in the forest, and diverse shade systems were developed. These often involved both native forest trees as well as species cultivated for other end-uses. While various shade systems became typical by the 20th Century, since the 1970s there has been a trend towards shade removal, or "technification", of coffee plantations. The typology reported by Moguel and Toledo (1999), describing five stages along the management spectrum in the Mexican context, is widely cited, although not used ubiquitously. Rice and Ward (1996) used this as a basis for five coffee "types": "Rustic coffee" describes the growth of coffee under little-altered forest canopy. This system involves low capital investment. "Traditional polycultures" maintain similar structural attributes, but have altered species composition due to the planting of "useful species". "Commercial polycultures" involve higher inputs as well as other marketable species in addition to coffee. "Specialised shade" involves coffee shaded by a single species, which is highly managed. Finally, "open sun" systems are monocultures with no shading (Rice and Ward 1996). In Indonesia there is not such a clearly documented trend of transition from 'traditional' shaded systems to 'open sun' systems. However a full spectrum of cultivation conditions does exist there. Siebert (2002) described coffee grown under a secondary forest canopy in Sulawesi, whilst in Java, Potter (2005) cites records of colonial era 'forest coffee', grown under a thinned, and possibly species augmented forest canopy. In Lampung Province of Sumatra 'monoculture' (equivalent to 'open sun' coffee) as well as 'multistrata' coffee gardens have been documented (Verbist 2001). Also in this Province, the

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[3] The term 'garden' here is used to describe an area under coffee cultivation, regardless of form, to allow possible distinction of these areas from 'plantations', as this term has implications of homogeneity and wide spatial coverage.

growth of coffee within Bukit Barisan Selatan National Park has been recorded, although it is unclear whether any of this occurs below the forest canopy or in fully-cleared gaps (O'Brien and Kinnaird 2003).

2.6.3.2 Harvest and processing

Coffee harvest can occur by selective picking of ripe berries, occurring at seven to ten day intervals spread over up to nine months. However, due to the high labour costs involved in this, sometimes strip-picking is used, by which all of the berries along the branch are harvested simultaneously. Over twice as much coffee is harvested by a worker in one day in Lampung, where coffee is strip-picked, than in Aceh where it is harvested selectively (van der Vossen, Soenaryo et al. 2000). Beyond the normal levels of economic incentives driving strip-picking, Potter (2005) describes the economically difficult period in South Sumatra in 2001; strip picking and sale of unripe coffee was practised to deter thieves. Post-harvest handling also varies, with two main methods practised. The wet process, which is dominant in Latin America, involves pulping of ripe fruits within one day of harvest. The dry process is practised in Lampung and is better suited to the mixed ripeness of the berries harvested there by strip-picking. It involves drying for three to four weeks in the sun, although this can also be done in ovens. The coffee is then hulled to remove the dried fruit and skin. The coffee beans are contained in 60-70 kg bags and can be stored for up to two years. The coffee is graded for quality by merchants and sold to exporters or local roasters (van der Vossen, Soenaryo et al. 2000).

The variety of horticultural practices possible for coffee cultivation has already given rise to comparisons between different types of coffee garden, and particularly between gardens with different shade characteristics. These comparisons include economic factors, effects on soil and biodiversity. In Nicaragua, soil erosion rates are found to be significantly higher on gardens where the shade cover has been reduced from traditional shaded systems (Rice, 1991 cited in Rice and Ward 1996). In Lampung, preliminary measurement of runoff and erosion showed that open plots had higher levels of erosion than does forest, but it is unclear if there were differences between ‘multistrata’ and ‘monoculture’ coffee plots (Masjud, 2000, cited in van Noordwijk 2000). In the same region, carbon stocks in the upper 30cm of soil were, as a percentage of those expected for Sumatran primary forest: 79% for forest remnants, 60% for shade coffee and 45% for sun coffee (van Noordwijk, Rahayu et al. 2002). Thus, there seems to be some clear biophysical advantages of maintaining shade coffee rather than sun coffee, yet conversion from forest even to shade coffee still represents a substantial loss of carbon.

Financial comparisons between coffee systems have often focused on the contrast between long and short term returns, frequently with an additional emphasis on risk-spreading. In particular, the high variation in world price for coffee suggests that farmers are less vulnerable if they have additional sources of income (van der Vossen and Wessel 2000). However, many factors can intervene in adjusting the profitability of garden types. These include land cost, land tenure, use of external inputs such as fertilisers, management style, labour costs, market availability and price of commodities. In Lampung, Budidarsono *et al.* (2000) characterised systems in terms of tenurial security, intensity of land management and complexity of vegetation structure. Over the 25 years studied, the most expensive of the seven studied types of coffee gardens to establish and maintain (in terms of labour costs) were the simple gardens with tenurial insecurity and high intensity land management. In contrast, the cheapest gardens to establish were those with complex vegetation, tenurial security and medium-intensity land management. This system also showed by far the highest returns to land (profitability) as well as returns to labour. This was attributed to the ability of farmers to sell other products such as fruit. In contrast, pioneer systems had the lowest returns to land and labour. One complicating factor is the adjustment of wages paid for coffee harvest with the price of coffee beans. Thus, an increase in coffee prices may not always lead to an increase in profits for the farm owner.

2.6.4 Coffee and biodiversity

Biodiversity has also been a focus of comparisons between different coffee garden types, with such studies having added importance because of the usually high concentration of species in the tropical areas where coffee is grown. Thus far, studies have largely centred on the areas of Central and South America (Donald 2004). However, it is also informative to recognise similar research in cocoa (*Theobroma cacao*) gardens, which have many apparent similarities with coffee cultivation. These features include geographic distribution, physical characteristics, and horticulture. Cocoa is also a perennially fruiting bush or small tree crop that can be grown with or without a shade canopy (although shade tolerance is higher than that for coffee) (Wessel and Toxopeus 2000). Additionally, these gardens provide a model for very long established systems of the 'rustic' type, with cultivation in Mexico said to have occurred "in this manner for 2000 years before the Conquest" (Perfecto, Rice et al. 1996).

Plants

In Lampung Province, plant biodiversity in coffee gardens, as indicated by functional plant types and species richness, was found by Gillison *et al.* (2004) to be lowest in simple, unshaded systems and increase with the structural complexity of the system, to reach a maximum in forest. To some degree, these findings seem tautological, as garden definition was also derived from botanical features. However, analysis also extended to tenurial status and age of garden. There was a strong correlation between biodiversity measures, mean canopy height and basal area, age of the land-use type, tree dry weight and various soil nutrient parameters. However, none of the agroecosystems examined approached the plant species richness or functional type richness of forest or scrub (Gillison, Liswanti et al. 2004). Furthermore, whilst it seems likely that the maintenance of high local biodiversity in many locations may lead to high overall species richness, this may not be the case if those incorporated species are not native to the area. Thus, local endemics may not be conserved within these systems if they are not perceived as being ‘useful’. In Latin America, where indigenous coffee systems incorporate local forest trees, this may be less of a problem. In a review of literature, tree species richness in these traditional coffee agroforests ranged between 13 and 58 species. There are also a large number of herb species, but few shrubs, as this is the layer that is replaced by coffee. Epiphytes are also reported as occurring frequently in traditional systems that Moguel and Toledo (1999, p. 14) describe as “humanised forest remnants”.

Invertebrates

In Costa Rica, there have also been high levels of arthropod diversity found in traditional coffee gardens. The diversity and abundance was higher in complex shade of gardens than in simple shaded gardens (with an *Erythrina poeppigiana* overstorey) or coffee monocultures (Perfecto, Vandermeer et al. 1997). Whether the invertebrates collected constitute pests to either coffee or the other plants in the system is not known. However, it was suggested from a study of arthropods between the ground and 2 m in a diverse shaded coffee garden in Mexico that equilibrium existed between potential pests and predators. Thus, this garden had no insect pest problems evident (Ibarra-Nunez 1990, cited in Moguel and Toledo 1999). In the Costa Rican study previously mentioned, the numbers of ants and beetles collected from individual tree canopies was claimed to be in the same order of magnitude as for forest trees (Perfecto, Vandermeer et al. 1997). Similarly, in the Mexican study, the structure of the arthropod community was similar to that in forest (Jansen 1973 and Ibarra-Nunez 1990,cited in Moguel and Toledo 1999). Thus, such agroecosystems may provide a substantial contribution to conservation in these regions. In Sulawesi, the number of arthropod species found in mid-elevation forest was slightly over half that found in coffee plantations (Stork and Brendell 1990, cited in Perfecto, Rice et al. 1996). In contrast, also in Sulawesi, the overall diversity and abundance of trap-nesting bees and wasps were found to be correlated positively with land-use intensity, in a gradient between ‘intensively managed agroforest’ and ‘natural forest’. However, while this was the overall trend, not all groups responded in the same manner; trap-nesting eumenid wasps and solitary flower-visiting bees appeared to benefit from high intensity management, while social bees were disadvantaged (Klein, Steffan-Dewenter et al. 2002). Differences in coffee garden management were highlighted in a study in Costa Rica. Shade reduction was associated with a significant decrease in the diversity of ants that forage on the ground, but there appeared little impact on those found on the coffee bushes themselves (Perfecto and Snelling 1995). Perfecto *et al* (1996) also suggested that in highly managed plantations where there is little decaying wood and leaf litter, communities of saproxilic invertebrates suffer. In Chiapas, Mexico, Mas and Dietsch (2004) found the species richness of fruit-feeding butterflies in ‘rustic’ coffee gardens to be “on par with associated forests” and diversity to be significantly higher than in either ‘commercial polyculture’ or ‘shaded monoculture’ coffee gardens.

Mammals and herpetofauna

There are rather fewer studies of mammals in coffee systems. In Mexico, 77% of all local bat species were present in agricultural habitats such as coffee, cocoa and citrus. These bats may use both forest fragments and agricultural areas to fill their complete needs (Estrada et al.1993, cited in Calvo, Koontz et al. undated). Also in Mexico, a study of small mammals found high diversity of these animals in sites with a structurally diverse canopy. Over half of these mammal species were dependent on the canopy trees, and many included fruit in their diet (Gallina et al. 1992, cited in Perfecto, Rice et al. 1996). Studies of reptiles and amphibians in coffee systems are even fewer. One study in Mexico found that the herpetofauna in shade coffee sites with diverse native trees was depauperate in comparison with that of the forest (Rendon-Rojas 1994, cited in Moguel and Toledo 1999).

2.6.4.1 Birds and coffee

Birds are a more common focus than most taxonomic groups, for biodiversity studies in coffee systems. Most of these studies have been located in the Central and South American region. One possible reason for this is the region’s proximity to the United States, making it a convenient research destination for Americans and thus allowing research to attract funding. Additionally, the migratory patterns of many songbirds that spend the summer in North America, and overwinter in southerly coffee-growing areas, adds interest for these northern scientists (Rice and Ward 1996; Moguel and Toledo 1999). Rapid conversion of traditional plantations, where coffee grows under forest-like conditions, and even under the forest canopy itself, to open sun coffee provides a clear focus for studies of habitat value and change.[4] There is also immediate relevance for conservation, as declines of the migratory species using these gardens have been observed in recent years (Perfecto, Rice et al. 1996; Dewar 1997).

Species richness

An early study by Terborgh and Weske (1969), of the colonisation of secondary habitats by forest birds in Peru, encompassed two types of shaded coffee gardens as well as shaded cocoa, matorral (scrub), secondary forest and primary forest. Typically the numbers of bird species found in coffee and cocoa gardens fell short of predictions on the basis of the height of the canopy. Nevertheless, high numbers of species were found, with the greatest number found in coffee with scattered forest trees (101 bird species), followed by coffee with a low but dense shading canopy entirely composed of one type of *Inga* tree (72 bird species), then cocoa shaded by a more open canopy of the same tree (54 bird species). The authors considered features such as foliage height diversity and canopy profile insufficient to completely explain the diversity patterns found, suggesting that habitat responses were complex (Terborgh and Weske 1969). In a Sulawesi study, species richness differences between shaded coffee and open sun cocoa were marked, with 22 bird species found on the former farm, whilst none were seen on the latter (Siebert 2002). In Guatemala, Calvo and Blake (1998) found the abundance and species richness of birds (not including those flying overhead) to be greater in traditional coffee farms than in modernised ones (Calvo and Blake 1998). Also in Guatemala, Greenberg *et al.* (1997) found differences between the species richness of coffee gardens shaded by different tree species. While bird species richness was highest in forest, there were more bird species in *Inga* than in *Gliricidia* shaded gardens (Greenberg, Bichier et al. 1997). This indicates that details of garden design and management, beyond their categorisation as shaded or unshaded, may be important.

Bird assemblage differences

For biological conservation, localised species richness is not the only criterion to be filled. Some taxa are more vulnerable to habitat variation and disturbance than others and it is possible for species richness levels to be maintained while generalist species are substituted for sensitive species of higher conservation value. For example, comparison between Mexican forest types, ‘rustic coffee’ and ‘shaded monoculture’ and ‘sun coffee’ found the species richness in coffee habitats similar to that of forest. However, in spite of their high species richness, shaded gardens also contained a lower number of sensitive species than did natural habitats (Tjeda-

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[4] This body of work does not always share common terminology in describing the types of gardens studied.

Cruz and Sutherland 2004). In Guatemala, birds found in both traditional and modernised farm types were typical of disturbed habitats, such as forest edge. Forest interior birds, however, were more common in traditional farms (Calvo and Blake 1998). In India, Beehler *et al.'s* (1986) survey of coffee shaded by an exotic canopy, showed the avifauna to be dominated by three species; Red-whiskered Bulbul (*Pycnonotus jocosus)*, Red-vented Bulbul (*Pycnonotus cafer*) and a White-eye (*Zosterops palpebrosa*), which together comprised 51% of the individuals surveyed (Beehler, Raju et al. 1986). This high level of dominance by a few species may indicate that other, more specialist species had been unable to use the gardens successfully.

Guilds

A common method for defining ecological differences between the respective avifaunal assemblages is by guild comparison. In Mexico, Greenberg *et al.* (1997) found high species richness of omnivores in both 'rustic' coffee gardens, and those with a canopy dominated by *Inga* species. However, in the 'rustic' coffee, there were more commonly birds that include fruit in their diets, and more specialised species than in the *Inga*-shaded coffee (Greenberg, Bichier et al. 1997). Tjeda-Cruz *et al.* (2004) also found Mexican forest types, 'rustic coffee', 'shaded monoculture' and 'sun coffee' to have different bird guild compositions, with few insectivores and frugivores in shaded monocultures. Disturbed habitats had more granivores but fewer nectarivores, which the authors thought to result from greater herbaceous development in these habitats. Shade coffee gardens had high numbers of upper-stratum species, but few middle and lower-stratum birds. Few birds were observed foraging in the coffee layer, suggesting that the loss of the native understorey was limiting to the taxa that forage in these lower strata (Tjeda-Cruz and Sutherland 2004). Likewise, in Terborgh and Weske's (1969) study in Peru, birds studied in the natural and coffee habitats differed ecologically, with most forest birds found in the coffee with scattered forest trees. These were mainly canopy, rather than understorey birds (Terborgh and Weske 1969).

One apparently vulnerable group is understorey insectivores. Physiological and ecological characteristics that make these birds vulnerable are identified by Roberts *et al.* (2000). These traits include low dispersal ability, lowering of physiological thresholds when faced with altered microclimate and adaptations to low light levels, such as bulbous eyes. Their study of ant-following birds in Panama forest, shade coffee and sun coffee finds ant swarms and their attendant bird flocks in the first two of these habitats, but not in sun coffee. Both the lack of ant swarms and distance from forest conditions were thought to contribute to this difference.

Furthermore, whilst the shade coffee provided foraging opportunities for some of these specialised bird species, others were absent.

Migratory status

Research has also focused on migratory status of birds using coffee plantations, and this characteristic seems to be another general determinant of vulnerability to change from forest habitats. The habitat requirements of residents are considered frequently more specialised than those of migrants (e.g. Brosset 1986). In a study of shaded cocoa in Mexico the migrants were described as being generally small and insectivorous, and the residents as more frequently large and non insectivorous (Greenberg, Bichier et al. 2000). There were few resident forest specialists present in the plantations. Woodland associated migrants, however, were able to make use of these created habitats. The lack of forest residents was attributed to the lack of specialised habitat features, as well as there being insufficient food available to make reproduction successful. Simple shaded and 'rustic' coffee also supported many migratory birds throughout winter, and thus was complementary to other habitats (Greenberg, Bichier et al. 1997). A study in Guatemala found few inter-habitat differences in the numbers of migrants, but more residents in natural habitats (Greenberg, Bichier et al. 1997). For common forest migrants in coffee habitats, abundance was greatest in *Inga* shaded coffee, followed by *Gliricidia* and then sun coffee. The authors suggest that the deciduous nature of *Gliricidia* may affect the resources available to birds, causing migrants to be lost from these gardens at critical times. Perfecto *et al* (1996) also comment on the seasonal leaf loss of this species, as well as *Erythrina* spp. in Latin America, causing canopies dominated by these trees to be bare for the part of the year when migrant birds are present.

'Sun vs. *shade'?*

Greenberg *et al.* (1997) warn of dangers in constructing a simple dichotomy between sun and shade coffee, as there is potentially greater variation between the habitat value of various shaded gardens than between sun and shade coffee. The significant habitat variables in their study included tree height, number of tree species, tree dominance and also elevation. However, these only explained a small proportion of the variation in bird assemblages between habitats, indicating complexity in habitat relations. Some studies have focused particularly on the management-generated differences between plantation types and their respective bird assemblages. Recurrent findings include variation in weed management practices, as well as structural features and food resources due to canopy pruning and tree species selection. In Guatemala, the use of herbicides minimised growth of the herbaceous layer, and thus, feeding opportunities for omnivorous and granivorous birds (Greenberg, Bichier et al. 1997). Calvo and Blake (1998) also found higher frequency of herbicide application and rates of fertiliser application to distinguish 'modernised' farms from the more traditional farms in Guatemala, although the effects of these differences were said to be "difficult to quantify" (Calvo and Blake 1998, p.306). Greenberg *et al.* (1997) also compared their findings from Guatemala, with those of an overlapping team, Greenberg *et al.* (1997), in Chiapas, Mexico, where more canopy bird species were observed. These differences were attributed to higher structural diversity, lack of canopy trimming and infrequent use of insecticides in Chiapas. While flowering *Inga* trees may be an important resource for nectarivores, pruning of these is thought to reduce flower production (Greenberg, Bichier et al. 1997; Greenberg, Bichier et al. 1997). Differences in shade management practices within Guatemala were also highlighted by Calvo and Blake (1998, p.306). Traditional farms were maintained with higher structural diversity, as epiphytes were present. These features were also observed to provide feeding sites for insectivores. More severe pruning in 'modernised' farms resulted in lower canopy cover, as well as prevention of the development of fruit, important as a food source for some bird species. The finding is supported by the work of Greenberg *et al.* (1997). Similarly, the removal of 'weeds' with bird-dispersed fruit from Mexican shaded cocoa gardens was attributed with the sparcity of small frugivores and omnivores there. Consequently, Greenberg *et al.* (2000) suggested that the inclusion of more bird-dispersed fruiting species would improve habitat value of the gardens. However, in Mexico, comparison of diversely shaded "rustic" gardens with those having a canopy dominated by *Inga* species, found little difference in their avifauna. Thus, at least in this case, it seems that there may be at least moderate benefits of shade for avifauna, regardless of floristic factors (Greenberg, Bichier et al. 1997).

Resource use by birds

The resources used by birds is another area for consideration. In shaded coffee in the Dominican Republic, and in Guatemala, most birds were found in the canopy, rather than in the coffee layer. One reason suggested for the paucity of insectivores in the coffee bushes is the insect resistance of their leaves (Greenberg, Bichier et al. 1997; Wunderle and Latta 1998). In the Dominican Republic, the leaves of the *Inga* tree canopy are the most commonly used foraging substrate, whilst flowers are another source of prey for insectivores. However, for those birds that do forage within the coffee layer, the leaves are the most common foraging substrate (Wunderle and Latta 1998). In Guatemala, the birds Greenberg *et al.* (1997) found in the coffee layer were of subdominant species, so it was concluded that coffee provided poorer microhabitat than did other types of understorey, such as scrub. The use of shade coffee plantations by the Cerulean Warbler, and other neotropical migrants to Venezuela, appears to follow this same broad pattern (Jones, Perazzi et al. 2000). This warbler occurs in undisturbed forest and is also common in coffee gardens. It mainly gleans from the canopy and mid-storey foliage, while males are also seen foraging in dead leaf clusters of epiphytes. Birds are never observed foraging on coffee but in the shrubby undergrowth around the coffee bushes. They caught lepidopteran larvae, spiders and flies from the foliage. In the coffee gardens, birds also foraged in *Erythrina* flowers, which are bird-pollinated. While several, primarily insectivorous species were observed visiting the flowers, they were likely to be taking nectar or pollen (as few of the flowers sampled contain arthropods) (Jones, Perazzi et al. 2000). This demonstration of foraging by birds suggests that shade coffee plantations may provide suitable winter (non-breeding) habitat for some migratory species, but lack of an understorey additional to coffee may be limiting to the assemblage that can be supported.

Biogeographic considerations

Biogeographic characteristics also have consequences for birds in coffee farms.

