NPP Tropical Forest: Gunung Mulu, Malaysia,1977-1978, R1

Get Data

Revision date: October 23, 2013

Summary:

This data set contains seven data files (.txt format). Four files provide net primary productivity (NPP) data for contrasting lowland rainforests within Gunung Mulu National Park on the island of Borneo, Malaysia. Three files provide climate data from weather stations near Gunung Mulu.

The study areas are located along an environmental gradient of varying soil types at elevations ranging from 50 to 300-m within the 544 km^2 Park. The study sites are primary lowland evergreen rainforests, each about 1.0 ha in size.

The NPP files contain estimates of above-ground biomass, annual litterfall accumulation, standing litter crop, and nutrient content of different vegetation components and soils. The scientific expedition was carried out between June 1977 and September 1978. Estimates of litterfall, ranging from 886 g/m^2/year to 1,203 g/m^2/year, provide a minimum estimate of above-ground production.

The climate record for the study sites extends from 1915 through 1990. Mean annual precipitation is around 3,000 mm and mean average temperature is about 27 degrees C.

Data Set Revisions: Only the documentation for this data set has been modified. The data files have been checked for accuracy and are identical to those originally published in 1999.

Additional Documentation:

The NPP data collection contains field measurements of biomass, estimated NPP, and climate data for terrestrial grassland, tropical forest, boreal forest, and tundra sites worldwide. Data were compiled from the published literature for intensively studied and well-documented individual field sites and from a number of previously compiled multi-site, multi-biome data sets of georeferenced NPP estimates. The principal compilation effort (Olson et al., 2001) was sponsored by the NASA Terrestrial Ecology Program. For more information, please visit the NPP web site at http://daac.ornl.gov/NPP/npp_home.html.

Data Citation:

Cite this data set as follows:

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Table of Contents:

1. Data Set Overview:

Project: Net Primary Productivity (NPP)

Above-ground biomass, litterfall accumulation, litter standing crop (leaves, fruit/flower, twigs, and large and small branches on the forest floor), and nutrient content of different vegetation components, and soils were measured by nondestructive methods in four lowland rainforests on contrasting soils at the 544-km^2 Gunung Mulu National Park in Sarawak State, Malaysia. The park is situated close to the southern border of Brunei with Malaysia, about 100 km east-southeast of the town of Miri and 100 km due south of Bandar Seri Begawan, Brunei.

The Gunung Mulu study sites (centered at 4.08 N, 114.85 E) were each about 1.0 ha in size and spread along a 20-km transect, from an alluvial forest in the southwest, to a dipterocarp forest, then a limestone forest, and finally to a heath forest in the northeast. Soils range from peaty-podsolic, through red-yellow podsolic, to a shallow black organic soil (overlaying limestone), and a humus podzol.

The NPP studies were carried out by the joint Sarawak Forest Department/U.K. Royal Geographical Society expedition during 1977-1978. NPP was not determined, although estimates of litterfall ranging from 886 g/m^2/year (dipterocarp forest) to 1,203 g/m^2/year (limestone forest) give a minimum estimate of above-ground production. Above-ground biomass ranged from 25,000 g/m^2 (alluvial forest) to 65,000 g/m^2 (dipterocarp forest).

Precipitation and temperature data are available from a weather station at Miri (4.33 N, 113.98 E) near Gunung Mulu, and additional precipitation data from a weather station at Marudi (4.20 N, 114.30 E), about 50-60 km from the study sites. Climate is dominated by the Indo-Australian monsoon system, with the wet northeast monsoon from December to March and the slightly drier southwest monsoon from May to October. Variable winds and near-equatorial troughs and associated disturbances occur during the transition periods.

2. Data Description:

Spatial Coverage

Site: Gunung Mulu, Malaysia

Site Boundaries:(All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Elevation (m)
Gunung Mulu, Malaysia	114.8	114.88	4.14	4.02	50-300

Spatial Resolution

Each of the four study areas was about 1-ha in size (marked on the ground, not corrected for slope) with twenty-five 20 x 20-m sub-plots. One sub-plot (5 x 5-m) was selected at random within each of fifteen plots and divided into four (2.5 x 2.5-m) quadrats for litterfall collection. Small litterfall was collected in mesh sacks with a 0.5 x 0.5-m opening. Large litterfall was collected in the 5 x 5-m sub-plots. Standing crop of small litter was removed from 50 x 50-cm quadrats. Standing crop of large wood litter (> 2 cm diameter) was measured in the 20 x 20-m sub-plots.

