   

Conservation of Figs and Frugivores in Assam, India

Final Project Report – April 2011

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Executive Summary

Room for expanding the global protected area network is extremely limited, especially in countries such as India where demand for food production is high. A key 21st century conservation concern is how to manage and preserve biodiversity in human-dominated landscapes. This project sought to address this concern by looking at *Ficus* trees and frugivores in an agricultural landscape in Assam, northeast India. *Ficus* is amongst the most important plant genera for frugivorous birds and mammals in the tropics. As keystone structures, *Ficus* trees are a year round food source. Moreover, *Ficus* has considerable cultural and social importance. The Banyan fig (*F. benghalensis*) is the national tree of India, and several other species are sites of religious worship. In this project, we sought to (1) examine patterns of frugivory in human-dominated landscapes to determine to what extent *Ficus* trees act as dispersal stepping stones for birds. We then (2) explored local perceptions and practices pertaining to *Ficus* trees in the agricultural landscape context. By integrating these strands, we (3) sought to assess the possibility of implementing a community-based *Ficus* conservation project. The study was conducted over a period of 19 months. We mapped over 470 *Ficus* trees in the landscape, and carried out over 180 hours of bird observations. We conducted qualitative interviews with local people and ran 278 questionnaires within the local community. The study found that *Ficus* trees in the agricultural matrix supported 67 bird species, which were evenly distributed in the landscape. Rates of bird visitation and number of fruits consumed decreased as distance from remnant forest patches and land use intensity increased. As a consequence, seed dispersal declined. Green Pigeons (Treron spp) were the most important avian seed disperser in the landscape. Fruit-handling behaviour of birds varied with the size of *Ficus* seeds, and large-bodied species were more effective dispersers of figs with larger fruit. These larger frugivores (green pigeons, hornbills, imperial pigeons) were also more susceptible to being hunted. This suggests that dispersal of seeds of large fruited *Ficus* might be at risk in the landscape. We found that *Ficus* trees scored low in terms of economic value, and the main reason for them remaining in the landscape was because of religious attributes endowed upon them. Trees that had shrines were significantly larger than those that did not. However, with agricultural intensification, the number of mature *Ficus* trees declined and people cut down trees when they interfered with their daily activities. Local respondents were willing to plant *Ficus* in public places and suggested that a plantation scheme should be initiated through a tripartite association involving local youth, community leaders and conservation NGOs. In addition, there is an urgent need for implementing a *Ficus* awareness programme involving local youth and school children. This will generate local capacity development to monitor frugivores and raise the profile of fig trees locally. *Ficus* trees are indeed sacred groves at a very local scale. They provide a working example of how cultural practices may be harnessed to conserve biodiversity outside protected areas.

Acknowledgements

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Introduction

Conservation outside Protected Areas

Humans have fundamentally altered global patterns of biodiversity and ecosystem processes. Extensive conversion of forests and agricultural intensification in the tropics has resulted in the emergence of landscape parcels that are a heterogeneous mixture of agriculture, human-settlement and forest fragments. Indeed, a majority of the earth's surface is covered by such anthropogenic biomes (Ellis and Ramankutty 2008). However, much of modern-day conservation is motivated by a desire to conserve 'pristine nature' (Cronon 1996), and draws upon models of island biogeography that treats forest fragments as islands paying little attention to influence of the 'matrix' in between (Jules and Shahani 2003). Understanding of how the non-reserve matrix contributes to biodiversity loss (or preservation) is limited. To conserve biodiversity in the 21st century, it is vital that we (1) pay attention to patterns of biodiversity outside protected areas, (2) understand how human-environment relationships influence these patterns, and (3) manage human-modified landscapes in ways that enhance biodiversity conservation and promote sustainable livelihoods (Bhagwat et al. 2008; Chazdon et al. 2009).

Why Figs?

Ficus (figs; Moraceae) is arguably one of the most important plant genera in lowland tropical rainforests. Globally, a staggering number of vertebrates – over 1200 species – feed on *Ficus* (Shanahan et al. 2001). They have been described as keystone species (Bleher et al. 2003; Eshiamwata et al. 2006), and have a disproportionately large influence over their ecosystem in relation to both their abundance and biomass. At the population level, figs exhibit fruiting asynchrony and are a critical year-round food source when other fruits are not available.

Isolated *Ficus* trees may be keystone structures in human-dominated landscapes as they provide increased structural complexity and habitat for animals at local scales, and connectivity for both tree and animal populations over a landscape scale (Manning et al. 2006). Many fig species are pioneers and play a significant role in forest succession in the tropics (Harrison 2005). It has been suggested that the establishment of *Ficus* is a critical phase in the reassembly of forests (especially on islands), with plant colonization accelerating after the first figs begin to fruit and thereby to attract seed dispersers carrying the seeds of other species in their guts. They are thus an important resource for maintaining biodiversity outside protected areas, and their loss may result in undesirable ecological regime shifts.

Further, figs often survive in human-dominated landscapes because of their cultural significance. For instance, the Banyan fig (*Ficus benghalensis*) is the national tree of India and has considerable religious associations in Hinduism and Buddhism (Chandrakanth et al. 1990). Other species (e.g. *F. religiosa, F. virens*) are also deified or used as sites of worship, and these cultural factors contribute to the preservation of mature trees even in areas of high agricultural land use intensity. They may be considered sacred groves at very local scales, and are working examples of how cultural practices might influence the sustenance of biodiversity outside protected areas.

Project Background

Figs in India provide an excellent opportunity for understanding states of biodiversity outside protected areas, and may help develop innovative ways of doing conservation that link ecology and culture. Our research was focused in the northeast Indian state of Assam, a global biodiversity hotspot with a high diversity of *Ficus* and avian frugivores. Fig trees are prominent in the local culture, where they serve as symbols of fertility or as sites of worship (Barua 2009). The anthropogenic biomes of the state are broadly classed as rice paddy villages (Ellis and Ramankutty 2008), but at finer scales comprise of commercial tea plantations, home garden agroforestry systems and rice paddy (Das and Das 2005). Demand for food production in the state is high and 70% of suitable land is already under cultivation (Forest Survey of India 2005). There is little room for expanding protected areas in Assam, and efforts to promote long-term persistence of biodiversity in the region needs to look at the role of the non-reserve matrix in supporting biodiversity.

This project sought develop an interdisciplinary approach to conservation outside protected areas in Assam by (1) examining the ecology of frugivores using *Ficus* trees in different agricultural landscapes, and (2) exploring cultural practices relating to *Ficus* that contribute to their sustenance in human-dominated areas.

To this end, the project was focused on four distinct objectives:

Objective #1: Investigate the role of *Ficus* trees in agroecosystems as a food source for frugivores and as dispersal 'stepping stones' between forest fragments.

Objective #2: Explore local perceptions and social practices relating to figs in different elements of these agroecosystems.

Objective #3: Identify and assess threats to figs and frugivores in Assam.

Objective #4: Assess the feasibility of a community-based Fig conservation programme integrating land-use with village governance.

Study Area

This study was conducted in the non-reserve agricultural matrix surrounding Kaziranga National Park (26°35'– 26°45'N and 93°05'–93°40'E) and Panbari Reserve Forest in the Golaghat district of Assam (Fig. 1a). Panbari forest is a large remnant forest patch within the region. The non-reserve matrix consists of a heterogeneous mixture of large, commercial tea estates, small village home gardens interspersed with very small woodlots (<0.25 ha) that retain some amount of native vegetation, rice paddy cultivation and agricultural pastures. Land use is diverse and divided among many small landholdings. Most of the conversion of forests to tea plantations occurred over 100 years BP.

The focal study villages were typical of the non-reserve matrix in upper Assam, largely comprising of village home gardens, small-holder and large commercial tea estates and paddy fields. *Ficus* trees were scattered in this agricultural matrix (Fig. 1b). People in these villages were largely from the Assamese-speaking Hindu community, and their primary occupation was agriculture (mainly rice-paddy, supplemented by cash / subsistence crops).

Fig. 1(a): Matrix habitat outside Kaziranga National Park, Assam, India. Yellow polygon indicates study area.

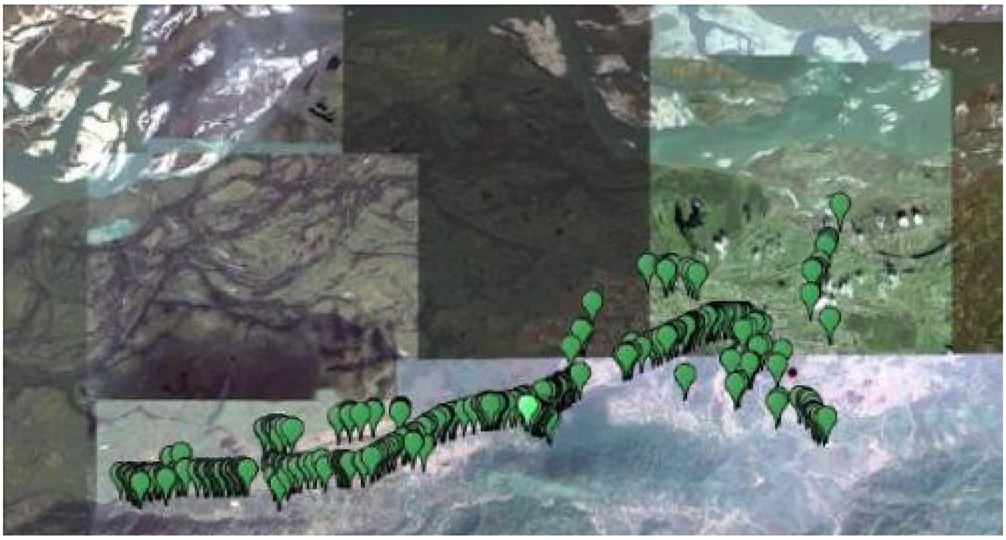


Fig. 1(b): Location of *Ficus* trees in the study area.

Objective 1: Frugivory Objective Patterns on *Ficus*

As part of our efforts to investigate the role of *Ficus* trees in agroecosystems as a food source for frugivores, and as dispersal 'stepping stones' between forest fragments, we focused on three distinct research questions:

(1) Do composition and foraging behaviour of avian frugivore assemblages on *Ficus* trees vary with agricultural landscapes?

(2) Are there differences in foraging behaviour and seed dispersal capacity when the size of the *Ficus* synconium increases? Are larger-bodied species more effective in dispersing seeds of *Ficus* with larger synconia?

(3) Is seed dispersal of *Ficus* by avian frugivores affected by agricultural intensification?

Methods

Site Selection and Sampling Regime

We initially mapped the number of mature *Ficus* trees (n=472) belonging to six species (*F. benghalensis, F. benjamina, F. racemosa, F. religiosa, F. rutusa* and *F. virens*) along a 10km gradient from the Panbari forest through intensive vegetation surveys. We then sampled fruiting *Ficus* trees over a twelve-month period (Sept 2009 to Sept 2010) at (1) varying distances from forest patches, and (2) in sites of different agricultural intensity. We had 59 (n=59) samples of 56 individual fruiting *Ficus* trees, broadly divided into samples on trees with large synconia (n=20) [*F. benghalensis*] and those with smaller synoconia (n=33) [*F. religiosa, F. rutusa, F. virens*]. Only the *F. Benghalensis* (n=20) and *F. religiosa* (n=20) samples were incorporated into the comparative analysis of dispersal capacity and synconium size.

