Diversity and composition of plant species in a communal agroforestry system at Manggatal, Sabah

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Abstract. Agrisilviculture, the practise of combining forest trees with crops and fruit trees, is common on smallholder and communal land in Sabah. This research aims to determine the diversity and composition of plant species in a communal rubber-based agrisilvicultural system at Kampung Ratau, Manggatal, Sabah. A 50 m x 200 m plot was established in an old rubber garden mixed with other plants. The plot is divided into 10 m x 10 m quadrats. All trees measuring more than 1 cm dbh, lianas and vines were recorded. Diversity indicated by the Shannon-Weiner index H’ value is 2.72 for all types of plants, 2.25 for trees, and 1.73 for lianas and vines, respectively. The Simpson index (D) is 0.87, 0.78, and 0.68 for all types of plants, trees, lianas, and vines, respectively. The Margalef index (Dm) is 5.69, 3.36, and 2.89 for all types of plants, trees, lianas, and vines, respectively. The dominant tree, liana, and vine species are Hevea brasiliensis (128), Smilax cf. laevis (96), and Lygodium cirinnatum (23). The agroforestry system can support moderately diverse plant species and contains several dominant species.

Keywords: Agrisilviculture; agroforestry; diversity; liana; vines.

1. Introduction
Rubber-based agroforestry, as the combination of rubber trees as the main tree crop with annual crops and fruit trees [1] is commonly practiced in Sabah, Malaysia. The rubber-based agroforestry system came about due to the community's needs for provisions, environmental services, cultural services and supplemental income from other plants than rubber. Agroforestry system is recognised as a land use that integrates trees, crops, pasture and other alternative production systems to provide benefits and services to humans while rehabilitating or conserving the ecosystems [2,3,4]. The system is ecologically sustainable and usually involves subsistence farming in the tropics [5].

The growth of Kota Kinabalu city and urban areas has infringed into traditional villages that were once considered rural. Many village pockets in the Kota Kinabalu district are now surrounded by modern housing, infrastructure and development. However, the old and new generations that inhabit these urban villages still retain most of their traditional way of life, including agrisilviculture and cultural practices on their ancestral land, and depend on natural resources, such as water and agroforestry produce for their daily provision and livelihood. The agrisilvicultural practices of smallholders are varied due to the holding size, preference, and level of reliance on the system for their livelihood. Smallholders retain green areas in various forms such as pasture lands, fish ponds, vegetable farms, cropland, rubber gardens, fruit tree gardens, and naturally regenerated bushes. The Dusun community of Kampung Ratau, Manggatal, traditionally planted various trees and perennial shrubs. The agrisilviculture practice is considered low-intensity management that allowed wild plants to thrive in the system. The availability
of green areas consisting of agroforestry ecosystem with wild bushes is appreciated by the villagers and visitors of the neighbouring eco-agro homestay and resort for recreation [6]. Agroforestry systems are varied depending on the main trees and crops planted to support community livelihood. For example, betel vine based Khasia-, pineapple and lemon-based Tripura-, short-term shifting- [7], timber tree-based-, industrial tree crop-based-, fruit tree-based, and mangrove-agroforestry [8].

In this study, we ask whether smallholder agrisilviculture practice in urban area support plant diversity and how does the system affect the dominance, evenness and richness of plant species? Green areas in an urban setting are under extreme pressure for land conversion and development. Documenting plant diversity, composition, function and value to local communities and visitors will provide a reason for maintaining green areas and ecosystems hidden in urban areas. We hypothesised that the rubber-based agrisilviculture practice support low to moderate plant diversity. The study aimed to determine the diversity and composition of plant species in a communal rubber-based agrisilviculture practice.

2. Methodology

2.1 Research site
The research site is at Kampung Ratau (6° 03' 59.4" N, 116° 10' 09.6" E) of Manggatal subdistrict on the outskirt of Kota Kinabalu city, west coast of Sabah state Malaysia. The rubber garden is interplanted with fruit trees, crops and contains natural regeneration in a narrow valley with a network of streams. The whole village relies on these streams for water supply. Therefore, land use is identified as a rubber-based agrisilviculture practice. In agrisilviculture, the management includes weeding and fertilizing around trees, crops, and medicinal plants, rubber tapping, and harvesting. Intercropping with food and medicinal plants is conducted on a need’s basis. Adjacent resort and homestay utilize the surrounding jungle and farms for trekking with the villager's permission. Land tenure is secure as the farmland are accorded native titles (NT) owned by individuals or group of individuals. The agroforestry system is considered communal because of the sharing access of agreed resources (water, bush area) of the privately-owned land.