Temporal Coverage

A floristic survey was carried out between June 1977 and September 1978. Above-ground biomass estimates were made in each of the four sites on one occasion between October 1977 and August 1978. Litterfall and standing crop of litter were collected on several occasions, as shown in Table 2. In addition, an investigation was made of some features of decomposition and element cycling in the four contrasting lowland forests. Climate data are available from January 1915 through December 1990 as shown in Table 3.

Table 2. Dates of field measurements

Parameter	Alluvial forest	Dipterocarp forest	Heath forest	Limestone forest
Small litterfall	09/09/1977-08/26/1978	09/13/1977 - 08/29/1978	09/02/1977 - 08/22/1978	10/28/1977 - 08/23/1978
Large wood litterfall (clearance & litter collection on sub-plot a)	11/01/1977 - 03/31/1978 (1st collection); 03/31/1978-08/06/1978 (2nd collection)	11/07/1977 - 04/24/1978 (1st collection); 04/24/1978- 08/14/1978 (2nd collection)	11/17/1977 - 04/16/1978 (1st collection); 04/16/1978- 08/10/1978 (2nd collection)	02/23/1977 - 07/22/1978
Large wood litterfall (clearance & litter collection on sub-plot b)	02/27/1978 - 07/28/1978	03/03/1978 - 08/01/1978	02/23/1978- 07/22/1978	--
Standing crop of litter	08/25/1977-	09/13/1977 - 05/27/1978	09/03/1977 - 06/07/1978	02/22/1978 - 05/27/1978

	07/13/1978			

Temporal Resolution

The diameters of all trees (≥ 10 cm dbh) in each of the sites were measured on one occasion. Small litterfall was collected bi-weekly. Large litterfall was collected at 4-5 month intervals, twice in one set of sub-plots and once in another set in AF, DF, and HF and once in LF. Standing crop of small litter was collected at 3-4 month intervals, four times in AF, DF, and HF and twice in LF. Standing crop of large litter was collected at 3-4 month intervals, three times in AF, DF, and HF and twice in LF. All NPP estimates are based on plant dry matter accumulation, expressed as g/m^2 (dry matter weight).

Climate data are expressed as monthly and annual precipitation amounts (mm) and monthly and annual average temperature (C). Monthly and annual climatic means are provided.

Data File Information

Table 3. Data files in this data set archive

FILE NAME	TEMPORAL COVERAGE	FILE CONTENTS
gnn1_npp.txt	1977/08/25-1978/07/13	Forest structure and litterfall data for an alluvial forest (AF) at Gunung Mulu, Malaysia
gnn2_npp.txt	1977/09/13-1978/05/27	Forest structure and litterfall data for a dipterocarp forest (DF) at Gunung Mulu, Malaysia
gnn3_npp.txt	1978/02/22-1978/05/27	Forest structure and litterfall data for a limestone forest (LF) at Gunung Mulu, Malaysia
gnn4_npp.txt	1977/09/03-1978/06/07	Forest structure and litterfall data for a heath forest (HF) at Gunung Mulu, Malaysia
gnn1_cli.txt	1962/01/01-1975/12/31	Monthly and annual precipitation data from Marudi weather station (elevation 31 m) about 50-60 km from Gunung Mulu
gnn2_cli.txt	1961/01/01-1990/09/30	Monthly and annual precipitation and average temperature data from Miri weather station (elevation 17 m) near Gunung Mulu, Malaysia
gnn3_cli.txt	1917/01/01-1990/10/31	Monthly and annual precipitation data from Miri weather station (elevation 17 m) near Gunung Mulu, Malaysia

NPP Data. NPP estimates for the Gunung Mulu site are provided in four text files (.txt format), one for each forest type (Table 3). The variable values are delimited by semicolons. The first 18 lines are metadata; data records begin on line 19. The value -999.9 is used to denote missing values. Above-ground biomass and standing crop of litter estimates are expressed as in g/m^2 (dry matter weight). Litterfall accumulation is estimated as $g/m^2/year$ (dry matter weight). Micro-nutrient concentrations in litterfall are given as percent (based on mg/g oven dry matter).