Each sample consisted of a flowering *Ficus* tree within a given landscape context. Agricultural intensity was defined within a 100 m radius circle cantered on the fruiting tree by estimating land cover within the area. Circles that included Q25% village woodlots or a diverse mixture of home gardens with native trees and tea estates were classified as low intensity, and those encompassed primarily rice paddy or peri-urban villages were classified as high intensity. Further, median distance of samples (2482.36m) from the nearest semi-evergreen forest patch was taken to regroup these sites as either near or far from forests. This resulted in four distinct matrix habitats: (1) near, low agricultural intensity sites and (2) near, high agricultural intensity sites [NL and NH respectively], and (3) far, low agricultural intensity sites and (4) far, high agricultural intensity sites [FL and FH respectively].

We initially compiled a list of frugivorous birds found in the adjacent semi-evergreen forest patches using previous data (Barua and Sharma 1999). This served as a reference list of frugivores found in the landscape. Frugivore activity at each focal *Ficus* tree was observed only once for three continuous hours from daybreak (generally 04hrs00-05hrs30 depending on the time of year) onwards, during fine weather. We used a pair of 10x40 binoculars or a 20x spotting scope to observe birds. The final sample consisted of 8 NL sites (n=8), 20 NH sites (n=20), 11 FL sites (n=11) and 17 FH sites (F=17).

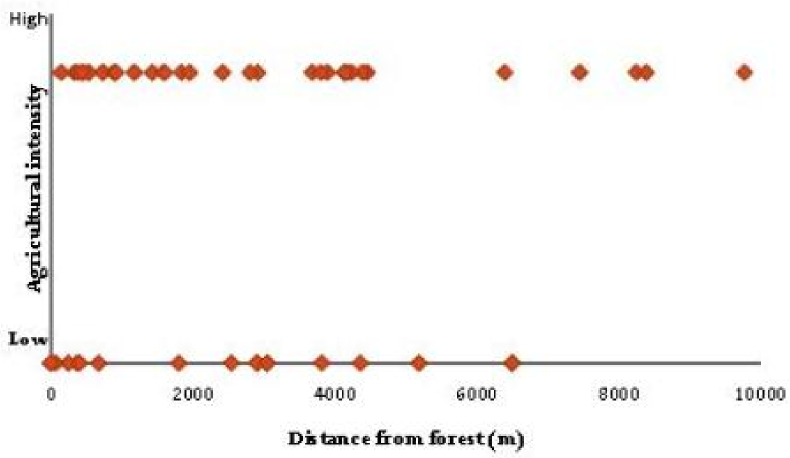


Fig. 2: Grouping of focal *Ficus* trees according to distance from forest and agricultural intensity.

Fruit Abundance

Birds may respond to variation in fruit abundance, so it was important to quantify differences in fruit abundance among focal trees. On the day of observation, immediately prior to collecting bird visitation data, we determined fruit abundance for the focal tree. The tree was scanned with binoculars and the percentage of visible fruit in each frame was counted. This was then replicated for the entire tree to generate an estimate of fruit abundance (in %age).

Species Richness and Visitation Rate

During each 3-h observation period, the number of bird species using the tree for perching, foraging or nesting was recorded. Species that could not be identified were not included in the estimation of species richness, so all reported values are conservative. Visitation rate was estimated as the number of individuals of each species visiting the *Ficus* during each observation period.

Foraging Behaviour

Foraging behaviour was recorded opportunistically during each observation period. We tried to obtain information on foraging behaviour for all obligate frugivores (Barbets, Hornbills, Green (Treron) pigeons), and other frequent groups (Starlings, Mynas) for each *Ficus* species in each of the different landscape contexts. Data were collected on the time that an individual spent in the tree (from arrival to departure), the number of fruits consumed during each visit (partial consumption was scored the same as the whole fruit), and fruit handling behaviour.

Fruit-handling behaviour may differ between bird species, and this has implications for a species' effectiveness as a seed disperser. We classified each species whose foraging we observed into one of three broad fruit-handling categories. Swallowers pluck synconia and swallow them whole, including all the seeds (e.g. Green Pigeons, Hornbills). Mashers also pluck the synconia but tend to manipulate them in the bill, crushing it between the mandibles before swallowing (e.g. Mynas). Some seeds may be discarded during this process and in relative terms may not be as effective as swallowers. Biters include species that peck at individual synconia while they are still on the stalk, or whose gape width or bill morphology does not allow them to swallow or mash whole fruits (e.g. White-eyes).

Data Analysis

Adequacy of sampling efforts for each landscape contexts was determined through the generation of sample-based species accumulation curves (S_{obs}) using the EsimateS software. We used 50 sample order randomizations for estimators (randomization without replacement). We also compared observed species richness for each landscape context with predicted (true) species richness using bootstrap and jack-knife statistical estimators calculated with EstimateS. These estimators represented a lower and upper bound, respectively, of true species richness in each context and were useful in determining the extent to which we underestimated actual species richness.

Mean values (± SE) for species richness, evenness (Brillouin index), visitation rate (number of visits per hour), amount of time spent in a tree per visit (mins), number of fruits taken per visit, were compared among the four landscape contexts. These features were also compared amongst the two *Ficus benghalensis* and *Ficus religiosa* samples. Variables that were significantly correlated with fruit abundance were analyzed using single-factor ANCOVA with fruit abundance as covariate. Other variables were examined using single-factor ANOVA. The Levene's Test of Homogeneity of Variances was used to determine whether the data met ANOVA assumptions. When data did not meet ANOVA assumptions, nonparametric Kruskal-Wallis (K-W) test was used. Post hoc multiple comparisons were conducted using Tukey's honestly significant difference (hsd) test or the nonparametric equivalent. All calculations were done using SPSS version 16.

Differences in proportions of fruit-handling behaviour on the two different *Ficus* species using a Fischer's Exact Test as the number of observed instances were few and this statistic handles smaller amounts of data more efficiently than a normal Chi-square test. A quantitative index of the relative importance of individual species to the dispersal of *Ficus* seeds was calculated as: (total visits x the proportion of all focal trees visited x no. of fruits consumed per visit) ÷ (primary fruit-handling behaviour) (Luck and Daily 2003). Visitation time was the total amount of time that an individual spent in the tree from arrival and departure. Fruit-handling behaviour was weighted as follows: swallowers = 1, mashers = 2, biters = 3. This assumes that swallowers collect and disperse the most seeds.

Results

Fruit abundance

Mean fruit abundance of focal trees differed significantly among landscape contexts (Fig. 3), with the highest number being recorded at NH sites. Further, fruit abundance was correlated with the number of individuals (Spearman's rho=0.045, p=0.035) and no. of visits per hour (Spearman's rho=0.048, p=0.024), but not with species richness or total time spent on the fig.

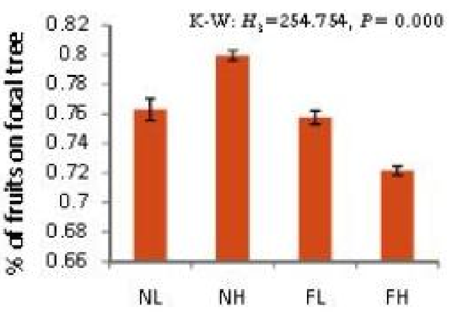


Fig. 3: Differences in fruit abundance in the four different landscape contexts.

Species Richness, Composition and Evenness

We recorded a cumulative total of 67 species using *Ficus* trees for perching, nesting or foraging. We recorded 34 species from NL contexts, 45 species from NH, 31 species from FL, and 50 species from FH contexts. Sample based accumulation curves flattened out for FL contexts, but showed a gradual increase for FH and NH. The number of samples was much lower for NL sites (n=8), but the curve was almost identical to that of NH (Fig. 4). Mean species richness did not differ among the four agricultural contexts (ANOVA F=0.793, p=n.s.) (Fig. 6). Species evenness was highest for NL sites (0.73), relatively consistent among other landscape contexts (Fig. 6). We did not consider Brillouin index values (constrained between 0 and 1) to be appropriate for standard statistical tests. We plotted bootstrap and jack-knife estimates of species richness across all *Ficus* in each landscape context and compared these with pooled observed species richness (Fig. 5). The extent of underestimation of species richness varied between contexts. In NL sites, observed species richness was 34 compared to bootstrap and jack-knife estimates (mean ± 1 SD) of 38.56 ± 2.17 and 43.63 ± 4.17 respectively. The values in NH sites were 45 vs. 50.58 ± 0.81 and 57.35 ± 2.85; in FL sites they were 31 vs. 33.82 ± 0.91 and 37.42 ± 2.12; in FH they were 51 vs. 56.31 ± 1.77 and 63.22 ± 5.06. The greatest underestimation was in high agricultural intensity sites (NH and FH).

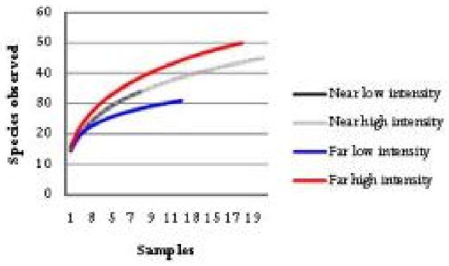


Fig. 4: Sample-based species accumulation curves for different landscape contexts. Shows: (1) NL, 8 samples, 34 species; (2) NH, 20 samples, 45 species; (3) FL, 12 samples, 31 species; (4) FH, 18 samples 50 species.

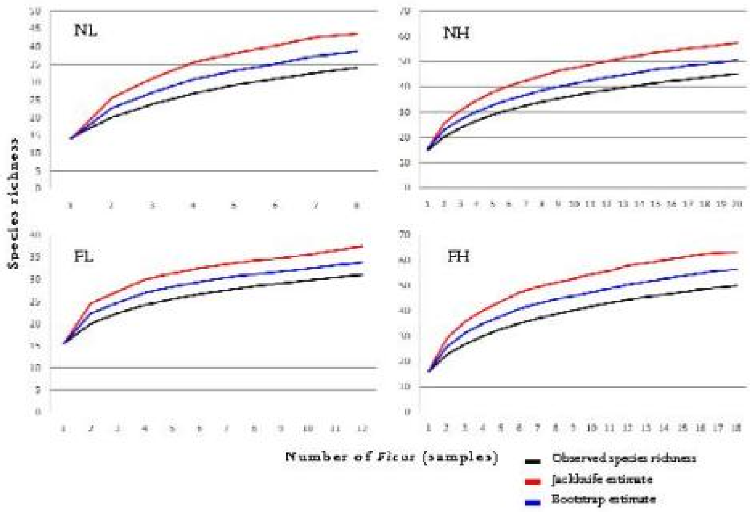


Fig. 5: The relationship between species richness and number of *Ficus* sampled in each landscape context. Species curves show observed species richness and bootstrap and jack-knife estimates.