Many forest birds forage in mixed flocks. However, this may limit the capacity of coffee gardens to support large numbers of birds. The 3.3 hectare size of farms described in Venezuela implies that each is only big enough for one mixed flock, due to territorial considerations (Jones, Perazzi et al. 2000). However, in Peru, birds that join mixed-species flocks were found on farms with forest trees, but not those with exotic shade trees (Terborgh and Weske 1969). This indicates an interaction between habitat quality and spatial factors for these birds. Distance from forest is often mentioned as a factor important in determining the avifauna of a garden (e.g. Greenberg, Bichier et al. 2000; Roberts, Cooper et al. 2000; Tjeda-Cruz and Sutherland 2004). In the Peruvian study, some of the inter-habitat differences were attributed to proximity to forest, as this provided a source for colonising birds. However, habitat quality may be sufficiently important to override this distance factor, as the secondary-growth avifauna resembled that of the *matorral*, in spite of the site being physically closer to forest than to *matorral* (Terborgh and Weske 1969). The inclusion of remnant patches is also thought to contribute to coffee garden avifaunal assemblages, including species seasonally unsuccessful in coffee (Beehler, Raju et al. 1986). Not only proximity, but connectivity with forest is emphasised by some authors (Roberts, Cooper et al. 2000). Several studies suggest the role that shaded coffee plantations near to forest can play in buffering them from other more intensively used agricultural land (Wunderle and Latta 1998; Roberts, Cooper et al. 2000). Furthermore, these buffer zones in areas that otherwise might be off-limits to local people may allow them to derive an income. Thus, Roberts *et al.* (2000) identify an opportunity for collaboration between agronomists and conservationists to meet farmer, as well as biodiversity, goals.

2.7 Farmer incentives

One manner by which farmer behaviour can be influenced, and farmers involved in regional conservation efforts, is by legislation penalising environmental damage (Hardin 1968). However, in the Sumberjaya context, prohibitive Government action has not achieved this goal in the past (Kusworo 2000; Kusworo 2000). True sustainability may require a more fundamental and long-term behavioural change that is better cultivated by provision of incentives, and most ideally, incentives that are themselves sustainable. Financial incentives may be the most immediately tangible form of reward for farming in a manner compatible with conservation objectives. Possible mechanisms include Government subsidies, as occurs in the United Kingdom. There, farmers are paid to maintain "set-aside", which is an uncultivated area, often located at a field margin, which provides a haven for farmland birds. This scheme also serves to meet European Community restrictions on agricultural production. Compensation is also paid for the establishment of hedges on farmland, as this provides useful habitat for the rapidly declining bird populations in agricultural land (DEFRA undated). Providing farmers with access to credit is also suggested as a means by which the viability of Sumatran jungle rubber systems may be maintained (Gouyon, Foresta et al. 1993). In Latin America, Governmental institutions have had a clear influence over the way in which coffee is produced. While in the past these have caused a change to 'technified' coffee with reduced shade and increased yields, it seems possible that they could act in the opposite direction, to increase quality and sustainability (Rice and Ward 1996). The role of Governmental bodies also extends beyond the country of production, as aid programs have also had substantial influence over the way in which coffee is produced (Perfecto, Rice et al. 1996).

While cash incentives may be vulnerable to syphoning, financial incentives could take the form of tax measures (Rice and Ward 1996). In some cases, the limitations that farmers experience due to insecure tenure make this a more fertile field for providing incentive. The local situation in Sumberjaya mandates my exploration of this topic. Other Government-provided incentives may include the increased access to markets allowed by improved roads (Gouyon, Foresta et al. 1993). The market itself can provide an alternative means for delivering financial reward for sustainable management by product eco-certification. This has been a focus of efforts to maintain and improve the habitat value of coffee plantations in Central and South America. Difficulties in community organisation and high costs of scheme establishment may be limiting to such projects. However, some other forms of incentive may be available on an individual basis, provided that sufficient markets exist for products. The ability of farmers to sell other products grown on the same land as their coffee may allow them to derive greater income, as well as stabilise incomes in the context of fluctuating commodity prices (Perfecto, Rice et al. 1996). Finally, there are many less easily measured incentives. A possible benefit to Mexican farmers of shaded cocoa is identified in the potential for migratory insectivores to control arthropod pests (Greenberg, Bichier et al. 2000). Other indirect motives may include watershed protection, personal satisfaction at creating a sustainable and productive system that can be inherited by future generations, pleasure in seeing animals using the garden as habitat and peace of mind from concern regarding the effects of industrially-produced fertilisers and pesticides. However, while Schalenbourg (2004) found well developed farmer interest in forest functions such as watershed protection and erosion control within the Sumberjaya area, he commented that "little importance seems to be ascribed to biodiversity conservation" (Schalenbourg 2004, p.42)

2.7.1 Eco-certification of shade-grown coffee

'Eco-certification' is commonly seen as a means for delivery of rewards, to producers of goods who operate in a manner more sustainable than that of conventional production. Since the 1990s, increased attention on the potential benefits of shaded coffee gardens for birds has given rise to a market for coffee with 'shade grown' origins being certified and attracting higher prices. Once again, these schemes are centred on Central and South America as source regions, while the main market lies in North America. However, there are complications that lie in product verification and assessment costs as well as consumer perceptions. A study into the effects of eco-certification on consumer choice in the electricity market found that education, socioeconomic status and level of environmental activism influence the interaction with the ecolabel in a complex way. The 'ecoseals', in that case, were seen as influencing consumers when they appeared to provide additional information about the product, without seeming inherently inconsistent with the consumer's prior knowledge. However, for products already seen as being 'green' or 'sustainable', there may be no additional benefit by certification. The diversity of schemes available and the vagueness of the information often provided to consumers was seen as problematic (Roe, Teisl et al. 2001). For small producers such as farmers in a global commodity chain, value adding requires them to be accepting of conditions created by 'key agents' in order to be allowed to participate (Ponte 2002). This is clearly the case for certification of a product such as coffee. Certification schemes are dependent upon clear rules and observable adherence to these, particularly in the instance that the mode of production is not observable in the final product. This is certainly true for 'shade-grown', 'organic' and 'fair trade' coffee that are commonly subject to certification in various combinations.

Several schemes have been developed for certifying coffee, acknowledging its growth under a shade canopy. The 'Eco-Ok' scheme, operated by The Rainforest Alliance, is applicable to other products as well as coffee. It addresses issues including community relations, use of agrochemicals, waste management and conservation of water, soil and fauna (Rainforest Alliance 2001). Companies that pay a licensing fee to use the logo participate in a 'chain of custody' audit that examines the passage of the coffee from its production to the consumer (Gorsline). Regarding shade trees, emphasis is placed on their deciduous or evergreen habit, rather than species composition (Mas and Dietsch 2004). The approach towards issues such as agrochemical use is also less strict than that of organic certifiers (Rainforest Alliance 2001). However, this may increase the amount of land that can be addressed by the scheme. There is emphasis on large producers, through which greater impact may be made on work practices. Mas and Dietsch (2004, p.645) describe the approach as "inclusive [using] attainable criteria to reach as many farmers as possible". Incentives in the scheme have also been described as 'informal', and education is also seen as playing a role in change (Greenberg undated).

In response to the market existing for certified coffees, but the lack of a comprehensive scheme that emphasises shade management for biodiversity conservation, the Smithsonian Migratory Bird Center (SMBC) created its 'Bird Friendly' certification system (Greenberg undated). Credibility is derived from this research institution that has created guidelines for farm inspectors, specifying how a garden 'should' look. Organic practices are also a pre-requisite for entry into the program (Mas and Dietsch 2004). The shade requirements for the 'Bird Friendly' scheme involve consideration of the structural diversity and species composition of the shade canopy. 'Rustic shade' gardens are the preferred model, with a minimum canopy cover of 40%, this being largely composed of forest trees (Smithsonian Migratory Bird Center undated). In planted shade gardens, a 'backbone' of trees provides the majority of shade. In South America many of these are of *Inga* species. *Erythrina* species and *Gliricidia sepium* are considered 'unacceptable' for biodiversity conservation due to their deciduous nature, removing shade during the dry season. Thus, they are considered acceptable only at low densities (<5% of canopy cover). It is recommended that not more than 70% of the canopy is composed of the genus *Inga*, and that individual species do not comprise more than 50% *Inga* trees. A minimum of ten tree species within a farm (of unspecified size) is also suggested. Shade cover is recommended to never fall below 40%, while backbone shade species should be at least 12-15 m tall. In order to achieve structural diversity 20% of the shade cover should be higher or lower than this. Secondary plant diversity, such as parasites or epiphytes, should be retained. Living fences should be maintained along borders to prevent desiccation. While these requirements are detailed, it is recommended by SMBC that inspectors synthesise them with reference to a *gestalt* classification. Within this schema, rustic, traditional polycultures and diverse commercial polycultures are considered acceptable for 'Bird-friendly' certification (Smithsonian Migratory Bird Center undated). Organic certification for coffee by the Organic Crop Improvement Association also has detailed requirements regarding shade treatment, that appear to follow the 'Bird Friendly' model (OCIA 2005). However, the restriction on the proportion of fruit trees that can be included in a garden may reduce some of the agroforestry benefits to farmers. There is a multitude of bodies that certify organic products, not all of which include shade specifications for coffee.

The products certified as 'shade grown' are available for purchase in North America and Europe, and by mail through the internet, but seem largely unknown in Australia (personal observation). Furthermore, the endorsement of shade-grown coffee sourced from outside of Latin America occurs regardless of the fact that very little research into the relationship between coffee production and biodiversity has occurred outside the Americas. This simplification in labeling was said to occur so as not to confuse consumers (Colter 2000), which is an attitude consistent with that expressed by the café chain Starbucks in the early days of certification (Dewar 1997). This chain, however, later "responded to pressure" and introduced certified coffee to its range (Cornell School of Industrial and Labour Relations 2002). Studies regarding the effectiveness of eco-labeling within the marketplace are limited. However, a United States study of the consumer response to various coffee'eco- labels' suggested that fair trade and shade grown coffee elicit a higher 'willingness to pay' than does organic certification[5]. Additionally, females were found to be more responsive to the three types of labels, whilst higher education is a significant factor in willingness to pay for shade grown and fair trade coffee (Loureiro and Lotade 2005).

Whilst the North American market has embraced the concept of shade-grown coffee, there is some counter-argument regarding its actual conservation benefits, and allegations that research and regulation have not kept pace with marketing (Higgins 2000; Rappole, King et al. 2003).

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[5] It appears that the 'organic' labeled coffee described in Loureiro and Lotade's Loureiro, M. L. and J. Lotade (2005). "Do fair trade and eco-labels in coffee wake up the consumer conscience?" Ecological Economics **53**: 129-138. study does not include the shade regulations used in the OCIA scheme.

Simplification of issues for the purposes of engaging consumers may have led to unrealistic public perceptions. In particular, insufficient distinction between different types of shade cover is said to mislead customers and over-state the benefits of some certified farms (Rappole, King et al. 2003). The literature marketing the 'Eco-Ok' scheme, as well as some of that from the Smithsonian Migratory Bird Center, makes little distinction between different types of shaded gardens, focusing instead on the sun-shade distinction (e.g. Rainforest Alliance 1996; Rainforest Alliance 2001; Rainforest Alliance; Smithsonian Migratory Bird Center undated). Even some of the more comprehensive literature implies that there is difference between garden types, but the overwhelming flavour is promotional (e.g. Perfecto, Rice et al. 1996). Consumers may be unaware of the different criteria for certification schemes, as well as the various philosophical perspectives by which they are justified.

There is minimal literature testing the outcomes of various standards of certification, with the study by Mas and Dietsch (2004) of birds and butterflies under different schemes pioneering in this field. Overall, the study found that biodiversity data support the management for biodiversity by certification criteria. In comparison of five programs operating in Mexico, including 'Eco Ok' and 'Bird Friendly' schemes, they found overall consistency in classification at the extremes of the spectrum: the 'best' farm (for biodiversity conservation) would be accepted by all schemes whilst the 'worst' farm would be rejected by all. However, intermediate farms received different results from the various programs due to differences in criteria. It is also noted that the programs have different objectives, for example Eco-Ok is an 'engagement program' (Mas and Dietsch 2004, p.650). Indeed, there are many variables that could be considered, which by different emphasis, would change classification of the gardens. Mas and Dietsch (2004) particularly identified structure depth and diversity as important for birds and butterflies, but commented that thismay be costly to measure for certification. They also commented that criteria for coffee bushes were not part of certification requirements, but that coffee height was correlated with butterfly species richness. However, setting requirements for coffee may be more difficult than for shade trees, due to farmer resistance. They suggest evaluation of programs not with relation to each other, but to identified conservation goals. "If goals include viable reproduction, then certification programs should include criteria associated with protecting forest fragments that may serve as population sources" (Mas and Dietsch 2004, p.652).

Other research indicates that some bird species are specialists in native forest types and do not occur in the shade plantations that are replacing them (Rappole, King et al. 2003). Biodiversity researcher Dina Roberts has been quoted as saying “You can’t use shade grown coffee as a panacea for the conservation of all bird species” (Higgins 2000).

It is not entirely clear what is the relationship between the shade coffee market and de-forestation patterns. Coffee cultivation has been, and remains, a substantial cause of tropical forest loss, including in Brazil and along the Bukit Barisan Range that forms a spine along the west of Sumatra (Nestel 1995; Laakonen 1996; O'Brien and Kinnaird 2003). There are also allegations that price premiums create incentive for further encroachment on forest to create new shaded plantations (Rappole, King et al. 2003; Rappole, King et al. 2003). Indeed, Kinnaird (2002) and O’Brien and Kinnaird (2003) suggest that there is a direct positive relationship between the price of coffee and rates of de-forestation in Lampung, although Dietsch *et al.* (2004) point out that this correlation does not indicate causality. Likewise, when coffee prices have been high in Mexico, production has been expanded by increasing the land under cultivation, rather than by increasing yields in pre-existing farms (Nestel 1995). However, with in-country institutional involvement by the promotion of technological packages, there has also been a trend to intensify production by removing and homogenising shade trees. This indicates the power that Governmental institutions can have over smallholder decision-making in the field. In response to the comments of Rappole *et al.* (2003), Philpott and Dietsch (2003) claim that most areas suited for growing coffee have already been largely deforested, and that the greater risk is conversion to more intensive agricultural systems that would be more damaging to biodiversity. Furthermore, this conversion is said to be more likely in the face of the low prices currently paid to coffee farmers. These authors call for more rigorous certification and direct rewards for farmers by integrating fair trade schemes. They also emphasise the need to involve farmers in conservation, as such large areas of the earth are used for agriculture. In reply, Rappole *et al.* (2003) argue that price incentives may make previously uneconomical areas, such as steep sites, feasible for planting coffee, that some retailers promote coffee as being ‘shade grown’ with insufficient verification and that overall, there are many conditions that must be fulfilled before any conservation benefits are guaranteed (Rappole, King et al. 2003).

Creation of a certified product with real conservation benefits is indeed a complicated task and there are many limitations due to institutional and economic factors. Ponte (2002) suggested that deregulation of the coffee market has reduced barriers to product diversification, but the extreme dominance of several multinational companies in the roasting stage of processing is now a limiting factor (Ponte 2002). Additionally, the high costs of farm inspection and certification may be a barrier for many farmers entering the certified coffee markets (Perfecto, Rice et al. 1996; Philpott and Dietsch 2003). Thus, there may be much coffee farmed that meets the requirements of certification that remains unlabelled (Rice and Ward 1996). This implies that these farmers may, in fact, be at a disadvantage due to the existence of such schemes; not only is their conservation contribution not rewarded, but the discrimination introduced in the market may limit demand for their product (Cornell School of Industrial and Labour Relations 2002). There may also be problems with the coffee from dissimilar gardens being mixed to provide enough volume to market. Rice *et al.* (1996) suggested that grouping in co-operatives can improve farmers' access to certification. Also, while "an increasing number of consumers are prepared to pay premium prices for so-called specialty coffees" (Perfecto, Rice et al. 1996, p. 606) by implication these products must also be of premium quality. This may limit the success of certification schemes in regions such as Lampung where lower quality 'bulk' coffees are produced. Indeed, O'Brien and Kinnaird state that certification schemes should be expanded to include monoculture robusta, as they believe that shade-grown arabica gardens are not suited to lowland conditions in Asia, such as are found in West Lampung (in Dietsch, Philpott et al. 2004).

As has been recognised in other types of conservation and development projects, and is highlighted by Philpott and Dietsch (2003), there is a need for incentives and rewards to be directly related to ecological benefits in order to maximise outcomes. Comprehensive faunal surveys are unlikely for all participating farms. Thus, there is a need to understand what types of farms are likely to contribute to conservation, and devise practical means for identifying and monitoring these in the field. On the scale of an individual small landholder, a shaded farm is unlikely to represent sufficient habitat contribution to support mobile bird populations as well as other specialists or resident species, some of which have high areal requirements. However, at the scale of natural communities, factors such as edge effects, minimum area requirements and the ability to move across the landscape may be more reasonably addressed if farmers co-operate.

2.7.2 Tenure

Tenurial security and the capacity to make resource-planning decisions also have great bearing on the way land is used. When conservation aims are involved, the balance between regulation and local autonomy seems a delicate one. A high proportion (nearly 90% of the land area of the outer islands) of Indonesia is claimed as state forestland. This empowers the Government to make resource use decisions regarding this area, under the Basic Forest Law (No. 5/1967)

(Moniaga 2001). The 'top down' approach of the Indonesian Government in allocating land for plantation development has been criticised due to its social implications, as well as inaccurate categorisation of land cover types (e.g. Kartodihardjo and Supriono 2000). In South Lampung, conflict between displaced farmers and oil palm plantation owners led to thousands of farmers cutting and selling trees. Most oil palm establishment, which is dominated by large scale enterprises, occurs by the conversion of production forest, and is subsidised by the state (Kartodihardjo and Supriono 2000). In contrast with this, in Sumberjaya, the encroachment of smallholder coffee farmers on protection forest areas resulted in a strong authoritarian response from the Government (Michon, Foresta et al. undated). Whilst the official types of forest classification differ in these cases, there is a common allegation that actual land cover types are not accurately recorded (Kartodihardjo and Supriono 2000). Furthermore, in the context of biodiversity conservation, there seems little difference between these types of forest encroachment. Nevertheless, it is true that smallholder coffee plantations continue to be developed at forest margins, and even within national parks (O'Brien and Kinnaird 2003).

While these 'pioneer systems' have developed from an indigenous shifting cultivation system, the more recent shortage of land, particularly that under forest, makes such a system less sustainable than it was. The management of these inherently insecurely tenured systems has a short-term focus, and contrasts with that where farmer tenure is established, and more complex, long-term oriented systems are developed. The greater likelihood of the chance to reap long-term rewards encourages farmers to increase investment in their farms (Budidarsono, Kuncoro et al. 2000; Gillison, Liswanti et al.). Shared cropping, however, may offer little incentive to the working farmer to make investment as the profits are divided with the other owners.

In Lampung, there have been recent efforts to use the incentive of greater tenurial security to encourage farmers to plant trees and protect the remnant forest. However, the actual arrangements are somewhat confusing, partly because of the progression of systems that have taken the name 'HKm' (*hutan kemasyarakatan*- community forestry') (Chidley 2002). This attempt at more participatory planning strives to leave behind the authoritarian approach of the past in regulating land management. It also aims to combat the *laissez-faire* situation that has allowed the rapid erosion of forest resources since the economic crisis and reformation of the government in the late 1990s (Kusworo 2000; Kinnaird 2002; Tjondronegoro 2002). Since this time there has been a reported perception that all the pre-existing laws and regulations became invalid, sparking a 'tragedy of the commons'-type of situation (Hardin 1968).

In the Pesisir region, which is where mature damar agroforests have been threatened by re-allocation by the state, Government allocation of the area as timber concessions and for oil palm plantation establishment caused great concern in the 1990s (Poffenberger undated). There is now official recognition of the traditional tenure and resource management and regulation by local people. The establishment of this special agreement (*Kawasan Dengan Tujuan Istemewa* – KDTI) was a landmark for co-operative landuse planning in Indonesia (Campbell 1998; Fay, Foresta et al. 2000; Poffenberger undated). The agreement acknowledges that a situation without apparent state regulation is not necessarily unregulated if the requisite local structures are in place. It is unclear whether such strong local systems might be established in less socially stable transmigration areas such as Sumberjaya, and Chidley (2002) cautions that the model's wider application may be limited. Indeed, it seems that one of the reasons for the stability of the damar system was its long isolation. However, even in long established communities, the development of community property rules is often insufficient to ensure that resources are sustainably managed, as indicated by the over-exploitation of resources such as *gaharu* in Kalimantan (Salafsky, Dugelby et al. 1993). Additionally, it must be noted, that in the Pesisir, the tenurial situation is less clear at the margins of cultivation, where pioneer coffee and damar systems are being developed, and are indeed encroaching on forest, including Bukit Barisan National Park (O'Brien and Kinnaird 2003).

