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Litterfall Production and Species Composition of Forest Types in Cambodia

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Abstract:- Litterfall production and species composition are critical factors in regulating forest ecosystem functions, particularly carbon storage and cycling. This study analyzed litterfall production, seasonality, mass, and carbon content across different forest types and locations in Cambodia. The study was conducted from January to December 2020 in four regions: Tamao Mountain Wildlife Zoo, Mondulkiri, Siem Reap, and the Russey Chrum forest community in Koh Kong, focusing on evergreen, semi-evergreen, and deciduous forests. The dominant species identified at each site were *Vatica philastreana*, *Dipterocarpus obtusifolius*, and *Parinari annamensis* (Tamao); *Shorea obtusa*, *Xylia xylocarpa*, and *Terminalia alata* (Mondulkiri); *Streblus asper*, *Dipterocarpus alatus*, and *Cleistanthus tomentosus* (Siem Reap); and *Pternandra caerulescens*, *Shorea siamensis*, and *Syzygium lineatum* (Koh Kong). Litterfall production varied significantly among forest types, with evergreen forests producing 21,035 kg/ha, semi-evergreen forests 8,662 kg/ha, and deciduous forests 7,059 kg/ha. These findings highlight the variability in litterfall production and species composition across forest types and emphasize their role in forest carbon cycling. Further research is recommended to explore seasonal dynamics and their implications for carbon management strategies.

Keywords:- *Litterfall Product; Species Composition; Forest Type; Deciduous Forest; Semi-Evergreen Forest; Evergreen Forest.*

I. INTRODUCTION

Forests play a crucial role in maintaining environmental balance and providing habitats for diverse biodiversity on the planet (Krumm et al., 2020). According to Cambodia's National Land Use/Cover Assessment in 2016, forest land covered an area of 8,510,807 hectares, equivalent to 46.86% of the country's total land area. These results included rubber plantations, palm oil plantations, and other perennial crops. Similarly, the REDD+ Program Forest Cover Assessment in 2016 reported the same forest coverage, categorized into 13 classes: evergreen forests, semi-evergreen forests, deciduous forests, flooded forests, regrowth forests, bamboo, mangroves, rear mangroves, pine forests, pine plantations, tree plantations, oil palm plantations, and rubber plantations. Among these, the main forest types were classified into three categories: evergreen, semi-evergreen, and deciduous forests (MoE, 2018). Semi-evergreen forests represent a transition between evergreen and deciduous forests, with evergreen species constituting 30–70% of the composition (Ashton & Zhu, 2020). These forests remain green year-round despite the higher proportion of deciduous species (FAO, 2011). Important species in semi-evergreen forests include *Shorea obbiusa, Xylia xylocarpa, Terminalia alata, Lagerstroemia calyculata, Croton joufra, Combretum quadrangulare, and Bombax anceps.* Deciduous forests are further divided into dry mixed deciduous forests and dry dipterocarp forests (Theilade et al., 2022). These forests shed their leaves almost completely during the dry season (Ishida et al., 2006). Human activities, such as fire, typically have a more significant impact on deciduous forests compared to other forest types. Dry dipterocarp forests naturally have an open canopy, with undisturbed areas having crown cover as low as 40%. This open structure, combined with soil and grass, influences the reflectance properties of these forests, making it challenging to differentiate them from shrubland during the dry season (Bowman et al., 2011). In Cambodia, deciduous forests cover approximately 4,481,214 hectares, equivalent to 24.68% of the country's total land area (FAO, 2011). Key species in these forests include *Dipterocarpus tuberculatus (Khlong), Dipterocarpus obtusifolius (Tbeng), Shorea obtusa (Phcek), Terminalia tomentosa (Chhlich), Pentacme siamensis (Reang Phnom), Dipterocarpus intricatus (Trach), and Xylia dolabriformis (Sokram).*

The primary objectives of this research were to identify the main species composition and estimate biomass through leaf turnover in deciduous, semi-evergreen, and evergreen forests. To achieve this, a standardized procedure for measuring leaf turnover rates in the field needs to be developed to ensure consistent and reliable data collection.