Table 4. Column headings in NPP files

COLUMN HEADING	DEFINITION	UNITS
Site	Site where data were gathered (code refers to site identification)	Text
Treatmt	Study area or forest subsystem type where measurements were made; treatment and long term management of site are described in metadata in data file	Text
Year	Year in which data were collected	Numeric
Month	Month in which data were collected	
Day	Day on which data were collected	
parameter	Parameters measured (see definitions in Table 5)	Text
amount	Data values	Numeric
units	Unit of measure	Text
Comments	Explanatory comments	Text

Table 5. Parameter definitions in NPP files

PARAMETER	DEFINITION	UNITS	SOURCE
height	Forest canopy height	m	Table 1[1]
leaflitter	Leaf litter standing crop at different times of the year	g/m^2	Table 3[3]
frtflolitter	Flower and fruit litter standing crop at different times of the year		
twiglitter	Small wood litter standing crop at different times of the year[2]		
	Total above-ground biomass (large woody biomass plus leaves, small twigs,		

ABbiomass	epiphytes, lianas, and other life forms)	g/m^2	Table 1[1]
climbers+epiphytes	Biomass of epiphytic vascular plants that grow within 3 m of the ground	g/m^2	Table 6[1]
undstory	Biomass of ground herbs	g/m^2	Table 6[1]
branchlitter	Large wood litter standing crop (> 2 cm - ≤ 10 cm diameter)	g/m^2	Table 4[3]
Stdead	Large wood standing crop (> 10 cm diameter), including standing dead boles	g/m^2	Table 4[3]
leaflittfall	Estimated annual leaf litterfall[4]	g/m^2/year	Table 1[3]
twiglittfall	Estimated annual small wood litterfall[2, 4]		
frtflolittfall	Estimated annual flower and fruit litterfall[4]		
trashlittfall	Estimated annual trash litterfall[4]		
Totlittfall	Estimated annual total litterfall (leaf + small wood + flower/fruit + trash)[4]		
branchfall	Estimated annual large wood litterfall (> 2 cm - ≤ 10 cm diameter)	g/m^2/year	Table 2[3]
leaflitter-N	Nitrogen concentration in leaf litterfall	percent	Table 5[3]
twiglitter-N	Nitrogen concentration in twig litterfall		
frtflolitter-N	Nitrogen concentration in flower and fruit litterfall		
trashlitter-N	Nitrogen concentration in trash litterfall		
leaflitter-P	Phosphorus concentration in leaf litterfall		
twiglitter-P	Phosphorus concentration in twig litterfall		
frtflolitter-P	Phosphorus concentration in flower and fruit litterfall		
trashlitter-P	Phosphorus concentration in trash litterfall		

Notes:

[1]Proctor et al. (1983a).

[2]Twigs = ≤ 2 cm diameter; pieces larger than this were broken off and discarded; separate bark fragments were included if they were ≤ 2 cm along their longest dimension.

[3]Proctor et al. (1983b).

[4]The litterfall estimates are based on the summed 2-week collections for each trap (n=35) extrapolated to one year.

Sample NPP Data Record: **gnn1_npp.txt**

```
Site; Treatmt; Year; Month; Day; parameter; amount; units; Comments

gnn; alvlfrst; 1977-78; -999.9; -999.9; height; 17.8; m

gnn; alvlfrst; 1977; 8; 25; leaflitter; 430; g/m2
gnn; alvlfrst; 1977; 11; 25; leaflitter; 330; g/m2
gnn; alvlfrst; 1978; 3; 24; leaflitter; 320; g/m2
gnn; alvlfrst; 1978; 7; 13; leaflitter; 420; g/m2
gnn; alvlfrst; 1977; 8; 25; frtflolitter; 11; g/m2
gnn; alvlfrst; 1977; 11; 25; frtflolitter; 7; g/m2
gnn; alvlfrst; 1978; 3; 24; frtflolitter; 6; g/m2
gnn; alvlfrst; 1978; 7; 13; frtflolitter; 1; g/m2
gnn; alvlfrst; 1977; 11; 25; twiglitter; 180; g/m2
gnn; alvlfrst; 1978; 3; 24; twiglitter; 140; g/m2
gnn; alvlfrst; 1978; 7; 13; twiglitter; 150; g/m2

gnn; alvlfrst; 1977-78; -999.9; -999.9; AGbiomass; 25000; g/m2; non-destructive estimate
...
```

The other three NPP files have a similar file layout structure.

Climate Data. Climate data for Gunung Mulu are provided in three text files (.txt format). See Table 3 for variables recorded and station locations. The first 18 lines of each file are metadata; data records begin on line 19. The variable values are delimited by semicolons. The value -999.9 is used to denote missing values.

