Research note

The Forest Community Surrounding Juhu Ecological Park: A Preliminary Forest Inventory and Its Ecological Implications

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【Summary】

A pilot study was conducted to survey forest habitats surrounding Juhu Ecological Park. The purpose of this study was to obtain empirical data on the status of the forests and gain preliminary insights into the composition and potential threats forest habitats are facing. Farmers in Juhu Ecological Park have reported gradual environmental degradation for 3 decades, especially of bird and plant diversity. Conversely, populations of mammals such as muntjacs and macaques have increased and are presently the greatest threat to agricultural practices of farmers and the success of natural forest regeneration. Results across the 8 plots surveyed in this pilot study show low plant diversity and a high similarity in species composition between plots. The data also showed that 61.4% of trees were slim trees (< 15 cm in diameter at breast height; DBH) and more than half were pioneering trees commonly found in disturbed areas. In the future, more plots should be surveyed to accurately represent the landscape and better assess forest health and biodiversity threats. This is the first stage of a long-term goal to develop a socio-ecological environment to bring together indigenous culture, improve agricultural practices, and sustainably manage and benefit from natural resources through ecological research.

Key words: forest inventory, plant diversity, forest composition, forest regeneration, Juhu Village, Taitung County.

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研究簡報

竹湖山居週邊的森林群落:初步的森林調查與其生態意涵

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摘 要

本研究是以竹湖山居周遭的森林棲地所進行的前導研究，目的藉以獲得森林狀態的觀察數據，並初步了解森林棲地組成及潛在威脅。竹湖山居當地農民的知識記述了三十幾年以來環境的逐漸退化，尤其是鳥類和植物的多樣性。相反，山羌和臺灣獼猴等哺乳類動物的數量有所增加，目前是對農民農事操作和天然林再生演替的最大威脅。調查的 8 個樣區中，結果顯示樣區之間的植物多樣性低，物種組成相似度高。資料也顯示，超過六成林木胸徑小於15 cm，其中一半以上是干擾地區常見的先驅樹種。未來，希望可以增加調查更多樣區，以更準確地呈現地景尺度，充分評估森林健康和生物多樣性威脅。這是長期目標的第一階段，即發展社會生態環境，匯聚本土文化，改進農業操作，並通過生態研究永續管理自然資源並從中獲益。

關鍵詞：臺東縣竹湖山居森林清查、植物多樣性、森林組成、森林更新。

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Juhu Ecological Park, located in Juhu Village, Changbin Township, Taitung (Fig. 1), started as an organic farm, producing tremendous amounts of bananas and other fruits. It also runs a hostel and outdoor adventure business. Juhu Village has a long history of multiple land-use changes. Different patches of land have been converted to water buffalo browsing, rice paddies, betel nut plantations, bamboo plantations, and citronella plantations (Chiu 2011). As a consequence, all of the forests surrounding Juhu Ecological Park are secondary forests which were once used for agriculture. The forests seen today are naturally recovered forests with patches ranging from 20 to 70 yr old.

Because of macaques (*Macaca cyclopis*) raiding crops and muntjacs (*Muntiacus reevesi*) over-browsing, the owners of Juhu Ecological Park could no longer fully depend on organic farming as their main source of income. Moreover, there have been reports of biodiversity loss of birds, snakes, and aquatic species over several decades. Driven to pursue other means of income, the owners are seeking opportunities to expand their business goals with the help of different stakeholders, such as academics, community facilitators, and ecologists. Habitat surveys are needed to understand the present environment of Juhu Ecological Park to develop economic opportunities and adapt to ecological changes caused by climate change and the increase in mammal populations.

There is a lack of comprehensive surveys of these forest patches following a variety of agricultural land-uses that haven't been surveyed. This pilot study is the first step towards assessing and understanding these areas. The first objective is to identify emerging patterns within forest patches which will inform future land-use management strategies, including management strategies for economic purposes, improved agriculture, and/or restoration interventions adapted from the findings of this study. The second objective is to scientifically validate reports of ecological degradation. If these reports are true, this highlights the urgent need for further surveys and interventions. Therefore, the primary focus of this pilot study was to determine the species composition of forests, identify any spatial variations in the landscape, and assess the successional stage of the forest patches. It is also essential to emphasize the importance of local ecological knowledge in understanding the environment. As such, this study's assessment incorporates the perspectives and insights of the local community.