II. MATERIALS AND METHODS

A. Site Selection

Based on primary studies and field observations in Cambodia, we selected four provinces—Siem Reap, Takeo, Mondulkiri, and Koh Kong—for litterfall collection. These provinces are covered by deciduous and semi-evergreen forests, except for Siem Reap Province, which contains only evergreen and semi-evergreen forests. Additionally, the selected sites were chosen based on agro-ecological zones to

represent the entire country of Cambodia. In the semi-evergreen forest, the main species composition included *Shorea obbiusa, Xylia xylocarpa, Terminalia alata, Lagerstroemia calyculata, Croton joufra, Combretum quadrangulare*, and *Bombax anceps.* In the deciduous forest, key species included *Dipterocarpus tuberculatus, Dipterocarpus obtusifolius, Shorea obtusa, Terminalia tomentosa, Pentacme siamensis, Dipterocarpus intricatus*, and *Xylia dolabriformis.*

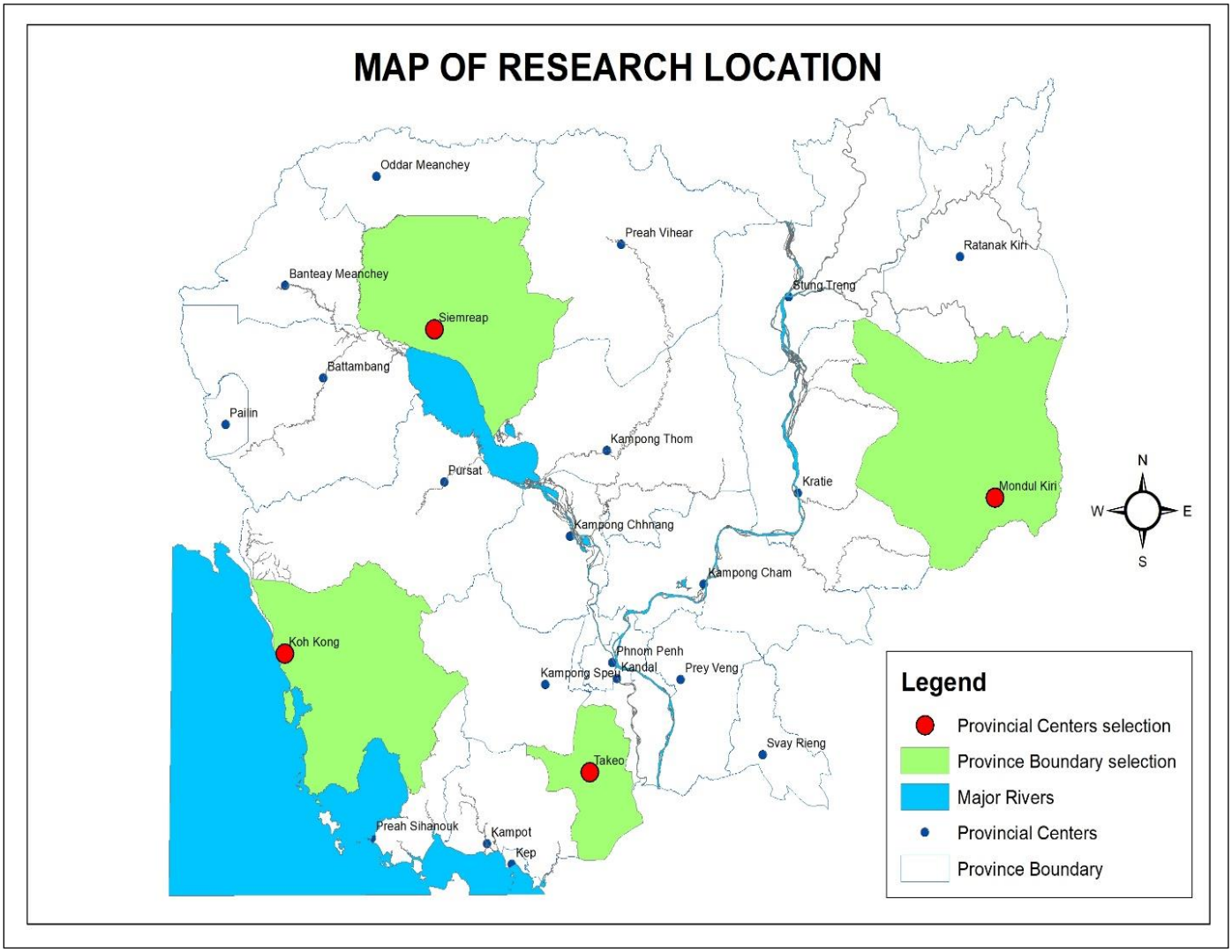

Fig 1. Map of the Research Site

Table 1. Leaf Turnover Collection by Province.

Provinces	Forest Type	Number of Sample plots