2.8 Conclusion

The situation of bird conservation in Sumberjaya is a complex one. It falls within the context of rapid de-forestation in Sumatra by which avifauna, and indeed the entire regional ecosystem, seems threatened. This situation is further complicated by issues of immigration and tenure. Regionally, coffee systems form one of the main land-uses, and thus the potential to maximise their biodiversity seems important. One way in which conservation and livelihood issues may be addressed simultaneously is in the creation of diverse agroforests. With particular regard to coffee, the claims made regarding the potential for conservation of avifauna within the traditional shaded gardens in Central and South America give some hope that these systems can be managed in a sensitive manner to lessen biodiversity losses. However, there are doubts regarding the ability of shaded gardens to support those species that have high conservation value. This uncertainty is particularly applicable in Southeast Asia, where the question has not been comprehensively researched. Additionally, the structure of the coffee market and poor incentives currently available, may limit the development of such systems. This mandates an investigation into the social and ecological potential for coffee gardens to be enlisted into regional conservation efforts.

Chapter 3 Physical and social conditions in West Lampung

The Eagle: (fragment)
Alfred, Lord Tennyson

He clasps the crag with crooked hands;
Close to the sun in lonely lands,
Ring'd with the azure world, he stands.

The wrinkled sea beneath him crawls;
He watches from his mountain walls,
And like a thunderbolt he falls.

The Black Eagle (*Ictinaetus malayensis*) is the emblem for Lampung Province.

Physical and social conditions in West Lampung

3.1 Introduction

Farming communities have many commonalities, such as dependence upon the weather and commodity prices, but many factors are locally specific. The situations of the coffee and damar farmers in Sumberjaya and the Pesisir are defined by many characteristics. Physical features include the locations, either side of the Bukit Barisan Selatan range in West Lampung, topography, geological history, including vulcanism and resultant soils. Biological characteristics include the lowland rainforest vegetation native to the area as well as the largely agricultural and successional vegetation now existing following land modifications. Historical aspects describe the settlement and cultivation of the area, as well as the sometimes coercive social and economic context in which commodities have been produced within the region. Demographic characteristics are also relevant in the context of population increase, largely through transmigration, which has also greatly altered the ethnic mix of the region. This has had further effect on the agronomic practices of the area, including the cultivation of coffee and other crops found in coffee-based systems. In turn, the management of these systems is influenced by factors such as accessibility, land tenure status and the local projection of the international coffee market. Each of these factors has bearing on the potential for this landscape to support biodiversity, and in particular, on the likelihood of farmer involvement and success of conservation projects.

3.2 Location and topography

Sumatra has an area of 434,000 km^2 and is the third largest island in Indonesia and the sixth largest island in the world. It straddles the equator from 5º 39'N to 5º 57'S, with its long narrow shape stretching diagonally over 1650 km (Figure 3.1). The Indian Ocean lies to the west while the Straits of Malacca and South China Sea are to the east. The closest point to Malaysia is only 45km across the water. The Sunda Strait separates Sumatra from Java in the south, with the narrowest section measuring 25km. Borneo is approximately 450 km to the east (van Marle and Voous 1988). In profile, Sumatra is approximately wedge-shaped. There is a chain of mountains, the Bukit Barisan, extending the length of the island in the west, including mountains over 3000m in height in northern, central and southern regions (Figure 3.1). The east is more low-lying, with gentle hills descending to alluvial plains with meandering rivers. Near the eastern and southern coasts there are extensive peat swamps and mangrove forests (van Marle and Voous 1988).

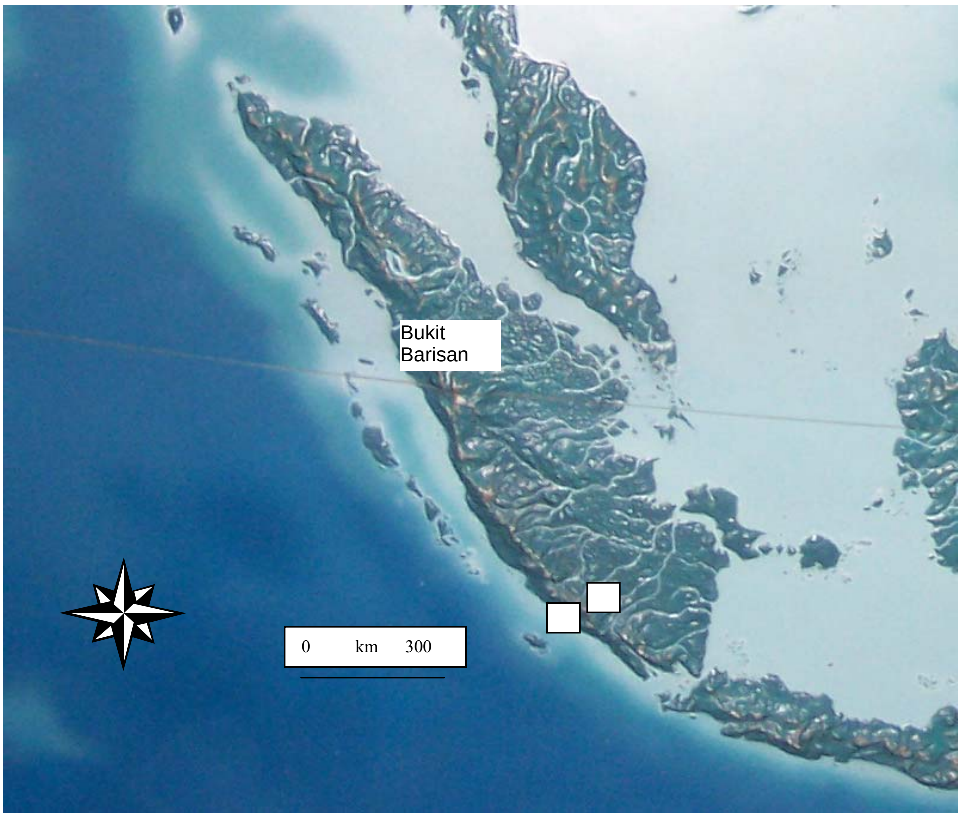

Figure 3.1 Sumatra, showing topographic relief, and the areas of field study of Sumberjaya and the Pesisir, respectively east and west of the Bukit Barisan Range.

Source: modified from Wis (2005)

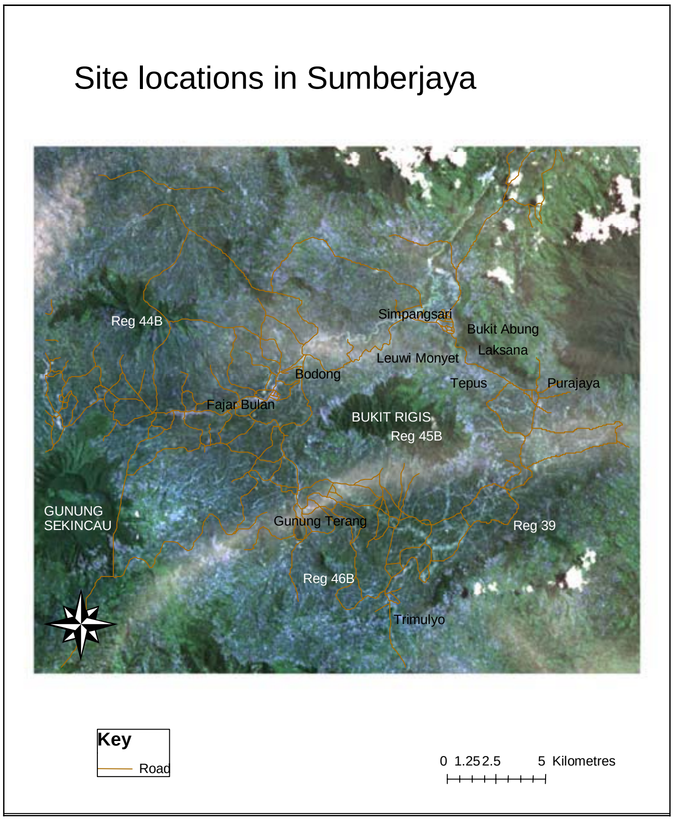

Figure 3.2 Sumberjaya study area.

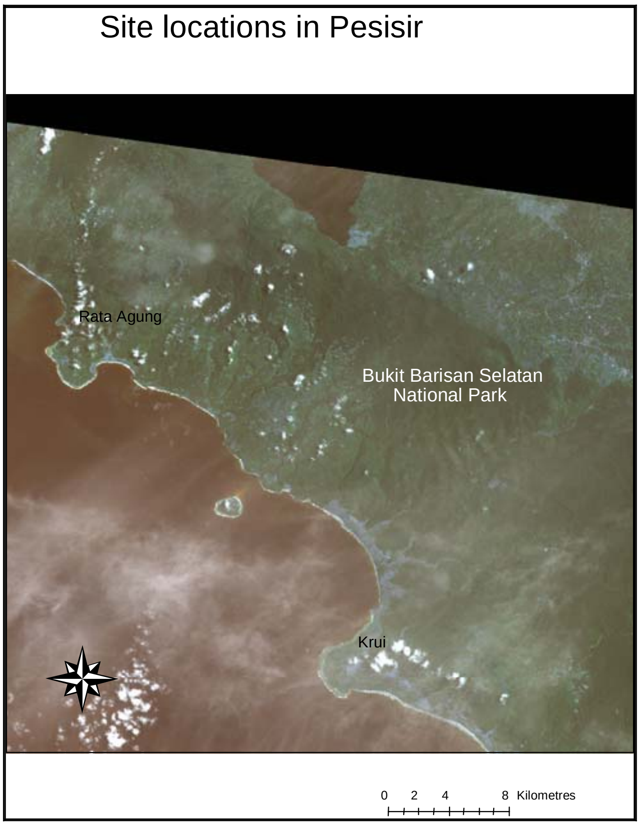

Figure 3.3 Pesisir study area

Areas enlarged are approximately those indicated in Figure 3.1 **(**Source:ICRAF)

Lampung is the most southerly of provinces, and covers the width of the island, thus having the same wedge shaped profile. This project was located on the low to medium altitude slopes of the eastern side of Bukit Barisan, as well as in the Pesisir, in the more low-lying area to the west of the range (Figure 3.2, Figure 3.3). The Sumberjaya subdistrict (*kecamaten*), is part of the district of West Lampung (*kabupaten Lampung Barat*), 4 º 56' 6" and 5 º 11' 25" S and 104 º, 17' 52" E and 103 º 33'51" N (Budidarsono, Kuncoro et al. 2000). The area is approximately equal to the catchment of the Way Besai. This is a main tributary of the Tulang Bawang River which flows to the east of the province (van Noordwijk, Tomich et al. 1997). Sumberjaya catchment occurs in a diamond shape, with a central hill, Bukit Rigis, as well as having more hills to the east, including Bukit Abung and in the south. Bukit Rigis rises to 1623m (DITTOP 1998). The Way Besai flows in a near circle around this hill. The hill's top is largely forested, whilst other patches of forest are also restricted to steep areas, located at the edge of the catchment (van Noordwijk 2001). The Pesisir region occurs in the narrow strip between Bukit Barisan and the western coast.

3.3 Climate

Sumatra has a generally humid tropical climate, although near the equator climates are highly variable locally. There is some seasonality, but the timing of this is changeable, and its definition is less pronounced than in Java (Whitten, Damanik et al. 2000). Humidity levels are relatively high and always above 80% (Mougeot and Levang 1990). Rainfall ranges from approximately 1500 mm to over 6000 mm annually, but more than 70% of rainfall measurement stations experience over 2500mm annually (Whitten, Damanik et al. 2000). Most rain falls torrentially in the afternoon (Smets 2002). The eastern side of Bukit Barisan experiences a rainshadow effect, and is thus drier than the west coast. In the south of Sumatra there is a single dry season, occurring in the middle of the calendar year (Whitten, Damanik et al. 2000). This is influenced by the southeast monsoon carrying dry air from Australia (van Marle and Voous 1988). The study area in Sumberjaya is at the convergence of several climatic zones, defined by Oldeman (1979, cited in Whitten, Damanik et al. 2000). It is approximately characterised by seven to nine months of consistently humid weather (>200 mm rainfall per month), with a short dry season, of less than two consecutive months (<100 mm per month) (van Noordwijk and Foresta 1998, after Oldeman et al. 1979). Annual rainfall for the subdistrict is 2500mm (Tomich, Chomitz et al. 2004). In Kotabumi, nearby to the north-east (but at only 32 m asl), the driest month is August (with mean rainfall of 97 mm), whilst the wettest is December, with 317.7 mm (Hoare 1996). The Pesisir study sites of Krui and Rata Agung, in the coastal area to the west of the mountains, are in one of the wettest regions of

Sumatra. There is 3000-4000 mm of rain annually on the coast, increasing to 5000mm annually on the mountain slopes (Smets 2002), causing rapid erosion (Mougeot and Levang 1990). This rainfall is distributed quite evenly throughout the year. Nine months of the year receive more than 200 mm of rainfall, while there is a short dry season from July to August, during which less than 100mm is received (Smets 2002). Lampung temperatures are quite constant throughout the year, with a mean of 26-27°C at sea level decreasing at a rate of 0.6°C per hundred metres increase in altitude. Maximum temperatures rarely exceed 35°C. The hottest period is at the end of the dry season (Mougeot and Levang 1990). In Krui the temperature is usually around 28°C (Smets 2002).

3.4 Geological history.

The Triassic period (250 Ma) was the beginning of a 100 My phase of sedimentation in the area that would become Bukit Barisan. During the Cainozoic (began 65 Ma), subduction of the northward moving Indian plate under the Asian plate margin resulted in continental buckling, creating the Himalayas. The sediments in western Sumatra were also uplifted to become a mountain range. Ensuing subsidence allowed further sedimentation during the Oligocene (35Ma). More mountain building activity followed, associated with faulting, which also resulted in the creation of rifts, as well as ongoing volcanic activity (Whitten, Damanik et al. 2000). Nine volcanoes remain active in Sumatra (van Marle and Voous 1988). The volcanic ejecta have contributed to the modern soils of Bukit Barisan, while Lampung soils have also benefited from the eruption of Krakatau in 1883 (Whitten, Damanik et al. 2000).

3.5 Soils

Most of lowland Sumatra is covered by yellow soils with a strong textural contrast between the A and B horizons (podzolic). These bleached, sandy soils are derived from permeable parent material in conditions of high rainfall. They can be highly acidic and of limited agricultural potential. In the mountains, the distributions of various forms of red-yellow podzolics derived from shales and sandstones are complex. On the west coast there are sandy and rocky soils (regosols). These are shallow, acidic and developed from unconsolidated sediments (Young 1976; Whitten, Damanik et al. 2000). Within Lampung province, the greatest proportion of soils has strong texture contrast (podzolics), while many are also highly leached of basic minerals and silica (latosols). They can form very hard crusts on exposure to air (Goudie, Atkinson et al. 1985; Mougeot and Levang 1990; Whitten, Damanik et al. 2000). Most of the province's coffee is produced on this type of soil, whilst it also supports cultivation of rice, maize and cassava in low-lying areas (Mougeot and Levang 1990).

The Sumberjaya study site falls on the boundary of the mountain and piedmont zones which are respectively characterised by soils derived from volcanic ash (andosols) as well as latosols of relatively high fertility and red-yellow podzolics (van Noordwijk and Foresta 1998, after Sholz 1983). Verbist *et al* (2005, p.264) describe the volcanic Sumberjaya soils as being "amongst the best in Lampung province", and very suitable for coffee cultivation. The local soils are characterised as being moderately developed and fine textured with some altered weatherable minerals (cambisols) as well as volcanic-derived and shallow, rocky soils (andosols and tropical regosols) in watershed areas. Lowland soils include anaerobic and waterlogged clay-rich soils (gleysols), as well as soils derived from alluvial sediment (tropofluvents) (Aubert and Tavernier 1972; Young 1976; Syam, Nishide et al. 1997; van Noordwijk and Foresta 1998; Anonymous undated; Valdosta State University undated). The soils on which coffee is growing are moderately developed, finely textured, pale reddish and slightly acidic. They are vulnerable to erosion (Budidarsono, Kuncoro et al. 2000). In the hills around the Krui region the soils are strongly acidic, highly leached red soils with texture contrast, having limited agricultural potential, although rice, coconut and cloves (Mougeot and Levang 1990; Michon 1985, cited in Smets 2002).

3.6 Vegetation

Sumatra is part of the vegetational zone of Malesia. This groups it with the rest of Indonesia, Papua New Guinea, Southern Thailand and the Philippines. Due to the longer persistence of land bridges to Peninsular Malaysia and Borneo, their biotic similarities with Sumatra are greater than those of Java (Whitten, Damanik et al. 2000). The natural vegetation of Sumatra is mainly tropical evergreen rainforests. These vary with soils, altitude and ground water. In the eastern coastal area there are mangrove forests, which grade into freshwater swamp forests and peat forests. As altitude increases with westward travel, lowland forest is encountered, which becomes montane forest on Bukit Barisan (van Marle and Voous 1988). At altitudes over approximately 3000 m, the vegetation becomes stunted and eventually characterised by subalpine assemblages of heath and grasslands (Whitten, Damanik et al. 2000). The potential climax lowland forest has a closed canopy, with natural breaks along watercourses or following tree fall. The canopy is generally 25-45 metres high, but is punctuated by emergents to a height of 67m, mainly dipterocarps of the genera *Dipterocarpus*, *Hopea* and *Shorea*. These may reproduce with a mast fruiting every few years, but are not widely used as a food source for vertebrates (van Marle and Voous 1988). Other common characteristics of lowland forest in Sumatra include trees with mesophyllic-sized leaves, large buttresses and flowers occurring on the trunk or main branches (cauliflory). Climbers, creepers and epiphytes such as orchids are also common.

3.6.1 Vegetation change

Vegetation characteristics are determined by the interplay of various sources of disturbance and subsequent succession. In tropical rainforests the occurrence of disturbance events may be so frequent that climax communities are rarely, if ever, achieved. High species richness is related to non-equilibrium state (Connell 1978). In the lowland rainforest native to much of Lampung, this disturbance may occur naturally due to storms, floods and occasionally, fires. However, the vegetation of Lampung has been altered to a much greater extent by its human inhabitants. Although long settled, most agriculture was small in scale and left large tracts of mostly undisturbed forest at the beginning of European colonisation in the 16th century. Even following this, populations were generally low until the beginning of intensive transmigration programs in the 20th century. Sumberjaya, in particular, seems to have been largely unsettled until the late 19th century. However, between the 1940s and the end of the 20th century the population of Sumatra more than doubled (Whitten, Damanik et al. 2000).

While estimations of characters such as forest cover and loss vary, the general pattern in recent decades has been extensive deforestation. This has occurred by logging as well as clearing and burning to provide land for agriculture and plantation establishment. While in 1999, 29% of Lampung was designated as ‘permanent forest’, only approximately 10% of the province was actually forested. Of the officially protected areas, ‘Conservation forest’ and ‘Protection forest’, only 52% had actual forest cover. This compares poorly even with the mean value for Sumatra, being 70% forest cover within designated protected areas (Tjondronegoro 2002, after Sekrektaris Badan Planologi Hutbun 1999). Rates of forest loss also remain high. Between 1985 and 1997 Sumatra suffered one third of Indonesia’s total deforestation for the period (Kinnaird 2002). During this time, the area under forest in Lampung contracted by 23,873 hectares per year, which is a 44.2% reduction over the period (Tjondronegoro 2002, after Holmes 2002) (Plate 1).

Plate 1 The margin of forest clearance for coffee planting at Bodong, Sumberjaya.

Plate 2 Sumberjaya landscape in the Laksana district.

In the foreground is a coffee garden, with a few shade trees of mixed species. Rice paddy is visible in the mid ground, behind which are hill areas cleared for agriculture. Only the top of the hill (Bukit Rigis) remains forested.

3.6.2 Sumberjaya vegetation

The study area in Sumberjaya, between altitudes of 750m and 1050 m asl (although local hills extend above this altitude), was once characterised by lowland forest[6]. However, during the 20th Century this has been subjected to widespread and ongoing clearance. The general impression today is a patchy landscape of rice paddies in the valley floors with coffee gardens

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[6] (The general boundary between lowland and lower montane forest is considered to occur at approximately 1200m, but this is subject to variation dependent on temperature, cloud level and mountain size Whitten, T., S. J. Damanik, et al. (2000). The Ecology of Sumatra. Oxford, Oxford University Press..

covering the majority of the hill slopes. There are some forest remnants on the hilltops, and patches of successional vegetation range from Imperata grassland to low and tall scrub (Plate 2). The forest remnants themselves have also been subject to pressures of small-scale timber extraction, thus, a fully closed canopy is rare, and the forests' condition cannot be considered 'pristine'.