Visitation Rate, Foraging Behaviour and Body Mass

Both the number of individuals on a particular *Ficus* and the visitation rate (i.e. number of visits per hour) were correlated with fruit abundance on a tree. Mean number of individuals on a tree differed significantly among the landscape contexts (ANCOVA F_4=5.641, p=0.000), being highest in NL sites (mean=10.17, SE=0.95). Similarly, visitation rates during the 3-h observation period also differed among landscapes (ANCOVA F_4= 5.720, p=0.000). Visitation rates were highest for NL sites (mean=3.35, SE=0.31), and lowest for FH (mean=2.59, SE=0.18) (Fig. 6). The number of minutes spent per tree was significantly higher in NL sites (Kruskal-Wallis H=15.165, p=0.002), but for other landscape contexts the multiple comparisons test did not indicate clear differences and confidence intervals overlapped (Fig. 6). Subsequently, the number of fruits consumed per visit was also significantly higher in NL landscape contexts (Kruskal-Wallis H =34.072, p=0.000). Multiple comparisons showed no difference between NH and FL sites, but FH landscape contexts were different from the rest (Fig. 6)

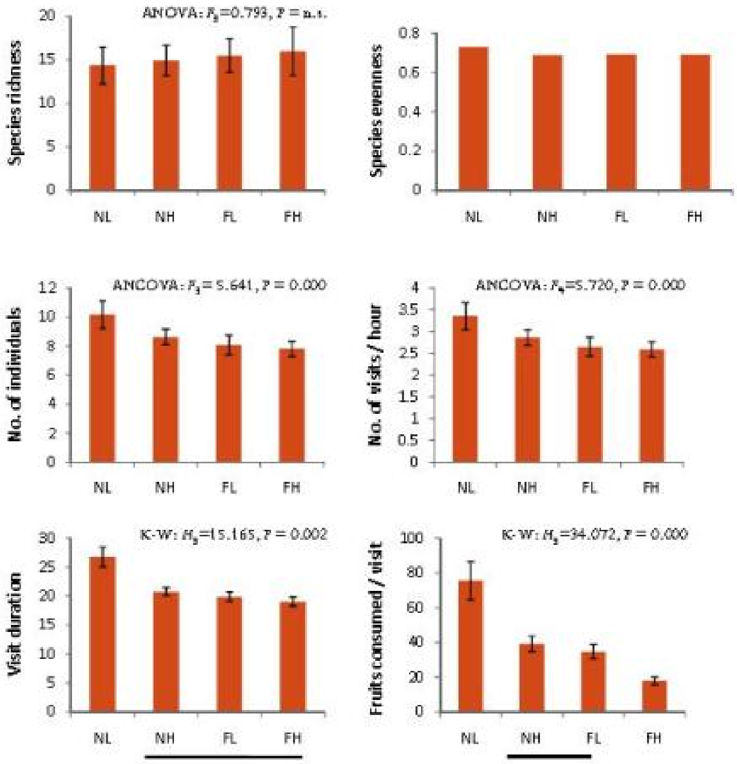


Fig. 6: Differences among landscape contexts (values in legend are 95% confidence intervals; values in panels are mean + 1 SE) for: (a) species richness; (b) species evenness; (c) number of individuals; (d) number of visits per hour; (e) number of minutes spent in tree per visit; (f) fruits consumed per visit. Values sharing the same level of underlining are not significantly different (the multiple comparison test did not indicate clear differences among contexts for number of individuals).

The proportion of individuals from each fruit-handling category also differed significantly among contexts (Kruskal- Wallis H3=32.333, p=0.000). In the FH sites, there were a greater proportion of biters and fewer gulpers.

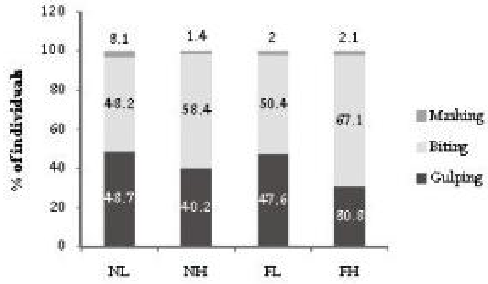


Fig. 7: Proportion of individuals of each fruit-handling category in the four different landscapes contexts.

Individual Species

Based on the mean number of visits per tree across all landscape contexts, the three most common visitors to *Ficus*, in decreasing order, were the Yellow-footed Green Pigeon, Jungle Myna, and Chestnut-tailed Starling (Table 1). A majority of the most common species were either in the pigeon, starling, barbet or bulbul guilds.

Visitation rates differed significantly among landscape contexts for only a few of species. Visits by Blue-eared Barbets were highest in NL sites, showing a gradual decline with distance from forest; their numbers were lowest in FH sites. The Great Hornbill was another other species that showed a similar clear-cut pattern: all records of these large frugivores were in NL landscape contexts; with no individuals being found elsewhere (ANOVA was not computed as there were records in only one category). The Hill Myna also displayed a similar decline in number of visits as distance increased.

Table 1: The number of visits per tree in each landscape context for bird species recorded taking fruit.

		Total no. of visits	NL Mean	SE	NH Mean	SE	FL Mean	SE	FH Mean	SE	P-value
1	Yellow-footed Green Pigeon	83.73	29.48	7.50	24.54	3.81	17.16	3.60	16.72	2.78	n.s.
2	Jungle Myna	47.46	15.21	2.82	11.04	1.34	17.88	4.67	14.02	2.20	n.s.
3	Chestnut-tailed Starling	34.75	11.03	2.34	12.27	2.12	12.95	1.98	10.93	2.03	n.s.
4	Red-vented Bulbul	34.31	5.69	1.04	8.49	1.18	7.93	0.86	8.19	1.66	n.s.
5	Common Myna	24.29	8.74	1.81	9.67	1.63	10.42	1.72	9.22	1.63	n.s.
6	Asian Pied Starling	23.42	11.08	3.64	12.92	2.50	11.09	2.09	8.05	1.32	n.s.
7	Coppersmith Barbet	15.56	5.11	1.27	4.78	0.70	3.67	0.60	4.14	0.62	n.s.
8	Thick-billed Green Pigeon	7.97	20.14	12.01	11.13	2.43	6.15	1.28	9.43	3.23	n.s.
9	Spot-winged Starling	6.46	0.00	0.00	9.50	2.35	7.40	3.25	24.36	7.36	n.s.
10	Red-whiskered Bulbul	6.27	24.33.	5.50	8.00	4.51	11.83	9.28	4.80	1.46	n.s.
11	Blue-throated Barbet	5.39	4.27	1.51	1.78	0.17	3.20	0.58	1.20	0.17	n.s.
12	White-vented Myna	4.54	7.88	1.94	3.89	0.43	2.80	0.49	5.83	1.27	0.011*
13	Oriental White-eye	3.49			10.75	4.21	7.17	1.89	17.14	6.14	n.s.
14	Rufous Treepie	3.17	2.43	0.34	1.60	0.12	1.48	0.11	1.84	0.26	n.s.*
15	Lineated Barbet	2.98	3.91	1.43	2.41	0.38	2.15	0.35	1.75	0.18	n.s.
16	Hill Myna	2.68	9.17	1.99	3.53	0.76	2.00	0.00	6.00	1.30	0.019
17	Green Imperial Pigeon	1.97	3.67	0.88	2.67	0.44	3.05	0.70	1.89	0.20	n.s.
18	Blue-eared Barbet	1.93	9.14	2.19	2.17	0.42	2.13	0.40	1.15	0.67	0.007*
19	Asian Koel	1.71	1.30	0.21	1.29	0.09	1.73	0.14	1.36	0.11	n.s.
20	Oriental Pied Hornbill	1.59	2.33	0.33	2.28	0.28	2.36	0.36	1.86	0.26	n.s.
21	Large-billed Crow	1.29	1.57	0.43	1.63	0.18	1.56	1.00	2.11	0.44	
22	Pompadour Green Pigeon	1.24	0.00	0.00	4.80	2.36	0.00	0.00	24.50	5.50	
23	Spotted Dove	0.51	0.00	0.00	1.50	0.29	1.80	0.37	1.54	0.10	
24	Oriental Magpie-robin	0.36	1.00	0.00	1.50	0.50	1.00	0.00	1.10	0.10	
25	Great Hornbill	0.34	4.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	
26	Common Iora	0.32	0.00	0.00	3.00	0.41	0.00	0.00	2.33	0.00	
27	Great Tit	0.25	1.00	0.00	1.50	0.29	2.00	0.00	3.00	1.00	
28	Black-hooded Oriole	0.20	0.00	0.00	1.00	0.00	1.00	0.00	1.67	0.17	
29	Common Tailorbird	0.17			2.00	0.58			2.00	0.00	
30	Fulvous-breasted Woodpecker	0.12			1.00	0.00	1.00	0.00	2.00	1.00	

*Indicates Kruskal-Wallis H test; all other tests are ANOVA

Seed Dispersal

When fruit-handling behaviour across all *Ficus* species is pooled to derive a seed dispersal index, Yellow-footed Green Pigeons emerge as the most effective quantitative disperser of *Ficus* seeds in the landscape (Table 2). The next four species include two species of Barbets (Coppersmith and Blue-throated) and Mynas (Jungle and Common). Whilst both Common and Jungle Mynas had greater number of visits on fruiting figs, Coppersmith Barbets scored higher than them on the dispersal index as their fruit handling behaviour was more efficient (i.e. swallowing). In fact, most of the species that scored high on the dispersal index belonged to either one of the three obligate frugivore families: Capitonidae (Barbets), Bucerotidae (Hornbills), Columbidae (Pigeons). Great Hornbills scored the highest for number of fruits consumed per visit; however their overall score in seed dispersal within the landscape context was low as there were very few records of this species in the non-reserve matrix (whilst they were common in the remnant semi-evergreen forest patch).

Table 2: Data on frugivory and *Ficus* dispersal index for each bird species; fruit handling category based on mode for records across all *Ficus* species pooled together (mode taken only when differences in fruit-handling significant)

	Species	Fruit handling	Obligate Frugivore Family	Adjusted total number of visits*	No. of fruits consumed per visit	Dispersal Index
1	Yellow-footed Green Pigeon	Swallower	Yes	4146.071	36.84	152759.88
2	Coppersmith Barbet	Swallower	Yes	803.25	24.97	20059.67
3	Jungle Myna	Biter	No	2550	11.87	10086.17
4	Common Myna	Biter	No	1305.057	21.90	9527.32
5	Blue-throated Barbet	Swallower	Yes	266.89	29.93	7988.51
6	Chestnut-tailed Starling	Biter	No	1830.36	12.88	7856.74
7	Thick-billed Green Pigeon	Swallower	Yes	151.07	46.78	7067.15
8	Red-vented Bulbul	Biter	No	1879.43	9.56	5990.45
9	Lineated Barbet	Swallower	Yes	119.43	45.16	5393.04
10	Asian Pied Starling	Biter	No	1110.54	9.00	3330.08
11	Oriental Pied Hornbill	Swallower	Yes	45.32	63.08	2858.89
12	Green Imperial Pigeon	Swallower	Yes	43.5	46.76	2033.85
13	Blue-eared Barbet	Swallower	Yes	32.57	59.85	1949.50
14	Rufous Treepie	Biter	No	153.61	22.00	1126.52
15	White-vented Myna	Biter	No	157.93	19.64	1033.91
16	Red-whiskered Bulbul	Biter	No	118.93	14.64	580.27
17	Hill Myna	Biter	No	50.79	23.01	389.54
18	Asian Koel	Biter	No	48.69	20.92	339.63
19	Spot-winged Starling	Biter	No	95.25	10.16	322.43
20	Great Hornbill	Swallower	Yes	1.07	153.85	164.84

*Adjusted for proportion of focal trees visited

Comparison of *Ficus benghalensis* and *Ficus religiosa*

Species richness, evenness were higher on *F. religiosa* than *F. benghalensis*, but differences were not significant (Fig. 8). Similarly, the number of individuals and visitation rate were higher on *F. religiosa*, but differences were not significant. However, time spent on *F. benghalensis* was greater than on *F. religiosa*, and differences were significant (Mann-Whitney

U = 581890.5, p=0.005). However, fruits consumed per visit was greater in *F. religiosa* than on *F. benghalensis* (Mann-Whitney U=10694.00, p=0.000).