Sample Climate Data Record: **gnn1_cli.tx**

```
Site;Temp;Parm; Jan; Feb; Mar; Apr; May; Jun; Jul; Aug; Sep; Oct; Nov; Dec; Year
```

```
mrd ;mean;prec; 390.0; 160.5; 177.7; 218.4; 239.2; 192.2; 166.7; 232.8; 218.2; 273.6; 293.1; 305.5; 2835.4;
mrd ;numb;prec; 13; 13; 13; 13; 13; 13; 14; 14; 14; 13; 14; 13; 11;
mrd ;stdv;prec; 488.8; 87.0; 82.2; 131.8; 56.6; 91.7; 84.1; 101.6; 124.1; 101.5; 81.8; 127.6; 523.4;
mrd ;1962;prec; -999.9; -999.9; -999.9; -999.9; -999.9; -999.9; 181.0; 264.0; 174.0; 274.0; 322.0; 340.0; -999.9;
mrd ;1963;prec; 1982.1; 279.0; 206.0; 46.0; 257.0; 126.0; 148.0; 301.0; 77.0; 235.0; 203.0; 173.0; 4033.1;
...
Where,
Temp (temporal) - specific year or long-term statistic:
  mean = mean based on all years
  numb = number of years
  stdv = standard deviation based on all years
Parm (parameter):
  prec = precipitation for month or year (mm)
```

Sample Climate Data Record: **gnn2_cli.txt**

```
Site;Temp;Parm; Jan; Feb; Mar; Apr; May; Jun; Jul; Aug; Sep; Oct; Nov; Dec; Year

mri ;mean;tave; 26.1; 26.2; 26.8; 27.2; 27.5; 27.3; 27.0; 27.0; 26.9; 26.7; 26.7; 26.4; 26.7
mri ;mean;prec; 294.5; 148.0; 168.6; 191.6; 169.7; 232.7; 206.2; 239.7; 247.3; 312.1; 322.5; 364.7; 2863.4
mri ;numb;tave; 18; 18; 20; 20; 19; 20; 20; 17; 20; 20; 19; 18; 15
mri ;numb;prec; 30; 30; 30; 29; 29; 28; 28; 27; 27; 24; 23; 21; 21
mri ;stdv;tave; 0.7; 0.6; 0.6; 0.5; 0.3; 0.4; 0.3; 0.4; 0.3; 0.2; 0.4; 0.4; 0.2
mri ;stdv;prec; 305.8; 107.7; 83.0; 90.4; 84.4; 96.1; 106.8; 118.0; 100.6; 100.1; 146.7; 144.0; 372.7
mri ;1961;tave; 25.9; 26.2; 26.7; 26.9; 27.8; 27.2; 26.9; 27.1; 26.7; 26.3; 27.1; 26.4; 26.8
mri ;1961;prec; 138.0; 181.0; 87.0; 195.0; 132.0; 383.0; 207.0; 183.0; 155.0; 245.0; 53.0; 315.0; 2274.0
mri ;1962;tave; 26.0; 25.8; 26.3; 26.9; 27.4; 26.8; 27.3; 26.3; 26.7; 26.8; 26.4; 26.2; 26.6
mri ;1962;prec; 447.0; 22.0; 216.0; 134.0; 265.0; 284.0; 48.0; 252.0; 350.0; 378.0; 509.0; 429.0; 3334.0
...
Where,
Temp (temporal) - specific year or long-term statistic:
  mean = mean based on all years
  numb = number of years
  stdv = standard deviation based on all years
Parm (parameter):
  prec = precipitation for month or year (mm)
  tave = mean average temperature for month or year (C)
```