2.2 Sampling design and data collection
A rectangular sampling plot measuring 50 m x 200 m (1 hectare) was established on an old rubber farm. Then, 10 m x 10 m quadrats were marked within the main sampling plot. All trees above 1 cm diameter at breast height (dbh), lianas and vines were included in the species count, abundance, dbh record and species identification. Each tree was labelled for identification and sample tagging purposes. Photographs, leaf twig with flower, fruit sample of each tree was taken and labelled for species identification and verification based on herbarium specimens and publication. The dbh size classification are as follows: (1) 1.0 – 5.0 cm, (2) 5.1 – 10.00 cm, (3) 10.1 – 15.00 cm, (4) 15.1 – 20.00 cm, (5) 20.1 – 25.0 cm, (6) 25.1 - 30.0 cm, (7) 30.1 - 35.0 cm, (8) 35.1 – 40.0 cm, (9) 40.1 – 45.0 cm, (10) 45.1 – 50.0 cm.

2.3 Data analysis
The plant samples were identified, counted and categorised into the family. Shannon-Weiner index, $H'$ [9], Simpson index, D [10], dominance (1-D), Margalef index (Dm) [11], Menhinick’s richness index [12] were determined using Paleontological Statistics (PAST) software [13,14]. $H'$ is a diversity index taking into account the number of individuals and number of taxa. The $H'$ value varies from 0 for communities with only a single taxon to high values for plant communities with many taxa [13]. When $H'$ <1.5 indicates low diversity, 1.5<$H'$<3.5 indicates moderate diversity and $H'$>3.5 indicates high diversity [15]. D is a measure of a community's evenness with values ranging from 0 to 1. Dominance (1-D) is represented by values 0 (all taxa are equal in number) to 1 (a single taxon dominates the community) [13]. $Dm$ is a diversity index that measures species richness and rests on assumption that there is a relationship between the number of species and the number of organisms in a sample [11]. When $Dm$<2.5 species richness is low, 2.5<$Dm$<4.0 is moderate, $Dm$>4.0 is high [16]. Menhinick's richness index is the ratio of the number of taxa to the square root of sample size [12].
3. Result and discussion
The agrisilviculture practice at Kampung Ratau consisted of rubber trees as the main tree crop and source of income with fruit trees, wild trees, lianas, and vines. There are 20 tree species, nine liana species and seven vine species. The dominant species are *Hevea brasiliensis* tree (128), and *Lygodium cirinnatum* vines (96) from a total of 466 plants in the 1-hectare plot (Table 1). There are lianas (45) and vines (134) because of less intense management and appreciation for wild species. The main economic activity is rubber tapping and harvesting crops and medicinal plants. Most of the tree species are small-sized, 34%, 42% and 11% of trees are in class 1, class 2 and class 3 dbh size respectively. The dbh class 4 and class 5 have 5% and 3% of trees, class 6 and class 7 have 2% of trees each. The dbh class 10 had 1% of the total trees. For *Hevea brasiliensis*, 33% and 56% are in dbh class 1 and class 2 from natural regeneration. The dbh of *H. brasiliensis* is no larger than class 5 because older trees died or were removed. The tree with largest dbh belongs to *Acacia mangium*. The species were found at the hillsides exposed to sunlight. The *A. mangium* had three distinct dbh classes with 46%, 31%, and 23% in dbh class 1, class 5, and class 10.

| Tree species | Species | n | Family | Species | n |
|--------------|---------|---|--------|---------|---|
| Apocynaceae  | *Alstonia macrophylla* | 7 | Fabaceae | *Spatholobus sp.* | 1 |
| Chrysobalanaceae | *Licaria splendens* | 5 | | *Spatholobus sp.* | 1 |
| Dilleniaceae  | *Dillenia suffruticosa* | 7 | | *Spatholobus sp.* | 1 |
| Euphorbiaceae | *Hevea brasiliensis* | 128 | | *Bauhinia dipera* | 8 |
|              | *Macaranga amissa* | 13 | | *Spatholobus ferrugineus* | 2 |
|              | *M. tanarius* | 3 | Gnetaceae | *Gnetum cuspidatum* | 1 |
|              | *Endospernum diadenum* | 9 | Menispermaceae | *Fibraurea sp.* | 1 |
| Guttiferae   | *Garcinia parvifolia* | 4 | Smilacaceae | *Smilax cf. borneensis* | 7 |
| Leguminosae  | *Archidendron clypearia* | 8 | | *Smilax cf. laevis* | 23 |
|              | *Acacia mangium* | 13 | TOTAL | 45 | 45 |
| Loganiaceae  | *Fagrea cuspidata* | 4 | Vines | *Flagellaria indica* | 10 |
| Melastomataceae | *Pternandra coerulescens* | 6 | | *Dicranopteris linearis* | 2 |
| Moraceae     | *Artocarpus odoratissimus* | 19 | Gleichiaceae | 2 |
|              | *A. heterophyllus* | 11 | Leguminosae | 3 |
|              | *A. integer* | 9 | Nepenthaceae | 4 |
|              | *Ficus aurata* | 15 | Passifloraceae | 7 |
|              | *F. uncinata* | 8 | Schizaeaceae | 108 |
| Myrtaceae    | *Syzygium samarangense* | 5 | | *Lygodium flexuosum* | 12 |
| Simaroubaceae | *Eurycoma longifolia* | 3 | | *Lygodium cirinnatum* | 96 |
| Symphlocaceae | *Symlocos polyandra* | 10 | TOTAL | 134 | 134 |
| TOTAL        | 287 | TOTAL | 287 | 3 |