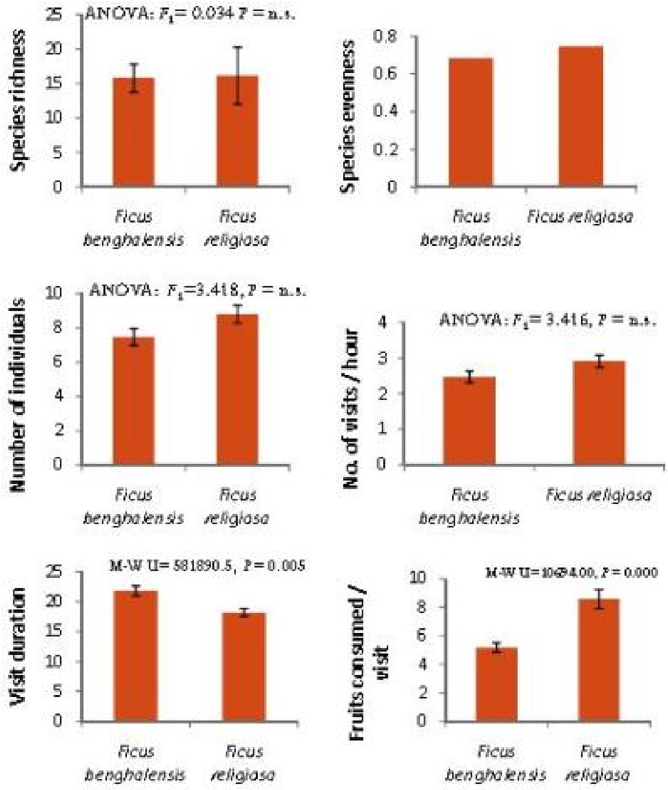


Fig. 8: Differences among two *Ficus* species (values in legend are 95% confidence intervals; values in panels are mean + 1 SE) for: (a) species richness; (b) species evenness; (c) number of individuals; (d) number of visits per hour; (e) number of minutes spent in tree per visit; (f) fruits consumed per visit.

At a species-level resolution, most species exhibited a similar trend of consuming more *F. religiosa* fruits as opposed to *F. benghalensis* (Table 4). As a consequence, the dispersal index for most *frugivores* was higher for *F. religiosa* than *F. benghalensis*. A case in point is the Yellow-footed Green Pigeon, which had greater number of visits on *F. benghalensis* but consumed far more fruits on *F. religiosa*. As a result, its dispersal index was higher on *F. religiosa*. Few species had a greater dispersal index on *F. benghalensis* than *F. religiosa* (Lineated Barbet, Oriental Pied Hornbill, Thick-billed Green Pigeon, Green Imperial Pigeon), but this was because the number of visits were greater on *F. benghalensis*.

Several small-bodied species swallowed more *F. religiosa* fruit as opposed to *F. benghalensis* (Table 3). This suggests that larger-bodied species may be more effective in dispersing seeds of *Ficus* with larger synconia. This is illustrated by the Lineated Barbet, which ranked #9 as a seed disperser overall for all *Ficus* behind other smaller bodied species of the same guild (Coppersmith Barbet, Blue-throated Barbet); however, it was among the top dispersers for *F. benghalensis* (ranked #5, ahead of Coppersmith ranked #7, and Blue-throated #10) (Table 4). This was because Lineated Barbets swallowed more fruits on *F. benghalensis* than Blue-throated or Coppersmith.

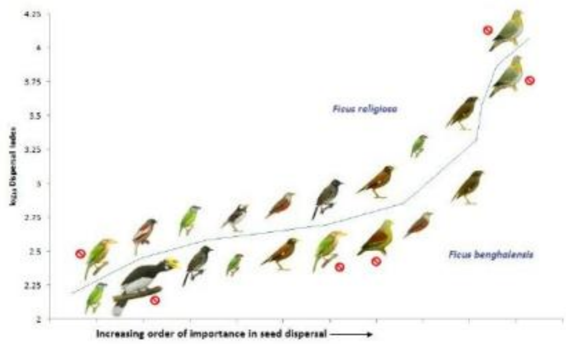
Table 3: Data on frugivory and dispersal index for each bird species on *F. benghalensis* and *F. religiosa*.

Species	Adjusted no. of visits		No. of fruits consumed per visit		Dispersal Index		Swallowing		Biting		Exact Chisqu-are	P
	Bengh.	*Rel.*	*Bengh.*	*Rel.*	*Bengh.*	*Rel.*	*Bengh.*	*Rel.*	*Bengh.*	*Rel.*		
Yellow-footed Green Pigeon	1395.20	915.20	6.38	14.27	8894.40	13056.88	74.40%	93.00%	23.20%	7.00%	7.883	0 .009
Jungle Myna	805.50	1097.25	2.78	2.71	745.84	2971.68	6.80%	57.40%	90.50%	39.30%	44.318	0.000
Coppersmith Barbet	190.40	270.75	4.06	6.19	257.83	1676.08	28.60%	78.10%	71.40%	21.90%	29.632	0.000
Common Myna	479.70	538.20	2.00	5.13	319.80	919.43	4.40%	35%	93.30%	63.50%	14.606	0.000
Red-vented Bulbul	380.70	931.95	2.00	2.67	253.80	828.41	1.50%	16.70%	96.90%	80.60%	10.142	0.002
Chestnut-tailed Starling	699.55	548.10	1.86	3.80	433.045	694.26	4.40%	11.30%	90.70%	88.70%	1.382	0.633
Asian Pied Starling	128.80	876.85	2.00	1.60	85.87	467.65	3%	1.8%	93.50%	98.20%	2.186	0.444
Blue-throated Barbet	86.70	52.00	4.38	6.26	126.44	325.69	32.60%	75.00%	65.20%	19.40%	17.569	0.000
Rufous Treepie	63.20	49.30	3.31	6.00	69.78	295.80	14.30%	65.50%	85.70%	27.60%	24.922	0.000
Lineated Barbet	44.80	14.00	7.27	11.60	325.82	162.40	61.50%	86.70%	34.60%	13.30%	2.860	0.199
Oriental Pied Hornbill	15.75	8.05	11.56	30.75	182.00	123.77	84.60%	80.00%	15.40%	20.00%	0.084	1.000
White-vented Myna	88.20	40.70	3.25	5.14	95.55	104.66	4.30%	37.50%	91.30%	50.00%	8.487	0.009
Thick-billed Green Pigeon	86.80	8.80	9.11	15.17	395.42	66.73	45.50%	85.70%	54.50%	14.30%	3.480	0.093
Asian Koel	27.00	11.70	2.50	6.00	22.50	35.10	11.10%	68.80%	81.50%	31.20%	14.581	0.000
Blue-eared Barbet	1.35	4.75	10.00	10.60	9.00	33.57	20.00%	66.70%	80.00%	33.30%	2.396	0.242
Spot-winged Starling	20.25	28.00	3.00	2.75	30.38	25.67	25.50%	11.10%	75.00%	88.90%	0.410	1.000
Red-whiskered Bulbul	6.00	56.35	4.00	1.00	12.00	18.78	16.70%	9.10%	83.30%	90.90%	0.215	1.000
Green Imperial Pigeon	19.00	2.80	7.50	10.20	71.25	14.28	66.70%	71.40%	33.30%	28.60%	0.053	1.000
Large-billed Crow	25.85	1.35	4.00	3.00	34.47	4.05	23.80%	100%	66.70%	0%	8.466	0.030
Hill Myna	37.50	1.20	3.29	2.00	61.61	0.80	30.80%	0%	61.50%	100%	1.857	0.630
Pompadour Green Pigeon	10.95	0	2.33	NA	12.78	NA	0%	NA	100%	NA	Not computed	

Table 4: Showing dispersal index ranks of *frugivores* on *F. benghalensis* and *F. Religiosa*

Species	Body Mass	Dispersal Rank	Species	Body Mass	Dispersal Rank
		Ficus benghalensis			*Ficus religiosa*
Yellow-footed Green Pigeon		1	Yellow-footed Green Pigeon		1
Jungle Myna	94	2	Jungle Myna	94	2
Chestnut-tailed Starling	44	3	Coppersmith Barbet	47	3
Thick-billed Green Pigeon	151	4	Common Myna	138	4
Lineated Barbet	170	5	Red-vented Bulbul	45	5
Common Myna	138	6	Chestnut-tailed Starling	44	6
Coppersmith Barbet	47	7	Asian Pied Starling	82	7
Red-vented Bulbul	45	8	Blue-throated Barbet	100	8
Oriental Pied Hornbill		9	Rufous Treepie	128	9
Blue-throated Barbet	100	10	Lineated Barbet	170	10
White-vented Myna		11	Oriental Pied Hornbill		11
Asian Pied Starling	82	12	White-vented Myna		12
Green Imperial Pigeon		13	Thick-billed Green Pigeon	151	13
Rufous Treepie	128	14	Asian Koel	190	14
Hill Myna	126	15	Blue-eared Barbet	38	15

Species	Body Mass	Dispersal Rank	Species	Body Mass	Dispersal Rank
		Ficus benghalensis			*Ficus religiosa*
Large-billed Crow	626	16	Spot-winged Starling	47.5	16
Spot-winged Starling	47.5	17	Red-whiskered Bulbul	42	17
Asian Koel	190	18	Green Imperial Pigeon		18
Pompadour Green Pigeon	151	19	Large-billed Crow	626	19
Red-whiskered Bulbul	42	20	Hill Myna	126	20
Blue-eared Barbet	38	21	Pompadour Green Pigeon	151	21



Dispersal indices for the ten most important seed dispersers of *Ficus benghalensis* (larger fruit) and *Ficus religiosa* (smaller fruit) in the agricultural landscape. Larger-bodied species are more important for dispersing seeds of *Ficus benghalensis*. Red marks indicate species on which hunting pressures are locally high.

Objective 2: Local Objective Perceptions of *Ficus*

The second strand of this project was to examine local perceptions of figs in order to identify potential cultural attributes that may be harnessed to preserve remnant *Ficus* trees in agricultural landscapes. Whilst the cultural value of *Ficus* is well known, proper assessments of how these values may inform conservation are lacking. This research focused on the following interrelated questions:

(1) What is the value of *Ficus* in comparison with other tree species grown in agricultural landscapes?

(2) What are local cultural values and uses associated with *Ficus* trees? Do they vary between species, the age and location of trees?

(3) To what extent do cultural features influence people to let *Ficus* trees remain in agricultural landscapes?

(4) What is peoples' knowledge of the ecological role of *Ficus* as a food source for frugivores?

Methods

Questionnaire Design

We initially conducted in depth semi-structured interviews with residents within the local community to explore local perceptions of figs (Browne-Nuñez and Jonker 2008). This involved asking people what they thought about *Ficus* trees, the number of species they recognized, the uses and values associated with them. These interviews were later analyzed to identify key themes and patterns (Ryan and Bernard 2003), and a structured questionnaire was designed thereafter. The questions were translated into Assamese and then back translated by an independent translator in order to test the linguistic appropriateness of the survey instrument. The initial item pool was made as broad as possible and the questionnaire was tested through a pilot run. Weak and poorly-defined items were removed and the set of questions reorganized to maintain flow.

The final questionnaire 17 items organized into the following sections:

1. Attributes of *Ficus* and frugivores: one question on the number of *Ficus* species people recognized, three questions on the biology of *Ficus*, and two questions on *frugivory*.

2. Values and Uses associated with *Ficus*: included one question asking people to list the trees they had in their home gardens, those that were planted and those that were there from before or had grown on their own, two questions on the social and religious values of *Ficus*, and one question on their uses.

3. Conservation of *Ficus* and frugivores: included three questions on the threats to *Ficus* and frugivores, one question on why *Ficus* remains in the agricultural landscape, and three questions on how *Ficus* trees should be conserved in the landscape.