The first step was the identification of potential sites for plot placement employing a combination of local knowledge and spatial analysis using QGIS. The area includes 2 distinct types of land: private land and indigenous reserves. Each land type was further categorized according to locality, such as near Sao-bie Stream or in mountainous forest. Each land-type was also further classified according to whether the understory forest was managed or not (i.e., managed vs. unmanaged

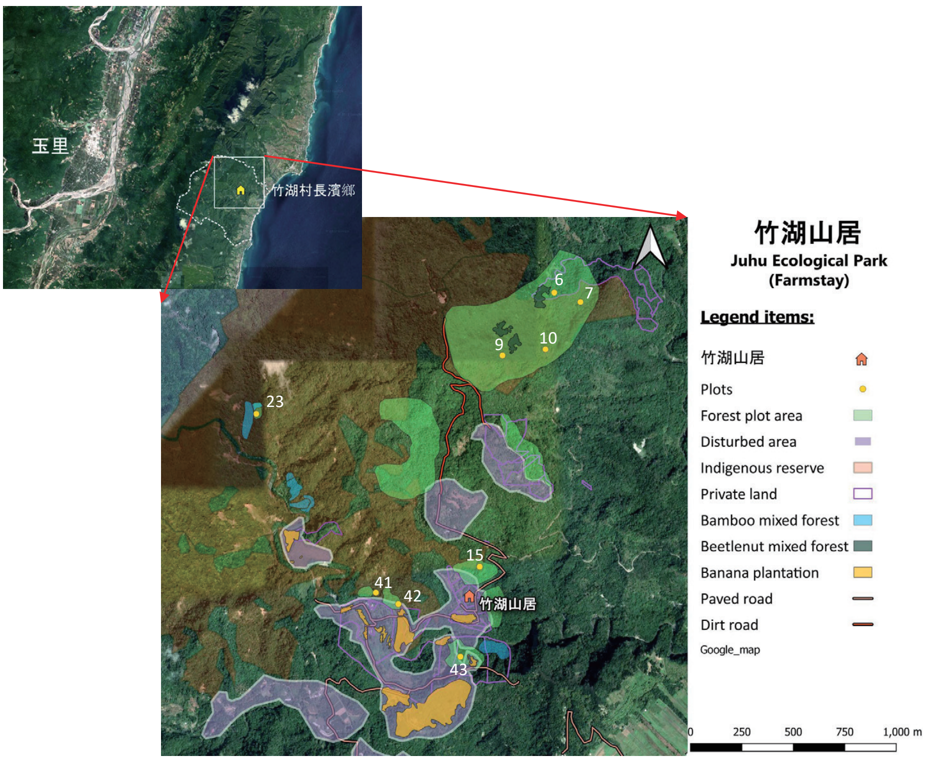

Fig. 1. Map of Juhu village zoomed to the area of the study (a total area of roughly 67 ha). (Geographic Coordinate System: TW97 ESPG 3826).

understory). Managed understory forests undergo regular weeding and removal of lianas. The second procedure was a filtering process to generate regular or random survey points. Excluding factors include edge effects (20 m from a road, disturbed areas, and/or plantations), disturbed areas (human settlements and active areas), abandoned plantations, and accessibility. A fixed distance of 200 m between points was set in large areas to generate regular points; meanwhile in areas smaller than 200 m in length, points were randomly generated. In the end, 9 out of 25 generated points were selected to conduct the survey. These points determined where plots of 20×20 m would be made on the field, with each plot sloped facing north. The total area of surveyed plots was 3600 m². One plot, however, was reforested land so was excluded from analyses and comparisons.

Data collected and the measured units are listed as follows: slope (°), elevation (m), GPS coordinates, species name, diameter at breast height (DBH) > 1 cm at 130 cm of woody species including branches, tag number, branch number, tree height (in 5-m intervals), understory vegetation coverage (in percentage intervals), seedling abundance, saplings, and stone coverage on the forest floor (in percentage intervals). The protocol was adapted from ForestGEO permanent plot manual (Condit 1998).

Several variables and indices were measured. For stand attributes of forest plots, the basal area, density, frequency of species, relative abundance (RA), relative frequency (RF), relative dominance (RD), and importance value index (IVI) were calculated. The IVI was calculated as RD + RA + RF (Cottam and Curtis 1956) and was used to understand the ecological importance and dominance of species in a community or between communities. The combined factors of tree species, IVI, basal area, proportion of DBH ranges, and proportion of tree height were considered to empirically assess the successional stage of the forest. For compositional attributes, diversity indices, namely, Shannon index, Simpson's index, Fisher's alpha, and dissimilarity indices, i.e., Jaccard coefficients, were estimated using functions provided in the 'vegan' package of R Studio. These indices can show spatial variations and similarities of species composition between plots and/or localities.