Siem Reap	Evergreen forest	2
Takeo	Deciduous forest	2
Mondulkiri	Deciduous forest	2
	Semi-evergreen forest	2
Koh Kong	Semi-evergreen forest	2

B. Procedure for Field Measurement of Leaf Turnover Biomass

The following tools and materials were required for permanent plots and measurement of litterfall biomass: compass (in degrees), GPS, clinometers, diameter tape, measuring tape (30m, 50m), colored rope, field forms, pens, pencils, erasers, markers, color sprayer, axes, knives, baskets, nets, weighing or hanging scales (up to 10-20 kg, with 0.05 kg precision), poly bags, ropes/elastic bands, mesh bags, stapler, stickers, digital camera, insect repellent, and first aid kits.

C. Plot Establishment

Background: The size and shape of the sample plots represent a trade-off between accuracy, precision, time, and measurement costs. The most appropriate size and shape may also depend on the vegetation type found in the sampling area. In the guidelines, a typical sample plot of 30m x 50m is applied for this work.

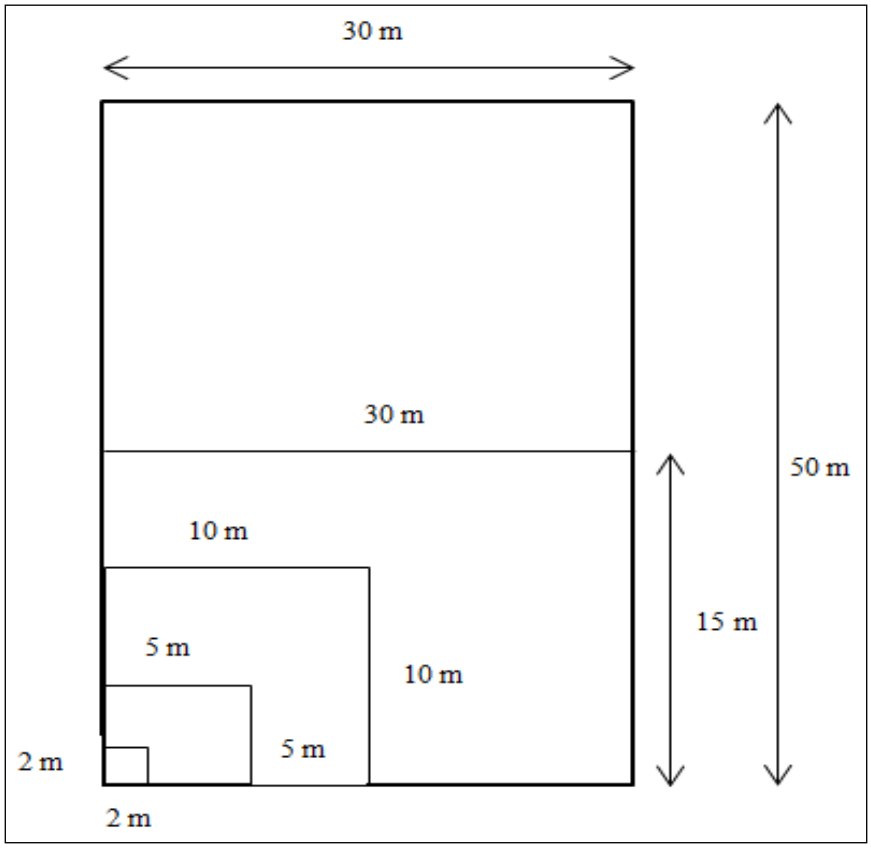

Fig 2. Rectangular Plot Layout.