Data Collection

The questionnaire was administered between April 2010 and October 2010. The study was restricted to the Assamese, Hindu-speaking community as they were the most prominent social group in the area. A household was randomly selected in a village and subsequently every third house on the right from there onward was sampled. Only individuals above the age of 18 were interviewed. The objectives of the study were explained beforehand and individuals were asked to either fill in the questionnaires or, as was more often the case, respond to the questions verbally (about 90% of the responses). Clarifications were made if individuals were unsure what a question meant. All interviews were conducted in Assamese, and as the interviewers were native speakers of the language, interpreters were not used. On average, each questionnaire took about 1-1.5 hours to complete. A total of 278 questionnaires (n=278) was completed. The overall response rate was 90% as it was a direct household interview.

Some individuals did not take part in the survey due to issues of time and availability. A majority of the respondents were male (89.5%; n=247) as our sampling was generally through households and men are the general spokespersons in the community. The mean age of the respondents was 37 years (range from 18 to 95). Average monthly income ranged from none to Rs. 15,000 (mean monthly income Rs. 4,700). The average education of the respondents was 9 years (ranging from no education to 17 years). None of these variables were normally distributed (Kolmogorov Smirnov Z test), and hence non-parametric statistics were used in further analysis.

Results

What are the most valuable trees in your garden?

A total of 58 different trees were mentioned by respondents (Table 5). Tree species were then ranked using a simple score (Number of times mentioned ÷ Total number of respondents). Mango scored the highest (0.71), followed by Jackfruit (0.53), Teak (0.42), Coconut (0.32) and Betelnut (0.31). All these species are valuable either for their fruit or timber. *Ficus* scored low: *Ficus religiosa* had a score of 0.04, followed by *F.benghalensis* (0.02), *F.virens* (0.01) and *F.racemosa* (0.01). This shows that the overall value people attach to *Ficus* in comparison to other trees is low. Amongst respondents who mentioned *Ficus* trees, 58% said that *F.religiosa* was present in their garden from before and that they did not plant them. For other *Ficus* species, all the *F.benghalensis* (100%), 80% of *F.rutusa*, and 40% of *F.racemosa* were either present from before or had grown on their own, i.e. they were not planted.

Table 5: Trees present in peoples' gardens. *Ficus* marked in bold.

	Species	Family	Local Name	Rank		Species	Family	Local Name	Rank
1	*Mangifera indica*	Anacardiaceae	Aam	0.712	30	*Averrhoa carambola*	Averrhoaceae	Kordoi	0.043
2	*Artocarpus heterophyllus*	Moraceae	Kathal	0.529	31	*Mesua ferrea*	Clusiaceae	Nahor	0.043
3	*Tectona grandis*	Verbenaceae	Segun	0.424	32	*Tamarindus indica*	Caesapiniceae	Teteli	0.043
4	*Cocos nucifera*	Aracaceae	Narikol	0.317	33	*Aegle marmelos*	Rutaceae	Bel	0.040
5	*Areca catechu*	Aracaceae	Tamul	0.306	34	*Terminalia arjuna*	Combretaceae	Arjun	0.036
6	*Gmelina arborea*	Verbenaceae	Gamari	0.284	35	*Citrus reticulate*	Rutaceae	Kamala	0.036
7	*Psidium guajava*	Myrtaceae	Madhuri	0.183	36	*Annona squamosa*	Annonaceae	Atlas	0.032
8	*Cedrela toona*	Meliaceae	Poma	0.137	37	*Cinnamomum tamala*	Lauraceae	Tezpat	0.029
9	*Syzigium spp.*	Myrtaceae	Jamu	0.129	38	*Mimusops elengi*	Sapotaceae	Bokul	0.025
10	*Musa spp.*	Musaceae	Kol	0.115	39	*Azardieachta indica*	Meliaceae	Maha Neem	0.025
11	*Melia azedeaeach*	Meliaceae	Neem	0.112	40	*Citrus grandis*	Rutaceae	Robab Tenga	0.025
12	*Zizyphus mauritiana*	Rhamnaceae	Bogori	0.108	41	*Ficus benghalensis*	Moraceae	Bor	0.022
13	*Aquilaria agallocha*	Thymeleaceae	Sasi	0.108	42	*Baccaurea remiflora*	Euphorbiaceae	Leteku	0.022
14	*Terminalia chebula*	Combretaceae	Xilikha	0.101	43	*Alstonia scholaris*	Apocynaceae	Satiyona	0.022
15	*Cassia fistula*	Caesalpiniaceae	Xonaru	0.086	44	*Ficus racemosa*	Moraceae	Dimoru	0.018
16	*Lagestroemia flosreginae*	Lythraceae	Aazar	0.083	45	*Ficus virens*	Moraceae	Jori	0.018
17	*Citrus spp.*	Rutaceae	Nemu	0.079	46	*Artocarpus chama*	Moraceae Sam	Kothal	0.018
18	*Albizia procera*	Mimosaceae	Koroi	0.076	47	*Shorea robusta*	Dipterocarpaceae	Sal	0.014
19	*Phyllanthus emblica*	Euphorbiaceae	Aamlakhi	0.061	48	*Dysoxylum binectifarium*		Bandordima	0.011
20	*Litchi chinensis*	Sapindaceae	Lesu	0.061	49	*Hedyotis diffusa*	Rubiaceae	Bon Jaluk	0.011
21	*Elaeocarpus floribundus*	Elaeocarpaceae	Jalphai	0.058	50	*Adina oligocephala*	Rubiaceae	Halodhi Sopa	0.011
22	*Bambusa spp.*	Poaceae	Bah	0.054	51	*Streblus asper*	Moraceae	Houra	0.011
23	*Dalbergia sissoo*	Papilionaceae	Sissoo	0.054	52	*Pithecellobium monadephum*	Mimosaceae	Moj	0.011
24	*Michelia baillonii*	Magnoliceae	Tita Sopa	0.054	53	*Moringa oleifera*	Moringaceae	Sajina	0.011
25	*Cordia dichotoma*	Ehretiaceae	Bowal	0.050	54	*Litcea monopetala*	Lauraceae	Xowalu	0.011
26	*Anthocephalus cadamba*	Rubiaceae	Kadam	0.047	55	*Bischofia javanica*	Euphorbiaceae	Oriam	0.007
27	*Bombax ceiba*	Bombacaceae	Ximolu	0.047	56	*Santalum album*	Santalaceae	Boga Chandan	0.004
28	*Ficus religiosa*	Moraceae	Ahot	0.043	57	*Palaquium obovatum*	Sapotaceae	Kathaluwa	0.004
29	*Tetremelos nodiflora*	Datiscaceae	Bhelou	0.043	58	*Garcinia Morella*	Clusiaceae	Kuji Thekera	0.004

Ficus species recognized by people

Four different *Ficus* species were most frequently mentioned by people: *Ficus religiosa* (local name Ahot), *Ficus benghalensis* (local name Bor), *Ficus virens* (local name Jori) and *Ficus racemosa* (local name Dimoru). Ability to recognize *Ficus* species differed between species (Cochran's Q=22.73, df=3, p=0.000), with fewer people recognizing *F.virens* than the other three prominent figs present in the landscape (Fig. 9). The category "*Ficus*" or "fig" was absent in the local terminology. People grouped these trees as "species related to *F.benghalensis* or *F.religiosa*". This suggests that future conservation strategies in the area need to use ethno categories that at least convey the meaning of scientific terminology, rather than imposing additional categories that may not be meaningful or to which people might not be able to directly relate.

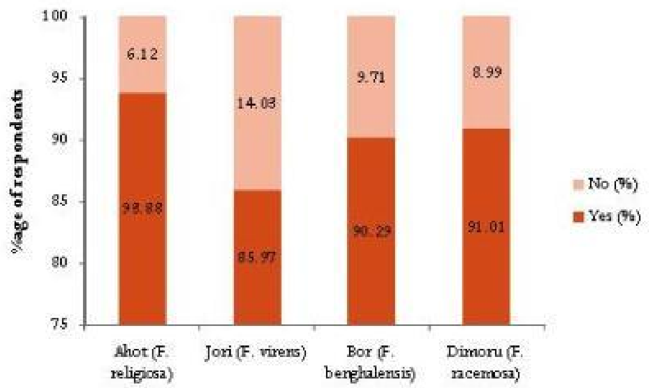


Fig. 9: *Ficus* species recognized by respondents; fewer respondents recognized *F.virens*.

Values associated with *Ficus*

Responses to the question "Do *Ficus* trees have any value?" showed that 70% (n=191) felt that these trees had some value, whilst 30% (n=82) said they didn't. A range of values and uses were associated with these trees, including religious value, use as firewood and timber, fodder for cattle, as food for birds or animals and social / community benefits (Fig. 2). The most frequent value associated with *Ficus* was religious, accounting for 46% of the responses (n=129). Religious values included use of some part of the fig in religious ceremonies or were innate religious attributes of trees (place for spirits, as shrines, etc). This was followed by social values or community benefits such as markers of place, resting space, etc. (6.47%; n=18), and as fodder for cattle (5.76%; n=16). Differences between the values mentioned were significant (Cochran's Q=5.65, df=7, p=0.000).

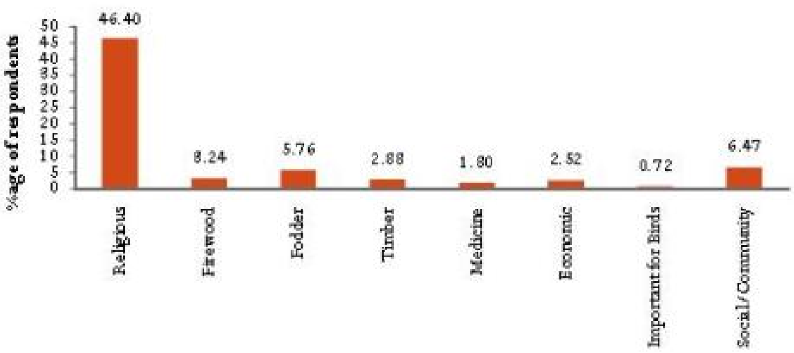


Fig. 10: Values and uses associated with *Ficus*; religious values were the main feature.

More people attributed religious values to *F.religiosa* (91%; n=253) (Fig. 11). This was followed by *F.benghalensis* (87%; n=241) and *F.virens* (83%; n=231). Religious attributes were lowest for *F.racemosa* (67%; n=185). Differences in religious values for different species was significant (Cochran's Q=1.03, df=3, p=0.000). Similarly, *F.racemosa* scored low for social / community values (18%; n=51), when compared to other *Ficus* species. Social values ascribed to different *Ficus* species was also significant (Cochran's Q=1.07, df=3, p=0.000). However, there were no differences amongst *Ficus* species in terms of their use as cattle fodder (Cochran's Q=0.00, df=3, p=1.00).

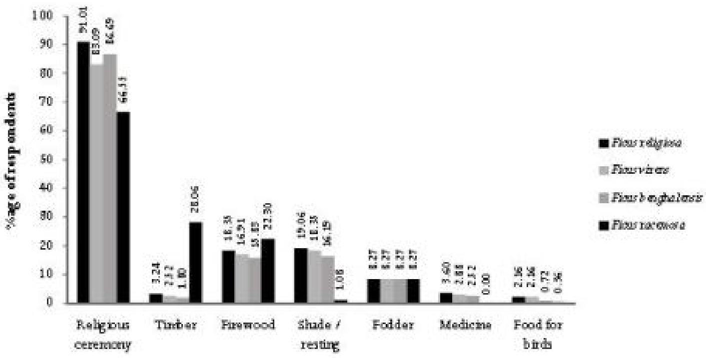


Fig. 11: Values and uses associated attributed to four different *Ficus* species.