3.6.2.1 Fine scale vegetation change in Sumberjaya

A remote-sensing based study of landscape change between 1970 and 1990, located in West Lampung, adjoining the western boundary of the Sumberjaya study area, shows that local vegetation characteristics viewed over time are complex (Syam, Nishide et al. 1997). Over the study period, primary forest decreased markedly reducing from 57% of the area studied in 1970 to 13% in 1990. The area of secondary forest remained more stable. Concurrently, plantations (mainly coffee) increased from none measurable to 42.72% of the study area during the period. Detailed consideration shows a more complex pattern of change. Plantations appeared for the first time between 1970 and 1978, by which time they covered 18% of the area. These lands were previously occupied by shifting cultivation, dense forest and upland field areas (Syam, Nishide et al. 1997). Verbist (2001) stated that aerial photographs from 1976, indicate that at this time, shifting cultivation was still occurring, and most of the small valley bottoms were still forested, but the sloping lands were already permanently deforested. According to Syam *et al.* (1997), grassland also increased markedly during this time. Most of the grassy areas were not at the same sites as those in the initial measurement, showing that there is great flux in this landcover. During the period from 1978 to 1984 plantation area doubled to become the largest land cover, mainly through conversion of grassland, dense forest and underbrush forest (scrub) areas. At this time there was also a move to convert monoculture plantations to mixed plantations. Syam *et al.* (1997) attribute this change to the leading farmers in the area aspiring to higher and more stable incomes. Additionally, in this period, dense forests were converted to underbrush forests, which were in turn changed to grasslands. During the final period of the study (1984-1990) this situation changed, with grasslands succeeding to underbrush forests, but also being converted to plantations, with very little new grassland being created. There was conversion both ways between underbrush forests and plantations. Monoculture plantations were also created from dense forests. Nearly half of the areas that were monocultures in 1984 were converted to mixed plantations. The authors attribute the changes in land use during this time to transmigration policies, with maximum numbers of people arriving in Lampung province between 1978 and 1984. The multi-step conversion of forests to grassland, monocultures and mixed plantations reflects the process of farm establishment and development over the period. It also demonstrates that reclamation from the notoriously persistent Imperata grasslands is indeed possible, at least within controlled fire regimes.

Analysis of Sumberjaya vegetation change was updated by Eka Dinata (2002) who classified Landsat Enhanced Thematic Mapper satellite (ETM) imagery of 2000 and Multi Spectral Scanner (MSS) of 1986 and 1973 to derive subsequent changes in cover for different land uses (Figure 3.4). He found that forest cover declined steadily between 1970 and 1990, after which it stabilised. During the period, coffee cultivation increased dramatically, but shaded coffee also gained importance with time. Pioneer vegetation such as shrubs and grassland fluctuated throughout the period, whilst rice paddies were largely unchanged, perhaps because the valley bottoms had already been claimed for this at an earlier time. Between 1990 and 2000 the decline in forest cover halted, but shrub cover was reduced to almost none over the same period. Conversely, grassland, which was minimal in 1990, again increased. This may possibly have been an effect of coffee farmer evictions early in the decade. Coffee cultivation continued to expand during the period, but diversified in character. There were some new plantations, presumably many being established by farmers returning to areas formerly reclaimed by the government, but also expansion of shaded coffee gardens.

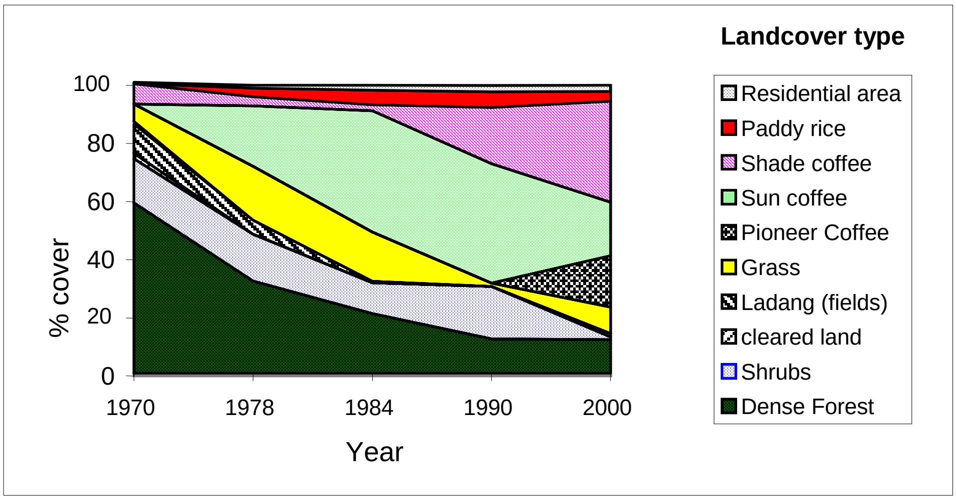


Figure 3.4 Land use change in Sumberjaya 1970-2000

modified from (Verbist and Putra 2002). after (Syam, Nishide et al. 1997) and (Eka Dinata 2002).

While conversion of forest has indeed been rapid, it should be noted that it has not been entirely without local regulation. Kusworo (2000) notes that while near some villages (including Fajar Bulan and Trimulyo), most of the forest has been removed, near others (including Simpangsari), there are patches of forest of greater than 500 hectares. These have been classified as *hutan tutupan* (forbidden forest), *hutan desa* (village forest) for those areas designated for protection, or as *hutan cadangan* (reserved forest) for area designated for conversion to farms. The main reasons provided for this zonation and preservation of some areas is the protection of springs, and reduction of landslide risk.

Successional vegetation

Syam *et al*. (1997) noted the creation and subsequent reclamation of grassland between 1970 and 1990. The tropical climate also favours rapid colonisation and growth by opportunistic species. With little disturbance, succession to thick scrubby vegetation may be quite rapid. One of the limiting factors is fire. This is recognised as providing a competitive advantage in the growth of *Imperata cylindrica* grass, although this varies with seasonal timing of burning and area of grass patch burned (Florece 1996; Garrity, M. Soekardi et al. 1997). Imperata is one of the most widespread and problematic weeds in Southeast Asia (Anonymous 1996), although in some areas it has been put to practical use (Dove 1986). It spreads both by seed and rhizomes, which are thought to release exudates harmful to the development of other species (Carrere and Lohmann 1996; MacKinnon, Hatta et al. 1996; Yamada 1997; Whitmore 1998).

The spread of Imperata grassland has occurred due to land clearance and repeated fires in the area around Trimulyo, which lies in the southern part of the Sumberjaya area (Suyanto, Permana et al. 2005). This location is officially at the edge of the Bukit Barisan Selatan National Park, and contains 'Protected Forest' areas. However, rather than being actual forest, grassland and low scrub predominate, as well as largely monocultural coffee gardens (personal observation). Verbist (2002) commented that this successional vegetation forms a type of fallow phase in coffee cultivation in the area, which is grown in a shifting cultivation derived system. This analysis is supported by the remnants of old coffee bushes found in scrub areas. However, following the enforced clearance of the coffee gardens formerly present, ongoing burning may have restricted successional development of the vegetation (Suyanto, Permana et al. 2005). In 1997 and 2000 burnt patches were identified with a mean area of greater than 80 hectares. Suyanto *et al*. (2005) also relate fire regimes to (lack of) tenurial security. Given sufficient time, soil condition and sources of seed these pioneer landscapes return to a forest-type cover, although there is a long successional process. A likely sequence described by Whitten *et al.* (2000 p.84) is "bare ground-*alang-alang* -scrub-secondary forest-primary forest". The stochastic nature of recruitment and large regional species richness may cause the new forest to be composed rather differently from the original, even at its apparent “climax” (Whitmore 1998).

3.6.3 Pesisir vegetation

In the Pesisir region there were study sites located in the mature damar agroforests, around Krui, as well as at the coffee cultivation frontier at the forest margin to the north, near Rata Agung.

3.6.3.1 Krui

The forest in the Krui region was opened by Semendo immigrants in approximately 1850. Hill vegetation was cleared and replaced with upland rice for one year. Plantations of vegetables, pepper and coffee followed. These cash and subsistence crops were planted in conjunction with other species, which provided supplementary sources of income as well as support and shade for the main crops (Ali 2002, pers. comm.; Michon 2005). One of these species is damar (*Shorea javanica*). This hardwood species is native to Sumatra (BAKOSURTANAL 2000) and is a member of Dipterocarpaceae, a dominant family in the rainforests of southeast Asia (Whitten, Damanik et al. 2000). Dipterocarps are known for their infrequent mast-fruiting behaviour, and have natural regeneration made more difficult by their lack of seed dormancy and requirement for mycorrhizal associations (Michon, Foresta et al. 1998). This has also frustrated some silvicultural efforts (Campbell 1998). However, the community in the Pesisir region successfully transplanted seedlings from the forest to nurseries, and subsequently to their agroforests. The species was planted more intensively from 1927, following the encouragement of a merchant with connections in Malaysia and Singapore, who recognised the market there. Whilst initially used as a shade tree for coffee plantations, in the Krui region these trees have grown to outshade the coffee and pepper. Damar subsequently became the main crop, although coffee was maintained in the area until the 1940s or 1950s. Whilst many damar trees die at an age of approximately 60 years, some remaining trees are now at least 150 years old and 35 metres tall.

Tapping can only occur at an age of 20-25 years, a factor that both relies upon, but also helps to create, a successional system with consideration of intergenerational interests. The tapping process involves the cutting of rows of triangular holes in the bark. These fill with sap that solidifies on contact with air. This solid sap is then chipped with a small pick and collected (Plate 3). Whilst the opening of wounds in the bark exposes it to fungal infections and insect pests, making the tree more vulnerable to breakage in stong winds, trees that are not tapped too intensively may continue to be productive for many decades. Those trees that do break are sawn into timber logs. Thus, whilst the industry is extractive, it allows not only the continued existence of mature damar trees, but also the development of an extensive understorey (Campbell 1998; Ali 2002 pers. comm.).

Plate 3 A damar harvester in Pahmungan, Krui.

He uses a small pick to chip resin, which is collected in a basket. He is supported by a band around his waist.

Some plant species are planted by the agroforests' owners, whilst others germinate independently, but are subject to the damar farmers' tolerance and perception of their usefulness (Ali 2002 pers. comm.; Delmi 2002 pers. comm.). As described in Chapter 2, the systems are botanically rich in comparison with many other types of agriculture, although less so than tropical forests. Surveys have found approximately 40 common tree species, in addition to other associated trees, shrubs, liana, herbs and epiphytes. In one study there were 120 plant species found in damar agroforest plots, in comparison with 230 in rainforest and only 10 species living in rubber plantation plots (Campbell 1998). Within the gardens, approximately 20-25% of the trees are economically important fruit species. These include durian, *petai*, *dukuh*, *langsat*, mangosteen, rambutan, jackfruit, sugar palm and guavas. The trees grow to form multiple strata in the canopy, emulating the structure of a forest, and are supplemented by wild trees including bamboos (Michon, Foresta et al. 1998). Timber trees are naturally germinating and seeds are thought to be carried up to 12 km from the forest, by the wind and birds (Delmi 2002, pers. comm). There is also an understorey including many opportunistic colonisers. Over time the herbaceous layer declines and the agroforest floor again becomes more open. The planting of young trees in a variety of species is ongoing, resulting in an uneven age class of any given species (Michon, Foresta et al. 1998). Older trees are felled for timber on an individual basis, rather than as a stand (Campbell 1998). Annual income from a damar agroforest is estimated to be US$1200 to $1800 per hectare (Campbell 1998).

3.6.3.2 Rata Agung

Rata Agung is a village located at the northernmost frontier of coffee cultivation in recently deforested areas. Over the past 150 years the margin has progressively shifted northward and southward from the central Pesisir region, around Krui. The overt boundary has reached Bukit Barisan Selatan National Park, but there is also some evidence of encroachment within the park itself (personal observation). Rata Agung achieved the status of “village” in 2001 (Ashabi 2002, pers. comm.). This may help strengthen local tenurial claims.

The coffee gardens in the region are presumably similar to those planted around Krui over a century ago. They include both coffee and shade trees of several varieties, but particularly *Erythrina* spp. These are also used as supports for cultivated pepper. Some gardens include a mixture of other fruit and timber species, including young damar trees. Some of these gardens are created by descendents of the Krui damar growers, who have shifted to new areas due to increasing land pressure. Whilst these farmers have not inherited established gardens, much of the ideology surrounding the garden maintenance in the older region appears to have remained (personal observation). Gardens of a much more monocultural form also exist, particularly close to the forest boundary. However, given suitable social, political and market conditions for sufficient time, there appears to be potential for these areas to emulate the mature and diverse damar agroforests of the central region.

3.6.3.3 Vegetation change in the Pesisir

Whilst the damar system has frequently been seen as a stable one that has contributed to forest protection, there is also ongoing deforestation and landcover change in the region.

Between 1997 and 2002 approximately 5% (10, 000 ha) of the forest in the region was lost (WCS unpublished data cited in Ekadinata, Kusters et al. 2005). Additionally, there are reports of coffee cultivation within the forest margin (Ashabi 2002, pers. comm.; Kinnaird, Sanderson et al. 2003; O'Brien and Kinnaird 2003). Ekadinata *et al.* (2005) concluded that the majority of forest loss between 1997 and 2002 was for the establishment of coffee gardens. Further, they estimated that in 2002 there were 20, 000 hectares of coffee and pepper gardens "between the forest and the national park" (Ekadinata, Kusters et al. 2005, p.16). This ongoing encroachment complicates the assessment of the ecological role of damar agroforests in the region, which have been frequently lauded as an example of sustainable community-based management. The role of immigrants from other regions complicates this further (Ashabi 2002, pers. comm.).

3.7 History of settlement, cultivation and trade in western Indonesia

3.7.1 Population, colonisation and commodity control

The earliest modern human settlers of Indonesia were hunter-gatherers, of various origins, who migrated there following the end of the ice age10, 000 years ago. They may also have practised slash and burn agriculture (Lubis 1990). Subsequently the Malays arrived over several millennia, and by the seventh century AD, Indian-influenced kingdom states emerged (Turner 1994). Mediaeval Arabian merchants facilitated the spread of Islam from the north of Sumatra to the more southerly provinces, with the first clear evidence of Muslim Indonesians in Sumatra provided by Marco Polo in 1292 (Rickleffs 1993). The lucrative spice trade between Indonesia and Europe was mainly dominated by these Muslim merchants. However, in the 16th century, the commercial opportunities attracted Portuguese, and subsequently, Dutch traders who initially made very high profits (Palmer 1965; Rickleffs 1993). These initially competing traders merged in 1602, in order to better control prices. They formed the Vereenigde Oost-Indische Compagnie (VOC or United East India Company) and constructed treaties with ambitious aims to control trade of commodities throughout Asia (Rickleffs 1993). In Lampung, due to strategic support provided to the ruling Sultanate of Banten, the VOC secured a monopoly over the pepper trade within its territory in 1662.

3.7.2 Coffee cultivation

Following the acquisition of territory by the VOC in deals made with local rulers, the first coffee was transplanted from southern India to Java shortly before 1700. In 1711 the company received its first 100 pounds of coffee, but growth after this was rapid, with production of 12 million pounds in 1723. With such high production, control of prices and labour was initially difficult for the company. By the mid 1700s a new system was established which was reliant upon the agreements with local rulers which had provided the VOC with sovereignty in much of Java. Prices became fixed and annual planting of a fixed number of coffee trees compulsory. This was overseen by local regents under authority of the VOC (Palmer 1965). Interestingly, long before the widespread popularity of agroforestry techniques, some of these early plantations were shaded by the introduced legume *Leucaena leucocephala*, which also provided support for the climbing crops of vanilla and pepper, as well as firewood, forage, green manure and erosion control along contours (Parera 1986).

3.7.3 Forced cultivation systems

During the early 19th century coercive agricultural systems were implemented by the new British colonists. These were continued following the return of Java and Bengkulu to the Dutch, as farmers were forced to pay rent for their fields or cultivate 20% of their land with a designated crop. This was collected as a tax in-kind. The growth of cash crops, such as coffee, to create wealth for the administration sometimes led to local famine (Palmer 1965). Between 1833 and 1879 coffee cultivation was encouraged along the west coast of the province (Mougeot and Levang 1990). While the system of forced cultivation was generally abolished from 1860 to 1870, coffee was excepted, and was produced compulsorily until 1916. The Agrarian Law of 1870 permitted long-term hereditary leases of Government-owned and private land (Palmer 1965). From 1885, Dutch settlers were able to open private plantations. These included rubber, pepper and coffee (Mougeot and Levang 1990).

3.7.4 Settlement of Lampung

As the Dutch control of the trading situation in Lampung deteriorated, the area became subject to the influence of pirates from Malaysia. The Sultans of Palembang and Banten also attempted to gain control of the province. In 1857 the Dutch established direct administration in Lampung (Rickleffs 1993). A new system of land ownership was also created by the colonists. As this only recognised ownership within the vicinity of villages, the other surrounding state land became available for new colonists from outside Lampung (Kusworo 2004). The growth and trade in pepper in Lampung was an influential factor socially, economically and environmentally. This was grown in a shifting cultivation system, beginning with forest clearance and rice cultivation. Later in the 19th century these gardens also involved coffee. The location of trading networks along navigable rivers, and at locations such as Krui on the coast, encouraged migration of native Lampung people from highland to lowland areas. This largely vacated the highland locations (Kusworo 2004).

During the 19th century, Indonesia’s population growth was very rapid, particularly in Java. The indigenous populations of Java and Madura had risen from an estimated 5 million in 1800 to approximately 28.4 million in 1900. This great population, occupying only seven percent of

Indonesia's land area, in combination with the devotion of some of this land to non-subsistence crops such as sugar, caused food shortages. In 1905 the Dutch administration began the first transmigration programs to resettle people from Java to more outlying islands, beginning with Lampung Province in Sumatra (Rickleffs 1993). In 1905 and 1906 they shifted approximately 700 families to Bagelen and Gading Rejo, near the contemporary Lampung capital of Bandar Lampung. By 1930 over 90, 000 Javanese were living in Lampung, representing over 25% of the population (Mougeot and Levang 1990). However, the population was still relatively low, in comparison with Java, which still had a population of 38 million (Verbist and Putra 2002).

3.7.4.1 Sumberjaya

Indonesia has 538, 86 and 15 ethnolinguistic groups defined as containing small, medium and large populations respectively (Clay 1993). Within Lampung, the indigenous people belong to four main groups; the Orang Pesisir, Menggala, Abung and Pubian. The Orang Pesisir were traditionally found in the Krui area, whilst within 50 km to the east of Sumberjaya, there were groups of Pesisir, Abung and Pubian, but none in the Sumberjaya area itself. The area was thus nearly completely forested in the 19th century (Kusworo 2000; Verbist and Putra 2002). In 1876 the Semendo people of South Sumatra began to migrate southwards into Lampung, facilitated by the new land ownership laws, and encouraged by the better access to trade networks in the province (Kusworo 2004). They were shifting cultivators who cleared forest and, on the hill slopes, established coffee gardens shaded by *Leucaena glauca* and *Erythrina lithosperma,* whilst growing paddy rice in the valley floors. The first settlement in Sumberjaya was Sukaraja village, which was established in 1891 in the Way Tenong area to the west of Bukit Rigis (Kusworo 2000; Verbist and Putra 2002).

In 1946, during the War of Independence, there was forest clearance near Dwikora, to the immediate north of Sumberjaya, in the Bukit Kemuning subdistrict. This was executed for the growth of food to support the army barracks in Bukit Kemuning town. A new town was also established (Kusworo 2000). The next major wave of migration to come to the Sumberjaya area resulted from a scheme, beginning in 1951, to resettle soldiers following the war. This transmigration program was operated by the BRN (*Biro Rekonstruksi Nasional*, the National Reconstruction Bureau) but was personally approved and even attended by then President Sukarno and Vice-President Hatta. The settlement program mainly involved Sundanese people, from West Java, but also Javanese from Central Java (Kusworo 2000). Following this official effort of settlement, there was also spontaneous migration, mainly from Java island, but also from other parts of Lampung (Kusworo 2000; Verbist and Putra 2002). These immigrants were attracted, not only by the availability of jobs as labour, but also because of the good soils (Verbist 2001). The high price for coffee in 1975 encouraged high levels of spontaneous migration for the next decade, and rapid expansion of coffee gardens. However, by the late 1980s, the population had stabilised, and Sumberjaya even became a source of outmigration (Verbist and Putra 2002).

3.7.5 Demography

The first census of Lampung took place under the Dutch regime, in 1858. The population was recorded to be 83,000 inhabitants. In 1905 there were 156, 518 people recorded, including 155, 030 natives, 1186 Chinese and 146 Europeans (Mougeot and Levang 1990). From 1971 to 2000, the population of Lampung grew very rapidly, to reach 6, 741, 439 people. The mean rate of increase over this period was 8.1% per annum, whilst that of Indonesia's national population during the same period was 5.8% per annum. Indeed, during the period from 1970 to 1980, Lampung's population was growing at a greater rate than any other province in Indonesia. The main reason for this disproportionate increase was the popularity of both organised transmigration programs and spontaneous migration to the province. The population density in 2000 was 191 people/km², which whilst well above the national figure of 109 people/km², as well as other provinces in Sumatra, was still much lower than in provinces of Java island (BPS Statistics Indonesia 2003). Nevertheless, outside Java, Bali and West Nusa Tenggara, it is Indonesia's third most densely populated province (Kuncoro, Budidarsono et al. 2003).

The ethnic character of the Lampung population has also been changed by transmigration. The percentage of the population who are Javanese increased from none in 1858 to 25% in 1931 and 78% in 1987 (Verbist and Putra 2002). Currently it is estimated to be at least 65%, while native Lampungnese comprise15% and Sundanese 12% (Kuncoro, Budidarsono et al. 2003). In Sumberjaya some of the Javanese labourers who arrived in the coffee boom period of the late 1970s stayed in the area and opened up additional forest areas for new coffee farms. The greatest rate of population growth occurred between 1978 and 1988, during which time it reached 7.48% annually (Budidarsono, Kuncoro et al. 2000). Sumberjaya's population stabilised in the 1980s and remained around 80,000 people for the subdistrict in the 1990s (Figure 3.5). During the early 1990s there were two phases of evictions in Sumberjaya, which marginally reduced the population. Late in the decade there were also many young families who voluntarily moved to Bengkulu to establish coffee farms on newly opened forest areas (Verbist and Putra 2002). In 1998 there were 79, 651 residents recorded, amongst 18, 856 households, with a population density of 147 people per km² (Budidarsono, Kuncoro et al. 2000). Some villages in the area were predominantly Javanese whilst others are Sundanese and some had larger numbers of Sumatrans. This was usually evident from the local architectural style. There are few native Lampung people locally.