Sample Climate Data Record: **gnn3_cli.txt**

```
Site;Temp;Parm; Jan; Feb; Mar; Apr; May; Jun; Jul; Aug; Sep; Oct; Nov; Dec; Year

mri ;mean;prec; 305.6; 164.8; 151.4; 182.1; 206.3; 236.6; 204.3; 218.4; 283.5; 338.4; 355.3; 344.6; 3024.9
mri ;numb;prec; 62; 61; 63; 64; 62; 63; 62; 59; 62; 64; 62; 62; 56
mri ;stdv;prec; 243.4; 123.6; 81.3; 98.5; 97.0; 103.8; 104.6; 131.3; 118.1; 107.7; 132.4; 163.6; 481.6
mri ;1917;prec; 263.0; 349.0; 317.0; 103.0; 170.0; 183.0; 76.0; 501.0; 434.0; 293.0; 275.0; 314.0; 3278.0
mri ;1918;prec; 744.0; 335.0; 77.0; 224.0; 120.0; 336.0; 87.0; 185.0; 128.0; 241.0; 400.0; 305.0; 3182.0
mri ;1919;prec; 131.0; 29.0; 77.0; 62.0; 213.0; 195.0; 279.0; 4.0; 110.0; 546.0; 402.0; 749.0; 2797.0
...
Where,
Temp (temporal) - specific year or long-term statistic:
  mean = mean based on all years
  numb = number of years
  stdv = standard deviation based on all years
Parm (parameter):
  prec = precipitation for month or year (mm)
```

3. Data Application and Derivation:

The NPP study was carried out in conjunction with a floristic, faunistic, and geomorphological survey conducted by the joint Sarawak Forest Department/Royal Geographical Society Mulu Expedition from June 1977 to September 1978. The NPP investigation was undertaken to quantify the rate of litterfall in the four contrasting lowland forests and measure litterfall nutrient content as an important pathway for the transfer of organic matter and chemical elements from the vegetation to the soil surface in tropical forest ecosystems. When combined with other measurements of biomass, standing crop and fluxes, the litterfall estimates provide much information on production, decomposition, and nutrient cycling of these study sites as well as indications of limiting nutrients and nutrient use efficiency in the forests. Prior to this effort, there was little published information on these aspects for any tropical forests in the Far East and the Gunung Mulu National Park offered an ideal study area.

NPP was not determined directly, although estimates of litterfall give a minimum estimate of above-ground production. These estimates are provided for comparison with models and estimation of NPP. Climate data are provided for use in driving ecosystem/NPP models.

4. Quality Assessment:

Above-ground biomass estimates for the four Gunung Mulu sites were compared with those of other lowland rainforests and tropical semi-deciduous forests in Proctor et al. (1983a). Small litter standing crops and total small litterfall are compared in a range of lowland tropical rain forests (Tables 9 and 10, respectively, in Proctor et al., 1983b and Table 8 in Anderson et al., 1983). At the time of this study, there were few comparative data on large-wood and tree fall and the dead large-wood on the forest floor for lowland tropical rainforests.

Above-ground biomass estimates range from 25,000 g/m2 for the AF to 65,000 for the DF, which is clearly very high. The estimates of small litterfall (leaves, small wood and bark pieces $\leq$ 2 cm diameter, fruit and flowers, and trash) for the four sites were surprisingly similar (ranging from 886 g/m^2/year in the DF to 1,203 g/m^2/year in the LF), especially in light of the large differences between the forests in above-ground biomass, species-richness, and the measured properties of their soils.

The 95% confidence limits for total small litter fall estimates during the sampling period were fairly wide (as a percentage of the mean): 17% for AF; 7.3% for DF; 12% for HF; and 10% for LF. A greater replication or a larger litter trap size or both would have been desirable. Also, measurements were made for a little less than a year; other studies elsewhere of two or more years have shown substantial differences from year to year. Similar methodological problems were encountered also with measurements of small-litter standing crop, with the additional complication that the distinction between litter and soil organic matter is not the same for all field technicians.

Results for wood fall >2≤10 cm diameter showed wide confidence limits although the standing crop of this fraction seemed a reasonable estimate. Estimates of the standing crop of dead trees and large (> 10 cm) branches also had wide confidence limits. The investigators concluded that no studies in lowland tropical forests have adequately sampled the fall and standing crop of dead trees and large branches (> 10 cm diameter).

Sources of Error

Information not available.

5. Data Acquisition Materials and Methods:

Site Information

Gunung Mulu National Park, Sarawak has an area of 544 km^2, most of which is covered by primary forest on different soil types. The study sites are spread along a 20 km line, from an alluvial forest in the southwest, to a dipterocarp forest, then a limestone forest, and finally a heath forest in the northeast.

Table 1. Gunung Mulu Sub-Sites

Sub-Sites	Elevation (m)	Longitude	Latitude
Alluvial forest	50	114.80	4.02
Dipterocarp forest	225	114.85	4.02
Limestone forest	300	114.88	4.12
Heath forest	170	114.88	4.14

The Gunung Mulu sub-sites were chosen as being good examples of primary forest of each type. Three of the sites (alluvial, limestone, and heath) have had almost no human disturbance. The dipterocarp forest included a plot of 0.4 ha with some minor disturbance associated with previous field work. The main Gunung Mulu path (about 1-m wide) runs through this site but was thought to have negligible impact on it.