Responses to the question "Do *Ficus* trees have religious value?" showed that 96% (n=269) thought they did. Most respondents said this was valid for all *Ficus* trees (71.58%; n=199). Others mentioned specific localities: *Ficus* associated with temples (245; n=67), those in villages (5.40%; n=15) and trees by the roadside (5.04%; n=14). Differences in the mention of these localities were significant (Cochran's Q=78.77, df=2, p=0.000), with temple trees scoring higher than villages or trees by the roadside lends to their religious value.

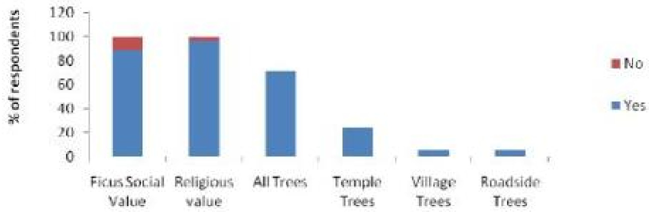


Fig. 12: Do *Ficus* trees have religious value? If so, which trees?

Further, we mapped 473 individual *Ficus* trees belonging to 7 different species in the study landscape, and divided these into quintiles on the basis of their DBH (see next section under Objective 3). Of these, 64 trees had shrines or temples associated with them. There was a significant difference in the proportion of shrines in each DBH category: trees with higher DBH (Quintiles 4 and 5) had a greater proportion of trees, whereas those with smaller DBH had fewer trees (Table 6). Similarly, there were a greater proportion of shrines or temples on *F. Benghalensis*, *F. Religiosa* and *F. Virens* than other *Ficus* species (Table 6), and this supports questionnaire findings that people attribute greater religious values to *F. Benghalensis* and *F. Religiosa* than other species. Moreover, *F. Benghalensis* trees that were used as shrines had a larger DBH than those that did not (Table 7). *F. Virens* exhibited a similar trend, where trees with shrines were considerably larger than those without. Mean DBH of *F. Religiosa* with shrines were slightly larger than those without, but differences were not significant.

Table 6: Distribution of shrines according to *Ficus* (1) DBH and (2) species; +++=over-abundant, *P*<0.001; *=under-abundant, *P*<0.01; **=under-abundant, *P*<0.01.**

	All individuals (n=473)	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5		
Religious shrine present[1]	64	S**	13	11	17++	18++		
		F.benghalensis	*F. elastica*	*F. religiosa*	*F. benjamina*	*F. racemosa*	*F. rutusa*	*F. virens*
Religious shrine present[2]	64	18+++	1***	23+++	1***	-	4***	17+++

1Chi-square= 11.488, df=4, *p*=0.020; 2Chi-square=44.750, df=5, *p*=0.000

Table 7: Comparisons of DBH of *Ficus* trees with and without shrines.

Species	Shrine Absent			Shrine Present			t	P value
	N	Mean DBH	SE	N	Mean DBH	SE		
Ficus benghalensis	48	3.50	0.23	18	4.71	0.65	-2.238	0.029*
Ficus religiosa	113	3.09	0.13	23	3.72	0.37	-1.865	0.064
Ficus virens	155	3.38	0.17	17	5.09	0.55	-3.003	0.003***

Perceptions of Frugivory

People were well aware of the role of birds and mammals in the dispersal of *Ficus* seeds, with 62.3% (n=173) saying that they aid in seed dispersal (Fig. 13). A large number of people however said that only birds were involved and not mammals (20.86%; n=58). Further, people were well aware of the different frugivores feeding on *Ficus*, and most people were able to pinpoint the key guilds that feed on *Ficus* in the landscape (Fig. 14). Most people (62.59%; n=174) mentioned Green Pigeons (*Treron* spp), which was also the commonest *frugivore* recorded in the landscape (Table 2; preceding section). Barring parakeets which scored high on the number of times mentioned by people (22.30%; n=62), all other groups mentioned were commonly found feeding on figs in the landscape.

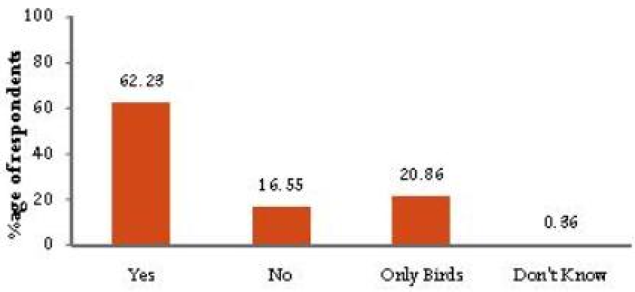


Fig. 13: Do birds and animals aid in the dispersal of *Ficus* seeds?

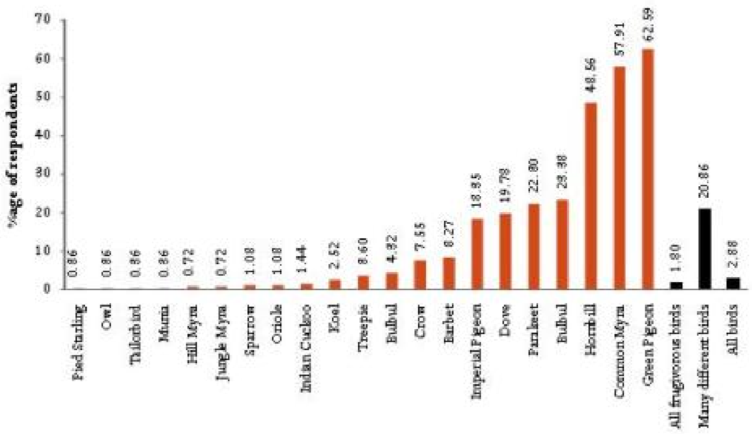


Fig. 14: Which birds feed on fruiting *Ficus*?

Objective 3: Threats to Objective figs and frugivores

In order to identify and assess threats to figs and frugivores in the landscape, we adopted a mixed methods approach, drawing from both ecological and social survey data. To gain insights on potential factors that might affect *Ficus* and frugivore declines, we focused on the following questions:

(1) To what extent does land use intensity affect the distribution of *Ficus* trees in a human-dominated landscape?

(2) What reasons do people attribute to *Ficus* remaining in such landscapes? What are the perceived threats to *Ficus* trees in the area?

(3) Which frugivores are most frequently hunted?

Methods

Ficus Census

All *Ficus* mature trees within the landscape were systematically searched for on foot along all major roads, in paddy fields, village woodlots, home gardens and tea plantations. We did not count *Ficus* trees at the epiphytic stage as they were extremely abundant and it was difficult to get exact measures of their number. The height, DBH and crown diameter of *Ficus* trees were measured, and their locations marked with a GPS unit. For each tree, the following were recorded: surrounding habitat type and land use intensity (simplified into three distinct matrix types: home gardens, tea plantations and rice paddy), presence / absence of temples, shrines or other structures. These efforts did not locate every *Ficus* in the research area; the smallest DBH are certainly under-represented. Nonetheless, a conservatively estimated Q80% were recorded. The *Ficus* located are considered a mapped, rather than sampled, point pattern.

Questionnaire Surveys

Questions pertaining to why *Ficus* remained in a landscape, perceived threats to *Ficus* and frugivores were evaluated using the questionnaire-based survey instrument described in the preceding section.

Data Analysis

A total of 473 *Ficus* trees were mapped in the landscape, of which the DBH of 437 were calculated. The DBH of some trees were left out due to poor accessibility / difficulty in measuring the base due to dense vegetation. This sample of 437 (n=437) was considered in the final analysis. These trees were grouped into five distinct categories (quintiles), with small trees being considered younger than larger ones (Duvall 2007). Habitat preferences were assessed using χ^2 analysis. Based on the size of each quintile, the expected and observed numbers of *Ficus* per quintile per factor were compared.

Results

Distribution of *Ficus* trees

The mean DBH of the 437 *Ficus* samples was 3.61 (SE=0.10). The number of trees per quintile ranged from 84 to 92 (Table 8). There were no differences in the distribution of different *Ficus* ages in home gardens or in tea estates, where representation of all DBH classes were equal (Table 9). However, in paddy fields older trees (Quintile 5) were under-abundant, and trees in younger classes were over-abundant (Table 10). Paddy fields were also the sites with the highest land-use intensity. This suggests that in paddy fields, mature trees are cut down by people and the ones that grow there are younger trees that are gradually establishing themselves.

Table 8: *Ficus* quintile characteristics.

Quintile	*Ficus* DBH	*Ficus* per Quintile
1	≤1-1.948	87
2	1.949-3.000	92
3	3.001-3.800	89
4	3.801-5.100	85
5	≥5.101	84

Table 9: *Ficus*-habitat associations. Symbols used to indicate statistical significance: +++ = over-abundant, P < 0.001; *=under-abundant, P < 0.001.**

		All individuals (n=473)	FQ1	FQ2	FQ3	FQ4	FQ5
Land use category	Home gardens[1]	164	35	32	43	28	26
	Tea estates[2]	157	20	34	28	39	36
	Paddy fields[3]	80	30+++	20	11	12	7***
Ficus species	*Ficus benghalensis*[4]	66	11	18	14	14	**9**
	Ficus religiosa[7]	136	21	39	39	25	12***
	Ficus racemosa[6]	17	0	3	4	8	2
	Ficus rutusa[7]	38	7	4	1	6	20++
	Ficus virens[8]	172	46	28	28	32	38

[1]Chi-square=5.451, df=4, p=0.244; [2]Chi-square=7.236, df=4, p=0.124; [3]Chi-square= 20.875, df=4, p=0.000; [4]Chi-square=3.545, df=4, p=0.471; [5]Chi-square=20.324, df=4, p=0.0.000; [6]Chi-square=4.882, df=4, p=0.181; [7]Chi-square=28.053, df=4, p=0.000; [8]Chi-square=6.837, df=4, p=0.145

Perceived threats to *Ficus* in the landscape

A range of explanations were given when people were asked why *Ficus* trees remained in the landscape (Fig. 15). Their use in religious ceremonies was the most frequent response (47.12%; n=130), followed by their social value as places of shade or for resting (25.18%; n=70). Respondents also said that figs remained in the landscape because they were inhabited by gods or spirits (12.59%; n=35). Other explanations were more simplistic and direct, e.g. "Because they are preserved by people" (11.87%; n= 34), "Because no one cuts them down" (12.23%; n=34). Overall, the number of people attributing religious reasons for their preservation in the landscape was prominent.

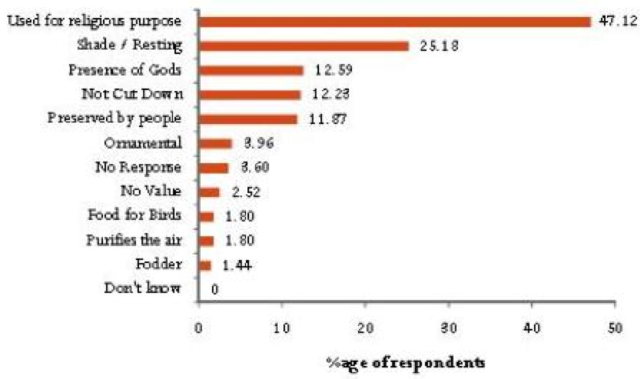


Fig. 15: Why does *Ficus* remain in the landscape?