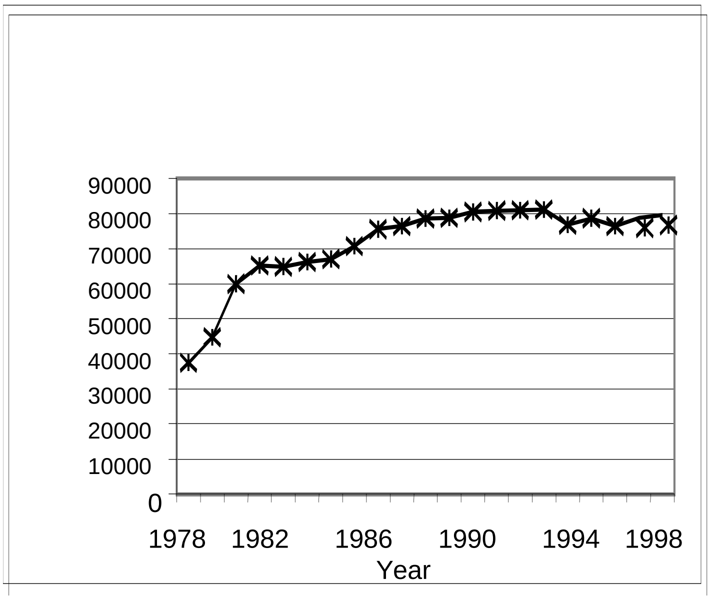


Figure 3.5 Growth of the human population in Sumberjaya sub district 1978-1988

(BPS, Dalam Angka, Kecamatan, Sumberjaya 1978-1998**)**. after Verbist (2002).

3.7.6 Land tenure history

3.7.6.1 Sumberjaya area

Uncertainty regarding tenurial security is an ongoing problem for land management planning in the Sumberjaya area. During the 19th century the Dutch declared traditional *marga* systems of tenure and administration to be illegal and replaced them with a system modelled on that of Java. Whilst local land claims were recognised up to 6 km from villages and 3 km from less permanent settlements, all land in between was claimed by the state. After twelve years this system was abandoned and a modified *marga* system was re-instated. Meanwhile, the Dutch forestry department worked with local elites to use traditional structures to facilitate tax collection. In the Sumberjaya area, maps delineating the forest area were created by the Government in 1935. Under Residen Besluit No.117, 19 March 1935 the main forest area in Sumberjaya, which was on Bukit Rigis hill, was designated as Register 45B protection forest, although parts of Registers 32, 33 and 39 also fall within the area (Verbist and Putra 2002; Kuncoro, Budidarsono et al. 2003) (Plate 4).

Plate 4 Bukit Rigis hill, in the Bodong area, Sumberjaya.

This is designated as forest register 45B. The area defined as “Protection Forest" extends well below the visible forest margin, and includes many coffee gardens.

Following Indonesian independence the system was again changed, with apparently uncultivated land reverting to state ownership. A dual system of traditional and bureaucratic land control existed until 1960. This allowed some recognition of traditional rights, however, these were often not formally recorded. In contrast, owners of commercial estates had their lands registered. In 1960 this system was abolished, with the passing of the Agrarian Law (UU/5/1960), which also removed the previous recognition of traditional rights. However, insufficient alternative regulation led to *ad hoc* land clearance and settlement (Verbist and Putra 2002). In some cases official permission for settlement was granted, such as in the case of Dwikora village, which in 1965-66 was given clearance by the Head of the Lampung Forestry Service to exist within Register 34 Protection forest zone (Kusworo 2000). However, due to concern at deforestation rates, in 1977, the Government issued a decree overriding settlement permission previously granted (Kuncoro, Budidarsono et al. 2003). In 1982 it began efforts to remove the Dwikora population by resettlement to North Lampung. In 1994 the construction of a hydroelectric dam began in the area. Preparations for this project included plans to re-afforest much of the area that had been cleared for cultivation by villagers.

In 1995 a new phase of evictions began. Following a Governor’s decree, hundreds of houses and farms were destroyed by forest rangers, forestry workers, armed police and elephants. Official abolition of the village occurred in 1996, and some households were resettled in a transmigration project outside the district. However, resistance by villagers was ongoing, including protests at the Governor's office compound in the capital of the province, Bandar Lampung. A second attempt at physical removal of villagers was also resisted with forest officers being threatened with drawn swords. Negotiation in 1999 led to the compromise of a seven square kilometre area being excluded from the forest zone. By 1998 more than half of the 6, 000 hectare reforestation zone had been re-cleared for coffee gardens.

Similarly in the Sumberjaya villages of Purajaya, Purawiwitan and Pura Mekar, a program of evictions began in 1990 and 1991, with villagers relocated to North Lampung. Subsequently, in 1994 another wave of expulsions occurred from 86 sub villages in the state forest zone, and over 700 ha of coffee farms were cleared. In 1995, another arm of the operation to clear Dwikora was exercised in Sumberjaya. Forestry Department officers delineated the forest boundary and decided that the settlements and farms of Sukapura, Purajaya, Purawiwitan, Muara Jaya, Simpang Sari, and Tribudi Sukur villages were within the protected zone (Kusworo 2000). It is alleged that these boundaries correspond with those on the 1925 Dutch maps, and bear little relation to current forest cover. Nor do they recognise the Government land grants of the 1950s and 1960s (Verbist and Putra 2002). This designation was challenged by villagers, and whilst there have been assurances that destruction of villages will not re-occur, there is also no recognition of land ownership within these protection forest areas, and so conflict and uncertainty are ongoing (Kusworo 2000). Indeed, since the removal of the Suharto Government in 1998, the feeling that previous laws are invalid or that enforcement will be minimal, has led to much re-settlement of areas previously subject to eviction or re-afforestation campaigns. In addition, in the absence of recognised tenure, unofficial "taxes" have been collected in an *ad hoc* manner by local authorities in return for their tolerance of tree clearance and coffee cultivation within the state forest margin. It is thought likely that this practice increased between 1997 and 2001 (Budidarsono, Kuncoro et al. 2000; Verbist and Putra 2002). Meanwhile it has been estimated that by July 1998, 115, 000 ha of the 410, 000 hectares of state forest land in Lampung was cleared for coffee cultivation, demonstrating that the situation is both dire and complex (Budidarsono, Kuncoro et al. 2000).

3.7.6.2 <u>Krui area</u>

The damar gardens in the Krui area have created a precedent in recognition of community tenurial rights. Although there are accounts of damar cultivation in southern Sumatra in the late 18th century, the first damar gardens at Krui were created in the 19th century (Campbell 1998). They were a mixture of trees planted for their commercial and practical usefulness, and plants that grew opportunistically, but were retained by the farmers. As described in Chapter 2, over time these gardens grew to somewhat resemble the rainforest native to the area. Indeed, from satellite imagery, they were largely indistinguishable.

The Dutch administration established a forest reserve in 1937. This subsequently became the Bukit Barisan Selatan National Park in 1991. Although the local people were not in complete agreement with the principle of the reservation, it was conducted in consultation with them and its borders were far from their agricultural areas at that time (Michon, Foresta et al. 1998). The allocation of a commercial timber concession to the area, including three million trees planted by local people recognised no tenure held by these farmers. This threatened both their immediate livelihoods and the ongoing practice of a system widely used as an example of integration of economic, cultural and environmental goals. However, previous research into the values of this system, and mapping of its extent was useful to a collaborative team of NGOs, research institutions and local people in applying to the Department of Forestry for consideration of these attributes, and negotiation regarding tenure status (Fay, Foresta et al. 2000).

3.8 Agriculture

In Lampung province, agricultural activities are very important both socially and economically; in 1990 they were reported to have involved 87% of the working population and provided 80% of rural income Most of these were small landholders, with farms having a mean area of only 0.7 ha (Mougeot and Levang 1990). In 2000, 63% of Lampung was classified by the Indonesian Bureau of Statistics (BPS) as being used for primary production. This includes amongst its categories, various types of agriculture, fish-ponds, cash crop estates and grazing land. Even wetland areas are classified in this category, as they are cultivated with rice. Rice paddies in Lampung covered an area of 460,690 ha in 2003 (BPS Statistics Indonesia 2003). In 2000 the largest section was used for dryland crop cultivation (annuals), whilst the next largest sector was estate crop cultivation (Figure 3.6).

3.8.1 Food crops

In 1984 the major food crops were rice and cassava. These are both usually grown in open conditions, although cassava can form part of an agroforestry system. There is some disagreement between sources, regarding whether or not earlier inhabitants practiced irrigation of rice. However, extensive development of valley floors for rice production occurred following the immigration of Javanese and Sundanese in the 20th Century. In Sumberjaya this occurred during the 1950s. In 1978, three percent of the Sumberjaya area was used for irrigated rice production. This rose to five percent by 1984 and remained stable to 1990. Lampung's production of rice more than doubled between 1972 and 1983 and Government assistance schemes of the 1990s encouraged further development of irrigated rice-fields (Mougeot and Levang 1990; Verbist 2001) (Plate 5). Other food crops grown for family consumption and sale include vegetables, as well as fruits such as bananas and rambutans.

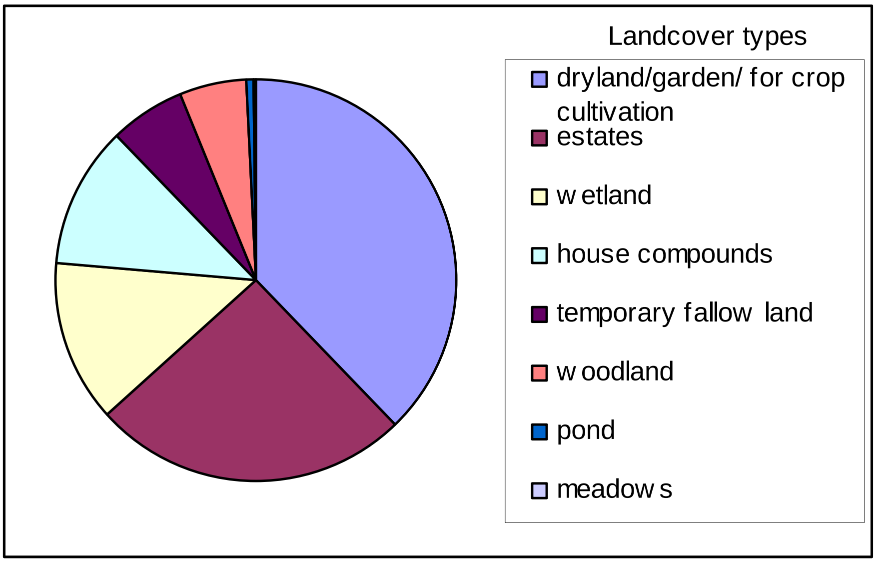


Figure 3.6 Allocation of land for food production in Lampung province in 2003.

Whilst dryland crop cultivation covered the largest area, estates and wetland areas (including rice cultivation) also covered a considerable part of the province. Source BPS Statistics Indonesia (2003).

Plate 5 Rice paddy below Simpangsari village.

The farmers construct many elaborate devices to scare flocks of birds such as munias and sparrows, which eat the ripening grain.

3.8.2 Tree crops

By 1984 coffee was the most extensively cultivated tree crop in Lampung, followed by coconut, pepper, rubber and cloves (Mougeot and Levang 1990). Whilst some of these products were for local consumption, the majority was exported locally or internationally, and thus provided cash income to producers. In 2002 Indonesia exported coffee to the value of US$218.8 M. This was a 19.8% increase over the previous year (BPS Statistics Indonesia 2003), in spite of the low prices. However, conditions have not always been good for coffee production. Epidemics affecting the early arabica plantations (*Coffea arabica*) required them to be replaced by robusta *(C. canephora*). Political events in the first half of the 20th century also did not favour the development of the coffee industry. However, since 1961 it has expanded greatly. In 1977 the low production in Brazil increased the world price of coffee, and encouraged expansion of gardens (Mougeot and Levang 1990). In Lampung, there was an 8.25% annual growth in the area under coffee cultivation between 1970 and 1980, whilst the increase in the year 1977 alone was 134.9% (Budidarsono, Kuncoro et al. 2000 after Badan Pusat Statistik). By the 1980s Lampung was the foremost region for coffee production in Indonesia. However, partly due to the preparation of coffee beans after harvest, quality is not always good (Mougeot and Levang 1990). The area of the province planted with coffee again increased substantially between 1996 and 2001, while in 2002 further plans to increase this area under cultivation were published (O'Brien and Kinnaird 2003). Within Lampung, Sumberjaya is one of the main coffee areas, providing 18 - 26% of the province’s production between 1992 and 1997. Within the West Lampung district, a very small amount of coffee is arabica (4.2% in 1997) (Budidarsono, Kuncoro et al. 2000). Since robusta coffee was introduced to Sumberjaya in 1935 it has been the more popular choice, and arabica has been restricted to growth in higher areas (Verbist and Putra 2002). Although farmers recognise the higher global price for arabica coffee, it is suggested that they do not choose to plant it due to the farm gate prices being equal to that of robusta coffee, whilst plants are more difficult to cultivate (Budidarsono, Kuncoro et al. 2000).

In Lampung, coconuts are often intercropped with cloves, and are grown in coastal areas. Most are used for production of oil. Pepper is also produced in large quantities; the province produces 70% of Indonesia’s total crop. Production of cloves has dropped substantially since 1981, when a virus caused widespread death of trees. Locally, in Sumberjaya, there are clove trees in some mixed coffee gardens. There is some debate regarding the respective allocation of land to subsistence food and cash crop production. Rice shortages have been predicted for both Lampung and Indonesia as a whole. Even crops such as cassava, which have the potential to provide both food and cash, are vulnerable to price fluctuations (Mougeot and Levang 1990).

3.8.3 Coffee gardens

The terminology used by Eka Dinata (2002) to describe coffee gardens in Sumberjaya is slightly different to that of Syam *et al.* (1997), but the categories of 'sun coffee' and 'shade coffee' are presumed to correspond broadly with 'monocultures' and 'mixed plantations'. In any case, such a dichotomy is rather a simplification of the real situation. Nearly absolute monocultures are still quite common, but there is a gradation of levels of canopy cover and tree species richness between the monocultures and the mature 'multistrata' agroforests. There is a range of trees planted with coffee that primarily provide shade. Amongst the most popular species are *Gliricidia sepium*, *Erythrina* spp. and *Leucaena leucocephala*. Such systems are classified by Kuncoro *et al.* (2003) as 'shade-based systems'. These trees are all leguminous nitrogen fixers and so condition the soil. They are often planted in a rather simple system, with only one or two species in addition to the coffee. However, in addition to trees with the primary function of providing shade, some gardens include a range of species that have the potential to provide fruit, timber or other commodities. These include jackfruit, mango, avocado, coconut, cinnamon and mahoghany. Understorey crops that may be interplanted with coffee include ginger, chilli, cassava and taro, whilst pepper is often grown using *Gliricidia* shade trees as a support (Kusworo 2000; Kuncoro, Budidarsono et al. 2003). In one local study, in thirteen 50 m x 10 m plots, 66 economically valuable species were found, with plot species richness ranging from 10 to 32 species (Wulan 2001). There were also some wild species present. Gardens containing a range of plants such as these are likely to be what Verbist (2002) terms "traditional mixed shade coffee polyculture gardens", which were present in seven percent of the landscape from 1970-2000. These other species increase long-term income security for coffee-farming families, and the benefits that they provide are particularly important at times when coffee prices are low (Budidarsono, Kuncoro et al. 2000). Additionally, they can provide for other household needs, such as fuel. Rural Indonesians are highly dependent upon wood for energy provision, with more than 70% using fuel wood in 1997 (Kuncoro, Budidarsono et al. 2003).

Early cultivation of coffee by the Semendo people occurred in a shifting fashion. Little input was made, and when yields dropped, new plantations were opened. However, with the in-migration of people from Java, more fixed forms of cultivation became popular and new crop care techniques have been introduced. These include grafting, pruning of coffee bushes to a height of 1.2-1.5 metres, cutting of twigs, fertilising, weed removal and digging of holes for accumulation of water and organic material. Seasonal pruning is considered necessary to allow the bush to continue to bear fruit over a long period. However, following an extended period, some farmers take the measure of 'stumping'; cutting the main stem to near the ground, in order to rejuvenate the bush. This is an alternative strategy to moving plots to a newly cleared area. Whilst the culture of preferred garden maintenance may have changed, some farmers find their activities constrained by limited capital (Budidarsono, Kuncoro et al. 2000).

3.9 Financial factors in Sumberjaya coffee gardens

Most Sumberjaya farmers are smallholders and face constraints in availability of capital, labour and transport. The profitability of coffee crops is affected by the model of garden created by the farmers, who are also subject to local and international conditions regarding coffee demand and price.

Within the region three main trends in coffee cultivation have been recognised. Firstly, permanent cultivation is displacing shifting models, although the latter still occurs, particularly at the forest margins. Secondly, management is increasing in intensity, including weeding, pruning and soil management, with the aim of increasing productivity per unit area. Thirdly, in association with this, there is increased demand for more productive varieties of plants, including grafted specimens (Budidarsono, Kuncoro et al. 2000). These management decisions made by the farmers on a gradient from monoculture to mixed multistrata are governed by factors including price; of coffee, transport, labour and inputs such as fertiliser; biophysical factors, labour availability, market accessibility, subsistence needs, land availability and tenure.

3.9.1 Coffee prices

In Indonesia, the price paid to producers of robusta coffee rose from 48.75 US cents per pound in January 1994 to reach a high of 135 c/lb in October of that year. It then fell steadily to reach 18.7 c/lb in January 2001. In the same months the retail prices paid in the US were 253 c/lb (January 1994), 445 c/lb (October 1994) and 322 c/lb (January 2001). Thus it seems the link between the prices paid by consumers and those accepted by growers is indistinct, with growers subject to wide fluctuations, and sometimes only receiving a very small proportion of the retail price (International Coffee Organisation 2004). The export of coffee must be accompanied by a certificate of origin (International Coffee Organisation 2000), which may be one tool for ensuring accountability in event of ecocertification being developed. While farmers recognise that arabica coffee attracts a higher price than robusta on the global market, they are largely disinterested in planting this species as there is no local price differential. Lower yields and more challenging management than for robusta also increase the disincentive (Budidarsono, Kuncoro et al. 2000). Additionally unequal relations between merchants and farmers serve to minimise prices paid. Whilst prices are reduced for poor quality coffee, they are not increased for beans of high quality (Mougeot and Levang 1990).

3.9.2 Garden maintenance

Budidarsono *et al* (2000) divide local coffee systems into three types, according to intensity of cultivation. This provides a useful way of summarising some of the management choices made by farmers. The traditional-pioneer system is characterised by the general monocultural nature and absence of shading trees as well as a short production cycle, in which a plot is abandoned after approximately three years following maximum production. There is also no, or minimal, fertiliser input, and the main activity is bud cleaning and weeding which is concentrated during the first three to five years. It is also generally extensive. Semi-intensive systems are developed from formerly low-intensive systems, or from bush clearance. They are characterised by low to medium use of fertiliser, with total application of 150 to 400 kg/ha per year. The main crop management activities are bud cleaning, weeding and pruning of coffee bushes to 1.5m. Production is maintained as long as possible, with use of techniques such as *rorak* sedimentation pits to retain soil nutrients. Whilst there may be shade trees, these are not always present. High intensity farms are characterised by great efforts made to improve productivity, including high fertiliser use, from 800 to 1000 kg/ha per year, grafting and tree rejuvenation. Credit may be sought to fill capital needs (Budidarsono, Kuncoro et al. 2000). While in recent years the prices paid to coffee farmers in Lampung have reduced, as has the yield per area, simultaneously there has been high inflation, and subsidies on commodities including fertilisers and fuel have been reduced (O'Brien and Kinnaird 2003). This affects the financial situation of farmers and their capacity to make choices in farm management.

3.9.3 Labour

Belief that the historical tendency of Sumatra to have higher land than labour availability is now changing. Government transmigration programs, and also devotion of land to large industrial plantations, has changed the past situation. Sumberjaya has been attractive to spontaneous settlers over the past two decades (Budidarsono, Kuncoro et al. 2000). It seems that from a farmer decision-making standpoint, this may encourage intensification, rather than extensification of systems, and thus increase rates of pruning and fertiliser application, but possibly also tree-planting.

3.9.4 Coffee harvesting and processing

The coffee grown in West Lampung is mainly of the lesser quality robusta type. Other local harvesting and processing related factors are also damaging to the coffee quality there and so limit the prices available to farmers. These practices include the non-selective ‘strip-picking’ that includes unripe berries, inadequate drying causing mould growth, drying directly on the ground thus introducing contamination, breakage of beans by local hulling techniques and sale of high-moisture coffee to maximise weight (Mougeot and Levang 1990).