In total, 885 individual woody plants (shrubs and trees) were recorded in 8 plots, including 38 species (Table 1). The major genera (and families) included *Ardisia* spp. (Myrsinaceae), *Lagersteomia* spp. (Lythaceae), *Ficus* spp. (Moraceae), *Maesa* spp. (Myrsinaceae), *Glochidion* spp. (Euphorbiaceae), and *Litsea* spp. (Lauraceae). Proportions of tree heights, in the ranges of 0–5, 5–10, and 10–15 m, were 41.3, 48.1, and 10.5%, respectively (not including saplings). Proportions of the first 3 DBH ranges of 0~5, 6~10, and 11~15 cm were 46.5, 41, and 17.5%, respectively. Furthermore, it was observed that 61.4% of trees were slim trees (< 15 cm in DBH), while relatively large trees (> 31 cm in DBH) accounted for 3%.

More-frequent plant species with the highest IVI were *Ficus ampelos* (菲律賓榕), *Lagerstroemia subcostata* (九芎), *Ficus irisana* (澀葉榕), *Ardisia sieboldii* (樹杞), and *Glochidion philippicum* (菲律賓饅頭果). Rarer species, recorded with the lowest IVI included species such as *Leea guineensis* (火筒樹), *Radermachera sinica* (山菜豆), Clerodendrum canescens (白毛臭牡丹), *Clerodendrum trichotomum* (海州常山), and *Rhamnus formosana* (桶鉤藤). The most common understory medium-short shrubs observed were *Ardisia sieboldii* (樹杞), *Maesa perlaria var. formosana* (臺灣山桂花), *Callicarpa formosana* (杜虹花), *Ardisia virens* (黑星紫金牛),

and *Murraya paniculata* (月橘). The top 5 dominant canopy species were *Lagerstroemia subcostata* (九芎), *Ficus ampelos* (菲律賓榕), *Ficus irisana* (澀葉榕), *Dendrocnide meyenia* (咬人狗), and *Broussonetia papyrifer* (構樹). Species that were less dominant (< 4%) but still present in half of the plots included *Murraya paniculata* (月橘), *Morus australia* (小葉桑), *Ficus septica* (稜果榕), *Glochidion philippicum* (菲律賓饅頭果), and *Litsea hypophaea* (黃肉楠). In total, 18 sapling species were recorded. The most dominant sapling species (and their abundances) were *Ardisia sieboldii* (樹杞) (49), *Murraya paniculata* (臺灣山桂花) (37), *Ardisia virens* (黑星紫金牛) (32), *Litsea hypophaea* (黃肉楠) (16), *Ficus ameplos* (菲律賓榕) (11), *Glochidion philippicum* (菲律賓饅頭果) (10), and *Ficus septica* (稜果榕) (7). Diversity indices were higher in mountain areas than in stream areas; however, the difference was not statistically significant (Table 2). Furthermore, all Kruskal-Wallis tests between categorical factors (management type and locality) and basal area, seedling abundance, sapling abundance, species richness, and total DBH were also not significant. When comparing similarities between plots, results from the Jaccard similarity index showed that more than half of the plots had a high similarity of > 0.70 (Table 3).

Since the IVI is a proxy for the ecological importance of a group of species, a naturally regenerated mountain area after abandonment resulted in an ecosystem habitat that seemingly has not yet reached a stage of maturity. Most trees were thin trees, which is an indication of a forest ecosystem that is still disturbed. It is estimated that it takes up to

Table 1. General information of each plot

Plot ID[a]	Locality[1]	Management[2]	Land rights[3]	Elevation (m)	Slope (°)	Understory coverage[4]	Stone coverage[5]	Tree height[6]	No. of seedlings	No. of saplings	No. of species	Absolute abundance
6	M	UNM	P	214	24.3	62.5%	17.5%	7.5	39	43	22	203
7	M	MA	IR	248	33.8	12.5%	17.5%	7.5	38	53	20	144
9	M	UNM	IR	276	23.8	25%	37.5%	2.5	15	39	11	104
10	M	MA	IR	295	14.5	17.5%	17.5%	7.5	37	2	13	83
15	M	UNM	IR	152	13.8	17.5%	62.5%	7.5	13	4	13	72
41	S	UNM	IR	127	18.5	50%	37.5%	7.5	144	6	14	63
42	S	MA	IR	123	12.5	37.5%	37.5%	7.5	73	20	17	99
A[b]	M	MA	P	132	37.5	50%	17.5%	7.5	4	0	7	32
23	S	MA	IR	227	22.3	88%	17.5%	2.5	38	15	16	85

Notes:

[1] Locality refers to the location in Juhu Village, either in a mountain area (M) or stream area (S).