The National Forest Inventory is the assessment, at a national scale, of forest variables at a certain point in time. Repeated inventories may provide trends over time for such variables. Among these variables, the most relevant has historically been timber volume. Biomass and other carbon stocks are currently being added to modern inventories, along with variables related to the socio-economic use of forests. In this work, four new permanent plots were established in Takeo and Koh Kong provinces. Setting up a permanent plot for measurement should follow standard plot sampling methods with the following criteria:

- The sampling strategy should be determined before the fieldwork. Field constraints often lead to modifications of the initial sampling plan, and the following steps should be considered: Look for an area with less disturbed forests where large trees are present.
- In the sampling area, set the "start point" with a stake.
- The plot size is 30m x 50m. This is called a rectangular plot.
- One person stands at the "start point" and uses a GPS/compass to indicate the direction for the sides of the plot, following the Pythagorean Theorem.
- Another person, using the measuring tape, measures the distance from the "start point" along the direction of the plot sides. The sides must be horizontal. Set a stake every 5m.
- To ensure the plot is rectangular, the corners between two sides of the "start point" must be 90 degrees.
- After setting up the plot with stake markers every 5m (or wider, depending on topographical conditions) on each side of the rectangle, use poly ropes to mark the plot through the stake markers.
- Place tree tags on the sample trees.
- Record general information (location, coordinates at plot center) in the field data form for plot measurement of woody forests.
- Use a camera to take pictures of the sample plots and plot measurement-related activities.

D. Data Collection

The data collected includes:

- Environmental data observations
- DBH (Diameter at Breast Height) measurements of trees
- Species and number of trees recorded
- Tree height measurements

E. Field measurement of Leaf Turnover Biomass

While permanent plots were established, the measurements of leaf turnover biomass were carried out as follows:

- Permanent plots of 30m x 50m were used.

- The area around the plot was cleared before setting up the baskets or nets (for safety purposes).
- Baskets were placed in the middle of the 30m length, starting from the east (15m); baskets were placed at 5m intervals, totaling 10 baskets.
- Baskets were secured with poles to protect them from wind, rainfall, and other disturbances.
- Samples were collected every three months (four times per year).