3.9.5 Road development and accessibility

The farmers of Lampung face additional barriers in reaching markets and attracting higher prices for their coffee. These include the remoteness of the area and restricted transport networks (Mougeot and Levang 1990). The local development of the Sumberjaya area has also been limited by this accessibility. The accessibility of the area in general was greatly improved by the construction of the local section of the Trans Sumatran Highway, in the 1950s (Verbist and Putra 2002). However, in the 1970s in Trimulyo, which is located in the southern frontier area, it still took coffee growers several days to walk to the markets with their coffee to exchange it for rice (Kamat 2002, pers. comm.). This area still has limited accessibility, especially in the wet season when the unsealed roads are muddy. In 1978 a car ferry service was established between Java and Bakauheni, to the southeast of Bandar Lampung. This has increased the ability to transport goods, especially those that are perishable (Mougeot and Levang 1990). In 1997, farmers in the Sekincau area to the west of Sumberjaya were sufficiently impatient with Government road building efforts to privately contract road builders to improve access to their villages. During a period of high coffee prices, the improved ability of farmers to transport their crops made this a profitable action (Verbist and Putra 2002).

The condition of many roads remains poor (Plate 6). Average maximum speeds have been quantified as 25 km per hour for the better district roads, and only 10-15 km per hour on village access roads during the dry season (Mougeot and Levang 1990). Road building and sealing activity in the eastern side of Sumberjaya was ongoing in 2002. Private car ownership is generally low. Transportation of coffee is often contracted to owners of, either motorcycles (*ojek*), or four-wheel drive vehicles. If farmers do not have access to their own transport, they are subject to the rates charged by couriers (*tukang ojek*). Small-scale transportation of goods and people between markets occurs by bus, on the main road, by shared taxis (*angkotan desa*) or on foot (Mougeot and Levang 1990).

Plate 6 Road from Simpangsari to Tepus and Laksana areas.

Poor road conditions limit transport options, particularly during the wet season.

3.9.6 Coffee growing systems and tenurial security

Gillison *et al.* (2004) classify the coffee garden types in the Sumberjaya area as ‘pioneer’, ‘simple monocultures’ and ‘complex systems’ and associate these with varying security of tenure. Forest is cleared for the establishment of pioneer systems. Often this is State Forest land, gazetted as ‘protection forest’ or ‘conservation forest’; including areas in the Bukit Barisan National Park (O'Brien and Kinnaird 2003). These insecure systems aim to maximise coffee production over a term of between five and seven years. Inputs are low and shade trees absent. After yields decline the land is left to become fallow. This swidden type system was used by the early Semendo inhabitants, and is now less frequently used, but still occurs at the forest margins. In contrast, simple monocultures are maintained over a longer time, being pruned after eight years as well as being fertilised. These gardens may also be derived from forested area, but they are more common in areas designated for watershed protection than for conservation, but are not necessarily secure. In other cases they may be created in abandoned coffee gardens from the previous generation. New immigrants may burn the area and replant, rejuvenate the old coffee by pruning, or enter a sharecropping arrangement with the owner. Shared cropping, however, may offer little incentive to the working farmer to make investment as the profits are divided with the other owners.

The areas of secure tenure, located outside of the protection forest zone, are the most likely to receive investment of money and labour over a long term. This may include fertiliser use and grafting (Gillison, Liswanti et al. 2004). It seems likely that it would also include measures such as tree planting, which is an investment in the long term productivity of a coffee garden. In contrast, in the context of coffee cultivation in newly cleared forest areas, investment in securing the site must be made by unofficial payments, which in 2000 was estimated to be 50, 000 Rupiah per hectare per year (Budidarsono, Kuncoro et al. 2000).

3.9.7 Community Forest Management (HKm)

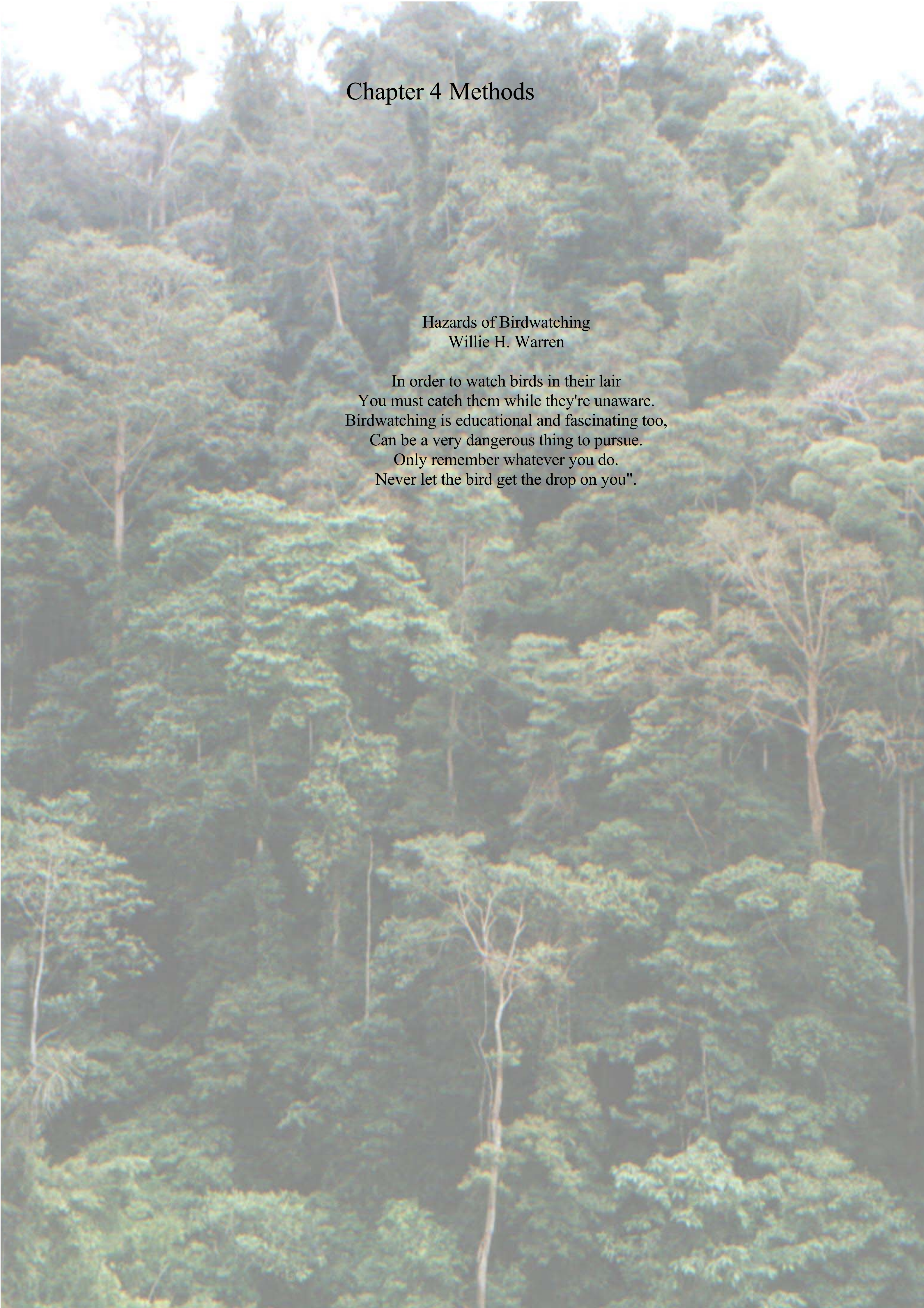
In response to the ongoing conflict between maintenance of forest for biological conservation and watershed protection, with the use of land for farming of coffee by smallholders, a new scheme of land use allocation and tenurial recognition is being developed. This is known as community forest management (*Hutan Kemasyarakatan – HKm*). For this, the Minister of Forestry Act 31 Kpts II/2001 defines community forestry as "state forest whose management is conducted by the community, in order to empower the community without disturbing the forest's main functions" (Kuncoro, Budidarsono et al. 2003). In association with local Non Governmental Organisations, structured farmer groups make an application for probationary tenure of the state forest land upon which their coffee farms exist. Maintenance of this tenure seems dependent upon their establishment of trees, and maintenance of forest margins, whilst those trees planted cannot be harvested (Kuncoro, Budidarsono et al. 2003). However, the regulations remain rather uncertain concerning acceptable tree species and the exact ownership rights of farmers over these trees (Verbist, Putra et al. 2005).

In West Lampung district the local government has designated over 400 hectares of state forest land in Register 45B Rigis Jaya to be managed by the local community. This agreement commenced operation without the ratification of the national Government. The scheme allows farmer groups within the designated protection forest zone (which is not necessarily forested) to manage land as multistrata coffee. Thus there is incentive for groups to plant trees, as well as a requirement to defend the current forest margin. However, there is also concern that there could be a perverse incentive to encroach upon this margin in order to gain tenure in previously forested areas. This dilemma is salient to the debate between public and private management for conservation; the scheme attempts to enlist locals to assist in conservation of core areas, but achieves this by compromising the Government's control over land use in marginal areas. Whilst its parameters and their effectiveness are rather unclear, the scheme is not without regulation, with the farmer group agreements being subject to a five-year probationary period before 25 year licences are granted. However, in 2005, the transition from temporary to longer term licences seems uncertain, due to its dependence upon the Provincial Government designating the HKm areas for the entire province (Kusworo 2005, pers. comm.).

3.10 Conclusion

The decision-making of farmers in West Lampung is influenced by many factors; physical, economic, agronomic, historical and sociological. Some understanding of the way in which these impact upon the development of livelihoods on both a personal and regional basis is necessary for interpretation of the manner in which farm management could realistically be integrated with local biodiversity conservation.

Chapter 4 Methods



Hazards of Birdwatching
Willie H. Warren

In order to watch birds in their lair
You must catch them while they're unaware.
Birdwatching is educational and fascinating too,
Can be a very dangerous thing to pursue.
Only remember whatever you do.
Never let the bird get the drop on you".

Methods

The field-based activities of this project fell into three main categories: vegetation surveys, bird surveys, and interviews of local residents. Whilst interpretation of the local situation involves all of these fields, the divisions were preserved for the presentation and analysis of results in Chapters 5-7. The surveys of birds and vegetation were undertaken in 45 plots, each measuring 60 m x 60 m. Based on the analysis of vegetation survey data, these were subsequently allocated to ten habitat types. Surveys of birds were conducted using an area search method, with each count lasting 40 minutes. These were undertaken nine times at each site, spread across wet and dry seasons in 2001 and 2002. Analyses of the data used both non-parametric univariate, and multivariate techniques. These focused on relationships between the measured vegetation characteristics and bird survey results. Social surveys targeted the owners and managers of these same plots, with the aim of clarifying the site histories, management practices employed, and attitudes of the residents.

4.1 Site location

The study sites were divided between small regions, defined by local area names. Usually these equated with groups of sites between which I would generally travel on foot to do bird surveys within a morning. Site names were established by using the local name assigned to the region, and a number for within the group. The regions were: Bukit Abung, Bodong, Fajar Bulan, Gunung Terang, Krui, Laksana, Leuwi Monyet, Purajaya, Rata Agung, Simpangsari, Tepus and Trimulyo. These regions were used to explore differences in vegetation, birds and interviewee responses. On a different scale, the sites studied were divided between two broad areas; Sumberjaya, located in the foothills on the east of the Bukit Barisan range, and the Pesisir, located on the western, coastal side of the range (Figure 4.1,Figure 4.2). All of the aforementioned regions, except for Krui and Rata Agung, are part of the Sumberjaya area.

Figure 4.1 Sumberjaya region, showing study site locations.

Source: Landsat ETM image (TRFIC 2000)

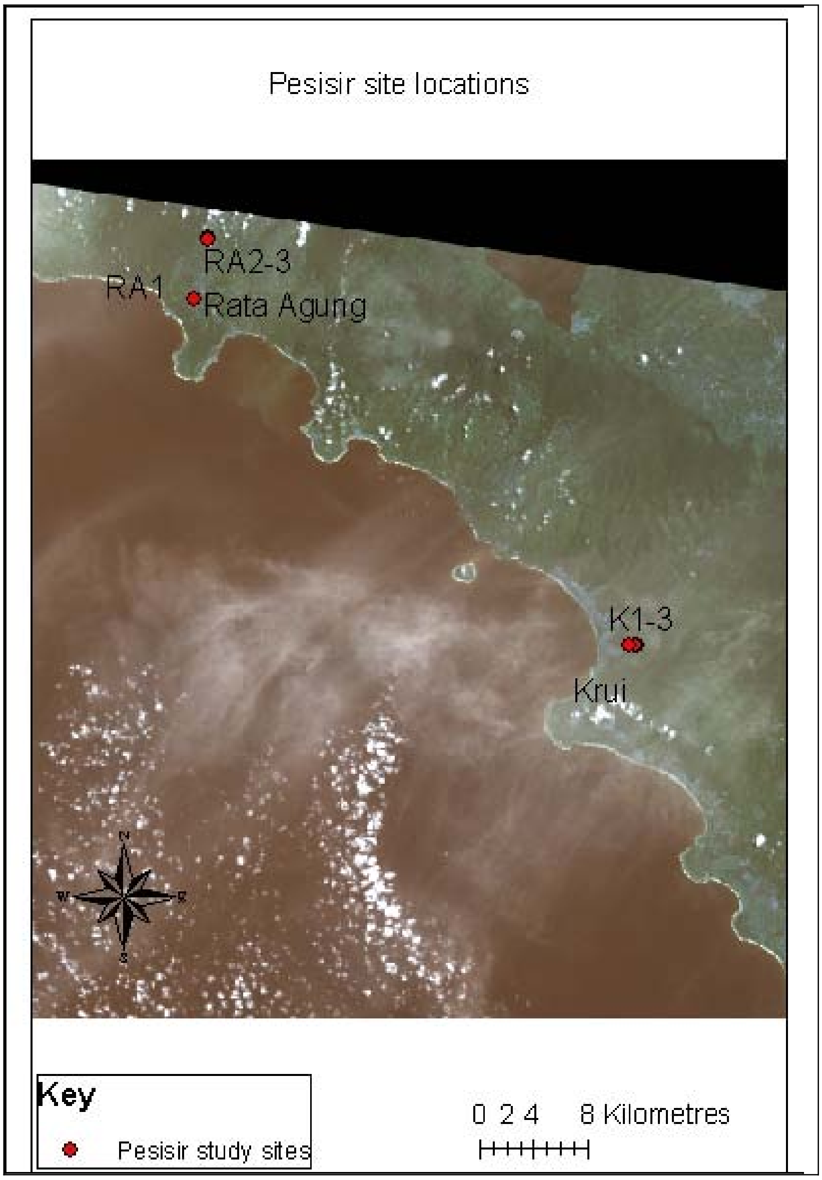


Figure 4.2 Study site locations in the Pesisir Region.

Source: Landsat ETM image (TRFIC 2000)

Sites were selected across the Sumberjaya region according to their vegetation cover, with the aim of representing the range of vegetation present. In the Pesisir region, sites were chosen to represent both the mature damar agroforests, as well as to replicate forest and coffee garden habitat types studied in Sumberjaya, in order to control for inter-regional differences. Within Sumberjaya, 1:24, 000 scale aerial photographs (BAKOSURTANAL 1993) and satellite images (Space Imaging 2000; TRFIC 2000) were used to identify overall distribution and variation in vegetation cover, and locate areas of interest. A Global Positioning System (Magellan, USA) was used to identify and record locations.

4.2 Vegetation survey

4.2.1 Vegetation description

In order to classify sites and interpret bird records with relation to available habitat I made brief studies of the vegetation at each site. I drew a plan of each plot including each tree of greater than 0.1 m diameter at breast height (after Kuncoro, Budidarsono et al. 2003, in a study made in the same area), and of at least four metres in height. This allowed an approximation of canopy cover to be made, although overlapping canopies were somewhat confounding. Where possible, a list of all species present in the plot was also made, including understorey plants. This list was later divided into abundance categories. As nitrogen-fixing leguminous species are particularly popular as shade trees, and often amongst the first trees planted by a farmer, these were distinguished from the non-leguminous vegetation types. The large number of unfamiliar species prevented me from making complete lists in the non-agricultural systems, and precluded any floristic records from the forest sites, although some of the scrub species could be identified later from specimens taken. For this reason, I could not include forest sites in any analyses involving plant species richness. However, previous botanical studies of various habitats in the Sumberjaya area have found forest to have very high species richness, with some sites containing over 100 identified species within 40m x 5m plots (Gillison, Liswanti et al. 2004). Thus, these habitats were likely to be the most vegetatively species rich in my study.

Maximum height and mode height classes of the tree and coffee layers were estimated, as was the continuity of their cover within classes of ‘open’ (more than one canopy diameter separation), ‘medium open’ (less then one canopy diameter of separation) and ‘closed’ (canopy touching) (after Johns 1988) (Table 4.1). These were later ascribed the scores 1-3, with the score increasing with closure. Other habitat features were also recorded including presence of dead branches on standing trees (possibly useful as perches), and dead wood on the ground, in the categories of ‘logs’ and smaller ‘fallen wood’. A value on a 1-5 scale for abundance of grass and weeds, and also a 1-5 value for the cover of leaf litter, were assigned to each plot on the basis of observation. Calibration of the subjective measure for leaf litter cover is described below.

Table 4.1 Vegetation descriptors used in study plots

Variable	Explanation
*Number of trees in plot	'tree' defined as having a trunk greater than 0.1 m diameter at breast height (DBH), and height greater than 4 m.
*Canopy cover	Derived by adding the canopy areas of mapped trees, assuming circular canopy and 100% shade within canopy boundary. This measure does not indicate amount of open sky, as more than one stratum may be present, although this was rare in coffee sites. Thus it is more an indicator of total available foliage space. This also implies that it is possible for the measure to achieve more than 100% cover at some sites.
*Dominance	This was determined by a combination of two quantifiers, to account for the possibility of a plot having many small trees of a single species, or few large trees, either of which may physically dominate the plot. Spatial dominance was thus calculated as the percentage cover by the species covering the greatest area. Numerical dominance was calculated as the percentage of individual trees in a plot contributed by a single species. An overall index of dominance was obtained by taking the mean of these two values, and the dominant species for each plot identified as that with the highest overall score.
*Tree species richness	Number of tree species present in plot.
Understorey species richness	Number of non-tree plant species in plot.
*Maximum tree height	Estimated height, in metres, of tallest tree within plot.
Mean of mode tree height	The modal range of tree height was estimated in the field, and the mean value of this later taken to provide a single quantifier for the height of the majority of canopy in the plot. Although providing some duplication with 'maximum tree height', the combination of these variables can partly differentiate between sites with simple and complex profiles.
Canopy depth	Difference between the maximum and mean of mode tree heights.
*Maximum coffee height	Estimated height, in metres, of tallest coffee bush within plot.
Mean of mode coffee height	As for mean of mode tree height, but describes coffee.
*Coffee canopy closure	Field descriptions were converted to an ordinal measure, scored one for open, two for medium closed and three for closed canopy.
Leaf litter (score from 5)	The leaf litter cover was given a score from zero (bare ground) to five (dense cover).
Weeds (score from 5)	The density of grass and other weedy ground covers given from zero (no weeds) to five (dense weed cover).
Exposed dead perches	The presence of dead branches potentially suitable as exposed perches, recorded as y/n.
Logs	The presence of large fallen timber recorded as y/n.
Fallen wood	The presence of small fallen timber and twigs recorded as y/n.

4.2.1.1 Leaf litter cover scale calibration

The scales used to describe leaf litter and weed cover in plots were subjective, with 'five' representing the maximum leaf litter cover observable within the region. I made approximate calibration of the leaf litter scale as follows: two examples were selected of each 'score', and the free surface litter collected from 0.5 m x 0.5 m quadrats, excluding woody material greater than the diameter of a finger (Figure 4.3). The samples were washed to remove soil and then air and oven-dried and weighed. Variation in the density of the litter components, due to inclusion of materials such as sticks and woody fruits, meant that the relationship between mass and volume was also somewhat variable. The limited number of samples used does not allow a full description of the variance in each category, but are considered suitable to provide some indication of the approximate quantities of leaf litter present.

Figure 4.3 Collection of leaf litter for calibration of leaf litter scale.

For each sample, the surface litter within a 0.5 m x 0.5 m wire square was collected, washed, oven dried and weighed.

4.3 Bird surveys

4.3.1 Survey parameters

The field situations and aims of bird studies vary so greatly that there is no census method accepted as an absolute standard (Bibby, Burgess et al. 2000). In this study the methods were defined to enable comparisons between the bird assemblages observable in pre-existing habitats, by using bird counts that could be interpreted relatively by the use of site vegetation descriptions. Within these parameters a range of possible methods were derived with reference to the literature of bird surveys. The most promising of these were then tested during a pilot study to select and adapt a survey method suited to the conditions in my study area. In summary, the method chosen was an area search method, with each survey undertaken for 40 minutes in a plot of 60m x 60m. All birds' taxonomic identity, height above the ground, activity, microhabitat and species of vegetation used were recorded. Surveys were repeated nine times at each site.

Within the Sumberjaya and Pesisir regions, some of the existing habitats have been created over many years and are owned and maintained by many different parties. Thus, the field situation suggested a 'space for time' approach as manipulative experiments were not suitable. This approach compares the state of sites that were similar before the intervention of different management techniques. This method cannot demonstrate causality but may infer the impacts of long-term management practices in a real world situation (Robinson and Robinson 1999). The urgency of research relevant to biological conservation favours the use of such pragmatic methods.