Most people felt that there were no major threats to *Ficus* saplings (76%; n=205) or to mature trees (74%; n=201). Those who did say there were threats identified animals (mainly goats or cattle) as the major threat to saplings, and wind or storms as a threat to mature trees. Some individuals did mention cutting of trees or weeding out of saplings as reasons, but these were few in comparison.

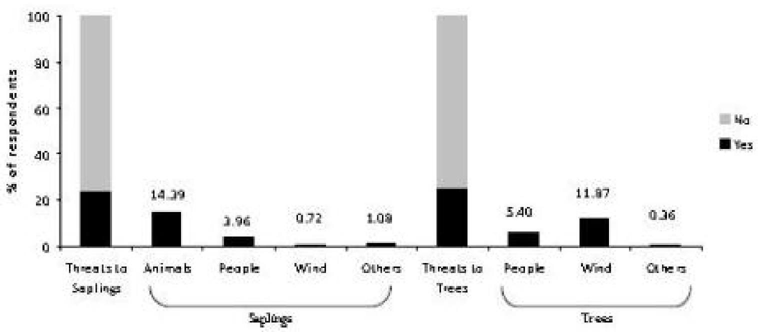


Fig. 16: Are there any threats to *Ficus* in your landscape? If so, what are they?

Fifty-three percent (n=147) of the respondents said they *Ficus* trees, whilst 47% (n=131) said they didn't (Fig. 17). Most people said they either cut branches or plucked leaves from the tree. Less than 1% said they cut the whole tree down or removed saplings. The main reason for plucking leaves was for use in religious ceremonies, whilst branches were cut either to obtain firewood or when there was excessive growth and it interfered with peoples' activities. Such cutting of excessive growth was most prevalent in peoples' home gardens or in paddy fields, and this is reflected by the paucity of older trees in paddy field habitats. The large number of people who said that they did not cut down the tree suggests that religious values attached to *Ficus* are potentially important in their conservation in the landscape.

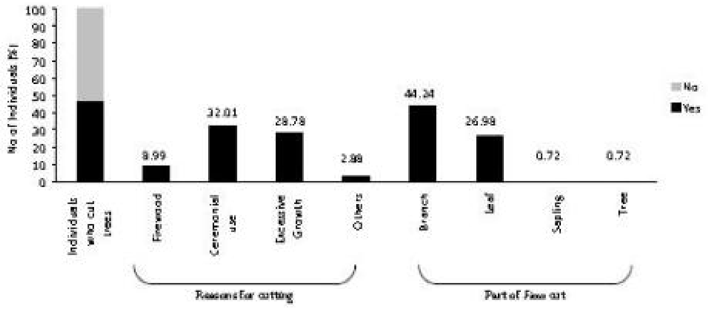


Fig. 17: Do people cut *Ficus* trees? Why? What part of the tree do they cut?

Threats to Frugivores in the Landscape

It was difficult to estimate the number of individuals of each frugivore killed when visiting *Ficus* trees, as people were not willing to disclose such information. This is reflected by the large number of respondents who were unwilling to respond (5.40%; n= 15), gave conservative answers such as “no birds are killed” (17.99%; n=50), or gave vague replies “all birds are killed” (28.78%; n=80). However, we were able to glean which species were most vulnerable when visiting fruiting *Ficus* trees through triangulation, i.e. asking people which species others killed in their vicinity. Green pigeons appeared to be the most common target with 30.58% (n=85) mentioning the species. Green pigeons were also amongst the most abundant frugivores within the landscape, as indicated by our bird surveys (Table 2; Fig. 18). The other frequent category were Columbines – Green Imperial Pigeon (8.98%; n=25) and Doves (11.51%; n=32). Hornbills also featured on the list (9.71%; n=27). Most birds mentioned were large bodied, suggesting that large-bodied species may be more vulnerable when venturing out into the matrix to feed on *Ficus*.

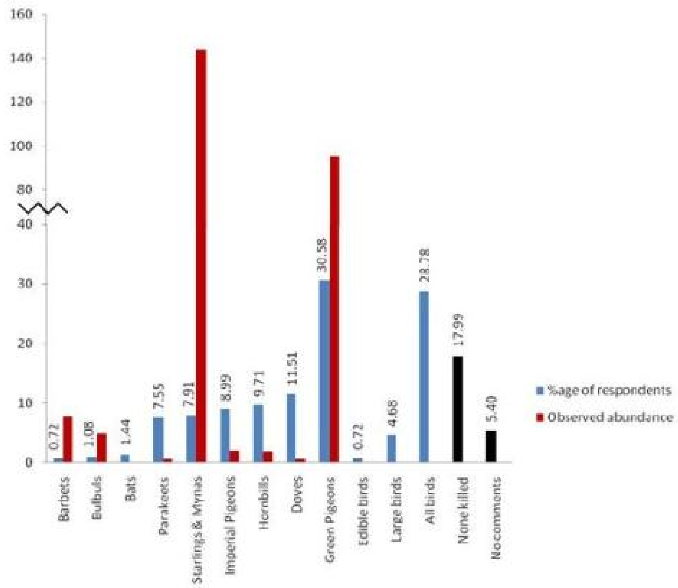


Fig. 18: Which frugivores are killed by people when they visit *Ficus* trees? Percentage of respondents indicates number of people mentioning the species; observed abundance = [total number of individuals of a species seen during the bird survey] ÷ [number of samples (n=59)].

A number of reasons for killing birds were mentioned. These included (1) killing for meat (70.86%; n=197), (2) killing for fun (6.47%; n=18), (3) killed because they are pests (0.72%; n=2). Some respondents said these birds were killed “because of their large size” (1.80%; n=5), a feature related to killing birds for meat. Some individuals gave guarded replies, saying “no birds are killed” (1.08%; n=3) or refused to comment (5.76%; n=16).

Objective 4: Feasibility of a community-based conservation programme

In order to assess how feasible it would be to device a community-based *Ficus* conservation programme, we included a series of questions on ways of conserving *Ficus* in the questionnaire instrument. This was followed up by focus-group interviews with key informants in villages to understand how the village community might be involved in conserving *Ficus* trees in their vicinity.

Perceptions of Conserving *Ficus* in the Landscape

Most people felt that *Ficus* in village spaces or near the national highway (where a lot of *Ficus* were distributed) was public property (Fig. 8). Respondents also said that the onus of conserving these trees was on the public. However, there were differences in opinion as to whether trees in villages and those by the highway were public property (villages $\chi^2_{[1]}=121.78$, $p<0.0001$, national highway $\chi^2_{[1]}=50.82$, $p<0.0001$). Similarly, more people thought that trees by the highway was the government's property as opposed to those in village spaces (villages $\chi^2_{[1]}=160.95$ $p<0.001$, national highway $\chi^2_{[1]}=53.24$, $p<0.0001$). More respondents said it was their property to conserve *Ficus* trees in villages (22.06%), as opposed to those by the highway (no respondents; 0%).

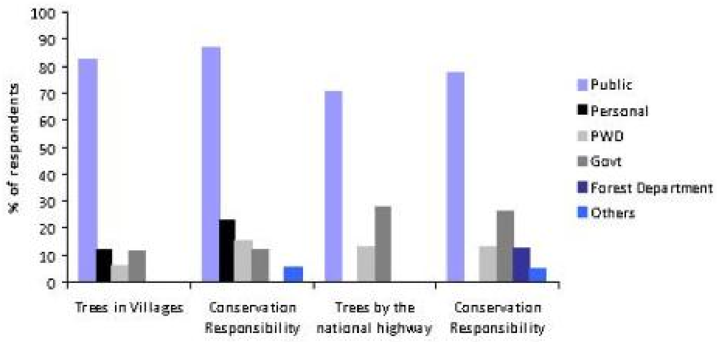


Fig. 19: Whose property and conservation responsibility are *Ficus* in villages (first two sets)? Whose property and conservation responsibility are *Ficus* near the national highway (third and fourth sets)?

When asked "What measures should be taken to conserve *Ficus* trees?", a majority of the respondents (58%) said they didn't know or didn't respond to the question (Fig. 20). A range of other measures were mentioned, including planting saplings, prevention of cutting down trees, taking care of saplings and protection from animals (cattle, goats). A few respondents said that people should be made more aware of *Ficus* and its conservation values.

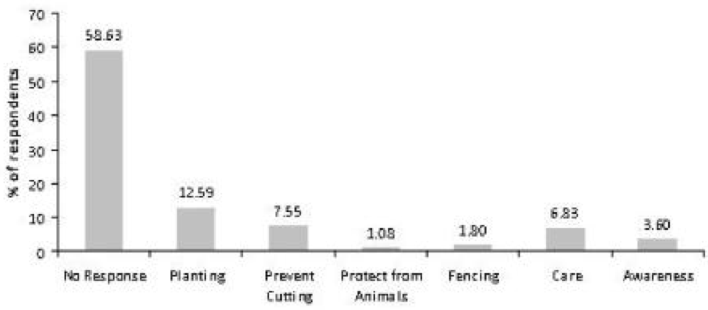


Fig. 20: What measures should be taken to conserve *Ficus* trees?

However, only 47% of the respondents were willing to plant trees. There was a local belief that one should not plant trees unless for some religious purpose, and this may have been a contributing factor to the low rate of responses in willingness to plant *Ficus*. Moreover, the fact that very few people had them in their gardens, and when present these grew by chance, suggest that planting might not work unless initiated by third-party actors. More people (30.58%; n=85) thought *Ficus* should be planted by the roadside, as opposed to other village spaces (26.62%; n=74) or in their own homes (8.63%; n=24) (Cochran's Q=52.86, df=2, p=0.000). Whilst a few people (7.55%; n=21) said that prevention of cutting of *Ficus* was one way of conserving them, fewer people were willing to prevent cutting of *Ficus* that belonged to other individuals (58.63%; n=163) as opposed to those standing by the roadside (79.1%; n=220) and those in temples (81.29%; n=226) (Cochran's Q=1.09, df=2, p=0.000).

Focus group interviews

We conducted two focus group interviews (10 people; 5 in each group) with village elders and individuals from local governance bodies to discuss the potential of managing *Ficus* trees in the landscape. For conserving *Ficus* trees, respondents highlighted the following key areas:

(1) Plantation of *Ficus*: respondents believed that trees should be planted in order to increase the number of fig trees in the landscape, and to enhance food sources for frugivores.

(2) Respondents also said that historically kings / monarchs had planted *Ficus* trees in different parts of Assam. Planting figs in the landscape would also be a symbolic act and would help people feel proud about their tradition.

(3) Plantation should be done in public places: so that mature trees / branches do not come in the way of individual households. The added benefit of planting such trees in public places was that they could provide a resting space for people. Places identified by people included village prayer halls, crossroads in villages or by the roadside where there was no rice paddy plantation.

(4) Plantation should be done in conjunction with third-party involvement: respondents felt that plantation of *Ficus* should involve school students, notable people in the village as well as a third-party (e.g. conservation NGO). This was because there is little initiative within villages to start planting on their own. Third-party involvement would provide the impetus for doing this work.

Overall, the results of the focus group interviews tally with the results from our questionnaire-based surveys of the need to plant figs, and that too in public spaces. There is great scope for continuing this community aspect of the project in the future.

Conservation Outreach, Conservation Outreach, Training and Impact

Whilst the main thrust of this project was to evaluate the current state of *Ficus* conservation in the region, we also conducted awareness programmes and capacity building exercises in order to develop a model for future conservation activities. Our focus was in two distinct areas: (1) conservation outreach amongst school children to highlight the importance of *Ficus* and frugivores, and (2) capacity-building amongst local youth to monitor frugivores.