Alluvial forest

Alluvial forest (AF) was formerly more widespread in Sarawak but much has been cleared for cultivation. The Park has some fine undisturbed examples developed mainly on alluvium, and inundated for a few days at the wettest times of the year. This forest type and the next are facies of tropical lowland evergreen rainforest which includes the most luxuriant of all plant communities and probably has the greatest number of species of any rainforest formation.

The study site is at an altitude of 50 m and is fairly flat with the highest point about 3.3 m above the lowest. This height difference is very important because of its relation to flooding frequency and soil type. The lower parts of the site were inundated on three occasions (for about 24 h each) during this study. On the lower flat ground, the drainage is poor and gley soils of the *Bijat* family occur. The water table generally occurs close to the surface, even after a dry period. The highest ground in the AF is probably a low terrace remnant and has weak incipient humus podzols of the *Buso* family. In these, gravel beds are encountered at depths of 20-40 cm. A thin layer of alluviated organic material is found just above the gravel beds or around the pebbles or both. The top soil is a pale loamy sand to sandy loam. Where drainage has been impeded, a thin layer of peat has accumulated on top of the humus podzol and in one area organic soils (50-100 cm deep) of the *Mukah* family occur.

Dipterocarp forest

Dipterocarp forest (DF) is well represented in the Park on red-yellow podzolic soils. The Sarawak foresters call this forest 'mixed dipterocarp forest' which distinguishes it from those forests (e.g., the *Shorea albida* peat swamps of northern Borneo) where one dipterocarp species is dominant. However the name is not used elsewhere in the Far East so the shorter name, dipterocarp forest, is used herein.

The site ranges from about 200 to 250-m altitude and occupies the crest and flank slopes of the lower end of an intermediate spur from the west ridge of Gunung Mulu. The soils are heavy-textured, red-yellow podzolics with a surface layer (up to about 15 cm thick) of reddish-brown fibrous organic matter. The topsoils commonly have silty loam or very fine sandy loam textures, but clay contents increase with depth, and silty clay loams or heavier clays are usually found within 15 cm of the surface. The soils are mainly of *Merit* and to a lesser extent *Tutoh* families.

Heath forest

Heath forest (HF) is often called by its Iban name of *kerangas*. It occurs on soils derived from siliceous parent materials, which are low in bases and coarse textured. It is developed in many places in the Park on terraces which are probably of Pleistocene age. This forest has several distinctive characters: many trees with small, hard, glossy leaves; abundant bryophytes on the ground; many insectivorous plants and myrmecophytes. Forests of this type occur in many places in the Far East (except East Malaysia) but are more extensive in Borneo than elsewhere and are associated with the formation of podzols or bleached sands.

The study site occurs at about 170 m altitude on a medium-height terrace of sandy deposits. There is about 2-m difference in height between the highest and lowest points. The soils are mainly humus podzols of the *Miri* family which has an indurated B_h horizon. Some *Buso* family soils were also found where the humus pan is less indurated and is penetrable with an auger. In less well drained part, these humus podzols have a peaty surface. Locally, deep *Anderson* family organic soils of 100-150 cm of reddish-brown peat are found.

Limestone forest

Forest over limestone (LF) occurs frequently in the Park although only a small proportion is found in the lowlands. Such forests are fairly common in South-East Asia. This study was restricted to the type occurring at the base of cliffs and ravines.

This study site is situated at about 300 m altitude and is on a mainly 25-30° slope. The site is 160 x 60-m (plus a plot of 20 x 20-m) and the longer sides lie along the contours (to minimize altitudinal effects). It has a ground area in horizontal projection of 0.85 ha. The ground surface is very irregular with limestone boulders protruding for 2-3 m. The soils are very shallow (average depth 11 cm; range 0-55 cm), highly organic and black with a mull-humus form. They occur as interstitial material between hard, sharply-angled or pointed limestone rocks. Bare rock accounts for 9% of the ground surface.