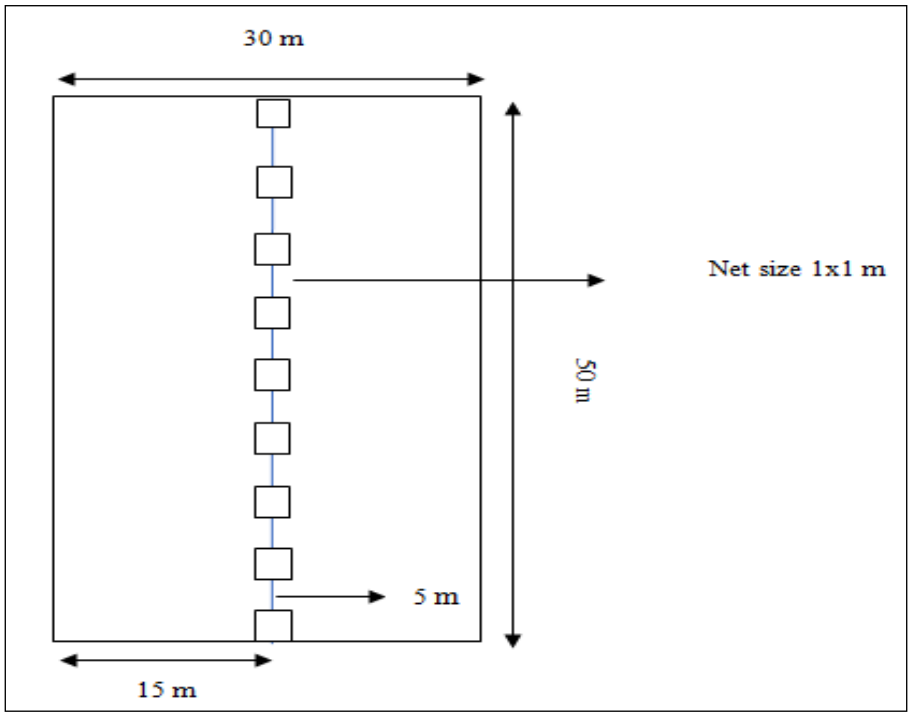

Fig 3. Rectangular Plot Setup for Leaf Turnover Measurement Using Nets

In the case of Mondulkiri and Koh Kong Provinces, where the dominant species are *Dipterocarpus tuberculatus, Dipterocarpus obtusifolius, and Dipterocarpus alatus* in the deciduous forest, larger baskets were needed due to the larger leaf size of these species compared to others. Therefore, the nets were replaced with ones measuring 1m², resulting in a total of 9 nets.

F. Laboratory Measurement

The required equipment for analysis:

- Dry oven
- Scale

G. Measurement for Estimating Dry Mass of Leaf Compartments

Below are the steps for estimating the dry mass of leaf compartments:

- Dry the samples in an oven at a temperature of 100°C (65°C if the samples are to undergo chemical analysis) until they reach a constant weight.
- Weigh the dried samples.
- Record all analytical data carefully in a spreadsheet format.

III. RESULT AND DISCUSSION

A. Species Composition and Litter Fall Production in Deciduous Forest, Takeo Province

The species inventory at Tamao Mountain Wildlife Zoo, including *Vatica philastreana, Dipterocarpus obtusifolius, Parinari annamensis, Cratoxylum cochinchinensis, Careya arborea, Nauclea orientalis, Polyalthia thorelii, Anisoptera costata, Acronychia pedunculata, Memecylon scutellatum, Markhamia stipulata, Diospyros pilosanthera, Gardenia philastrei, Micro tomentosa, Xylia xylocarpa Roxb., Sindora siamensis, Phyllanthus emblica, Scolopia spinosa, Aporusa gluta laccifera Pierre., Vitex pinnata L., Irvingia malayana, Morinda tomentosa, Peltophorum desyrhachis, Croton poilanei, Eriosolena composita, Shorea obtusa, Dillenia ovata, Pentacme siamensis, and Buchanania reticulata*, highlights the rich biodiversity of the region. Similarly, Heng and Shigeru (2002) documented a wide range of forest species in Takeo Province, reinforcing the ecological significance of the area. Giweta (2020) highlighted that the dominance of *Dipterocarpaceae* species, coupled with the presence of rare and economically valuable species, underscores the critical need for targeted conservation efforts to safeguard biodiversity hotspots. This emphasizes the ecological importance of such regions and the role these species play in maintaining ecosystem stability and supporting local livelihoods.

Table 2. Species Composition and Litter Fall Product, Takeo Province

Province	Plot #	Annual	Wet Leaf (g/m^2)	Dry Leaf (g/m^2)	Ratio
Takeo	Plot 1	Q1	303.42	282.00	0.93
		Q2	138.17	111.50	0.81
		Q3	106.92	56.50	0.53
		Q4	176.67	115.67	0.65
		Sub-total	725.17	565.67	0.78
Takeo	Plot 2	Q1	335.42	312.83	0.93
		Q2	212.17	147.17	0.69
		Q3	40.33	30.58	0.76
		Q4	153.50	105.33	0.69
		Sub-total	741.42	595.92	0.80

B. Species Composition and Litter Fall Production for Deciduous Forest in Upland, Mundlkiri Province

The deciduous forest in the upland areas of Mondulkiri Province is characterized by a diverse range of species, including *Shorea obtusa, Dipterocarpus tuberculatus, Xylia xylocarpa, Terminalia alata, Dipterocarpus obtusifolius, Garcinia delpyana, Sindora siamensis, Acacia megaladena, Terminalia mucronata, Careya arborea, Tomentosa roth, Croton cascarilloides, Syzygium* sp., and *Dalbergia nigrescens*. These findings align with Kim et al. (2023), who noted that Mondulkiri Province hosts diverse forest types, reflecting its ecological richness. However, Tsujino et al. (2019) reported a significant decline in forest cover in Cambodia, dropping from 73.3% in 1970 to 47.3% in 2016, highlighting the urgent need for conservation and sustainable forest management in the region.