Species diversity of the rubber-based agrisilviculture is moderate (1.5＜H' ＜3.5; [9]) for the overall plant community and the two categories of plants (Table 2). Plant diversity is high in the system because of the diversified needs of the farm owner. In comparison, the diversity of other tree-based agroforestry systems is more or less with the rubber-based agrisilviculture. Forest gardens have the highest plant diversity among other agroforestry systems in Mexico [17]. The H' values of betelnut agroforestry
(3.29), lemon agroforestry (2.85), pineapple agroforestry (2.24), secondary forest (2.71), shifting cultivation (1.94) in Bangladesh [7], and home gardens in Indonesia (2.84) [18]. Smaller home gardens in Indonesia tend to be more diverse than large home gardens but large home gardens have greater carbon stocks [18]. In Ethiopia, home gardens, parklands, and live fences had lower $H'$ (0.3–1.7) which is affected by holding size, species preference, and management. The farmers select trees that are suitable for their growth niche, planting density, and interaction with other trees and crops. Ethiopian farmers are constrained by arable land, seed availability, drought, land, and labor shortage [19]. At Kg Ratau, management is less intensive except for clearing weeds before harvesting and promoting the growth of valued plants. Similarly, land and labor shortage, holding size, and seed availability affect plant diversity. The taxa in agrisilviculture are closer to being even ($D = 0.87$) with low dominance ($1-D=1.13$) of any single taxon for the overall plant community. The $D_m$ value increases with the number of organisms sampled from the lianas and vines group (1.19) to the trees group (3.36) and the combined plant community (5.69). It shows that $D_m$ is sensitive to sampling, specifically the number of organisms [Death]. Comparatively, the $D_m$ of the Indonesian home garden was 4.52 to 5.10 [18]. Menhinick's richness index showed a lower value of 1.67 for the overall plant community and was not affected by the number of individuals (Table 2).

**Table 2. Diversity of rubber-based agrisilviculture at Kg. Ratau, Manggatal.**

|                       | Lianas & vines | Trees | All   |
|-----------------------|----------------|-------|-------|
| Shannon-Weiner ($H'$), Diversity | 1.731          | 2.251 | 2.717 |
| Simpson (D), Evenness  | 0.682          | 0.7808| 0.8699|
| Dominance (1-D)        | 0.318          | 0.2192| 0.1301|
| Margalef ($D_m$), richness | 2.892        | 3.357 | 5.696 |
| Menhinick, richness    | 1.196          | 1.181 | 1.668 |
| Individuals            | 179            | 287   | 466   |
| Taxa                   | 16             | 20    | 36    |

Rubber-based agroforestry primarily supports the community's livelihood from rubber-tapping and other plants provide daily provision for remote communities [1]. In Kg. Ratau, rubber-based agrisilviculture is additionally appreciated for providing water, goods, cultural and environmental services. Rubber tapping and harvesting from crops and medicinal plants are the main economic activity of the farm owners at Kg Ratau. Raw goods, semi-processed and processed products are sold around the village, supplied to agriculture retailers (Peladang, Sabah) and at Manggatal tamu (a local market place). The community values their way of life despite the access to modern infrastructure and exposure to changing lifestyles. Similarly, agroforestry land use in Colombia has a multipurpose function proven to support biodiversity (128 species), provide ecosystem services (water purification, wildlife habitat), provision (food, wood, medicinal plants), regulate (pest and disease, climate mitigation, biodiversity), food security and culture services (esthetic, recreation) [20]. Agroforestry systems are also important for carbon sequestration [18], reducing soil erosion and improving soil fertility [8]. In Mexico, different agroforestry systems were important for cultural identity, subsistence needs, and economics [17].

4. Conclusion
Rubber-based agrisilviculture in urban areas can support plant diversity consisting of the planted and wild plants because of nature appreciation, the multipurpose role of the smallholding, and dependency on the farm and surrounding forest for daily provision. The land use can contribute to the maintenance of the traditional way of life and sustainable development of urban areas.

5. References
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