[2] UNM, unmanaged understory forests; MA, managed understory forests.

[3] There were 2 types of land: P, private; IR, indigenous reserve.

[4,5,6] Values for understory coverage, stone coverage, and tree height presented in this table are the median converted to values.

[a] Plots were numbered before the selection of the 20 plots, therefore they are not in an ordered sequence.

[b] Plot A is leased, reforested land with trees planted by a local farmer. Hence, this plot was excluded from comparisons and statistical analysis. For more background information of each plot.

400 yr, depending on previous rates and types of disturbances, for tropical forests to mature back to pre-disturbance periods in Southeast Asia, which is the slowest recovering region compared to other tropical regions (Cole et al. 2014). Other region-specific studies show that the rate of recovery in tropical forests can return to pre-disturbed states in a matter of 10 - 15 years (Guariguata and Ostertag, 2001; Slik et al. 2002). No mature canopy species, except for *Ficus irisana*, were recorded in the sampled plots in this pilot study. Most canopy species recorded were characteristic of pioneer species commonly found in disturbed areas and near-stream habitats. This further indicated that these forests have not yet matured. Species occurrences were similar to other forests in the Taitung area, and forests in the village could belong to the *Ficus-Machilus* vegetation group, also known as the *Ficus-Machilus* semi-evergreen foothill forest (Chen et al. 2006*; Li et al. 2013). However, only 1* Machilus species, *Machilus japonica* (大葉楠), was recorded in the survey and its IVI ranked 14th. Sample sizes in mountain and stream areas were uneven, preventing a reliable comparison among them. As a result, direct comparisons among individual plots, regardless of their specific locality, revealed a substantial level of similarity, suggesting a

Table 2. Diversity indices for mountain areas and stream areas

Indices	Mountain areas (n = 5)	Stream areas (n = 3)
Species richness	29	26
Shannon index	2.777	2.637
Simpson index	0.917	0.898
Fisher's alpha	7.331	6.347
Jaccard coefficient	0.1076	

Table 3. Relative similarity (Jaccard index) of forests across plots

Plot no.	6	7	9	10	15	41	42	23
6	1							
7	0.705	1						
9	0.777	0.575	1					
10	0.7	0.563	0.655	1				
15	0.868	0.807	0.927	0.9	1			
41	0.896	0.875	0.872	0.894	0.805	1		
42	0.811	0.707	0.747	0.833	0.724	0.734	1	
23	0.726	0.653	0.748	0.833	0.783	0.777	0.617	1

notable degree of forest homogeneity within the study area. Preliminary findings of the study indicated that the forest composition can be characterized by a low degree of plant diversity and a high compositional similarity. However, it is expected that the number of species recorded should increase as the total sampled area increases (from 0.32 ha to 1 ha) (Palmer and White, 1994).

After gaining preliminary insights into the attributes used to inform forest regeneration, records of low seedling and sapling abundances may be the first indication of concern for the natural regeneration of these forests. A low record of seedlings and saplings may represent low recruitment rates due to a decrease in seed banks, which could be affected by the intensity of previous land-use (Guariguata and Ostertag, 2001). Nonetheless, regeneration has occurred, but it has mainly resulted in the dominance of understory species, as determined by analyzing sapling records (species of seedlings were not identified), such as *Ardisia sieboldii* (樹杞), *Murraya paniculata* (臺灣山桂花), and *Ardisia virens* (黑星紫金牛), and only two known canopy species, *Ficus ameplos* (菲律賓榕) and *Ficus septica* (稜果榕). The second concern are reports that muntjac populations are drastically increasing and that human-assisted replanting efforts of native canopy tree species have not been successful. Compared to 10 yr ago, saplings planted in the last several years have consistently been eaten, and none have survived according to farmers' reports, implying that the natural regeneration of canopy trees is affected by mammals to some degree, favoring trees not preferred by muntjacs and primarily dispersed by macaques. Interventions such as guarding native plants by wrapping a netted fence around them have been reported to be an effective strategy against herbivory and damage. Furthermore, also according to local reports, macaques have now been observed to feed on the shoots and leaves of tree species, such as those of *Ailanthus* spp., *Ficus* spp., *Zanthoxylum* spp., and others that were not previously observed in the past few decades, implying that macaques are expanding their food choices. Biological threats from macaques and muntjac populations are an ecological concern for forest health and the ability for natural regeneration to reach a functionally diverse state.