Table 3. Species Composition and Litter Fall Product, for Deciduous Forest, Mondulkiri (MDK) Province

Province	Plot #	Annual	Wet Leaf (g/m^2)	Dry Leaf (g/m^2)	Ratio
MDK	Plot 1	Q1	NA	NA	NA
		Q2	109.20	53.00	0.49
		Q3	84.79	64.65	0.76
		Q4	351.80	316.00	0.90
		Sub-total	545.79	433.65	0.79
MDK	Plot 2	Q1	580.00	468.50	0.81
		Q2	NA	NA	NA
		Q3	92.92	77.52	0.83
		Q4	229.80	218.60	0.95
		Sub-total	883.05	740.95	0.84

Semi-evergreen in Mondulkiri were *Shorea obtusa, Xylia xylocarpa, Terminalia alata, Albizia lebbeck, Sindora siamensis, Careya arborea, Acacia caesia, Bauhinia variegata, Canarium subulatum, Dipterocarpus intricatus, Terminalia bialata, Combretum quadrangulare*.

Table 4. Species Composition and Litter Fall Product, for Semi-Evergreen Forest, Mondulkiri (MDK) Province

Province	Plot #	Annual	Wet Leaf (g/m^2)	Dry Leaf (g/m^2)	Ratio
MDK	Plot 3	Q1	645.00	403.50	0.63
		Q2	NA	NA	NA
		Q3	84.04	72.72	0.87
		Q4	387.80	386.60	1.00
		Sub-total	1116.84	862.82	0.77
MDK	Plot 4	Q1	781.67	585.83	0.75
		Q2	NA	NA	NA
		Q3	106.08	91.28	0.86
		Q4	502.40	503.20	1.00
		Sub-total	1390.15	1180.31	0.85

C. Species Composition and Litter Fall Production in Siem Reap Province

The evergreen forest in Siem Reap Province is characterized by a variety of species, including *Streblus asper, Dipterocarpus alatus, Cleistanthus tomentosus, Stereospermum chelonoides, Baccaurea ramiflora, Lagerstroemia calyculata, Capparis micracantha, Erioglossum edul, Lepisanthes rubiginosa, Tetrameles nudiflora, Haldina cordifolia, Dysoxylum sp., Hydnocarpus annamensis, Diospyros sylvatica, Gardenia sootepensis, Cochlospermum religiosum, Diospyros bejaudii, Nephelium hypoleucum, Sandoricum koetjape,* and *Ficus microcarpus*. These findings align with CBNRM Learning Institute (2000), who reported that Siem Reap was historically covered by forests with diverse species compositions. However, Somaly et al. (2020) demonstrated that forest cover in Siem Reap Province decreased by 22% between 2000 and 2016, emphasizing the ongoing need for conservation efforts to protect these valuable ecosystems.

Table 5. Species Composition and Litter Fall Product, for Evergreen Forest, Siem Reap Province

Province	Plot #	Annual	Wet Leaf (g/m^2)	Dry Leaf (g/m^2)	Ratio
Siem Reap	Plot 1	Q1	876.42	616.83	0.70
		Q2	626.33	348.50	0.56
		Q3	839.75	396.00	0.47
		Q4	1784.83	793.42	0.44
		Sub-total	4127.33	2154.75	0.52
Siem Reap	Plot 2	Q1	1347.00	851.83	0.63
		Q2	NA	NA	NA
		Q3	702.32	240.68	0.34
		Q4	1221.04	611.20	0.50
		Sub-total	3270.36	1703.71	0.52