This study aims to describe and interpret each site's avifauna and habitat use in comparison to the other study sites, as in Recher and Davis (1994) and Thiollay (1994). For studies that focus on quantifying populations, absolute counts are used together with detailed information regarding range, territory and breeding success. These are useful for designing conservation plans for individual species and for direct comparison with other studies. However, Pyke and Recher (1984) identify a number of problems with attempts to quantify absolutely, and highlight the variability of results obtained in such studies. As little reliable information on bird densities is available, and its calculation rather complicated and error-prone, this was not a specific aim of this study (Bibby, Burgess et al. 2000). Thus, counts were made of species apparent by sight and sound in each plot, without making an attempt to estimate distances from viewer to bird.

The surveys were observation and call-based, similar to studies made in the region by Thiollay (1994) and Marsden (1998), rather than being capture based. Mist-netting has been used in some other studies (such as Fogden 1972; Fogden 1976; and Johns 1996) to provide detailed information regarding avifaunal use of habitat patches. Such studies are very time and labour intensive, requiring resources and expertise that were unavailable in this study. Thus, my surveys were made without any capture component and, instead, restricted to birds heard and observed.

4.3.2 Pilot study

My first month in the field was spent familiarising myself with the bird species of the region, and the local landscape. Potential survey sites were identified and I assessed the ease of my bird and vegetation survey methods. During this period, I was accompanied by a field assistant with some experience of bird surveys in Sumatra. Review of methods used in the literature suggested that a fixed-radius point count method would be most appropriate. This involved the observation of birds within a fixed radius from a central point, and has the advantages of involving minimal disturbance, and allowing counts in relatively difficult terrain. It was used in combination with mist-netting by Wunderle (1996) and Beehler (1986) in studies of coffee plantations in the Dominican Republic, and India respectively, and suggested as a suitable methodology in Rainey's (1999) study proposal in west African cocoa plantations. In the Indonesian context Marsden (1998; 1999) used variable radius point counts spaced along a transect to estimate population densities. The most similar published study to mine is one by Thiollay (1994) who integrated point count and transect methods in Sumatran agroforests. However, when I trialled point counts, the surveys did not yield sufficient data. Many of my trials did not allow any birds to be formally recorded. In order to increase the efficiency of my data collection I tried several other methods, including variations upon the point count and area search techniques. Several factors were limiting. One of these was that if the time spent on each survey were increased, likelihood of re-counting individuals would also increase. While Marsden (1999) suggested ten minute counts for tropical forest parrots, my trial surveys were already twice this length.

Another factor was the differential visibility imposed by the differing vegetation densities at each site. This restricted the maximum radius of a count point to 15 metres. Beyond this distance, I was not confident of observing cryptic birds in the denser plots, and assumptions of equal visibility would be seriously violated. An attempted compromise involved the use of an inner circle within which I could move, allowing greater visibility of the still undisturbed outer ring. However, the numbers of birds encountered were still insufficient, and the high number of 'empty counts' seemed likely to cause difficulties in later statistical analyses. Thus, I further sought a method that would provide a higher number of records whilst survey conditions were still adequately standardised. The 'x-species' method of constructing repeated lists to compare rates of species accumulation (also called the MacKinnon method) has been proposed as a rapid way of compiling species richness information in tropical environments (MacKinnon and Phillips 1993; Jepson and Djarwadi 1999; Bibby, Burgess et al. 2000). This is also one method endorsed by the BirdLife International Indonesia Programme (BirdLife International 2001). However, used alone it would not yield sufficient detail for this study. Trials of area search methods were more successful for collection of sufficient quantities of detailed data, and so this approach was pursued.

4.3.3 Area searches

Area searches are endorsed by Bibby (2000) as effective for rapid accumulation of bird data suitable for inter-site comparisons. In order to increase the number of bird sightings that could be formally recorded, I increased the survey area from that of earlier trials to a 60 m x 60 m square in which all birds encountered during a 40 minute search were tallied. During the pilot stage, species accumulation curves were constructed to aid in selection of sample size. Due to the greater area covered, it was considered appropriate to survey for a longer time than for point counts. The highly patchy nature of some of the study areas limited the plot size. I moved throughout the plot, actively searching for birds. I investigated areas of apparent bird activity and also searched for more cryptic and less gregarious species.

Within the plot I recorded the number of individual birds seen, and the microhabitat or substrate being used (grouped into the categories ‘air’, ‘canopy’, ‘branch’, ‘trunk’, ‘coffee’, ‘understorey’, ‘ground’ and ‘rice’). I also estimated the birds’ height above the ground and their activities (grouped into the categories ‘fly overhead’, ‘fly between perches’, ‘perch’, ‘forage’, ‘walk/hop/run’, ‘call’ and ‘combat’). In order to limit the number of categories, some activities were defined in a more functional than colloquial sense. For example, birds sitting on the ground were considered to be in the ‘perch’ category. Additionally, in the case of multiple activities, the activity that involved the closest clear engagement with the immediate habitat was recorded. For example, a bird that was perched and foraging was placed in the ‘forage’ category, whilst one that was perched and calling was placed in the ‘perch’ category. Aerial records were classified as ‘fly between perches’ if the bird was known to fly to, or from, a perch within the survey plot, whilst they were classified as ‘fly overhead’ if the bird was not known to have perched within the plot. Birds whose presence was detected only by sound were assigned to the activity category ‘call’. It is acknowledged that there is inherent bias in recording of activities, due to the differences in visibility of different activities, as well as ease of interpretation (Wiens 1989). Aerial foraging was not recorded due to a lack of reliable means for determining this behaviour. Birds engaged in this activity were thus recorded as ‘flying overhead’. For birds heard to call within the plot, but not seen, fewer details were recorded. Also, unless clearly more than one individual was present, only one sound record was taken for any one species in each survey. Birds detected outside of the plot during surveys, or outside of the survey times, were recorded separately as opportunistic sightings. Lack of control of survey effort and detailed habitat information limited the use of these opportunistic records in analysis, but they provided context for the interpretation of survey records, including indicating some of the species not recorded in formal surveys but clearly present in the area.

All species detected were recorded. Before fieldwork began a focus on Bukit Barisan Selatan endemic species seemed possible, according to the value placed on these by BirdLife (BirdLife International 2000). However, of these species, only the Sumatran Drongo was observed during surveys, perhaps indicating the general restriction of these species to tracts of less-disturbed forest.

4.3.4 Bird Identification

I identified all birds to the most precise taxonomic level possible under the circumstances; usually species. Visual identification of birds was made using 10 x 42 binoculars facilitated by reference to the field guides by MacKinnon (1993), Robson (2000) and King (1975). A tape recorder was used to record unknown calls, and sometimes later aided with identification. Difficulties in identification occurred for some groups, in which case they were recorded to a less detailed taxonomic level. In some cases birds were described and identifications determined later.

During the first season of surveys (counts 1 and 2), most bird counts were made unaided. However, all counts at forest sites, and some of those at 'tall scrub' sites, were made with the assistance of a local guide, Jufri, who had previously hunted birds recreationally and thus was knowledgeable regarding behaviour and calls of local species. In order to maintain comparability between sites, this help was limited to supplementary identification of birds that I had already detected. During the second season (counts 3-9 for Sumberjaya sites and 1-9 for Pesisir sites) counts were made with aid from the same assistant, including all birds noticed by both observers, though those only detected by my assistant were noted as such. Counts were made co-operatively, to ensure consistency and avoid re-counting. I confirmed my records at the end of each survey. To account for any variability in observers, inter-habitat differences in the number of birds observed only by Jufri were later tested using a Kruskal-Wallis test.

4.3.5 Timing of Surveys

Organisation and results of surveys were influenced by both annual and diurnal factors of timing. Potential changes with season include bird foraging behaviour and activities associated with breeding and raising of young, such as nest-building. There was also the arrival and departure of migratory species. Breeding of most bird species in the region occurs over the dry season with May, June and July defined as the general breeding season in south-west Sumatra by Thiollay (1994). According to MacKinnon (1993) this matches food abundance, which at the end of the wet season is highest for insectivores, followed by frugivores. Granivores breed later during the dry season.

Towards the end of the dry season, in September and October, palaearctic migratory species arrive, leaving behind food shortages brought by the approaching winter at their breeding grounds in northern Asia and Europe. Some pass through southern Sumatra to find wintering grounds further south and east, whilst others stay for several months. Eleven species have their principle wintering grounds in the Malay peninsular or Sumatra, though there are many others that also over-winter in the area (Whitten, Damanik et al. 2000). The migratory status of all bird species surveyed is indicated in Appendix A. During the Northern Hemisphere spring these species return to their northern breeding grounds (MacKinnon and Phillips 1993).

Each site was surveyed nine times between October 2001 and October 2002, including both wet and dry seasons, although the middle wet season months of January, February and March were not represented. Survey dates are included in Appendix B. The repetition of surveys at individual sites raises issues of data independence. Clearly, some individuals in this study would have been re-counted at successive surveys, particularly for species with a territorial nature. This is similar to the study of stability and long-term persistence of individuals, which requires repeated surveys, regardless of their apparent violation of independence (Wiens 1989). Species accumulation curves constructed over successive surveys in my pilot study, suggested that without survey repetition, surveys would not come close to recording the entire avifauna using each site. Wiens (1989) also illustrates how insufficient survey can be misleading, and defends the use of repeated surveys. Given that the aim of my surveys was to collect relative, rather than absolute data, the re-counting of individual birds in separate surveys can be seen as providing an indication that the site is important for these birds due to their repeated, rather than opportunistic, use. I was aware of the influence my ‘learning curve’ was likely to have on species lists, as I accumulated experience over the year. This was a further reason for spreading my survey effort across almost all sites every month. The practice also ensured that the chance of encountering migratory species was not affected by uneven survey distribution. The repetitions at Sumberjaya sites were generally spread quite evenly, so that when possible, all sites were surveyed before beginning the next repetition. Exceptions to this included the more remote sites in Gunung Terang and Trimulyo, which, for efficiency, were often surveyed twice during one trip, taken between two general rounds of survey. Also, the sites in the Pesisir region (Krui and Rata Agung plots) were surveyed in two intensive periods; June (end of wet season) and September (end of dry season) in 2002.

Bird surveys are ideally conducted early in the morning, when birds are actively feeding. Whenever possible they were conducted at this time. However, the need to conduct multiple surveys each day, as well as travel between sites, resulted in their spread over a range of times.

Whilst some twilight surveys were made, the majority of surveys were in the morning. The order of surveys within a region was rotated at each visit, in order to remove bias resulting from uneven representation at various times of the day. Survey times for each site are provided in Appendix B.

4.3.6 Connection with vegetation records

The vegetation records were made over the entire area of each bird survey plot, rather than in smaller sample quadrats, and thus allow interpretations of bird records to be made directly, with two caveats. The first is that the survey landscape was an extremely patchy one, and thus the neighbourhood of many plots was dissimilar to that contained within the plot. Thus, birds moving over an area greater than the plot size (probably most if not all species) may be reliant upon resources not present in that plot, as well as those within it. I attempted to take this landscape scale factor into account by documenting the surrounding land cover type. These records were honed to the proportion of the plot side neighboured by each of sixteen land cover types. Thus, any reliance by particular species upon closely neighbouring features might be recognised. Secondly, all birds seen within the plot area during the survey were recorded. This included birds soaring high above or flying directly through the plot. The interaction between these birds and the habitat features of the plot may be minimal, and so many studies do not include such records. However, these birds still occurred within the plot space during surveys, rather than avoiding it. Some taxa, such as swifts and raptors, are rarely seen to land, but are still part of the local avifauna, and so must be using some resources present. To minimise mis-interpretation of these records, the documented activity such as ‘flying overhead’, as well as height and recorded microhabitat, was used.

4.3.6.1 Environmental variables

At each survey site I recorded a suite of environmental variables. The patchy and intensively used landscape of my study area gave rise to many factors, which, while not the core focus of my study, could not be completely controlled. Thus, while I attempted to choose survey sites and conditions to limit the influence of extraneous factors, I also recognise that some variation did occur, and so have tried to make at least coarse-grained records of this. Any attempt to understand and plan landscape management in a living landscape must recognise that there are a wide range of factors that could act to confound plans derived from a sterile research setting.

The survey variables measured were air temperature, humidity and time of survey, whilst those estimated were wind strength, cloud cover (estimated as eighths of sky covered) and apparent noise disturbance (given a value on a 1-5 scale). These quantities were recorded in order to document and limit any bias occurring between surveys. Other site variables recorded included slope, which I gave an estimated value on a scale between one and five, and altitude, which in conjunction with spatial location, was derived from a Global Positioning System. Due to the human domination of the landscape it was impossible (and perhaps also undesirable) to avoid structures such as small shelters and paths being present within all plots, so these were simply recorded. However, features such as major paths were avoided due to the likelihood of an excessive level of disturbance.

4.3.6.2 Invertebrate samples

In this study I aimed to document the resources available to birds, particularly for foraging, and use this to interpret the guilds of birds found in various systems. Documentation of the plant species present in plots is advantageous for assessing the food potentially available to frugivores, nectarivores and granivores. However, measurement of food availability to insectivores may also be useful, as many studies of bird assemblages in the region have found several insectivorous guilds to be vulnerable to disturbance, although this is not always the case (Beehler, Raju et al. 1986; Mitra and Sheldon 1993; Thiollay 1994; Johns 1996; Johns 1997; Bawa and Seidler 1998; Marsden 1998). There were no local experts in invertebrate taxonomy, so identification of species or quantification of species richness was not possible. Instead I aimed to create measures of relative abundance and of approximate biomass between ‘multistrata’ and ‘monoculture’ coffee gardens, at ground, coffee, and aerial levels, as well as comparing samples of foliage from five common plant species.

Habitat

Eight sites were used for the first two parts of the study, four multistrata and four monoculture gardens. All of the traps were left for approximately 44 hours, being set up in late morning on day one, and collected in early to mid-morning on day three of each study. In order to quantify invertebrates walking along the ground and in the leaf litter, micro-pitfall traps (diameter 3 cm, depth 5 cm) were filled with alcohol and buried under coffee bushes, spaced at 10 m intervals along a 40 m north-south transect at each site (total n=40).

The invertebrates at coffee layer were caught in traps constructed from 600ml plastic bottles. The top was severed and inverted to make a slippery, funnel-shaped entrance. Inside the bottle was a small amount of aromatic fruit syrup. Invertebrates entering through the funnel were thus trapped inside the bottles. Alcohol was added to discourage bacterial and fungal growth in the humid conditions. The bottles were hung from coffee bushes at a height of 1.5 m above the ground micro pitfalls (total n= 40). Air-borne invertebrates were sampled using sticky boards.

As early trials of sticky boards, placed at various heights had limited success, this investigation was reduced to the use of one board (48 cm x 72 cm) with attached fly-paper, mounted on a 4 m pole halfway along the transect at each site studied. This height was the nominal minimum height for vegetation to be classified as 'trees' in this study (total n=8) (Plate 7).

Invertebrates were removed from bottle traps by rinsing each bottle over a fine sieve. They were then hand-extracted. The invertebrates from all trap types were counted and their approximate lengths were recorded, in order to later make an approximation of biomass.

Plant type

I also investigated the relative biomass of invertebrates in the foliage of different types of plants. I sampled coffee foliage, as well as four of the locally common coffee-garden tree species: *Gliricidia sepium, Erythrina* sp., *Paraserianthes falcataria* (*sengon*) and *Artocarpus heterophyllus* (*nangka*). For each species, eight foliage samples were taken each from different trees, divided evenly between two sites where these trees were found (total n=40) (not all species were found at the same two sites). The samples were taken by capturing the foliage of branches in plastic bags and sealing with rubber bands. The foliage was then hand inspected and shaken over a white card, and all visible invertebrates removed and recorded in the same manner as for the traps described above. The foliage samples were then oven-dried and weighed to provide a quantified sampling unit. The invertebrate samples have been preserved and archived at the International Centre for Research in Agroforestry, Sumberjaya field office.

Plate 7 Invertebrate traps.

In the foreground, a bottle trap is visible hanging from a coffee bush. In the background is a sticky board trap, designed to catch aerial invertebrates at the nominated mimimum tree height of 4 m.

4.3.6.3 *<u>Distance from forest</u>*

The distance from the survey site to the nearest margin of a forest patch with an area of at least one hectare was estimated in the field, when this was clearly visible within several hundred metres. For sites further from the forest, the distance was measured from satellite images of the area using panchromatic and thermal images using bands 1, 2, 3, 4, 5 and 7. (Sumberjaya and Pesisir Landsat ETM TRFIC 2000). In the case of the Sumberjaya coverage, an image that had been classified according to land cover was also used (Dinata 2002).

4.4 Interviews

The landscape in which this project was conducted is a human-dominated one. Whilst 70 percent of the area of Lampung is officially reserved as 'protection forest', in fact a great portion is used, particularly for agriculture (Tjondronegoro 2002; O'Brien and Kinnaird 2003). Thus, some insight into local perceptions of landscape, environmental resources and environmental conservation was salutory for useful interpretation of my survey results. In addition, the owners and maintainers of the coffee farms at which I surveyed birds seemed the best sources of information about the land history and management practices in that space.

4.4.1 Interview format

I conducted pre-arranged, semi-structured interviews with the landholders of the coffee and damar sites (Bartholemew, Henderson et al. 2000; Dunn 2002). These allowed some standardisation of information collected, but were sufficiently flexible to ensure clarity, record additional information when it was offered, and explore other relevant paths that emerged. The interviews ranged in length from 30 minutes to approximately 2 hours, depending on the talkativeness of each interviewee. The conversations were recorded using a small casette recorder (with informed consent), combined with some note-taking and summarised soon after. Avoidance of extensive note-taking aided concentration during the interviews and the recordings also helped me to clarify translation (Dunn 2002). In some cases the interviewee was not very familiar with speaking in Indonesian, preferring Lampung, Javanese, or most commonly, Sundanese. I was fortunate on these occasions to be accompanied by native speakers of these languages who were also fluent in Indonesian. These aides also assisted in clarifying Indonesian questions or responses when this was necessary. In most cases interviews were conducted at the homes of the interviewees but some also occurred in their coffee gardens. As my plots were not defined according to ownership boundaries, in some cases more than one party was involved in managing that area. In such cases I selected one of the relevant people to interview, when possible choosing the person managing the greatest portion. In order to increase the sample size and diversity (young women especially were rather under-represented by the interviews of farmers) I also sought further respondents to the questions regarding birds and conservation. Eleven such ‘extra’ interviews were made, bringing the total number to 45.

4.4.2 Interview content

I asked questions regarding ethnicity, land use history, current management practices (pruning, weeding, fertilisation, pest problems and control), perceptions of benefits and limitations of tree planting and maintenance in coffee gardens. I also explored the managers’ perceptions of avifauna using their gardens, and any trends noticeable over time. I made a poster with pictures of a range of the species that may occur in coffee gardens in the area, particularly including several with forest or forest-edge affinities (Plate 8). This exercise had several aims. The first was to focus the attention of the farmers on the birds they may have seen in their gardens. Secondly, I was conscious of the brevity and possible incompleteness of my surveys in the area and wanted to borrow from the farmers’ longer experience. Finally, I wished to make some assessment of the avifaunal knowledge held by these landholders, partly to aid in interpretation of the other information and opinions that they provided, and also to understand better the context for creating and implementing local conservation plans. The second and third aims of this exercise proved to be somewhat confounding and rather inconsistent in the absence of any 'absolute' knowledge of the birds present in the area.

Whilst I used pictures rather than asking for bird names, to reduce confusion in terminology, there was still some apparent ambiguity in taxonomy. In some cases this was easily apparent, and the identity of the bird described able to be resolved after further probing about its habits. From the outset I attempted one measure of 'control' by including pictures of two species that are not found in Sumatra, to test if farmers were claiming without sufficient consideration, to have all the pictured species on their farms. However, this seemed insufficient to indicate which other species were particularly confusing to identify, especially when considering groups such as sunbirds, which have a common shape and habits, but are divided among many species.

I asked a series of other questions to further explore the farmers' perceptions regarding the role of birds in the environment, their ecological needs and how these might be met within coffee gardens. Finally, I questioned respondents on their attitudes towards conservation; who should take responsibility, the effectiveness of co-operation between Government and landholders, threatening factors such as hunting, trapping for the caged bird trade and habitat loss. I questioned their familiarity with the HKm community forestry scheme as well as opinions regarding possible options for achieving conservation aims, including legislative or market-based programs such as eco-certification.

Plate 8 A farmer shows the bird chart used in interviews

My interview schedule was structured to include elements of both 'funnelling' and 'pyramid interviewing' techniques (Dunn 2002). Thus, simple fact-based questions were asked first, setting context and allowing the interviewees to become comfortable. Later, more conceptual and sensitive questions were broached, inviting the interviewees to express their opinions. The interview schedule is provided in Appendix C.

4.4.3 Additional investigations

In order to better understand the context within which coffee is grown and sold, as well as the conservation situation for birds in Lampung, I undertook further interview-based investigations into the local operation of the coffee market and the captive bird trade.