Conservation outreach amongst school children

We conducted awareness programmes amongst school children in different schools within the landscape to try and understand how future conservation outreach activities might be planned. Four village schools were targeted. Team members gave talks about *Ficus* trees in the landscape and their conservation value. There was high attendance, and we reached out to over 200 students and teachers. After the talk, selected students (age category 14-17) were taken the following day to a fruiting fig in the landscape to observe birds and learn more about frugivory. Students were taught basic skills in bird identification and how to observe birds in the field. Further, they were given on-ground demonstrations of how *Ficus* trees are pollinated by fig wasps, how their seeds are dispersed by birds and bats, and the ecological importance of these trees as keystone structures. A total of 24 students from four different schools took part in the field awareness programme that spanned over six weeks.

Box 1: Key Learning's from Outreach amongst School Children

- School children were aware of the presence of *Ficus* trees in their landscape, but had no knowledge of the different species present. They were not able to identify the common *Ficus* trees in the area.
- Similarly, children were able to identify the common and large-bodied species that feed on figs, but knowledge about *Ficus* seed dispersal and ecological role of trees was wanting.
- Whilst students were interested in learning about *Ficus* and frugivores, their attention span was limited. Teachers suggested that this should become part of a long-term programme so that the interest of youth could be captured.
- We believe there is considerable scope for future training of school children to watch and identify birds. This could (1) raise awareness of the environment and conservation issues, (2) help build a future pool of monitors for long-term observation of *Ficus* and frugivores in the landscape.
- Each school had an environmental studies programme, but there was limited field work involved in such programmes. In the future, a Ficus monitoring programme can be initiated with one or two schools as part of such an environmental studies programme.

Team training and Capacity Development

The most important conservation achievement of the project was in team training and capacity development. The main research assistant of the project (JT) benefited considerably in three distinct areas: (1) conducting ecological research, especially pertaining to *Ficus*, (2) conducting questionnaire-based social surveys, and (3) preliminary understanding of basic software programmes for data entry and statistical analysis. Further, during the course of the project, JT interacted with other project collaborators, notably academics and researchers from the School of Geography and the Environment, University of Oxford. This involved (1) an initial three-month survey with a research student doing dissertation work, and (2) an intensive four-day interactive session with Dr Paul Jepson of the School of Geography and the Environment, where an exchange of ideas and update on research progress took place.
The project enabled links to be formed between top conservation scientists and on ground practitioners. This is an important outcome as it provides a template for thinking about how

we might develop a new generation of conservationists on the ground by fostering exposure and contact with leading thinkers in the discipline.

The other tangible impact that the project had was that we were also able to involve six other local youth in mapping *Ficus* trees and monitoring frugivores within the landscape. Youth were trained in bird identification skills, and by the end of the year were able to independently collect data on frugivore usage of *Ficus*.

Box 2: Key Areas Identified for Future Capacity Development

> Impart some sort of formal training in ecology to promising youth at a national institute in order to strengthen local research capacity

> Enhance conservation outreach skills of key individuals so that dissemination and outreach is improved

> Build a team of monitors who can do effective long-term ecological and social research on conservation in the area

Conclusion: Key Findings

In this section, we summarize the main findings of the project, and discuss the future conservation implications of this work.

The role of *Ficus* trees in agroecosystems as a food source for frugivores and as dispersal 'stepping stones' between forest fragments.

There was no difference in frugivore species richness in different agricultural landscape categories, and the overall patterns observed in this study suggest that the landscape-matrix is conducive for sustaining frugivore populations, especially when remnant forest patches are present. *Ficus* is thus an important food source for frugivores and potentially act as dispersal stepping stones between forest fragments. However, with increasing distance and agricultural intensity of the matrix, there is a decline in forest-dwelling species (e.g. Great Hornbill, Blue-eared Barbet). However, both the visitation frequency of frugivores and the number of fruits consumed decreased as distance from forest and agricultural intensity increased. Similarly, fruit-handling behaviour changed in different landscape contexts, with the proportion of the most efficient dispersers (i.e. swallowers) decreasing in sites of high agricultural intensity. This suggests that as land use pressures increase, there may be an overall loss in the dispersal of *Ficus* seeds. Our study also found that the most effective dispersers of larger *Ficus* synconia were large-bodied species. Species showed shifts in fruit-handling behaviour as the size of the synconia increased: those that swallowed smaller fruit, pecked or bit at larger *Ficus* synconia, resulting in the decline in seed dispersal efficiency.

This suggests that for effectively dispersing seeds of species such as *Ficus benghalensis*, it is important to maintain large-bodied frugivores (e.g. hornbills, green pigeons) within a landscape.

Local perceptions and social practices relating to figs in agroecosystems.

This study shows that whilst the economic importance of *Ficus* is low. As a consequence, people seldom plant *Ficus* trees, but once individuals attain a particular size and morphology, religious values are endowed upon them. Trees become sites of worship, and various parts are used for local cultural purposes. This is particularly true for *F.benghalensis*, *F.religiosa* and *F.virens*. Further, trees also have a social value as a resting place or marker of place. Our study provides evidence that trees associated with shrines are larger in size, and potentially less vulnerable from being cut down by people. This is a significant finding, suggesting that cultural institutions might be a strong working force in the sustenance of figs outside protected areas. It allows us to think of figs as sacred groves at a very small (tree) scale. Conservationists might gain considerable purchase from developing this concept in the future.

Threats to figs and frugivores

Whilst people said that fig trees remained in the landscape because of the religious or social values associated with them, there was a tendency to remove saplings from home gardens or near paddy fields. Our mapping of trees in the landscape shows that the number of *Ficus* trees in sites of high agricultural intensity are lower than that in areas with less intense agricultural land use. As agriculture expands, it is likely that more individual trees will be removed, as a consequence of which isolation might increase and pollination / dispersal systems might break down. In the future, it would be important to model what population levels of figs are necessary to maintain stable populations in human dominated landscapes. Whilst traditional cultural institutions might work in favour of *Ficus* trees, such values are generally placed upon trees that are found in public spaces and not so much in private gardens. Here, conservationists could play a proactive role by supplementing traditional practices with conservation outreach.

Our study also suggests that there is some amount of hunting pressure on larger-bodied frugivores. Species such as Green Pigeons, Imperial Pigeons, and Hornbills might be particularly vulnerable. This is exemplified by the case of the Great Hornbill, which was only observed on a few focal trees, that too in low intensity land use contexts. Larger-bodied species are likely to be more effective seed dispersers (especially of *Ficus* with large synconia), but they are also more vulnerable to hunting. Hence, hunting of frugivores could potentially lead to a decline in seed dispersal of *Ficus* and aggravate long-term persistence of these trees.

Prospects for a community-based Fig conservation programme

Our research findings and interactions with the local community suggest that there is considerable scope for initiating a community-based fig conservation programme. Future conservation work will need to focus on three distinct areas:

(1) Preserving existing trees: here extant traditional institutions (e.g. temples, shrines) for conserving *Ficus* trees are already in place. Trees in public spaces are perhaps more vulnerable to being cut down. Here, generating awareness of the importance of *Ficus* could help supplement extant cultural values.

(2) Plantation of *Ficus*: our respondents felt that planting *Ficus* trees in public spaces was important. However, any future conservation programme will need to be a tripartite arrangement involving both village publics, individuals with leadership in the

community and a conservation organization / volunteers who might be able to take the initiative.

(3) Generation of awareness of figs and frugivores: this is essential if hunting pressures are to be reduced and if the ecological role of *Ficus* is to be popularized amongst the public.

Future Steps for *Ficus* Conservation in the Region

We believe that there is significant scope for developing interdisciplinary modes of conservation research and practice through further work on *Ficus* in the landscape. Moreover, the findings of the project are significant, and show exciting prospects for incorporating extant cultural practices to develop modes of doing conservation outside protected areas. The initial ground work done by this project is an ideal platform to do innovative work with the local community and to make an impact on *Ficus* and frugivore conservation. We identify areas for future activity that have emerged from the initial pilot project (see Fig. 21). This should entail:

(1) Further ecological research that will help understand the landscape system better:
   a. Leakage of frugivores from forest habitats and comparison with other feeding guilds
   b. Examine dispersal capacity of frugivores for different *Ficus* species (both bird and mammal dispersed)
   c. Understand fruiting phenology of *Ficus* in relation to other trees
   d. Look at sapling recruitment in order to better understand *Ficus* regeneration in the landscape

(2) Direct conservation interventions in the form of:
   a. Starting a *Ficus* plantation programme involving a tripartite arrangement of local youth, community elders and conservation NGOs
   b. More capacity building amongst local conservationists for conservation research, monitoring *Ficus* and outreach programmes
   c. Developing a sustained outreach programme with 2-3 local schools

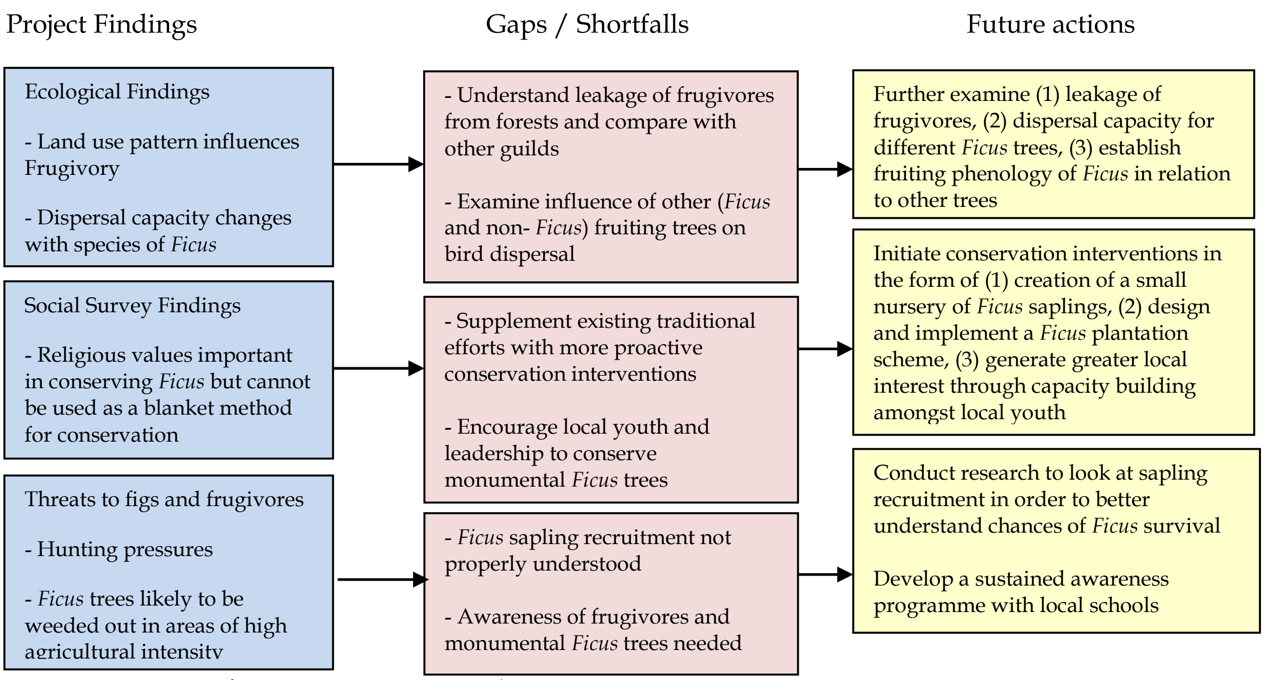


Fig. 21: Future steps for *Ficus* conservation in the region.

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