D. Species Composition and Litter Fall Production in Koh Kong Province

The Russey Chrum forest community in Koh Kong Province hosts a diverse range of plant species, including *Pternandra caerulescens, Shorea siamensis, Syzygium lineatum, Azadirachta indica, Lithocarpus elephantum, Hymenocardia punctata, Nephelium melliferum, Areca triandra, Parkia sumatrana, Dipterocarpus dyeri, Garcinia hamburyi, Argyreia obtecta, Anthocephalus chinensis, Calophyllum saigonense, Carypha umbraculifera, Lithocarpus polystachyus, Artocarpus chama, Heritiera javanica, Fagraea racemosa, and Dysoxylum loureiri*. Similarly, Khan (2012) reported that the Russey Chrum forest community is rich in natural resources, including a wide variety of forest species. This biodiversity highlights the ecological importance of the area and the need for sustainable management to preserve its natural resources.

Table 6: Species Composition and Litter Fall Product, for Semi-Evergreen Forest, Koh Kong Province

Province	Plot #	Annual	Wet Leaf (g/m^2)	Dry Leaf (g/m^2)	Ratio
Koh Kong	Plot 1	Q1	201.19	120.54	0.60
		Q2	397.70	153.69	0.39
		Q3	575.30	134.38	0.23
		Q4	476.81	198.91	0.42
		Sub-total	1651.00	607.53	0.37
Koh Kong	Plot 2	Q1	392.07	202.22	0.52
		Q2	552.92	216.63	0.39
		Q3	469.91	102.63	0.22
		Q4	472.31	188.50	0.40
		Sub-total	1887.21	709.98	0.38

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E. Litter Fall Biomass in Each Province

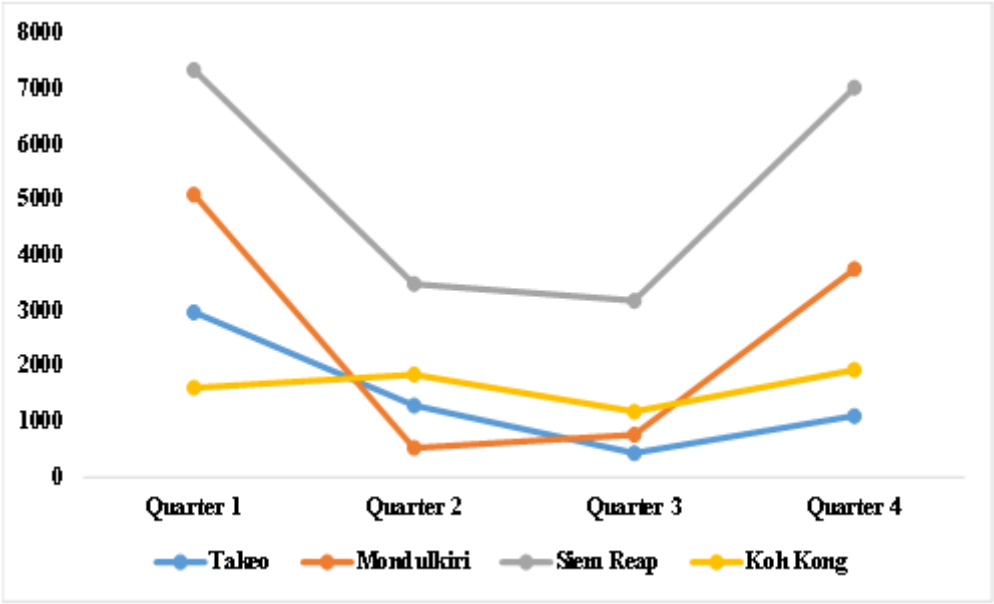

Fig 4. Litterfall Biomass by Quarter per Year in 4 Provinces

Looking at rainfall and forest cover data, there are essentially five ecozones: high, medium, and low rainfall, with the length of the rainy season decreasing from the coastal southwest to the mountainous northeast. The lowest rainfall is found in the northwest-southeast striking central valley. We should aim to cover these main zones and their respective forest types with forest plot data for model validation.