If forests have high similarity and low diversity, which this study showed, then it can also be implied that this may equally reflect low avifaunal and other pollinator species diversity, favoring only species that thrive and can adapt to the present forest habitat, which is dominated by only two Ficus species and very scarce understory coverage. In return, present pollinator species may take part in shaping the forest composition decades into the future. One study showed that macaques have been the main reason contributing to a loss in bird diversity due to high nest predation rates (Lai 2018) and, consequently, this presents a possible limitation for dispersion of tree seeds, especially for specialized trees. In addition, recovery of species composition post-agricultural abandonment is slower (or will change) than other measured attributes of recovery due to limitations in seed dispersal of late-successional species and the distance of remnant forests to recovered patches (Guariguata and Ostertag, 2001; Turner et al. 1998). According to local reports, bird societies of Taitung and Kaohsiung recorded at least 150 bird species 20 yr ago. Presently, about 50 bird species are common inhabitants. Another hypothesized contributing factor for this biological threat is the change in wildlife policies that have prevented non-indigenous people from hunting macaques, allowing increases in the populations of macaques and muntjacs. However, long-term observations, experimentation, and phenological data are required to confirm these implications.

Lastly, in combination with recorded baseline biodiversity data and local ecological knowledge, it is important to elaborate why these ecological concerns cannot be entirely explained as a natural and healthy phenomenon. There are two main arguments to support this claim. First, the landscape was once actively used by farmers and it is not known how different agricultural practices may have affected the forest's ability to recover. Different land-use histories and their intensities can affect soil fertility, species composition, and the rate of recovery post-abandonment (Guariguata and Ostertag, 2001; Guariguata et al. 1997; Moran et al. 2000). The longer and more intense the land-use type was, the more irreversible the effects were (Dupouey et al. 2002). What was presently observed, however, is that despite forest recovery, some common species representative of lowland broadleaf evergreen forests are now entirely absent or present in only very low numbers compared to other areas in Taitung, such as *Neolitsea* spp., *Machilus* spp., *Bischofia javanica, Celtis tetrandra, Cinnamomum camphora, Magnolia compressa,* and *Radermachera sinica* (Chen et al. 1990). This implies that the species composition of forest patches have shifted post-abandonment. This claim is supported by the local farmer who reports that many tree species are rarely found nowadays. However, more sampling plots are required to verify this implication. Furthermore, according to local knowledge, areas that were once used for water buffalo browsing are now mostly dominated by *Lagerstroemia subcostata* (九芎), which is not an indicator of a mature forest state. Second, because agricultural lands in Juhu Ecological Park are adjacent to forests, mammal populations have more food resources, because they can forage in both forests and on crops. In natural circumstances, resource limitations and predation control population numbers. However, in this situation, population numbers have reportedly multiplied in the last 3 to 5 yr. As a consequence, the overabundance of mammals is potentially presenting itself as an indirect anthropogenic stress on forest communities, which signifies a need for human-assisted management and solutions. In order to meet land-use goals, the forest inventory first needs to be completed. This can allow a confident assessment of biological threats to the forests around Juhu Ecological Park and aid in designing strategies for forest management. The forest survey is expected to be continued sometime in 2023.

In conclusion, results of this pilot study report the plant diversity around Juhu Ecological park is considered low and has very high similarity with preliminary evidence of unnatural disturbance in the forest due to only a few dominant canopy species and several understory shrub species. Presently, there are no spatial or compositional variations of plant species in forest areas from the sampled plots. The forests have not yet matured given the 20~70 yr of time to recover across different land-use histories. Moreover, seedling abundances were also low. Other than historical disturbance from various land-uses in the past, this pilot study was unable to provide evidence of factors correlated with the attributes measured. However, with the help of local knowledge of the area, there are preliminary indications of the threats forest habitats are facing, specifically from increasing macaque and muntjac populations, which can cause a cascading effect on other species. Future research needs to address relationships between herbivores and plants along with long-term monitoring in order to investigate the intensity of herbivore threats to the forests and neighboring agricultural land. The methods of that research need to be designed in a way that meet the developmental goals of local farmers and so the results of those studies can be used to achieve sustainable forest management.

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