Climate

Climate data for the Gunung Mulu sub-sites come from two locations: a weather station at Miri (4.33 N, 113.98 E) near Gunung Mulu and a weather station at Marudi (4.20 N, 114.30 E), about 50-60 km from the study sites. The Park's climate is controlled largely by the Indo-Australian monsoon system: the northeast monsoon from December to March and the southwest monsoon from May to October. During the transition periods, winds are variable and near-equatorial troughs and associated disturbances affect the region. Tropical cyclones do not affect the area. Rainfall usually occurs in the form of convectional showers, generally in the afternoon or night. Although rainfall occurs in all months of the year, there is a peak after each equinox (in October-November and April-May) during the transition period between the two monsoon systems. The rainfall remains high during the northeast monsoon; the southwest monsoon, particularly July-September, is drier because the air has passed over the land mass of southern Borneo.

Forest structure

All trees ($\geq$ 10 cm dbh) were measured for dbh and height, except for the LF where height was calculated using a regression equation based on height and diameter measurements of a sample of thirty-four trees. Estimates of numbers or biomass or both of small trees (< 10 cm dbh), lianas, ground herbs and ferns, and epiphytes (including ferns) $\leq$ 3 m from the ground were also made. Epiphytes >3 m from the ground and bryophytes were not enumerated.

The biomass values for above-ground tree wood and bark volume ($\geq$ 7 cm dbh) (volume calculated as: height x basal area x 0.5) were multiplied by 1.1 to give a rough estimate of total above-ground biomass (including leaves, small twigs, epiphytes, lianas and other life forms).

Small litterfall

Small litterfall (leaves, wood $\leq$ 2 cm diameter, reproductive parts, and trash) was collected and analyzed for quantity, seasonal distribution, standing crop of litter, and the concentrations of nitrogen, phosphorus, and other nutrients. Small litterfall was collected in mesh sacks, with a 0.5 x 0.5-m opening and supported about 0.7 m above the ground, which retained all particles greater than about 0.1 mm but which allowed free drainage of water. Thirty-five traps were placed in a restricted random design on each site between the dates shown in Table 2. The traps were emptied bi-weekly and sorted into four fractions which were weighed separately [(i) leaves; (ii) small wood ($\leq$ 2 cm diameter; pieces larger than this were broken off and discarded; separate bark fragments were included if they were ($\leq$ 2 cm along their longest dimension); (iii) flowers and fruits; and (iv) trash], and dried at 105 degrees C. The results for two consecutive collections were combined to give weights of litterfall per 28 days (or occasionally a slightly different period). Litterfall values were extrapolated to a yearly basis.

Large-wood litterfall

On the AF, DF and HF, a set of ten (5 x 5-m) sub-plots were selected on a restricted random basis and cleared of all large litter. The large-wood (>2 cm - ~10 cm diameter) litterfall was collected about five months later and again after four months. A second set of ten sub-plots was cleared about four months after the first set and the large-wood litter fall collected after about five months. In the LF a single collection was made from nineteen sub-plots about five months after clearance. The dates of clearances and collections are shown in Table 2. Extrapolations to a yearly basis were made as for small litterfall.

Small-litter standing crop

At a randomly selected position in each of twenty-five (20 x 20-m) plots on each site, all small litter was removed from within a 50 x 50-cm quadrat. The litter was dried at 105 degrees C, sorted into leaves, small wood (as defined earlier), and flowers and fruits, and immediately weighed. Trash could not be distinguished from fractions of soil organic matter and was not recorded. Four small-litter standing crop collections were made on the AF, DF and HF and two on the LF; the collection dates are given in Table 2.

Large-wood litter standing crop

The standing crop of the large-wood litter (> 2 cm diameter) was measured in the twenty sub-plots cleared to estimate large woody litterfall (one sub-plot was later lost on the LF and hence only nineteen sub-plots were used for the large wood litterfall estimate). The wood was sorted into two size fractions: > 2 cm - ≤ 10 cm diameter; and > 10 cm diameter. All wood that could be removed was weighed on a spring balance in the field and sub-samples were taken, oven-dried at 105 degrees C, and the field weights were then converted to oven-dry weights. Large logs (including some standing-dead boles) were measured and sections sub-sampled, oven-dried at 105 degrees C, and used to estimate the weight of the remaining wood.

Climate data

Climate was monitored at the Marudi weather station (elevation 31 m) about 50-60 km from Gunung Mulu and the Miri weather station (elevation 17 m) near Gunung Mulu, Malaysia.

DataDescrAccess

6. Data Access:

This data set is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive:

Web Site: http://daac.ornl.gov

Contact for Data Center Access Information:

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

7. References:

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