F. Litter Fall Biomass in Each Forest Type

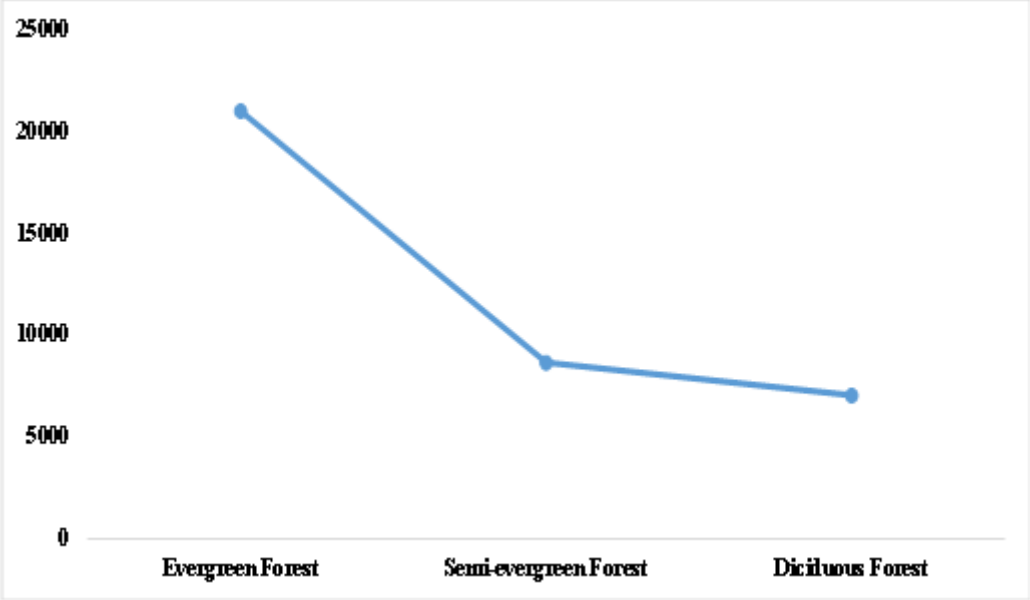

Fig 5. Litterfall Biomass by Forest Type

Fig 5. shows the data for forest types: Evergreen Forest was 21,035 kg/ha, Semi-evergreen Forest was 8,662 kg/ha, and Deciduous Forest was 7,059 kg/ha.

IV. CONCLUSION

Four provinces in Cambodia—Takeo, Mondulkiri, Siem Reap, and Koh Kong—represent different ecological zones in the country. In each province, litterfall traps were placed in three forest types: Evergreen Forest, Semi-evergreen Forest, and Deciduous Forest. A total of ten sample plots were

selected in each forest type to assess the litter biomass. The species composition in these areas varies, with Takeo's Tamao Mountain Wildlife Zoo featuring species such as *Vatica philastreana, Dipterocarpus obtusifolius, Parinari annamensis, Cratoxylum cochinchinensis,* and *Careya arborea*. In Mondulkiri, the dominant species include *Shorea obtusa, Dipterocarpus tuberculatus, Xylia xylocarpa, Terminalia alata, Dipterocarpus obtusifolius*, and *Garcinia delpyana*. Siem Reap is home to species like *Streblus asper, Dipterocarpus alatus, Cleistanthus tomentosus, Stereospermum chelonoides*, and *Baccaurea ramiflora*, while Koh Kong hosts species such as *Pternandra caerulescens, Shorea siamensis, Syzygium* lineatum, *Azadirachta indica*, and *Lithocarpus elephantum*. The litterfall compartments measured in these forests include leaf, twig, branch, flower, and seed. Biomass estimates for the forest types show that Evergreen Forest has the highest biomass at 21,035 kg/ha, followed by Semi-evergreen Forest at 8,662 kg/ha, and Deciduous Forest at 7,059 kg/ha. Overall, Evergreen Forests hold the greatest biomass across the forest types in Cambodia.

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