4.4.3.1 Coffee market

I made an extended interview with a local coffee merchant in Sumberjaya. I asked him to describe the following:

- processing of coffee from harvest to export
- destination of coffee sold – place, individual or company
- how many times coffee was sold before export
- the process for setting price, and the differential between different qualities, such as ripe and unripe berries
- the sufficient price for selection of highest quality only
- perceptions of organic products
- awareness of farmers of environmental issues with relation to coffee gardens
- the potential for establishment of a 'green' market
- a possible process for assessment of coffee gardens
- potential problems or benefits to farmers if such a market existed

4.4.3.2 Captive Bird Trade

I also made enquiries about the captive bird trade, as it seemed to be a prominent factor in the fate of birds in the area. I talked informally with local bird trappers, and visited markets in Sumberjaya villages where birds were being sold. I also visited the bird shops in Bandar Lampung, which were said to be the destination of many trapped birds, as well as the large bird markets at Jalan Pramuka in Jakarta. There I informally interviewed browsers and traders (ten customers and three shop agents in Bandar Lampung and ten shop agents in Jakarta). I asked questions regarding the nature of buyers, their reasons for buying and what species were sought. I also asked traders about the sources of birds. I recorded prices being asked for various species on sale, as well as making lists of other species available.

4.5 Analysis of data

Results of field surveys were analysed in three sections: vegetation, birds (also including invertebrate results) and interviews.

4.5.1 Vegetation

4.5.1.1 Definition of habitat types

This study was conducted in a real agricultural setting, where smallholders employ a range of management styles in production of coffee. Whilst it is recognised that there is a continual gradation of environmental variables between coffee gardens, a habitat-based division of plots was sought for later use in analysis of bird data. As there was no clear local typology for coffee sites available, I assigned categories according to the aims of the project. Structural and floristic characteristics of the plots were recorded in parallel with the bird surveys. These vegetation records were then used to assign the sites to categories, independent from the bird data collected at the sites. As this occurred independent of collation and analysis of the bird results, for the practical purposes of analysis, categorisation can be considered *a priori*.

The description of vegetation at each site was largely derived from the annotated maps created at each plot, and reduced to quantitative variables. Those parameters used for categorisation of shade coffee sites by Principal Components Analysis are marked with an asterisk in Table 4.1.

4.5.2 Division of sites

Site classification occurred in a step-wise fashion, in which the most distinctive site types were identified and then excluded to allow more detailed consideration of remaining sites. The non-coffee habitat sites chosen were distinctive in the field. A check of their characterisation was made by conducting Principal Components Analysis upon all sites, defined by eleven of the above variables. Primer 5 package was used for this, and all other multivariate techniques (Primer-E 2001). Subsequently, coffee sites were separated for more detailed division. Monocultural coffee sites were the next to be separated, according to their low canopy cover. Finally, the remaining pool of shaded coffee sites were categorised using additional variables.

4.5.2.1 Principal Components Analysis

Principal Components Analysis (PCA) was used to separate the sites into groups. This is a simple type of ordination recommended as being better suited to treatment of environmentally variable data than to species abundance data (Legendre and Legendre 1998; Clarke and

Warwick 2001). It is also better suited to continuously varying data than analyses such as hierarchical clustering.

Ordination of all sites was made on the eleven variables listed above (except those referring to coffee, which was not present at all sites, and tree dominance, which could not be satisfactorily defined for all sites). Monocultural, or nearly monocultural, coffee was also recognisable in the field, although the threshold for division from other coffee sites is clearly an arbitrary one. The limit was defined as 1/16th of the plot (6.25% total tree canopy cover). The exclusion of these sites from classification of shade coffee sites allowed additional parameters to be used for sites with a substantial tree canopy.

Subsequently, PCA was conducted on the variables ‘number of trees’, ‘canopy cover’, ‘index of tree dominance’, ‘maximum tree height’, ‘coffee height’, ‘tree species richness’ and ‘coffee canopy closure’. This reduced set was chosen from the initial set to minimise duplication and redundancy, as some of the initial variables are clearly correlated. The process was repeated temporarily excluding an outlying value (LM3), which had a skewing effect, reducing the variability that could be represented between the other points. The emergent clusters of sites were used to define the distinctions between types of shaded coffee.

4.5.2.2 Vegetation abundance scores

Vegetation maps were used to give each plant taxon an abundance classification, and subsequently a score for each site at which the plant was represented. The scheme was used as an efficient way to describe the plots floristically, as it does not require detailed percentage cover values for all species. Those plants not reaching the minimum size requirement to be considered as trees at that site were recorded as having ‘groundcover’ abundance. Plant taxa with at least one individual of tree size at a given site were classified according to the number of individuals present, if represented by fewer than five individuals, or by percentage cover in the plot for the more abundant taxa. The plant types in each abundance class at each site were assigned a score according to the abundance class. The level of these scores was set with relation to the approximate number of medium-large trees (canopy radius = 4 m) required to fill the minimum cover requirement for the class (Table 4.2).

Table 4.2 Vegetation abundance class types and scores

Abundance class	Class description	Abundance score
Groundcover	Non-tree status	0.5
Rare	1-2 individuals	1
Occasional	3-4 individuals	2
Frequent	>4 individuals<15% cover	5
Abundant	15%< cover < 50%	11
Very abundant	>50% cover	36

Additionally, each taxon was grouped with others according to their potential agroforestry function. This classification was used consistently across all sites and recognised the potential end use of the plant for a farmer. The groups used were 'understorey' (no known crop),'understorey crop', 'fruit tree', 'tree crop' (non-fruit), and 'timber'. The latter classification was used for any tree without the known potential to provide the farmer with fruit or other crops, as many types of tree are used opportunistically for timber or firewood. Scores for each functional group were summed for each site.

The consistent use of the functional classification across all sites, in conjunction with the allocation of scores according to current size, means that the score is a representation of actual abundance whilst also recognising the functional potential of the garden. For example, a young durian sapling may receive an abundance score of 0.5 consistent with its current non-tree size, but this score will contribute to the fruit tree score for the site. Conversely, a species usually considered of the 'understorey' functional type may achieve sufficient size, in some plots, to receive a high abundance score reflective of the number of individuals of tree size. A full list of all plant types surveyed and their functional classification is provided in Appendix D.

The scored plant lists were converted to a matrix of similarity between sites, used in a Multidimensional Scaling (MDS) analysis of these sites and habitats (see section 4.5.4.2). An ANOSIM test of the matrix was used to test significance of multivariate group differences on the basis of their species composition (see section 4.5.4.2). The matrix was also used in RELATE tests that compared the rank correlation between this vegetation floristic similarity matrix and those for bird assemblage and vegetation vertical structural features (see section 4.5.4.2).

4.5.3 Birds

The nature of the avifaunal assemblages in each habitat were examined in terms of species richness, diversity and turnover and species composition as well as guild and feeding group representation. Secondly, the way in which birds used these habitats was explored, including birds' use of microhabitat, height above the ground and activity.

A range of techniques was used to compare results of bird surveys. Univariate characteristics were tested by non-distributional statistical tests, using the package JmpIn version 5.1 (SAS Institute 2003). Due to the complex nature of the data, multivariate tests were also used. MDS was used to compare sites and habitats defined by multiple variables. Permutation-based ANOSIM tests were used to define and test the significance of grouping by multivariate characteristics, such as species assemblage, guild and feeding-group assemblage and bird activity. The relationship between dominant tree type and bird assemblage was tested using RELATE, which compares similarity matrices by rank correlation. The contribution of environmental variables in explaining inter-site and inter-habitat variation in bird assemblages was tested using BIOEnv tests (Primer-E 2001). The coffee habitats compared were 'monoculture', 'simple shade', 'multistrata', and 'closed multistrata', while the non-coffee habitats were 'paddy', 'damar', 'forest', 'tall scrub', 'low scrub' and 'Imperata' grassland. In some cases the large number of categories represented by a small number of samples made statistical analysis of difference inappropriate. In order for each group to have sufficient samples for some tests to be done, several of the groups were amalgamated in a simplified classification of habitats. These simple habitat types were 'paddy', 'monoculture coffee', 'shade coffee' (simple shade, multistrata and closed multistrata), 'successional' vegetation (Imperata, low scrub and tall scrub), 'forest' and 'damar'.

4.5.4 Statistical techniques used

4.5.4.1 Univariate tests

Descriptive statistics were used to present basic data on bird distributions between sites and habitats. In most cases, absolute numbers of birds, rather than proportional data, were used for analysis as they provide more information regarding apparent habitat availability or attractiveness to the regional bird assemblage. As data were not expected to be normally distributed, the less assumptive non-parametric tests were used for testing differences between groups. In cases of comparison between two groups, such as coffee and non-coffee sites, as well the dichotomy of shade coffee and monoculture coffee, Wilcoxon rank-sum tests were used with an alpha level of 0.05. For comparison of more groups, such as the entire suite of habitats, the equivalent Kruskal-Wallis test was used (Sall, Creighton et al. 2005). These tests were used to examine differences between numbers of birds in each habitat, as well as their representation in different microhabitat types, representation of guilds and feeding groups, activity and height above the ground. The outputs include a test statistic and significance level.

For the two group Wilcoxon test, the normal approximation, as well as the χ^2 approximation, are provided, while for the Kruskal-Wallis test of a greater number of groups, only the χ^2 distribution are given. Additionally, test outputs include mean rank scores for each group being compared. These indicate the relative position of each group within the entire pool of samples, determined by the ranks of each sample (this score is not the *mean* value for the parameter being compared between groups).

4.5.4.2 Multivariate tests

Multi Dimensional Scaling (MDS)

I have used MDS to plot the relationship between sites and habitats on the basis of the bird species assemblage, guild assemblage, feeding group assemblage, the number of birds using each microhabitat as well as the similarity of neighbouring habitats. MDS is an ordination technique, with a graphical output of similar appearance to that of PCA, but derived by different means. This ordination technique is derived from a secondary matrix of similarity between sites. Bray-Curtis similarities were used. These similarity values are used to rank the samples (e.g. sites) and then define their relative distances from each other in the multidimensional space defined by the variables (Clarke and Warwick 2001). It is an iterative procedure, the output of which is a plot that is defined to minimise the 'stress' caused to the pattern by projecting it in two or three dimensions. The technique is better suited to large numbers of variables than is PCA, although is perhaps more vulnerable to inaccuracy with few sites. Like PCA plots, MDS results can be viewed in either two or three dimensions, which can assist with clarifying the relative positions of points. Non-statistical interpretation of these plots with relation to individual environmental variables was made by overlaying the distribution with proportional circles indicating the magnitude of individual variables at each site. Clustering of similarly sized circles indicates that there is a relationship between that variable and the species composition that has created the plot distribution, although this relationship may not be a causal one.

ANOSIM test

'ANOSIM' tests were used to compare similarity of sites with respect to bird species composition (number of individuals of each species per site), guild assemblage (number of birds in each guild per site) and feeding group assemblage (number of birds in each feeding group per site), as well as differences between neighbourhood habitats. ANOSIM is a non-parametric multivariate test of difference analogous to the univariate ANOVA (Clarke and Warwick 2001). In practice, it can be used to assess the significance of difference between groups that can be identified visually in MDS plots. Based upon ranking of similarity scores between samples, the test calculates a statistic, R, in the range between –1 to 1 indicating the degree of discrimination between sites. An R value of zero suggests that the null hypothesis is true. The statistic R is recalculated under multiple random permutations which re-assign site labels to examine the likelihood of the distribution occurring by chance alone. Significance of overall differences is assessed by comparison between the R value associated with the real sample labels, and the distribution of R across all permutations tried. If R appears unlikely to fall within this distribution, the null hypothesis can be rejected.

In the comparisons made in this study the usual number of permutations calculated was 10,000. In addition to showing overall differences between all sites by calculation of the Global R statistic, the source of these differences can be identified by examination of pairwise R values. Thus, habitat groups were compared. These comparisons are also assigned significance values on the basis of the size of R, as well as the number of permutations calculated, which is limited by the number of replicates in each group. Thus, the test is limited in its ability to find significant differences between small numbers of samples (Clarke and Warwick 2001).

RELATE test

I have used the 'RELATE' test to compare the similarity of bird species assemblage with the similarity of neighbourhood habitats, in order to assess the influence of neighbouring plots on the bird assemblage, and also to compare pairings of the vegetation floristic assemblage, the bird assemblage, and the vertical vegetation structure. RELATE is a test of the "hypothesis of no relationship between multivariate pattern from two sets of samples" (Primer-E 2001). These samples may be both in the form of similarity matrices. It is a permutation-based test using rank correlation of the samples' similarity. Spearman's method for correlation was used to create the similarity matrices. The level of correlation is assigned a sample statistic Rho. The significance of the relationship is determined by repeating the test using randomly generated labels for the sites, and comparing the value of Rho belonging to the real site labels with the distribution of Rho from the random trials. Significance is achieved if few of the random trials exceed the real value of Rho. Output includes the Rho value and level of significance.

BioEnv test

'BioEnv' is another permutation-based test. It compares the similarity matrix of species assemblage with that of environmental variables measured at the sites. The set of variables that best explains the species assemblage is selected by maximising the rank correlation between the similarity matrices. The output is a series of combinations of variables with their associated R values, indicating the respective rank correlations.

4.5.5 Species characteristics

4.5.5.1 Species richness

The use of measures of species richness implies the identification of all taxa to species level. In the field, this was not always possible. Hence, I constructed a conservative measure of minimum species richness for each site. It involved considering all individual birds surveyed at an individual site, and whether those individuals that were not identified to species level were sufficiently distinct from all the species recorded at that site. If the individual was distinct, it was included as a new species, but if not, it was disregarded. In practice this means that all generic records were excluded if there was any bird recorded at that site in the same genus.

4.5.5.2 Species accumulation

Species accumulation curves provide a further method of exploring the species richness characteristics of a site, whilst also providing information on the adequacy of survey (as used by Tjeda-Cruz and Sutherland 2004). These curves were constructed using the mean species richness within each habitat type for each of the nine surveys. A continuously steep curve indicates rapid accumulation of species and thus high species richness is likely for the habitat type. The flattening of a curve suggests that most of the common species have been observed and few new ones are being added to the site list with subsequent surveys.

4.5.5.3 Species diversity

Alpha diversity

While the use of diversity indices has sometimes been criticised as misleading (e.g. Johns 1989) they are still widely used, and provide one descriptor allowing the relative abundance characteristics of species in their respective assemblages to be compared (Magurran 1988). Diversity indices depend upon identification of all taxa to the same level. In order to achieve some measure of bird diversity, taking into account both species richness and the level of assemblage dominance by a single species, Shannon-Wiener diversity was calculated for each site, and a mean taken for each habitat. In order to make best possible use of the taxonomic data available, this was repeated at several taxonomic levels. At each level, the analysis included only birds that were distinguished to that standard. Due to the exclusion of birds that were more difficult to identify, including cryptic and unfamiliar species, differences recognised between sites are likely to be less than their true magnitude. The Shannon-Wiener diversity index I used is as follows:

$$H' = -\Sigma p_i \ln p_i$$

Where H = Shannon-Wiener diversity, p_i = number of individuals of the taxon i, (Magurran 1988).

Species turnover and uniqueness

Measurement of habitat quality and ability to support species is scale dependent (Magurran 1988). This can be evaluated in terms of species turnover, also called 'internal beta diversity' or 'pattern diversity' (Wiens 1989). In order to compare the species turnover in coffee habitats six sites were randomly chosen from each of monoculture, simple shade and multistrata habitat groups.[7] Following random ordering, species accumulation curves were constructed by site for each habitat, showing the additional number of species added to the habitat list with the addition of each site. A curve that is steep and continues to rise with each additional site suggests that the habitat type contributes greatly to regional species richness. In order to assess the uniqueness of habitats, and their contribution of species to the regional assemblage, the number of species unique to each coffee habitat and each combination of habitats was also calculated. Also, to assess the overall contribution of coffee habitats to the regional bird assemblage, the numbers of taxa unique to, and shared between coffee and non-coffee habitats were compared in 14 randomly chosen sites in each group.

4.5.5.4 Guilds and feeding groups

McIntyre and Barrett (1992) suggest that classifying birds by habitat requirements is a useful compromise between the extremes of single-species and community wide approaches. Frequently, guilds and feeding groups have been used in studies of birds and habitat to define groups of species by their ecological characteristics (e.g. Gaither 1994; Thiollay 1994; Johns 1996; Greenberg, Bichier et al. 1997). The manner in which groups are defined is subjective and not consistent between studies. Choice of discriminating characters can greatly affect the results. Common characters used to define guilds are diet, foraging behaviour or location, nest site location and residency status (Wiens 1989). For the present study I defined 'guild' by the location and mode of feeding, while 'feeding group' was taken to indicate the type of food eaten. These were *a priori* classifications, defined after the species list for the area was known, but on the basis of literature, to ensure independence from the results of the survey. The sources used included field guides, published reports of field studies, historic accounts of birds present in the region and their characteristics and a check list for Sumatra (Robinson and Kloss

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[7] This random selection of sites was to overcome differences in numbers of sites per habitat, the smallest number being six, for simple shade coffee habitat.

1924; King, Woodcock et al. 1975; van Marle and Voous 1988; MacKinnon and Phillips 1993; Mitra and Sheldon 1993; Thiollay 1994; Holmes 1996; Simpson, Day et al. 1996; Andrew 1992, cited in Jepson and Ounsted 1997; Wells 1999; Flegg 2002). Parallel classifications of guilds and feeding groups were made using simple and complex classes. Simple classification allowed only one consumer type (such as insectivore) for feeding group or one feeding location (such as canopy) for guild, to be specified (Table 4.3). Complex definition allowed multiple food groups (such as understorey-canopy) or feeding groups (such as insectivore-frugivore) to be recognised (Appendix A). This was done so that the most detailed information available was used when the large number of groups created was not problematic; for example, in constructing matrices of similarity between sites. However, for statistical techniques, requiring larger group sizes, the less detailed classification was used. Analyses at different levels of complexities like these can reveal different patterns (Wiens 1989).

Table 4.3 Guilds and feeding groups

Guild	Feeding group
Water	Granivore
Ground	Frugivore
Understorey	Nectarivore
Trunk	Insectivore
Hawk	Piscivore
Upper-storey	Carnivore
Aerial	Omnivore

Differences between habitats on the basis of the number of birds in each guild and feeding group were tested by Kruskal-Wallis and Wilcoxon tests. The similarity of sites and habitats on the basis of their birds' guild and feeding group composition was investigated using Multidimensional Scaling, which also allowed relationships with vegetation variables to be explored.

4.5.5.5 Affinity to forest

Birds that are rainforest specialists are particularly vulnerable in the context of rapid deforestation. Thus, the dependence upon core rainforest habitat, or tolerance to more open habitats, by species in the surveyed assemblage was the basis for some analyses of habitat value. The closeness of each bird taxon's affinity to forest was given a score on the basis of literature. These scores are based on those assigned by Thiollay (1994), although with reference to the literature listed in section 4.5.5.4, the range of scores has been expanded from that study which focused on tall agroforests. The scores I have allocated here range from zero to three, with zero indicating a need for forest core, one indicating forest edge, two indicating moderate cover and three indicating use of open country habitat (Appendix A). Taxa not listed by

Thiollay were assigned scores according to other literature. In analysis, the frequency distributions of birds across the forest affinity groups' were compared visually, between habitat types, sample sizes being insufficient for statistical analysis.

4.5.6 Biogeographic factors

Distances from each study site to the nearest forest block were estimated in the field and from satellite images. These were compared with bird assemblages at each site using an ANOSIM test. Likewise, this test was used to explore the influence of region on the bird assemblage using the region definitions described in 4.1.

Similarity of sites according to the neighbouring habitats recorded in the field was explored using MDS. The significance of differences between bird assemblages in sites with different neighbourhood properties was tested using RELATE. BioEnv was conducted to select combination of neighbourhood habitats most influencing the assemblage surveyed. It is noted that these tests make the assumption that the neighbourhood, rather than any plot-based differences, are the driving variables.

4.5.7 Invertebrates

Length of invertebrates is sometimes used as a convenient measure from which to infer their biomass. An index was created by Rogers *et al.* (1976) using a range of taxonomic groups, and claimed it to suit various habitats. I modified this index on the basis of Schoener (1980) who suggested that, in tropical habitats, a lower exponent than that used in the general equation is suitable, and empirically found an exponent of 2.11 to suit samples from rainforest understorey in Costa Rica. Although the ratio of dimensions vary with taxonomic group, the general relationship is considered sufficiently robust to provide a good approximation of biomass, and if consistently used at all sites, can be confidently used as a relative measure.

The equation thus used is $M= 0.0305 \times L^{2.11}$

Where M=mass (mg), L= invertebrate length (mm)

Invertebrate biomass differences between habitat types and plant types were compared statistically using Kruskal-Wallis and Wilcoxon tests.

4.5.8 Interviews

The interviews were translated and summarised. They were added to the same JmP In database as the bird survey results. For those questions that were open-ended, response categories were created to cover all the actual responses. By coding each possible response in a binary format for each respondent, the possibility for multiple responses was preserved. Summary statistics were produced describing the responses to each question. For some cases differences in response between different farmer 'types' (damar, shade coffee and monoculture coffee) were explored, and tested using Wilcoxon and Kruskal-Wallis tests. Whilst statistical measures were useful in summarising characteristics, they overlooked many of the nuances in responses, for example, qualifying or clarifying comments. Thus, to recognise these, as well as record other useful information contributed by the interviewees, qualitative summaries were also made. This was particularly important for topics such as the allocation of responsibility for conservation and interest in sustainable coffee schemes.